

A mining research contract report
MARCH 1978

DEVELOPMENT OF A MACHINE MOUNTED RESPIRABLE DUST MONITOR

Contract H0166186
The Bendix Corporation
Environmental & Process Instruments Division

Bureau of Mines Open File Report 123-84

BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR



REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

DISCLAIMER NOTICE

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or recommendations of the Interior Department's Bureau of Mines or of the U.S. Government.

CERTIFICATION OF THE ABSENCES OF PATENTS AND INVENTIONS

This statement certifies that at the contract report date, no inventions have been developed from Contract H0166186. Consequently, no patents are pending.



Dale Grant, Manager
Integrated Logistic Support

REPORT DOCUMENTATION PAGE		1. REPORT NO. BuMines OFR 123-84	2.	3. Recipient's Addressing No. PBB # 207927
4. Title and Subtitle Development of a Machine Mounted Respirable Dust Monitor				5. Report Date Mar. 1978
7. Author(s) Richard M. Spooner and John L. Bennett				6.
8. Performing Organization Name and Address The Bendix Corp. Environmental and Process Instruments Div. 1400 Taylor Ave. Baltimore, MD 21204				9. Performing Organization Report No.
10. Project/Task/Work Unit No.				11. Contract/Grant No. (a) H0166186
				(b)
12. Sponsoring Organization Name and Address Office of Assistant Director--Mining Research Bureau of Mines U.S. Department of the Interior Washington, DC 20241				13. Type of Report & Period Covered Contract research, 6/30/76--3/16/78
14.				15. Supplementary Notes Approved for release June 14, 1984.
16. Abstract (Limit 200 words) This report encompasses the fabrication of a prototype respirable dust sampler and detector assembly for mining machine-mounted dust monitoring application, the design and fabrication of support electronics, and laboratory testing as defined in phase I of the work. The hardware was fabricated in accordance with the phase I design, and modified to improve the performance and to comply with customer requests. Modifications involved the filter media, electronic flow controller, motorized and manual lift mechanisms for the transitional heads, speed reducer for the filter media transfer drive, a power supply for each Geiger-Muller tube, and a pressure-sensitive tape roller bracket revision. The functional and environmental testing indicated the prototype hardware functioned within the specified requirements.				
17. Descriptive Analysis & Descriptors Mining research Beta absorption detection Transition Plenum Particle size selector Dust deposition and discrimination Respirable dust collection Geiger-Muller tube detectors and beta source b. Identifiers, Open-Ended Terms				
c. COSATI Field/Group 081				
18. Availability Statement Release unlimited by NTIS.		19. Security Class (This Report) Unclassified	20. No. of Pages 83	
		21. Security Class (This Page) Unclassified	22. Price	

FOREWORD

This report was prepared by The Bendix Corporation, Environmental and Process Instruments Division, 1400 Taylor Avenue, Baltimore, Maryland 21204, under USBM Contract Number H0166186. The contract was initiated by the Pittsburgh Mining & Safety Research Center. It was administered under the technical direction of PMSRC with Dr. W. Courtney acting as the Technical Project Officer. Ms. Elizabeth Rexroad was the Contract Administrator for the Bureau.

This report is a summary of the work completed as part of this contract during the period June 1976 to March 1978. This report was submitted by the authors on March 31, 1978.

Table of Contents

Section	Page
I. INTRODUCTION AND SUMMARY.....	8
A. Introduction.....	8
B. Summary.....	8
1. Mechanical Hardware.....	8
2. Electronic Hardware.....	14
3. Support Electronics.....	15
4. Testing.....	16
II. AIR MOVER AND PNEUMATIC SYSTEMS.....	17
A. Introduction.....	17
B. Air Mover.....	20
C. Pneumatic Capacitor.....	20
D. Fluidic Resistor.....	20
E. Flowmeter.....	21
F. Transitional Plenums.....	21
G. Heated Pneumatic Lines.....	21
III. PARTICLE SIZE SELECTOR ASSEMBLY.....	23
A. Introduction.....	23
B. Particle Size Selector Assembly.....	23
IV. FILTER MEDIA.....	27
A. Introduction.....	27
B. Phase II Status at the Beginning.....	28
C. Meeting with the Two Vendors.....	28
D. New Filter Media Search.....	28
1. Vendor Search.....	28
2. Functional Tests Conducted on Sample Specimens.....	29
3. Filter Media that Met Bendix Requirements.....	29
4. Results of the MESA Tests.....	29
5. Selected Candidate.....	30
V. BETA ABSORPTION DETECTION SYSTEM.....	31
A. Introduction.....	31
B. Detector.....	31
C. Beta Source.....	31
D. High Voltage Source.....	32
E. Solid State Preamplifier.....	32
VI. ELECTRONIC FLOW CONTROL.....	33

Table of Contents (Continued)

Section	Page
VII. SUPPORT ELECTRONICS.....	35
A. Control System.....	35
B. Counters.....	35
C. Clock.....	35
D. Internal Timing.....	37
E. Manual Switch.....	37
F. System Power Supplies.....	38
G. Interlock Action.....	38
H. Indicators.....	38
I. Operating Sequence.....	39
1. General.....	39
2. Long Term Tape Movement Sequence.....	40
3. Short Term Tape Movement Sequence.....	40
J. Microprocessor System.....	41
1. General.....	41
2. Input Assignment.....	41
3. Output Assignment.....	41
4. Program.....	42
VIII. TESTING.....	43
A. Introduction.....	43
B. Functional Testing.....	43
C. Environmental Testing.....	44
D. Dust Mass Calculations.....	45
IX. CONCLUSIONS AND RECOMMENDATIONS.....	48
A. Conclusions.....	48
B. Recommendations.....	48

A.	Test Data of the Original Flow Control System.....	49
B.	Filter Media Infrared Scan Preparation.....	51
C.	MESA Filter Media Test Data.....	53
D.	MMRDM Computer Program.....	55
E.	MMRDM Drift Data.....	63
F.	Environmental Test Plan.....	65
G.	Environmental Test Data.....	68
H.	Data Study - Computer Program.....	74
I.	Shock Test Report.....	76

LIST OF FIGURES

1.	Prototype Respirable Dust Sampler-Detector Assembly.....	9
2.	Prototype Respirable Dust Sampler-Detector Assembly.....	10
3.	Support Electronics.....	11
4.	MMRDM Housing.....	12
5.	Pneumatic System - Block Diagram.....	18
6.	Particle Size Selector Assembly.....	24
7.	Remote Inlet Location.....	26
8.	Electronic Flow Control Schematic.....	34
9.	Support Electronics Simplified Block Diagram.....	36

I. INTRODUCTION AND SUMMARY

A. Introduction

Phase II of the Machine Mounted Respirable Dust Monitor (MMRDM) contract included the fabrication of one prototype respirable dust sampler/detector assembly, (See Figure 1 and Figure 2), the design and fabrication of support electronics, (See Figure 3), and the laboratory testing of the MMRDM in accordance with the Phase I specification, (Section 1.4 of the contract). The prototype MMRDM design from Phase I required all hardware to be mounted on a common baseplate which would be housed and protected by a final assembly container (See Figure 4) suitable for environmental testing. The basic hardware included in this rugged container is as follows:

- Air Mover
- Particle size selector
- Filter
- Beta absorption detection system
- Complimentary hardware supporting the above

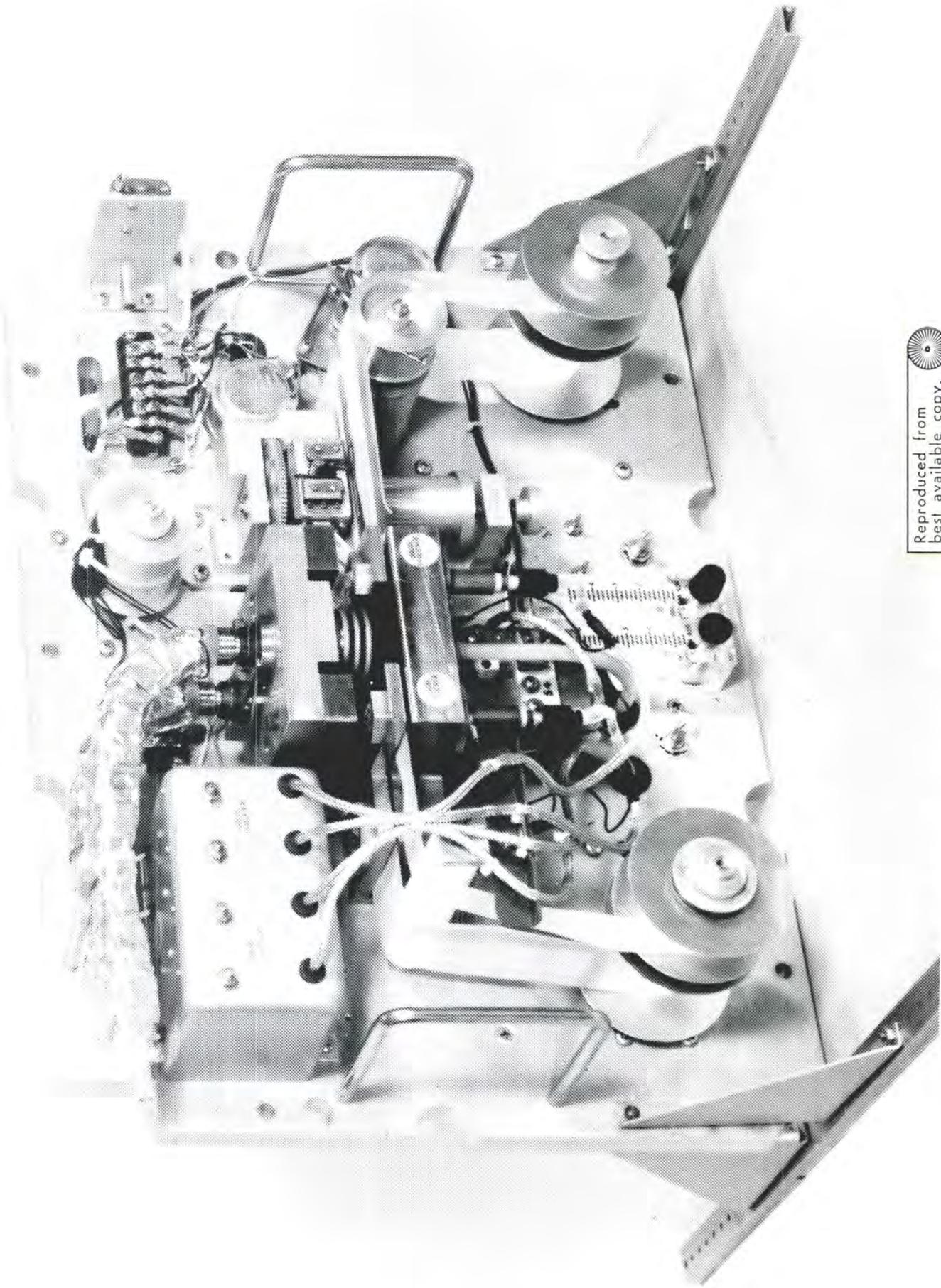
The support electronics was designed to give maximum flexibility for controlling the MMRDM within a reasonable cost. The self-contained support electronics is hardwired in a separate console for convenience when in use. Its purpose is to power, time, and control all functions initiated in the MMRDM; to tally the beta absorption counts; and to display the counts and the current time of each cycle both the long term (eight hour collection) and the short term (up to a fifteen minute collection). A microprocessor was used for implementing the controlling functions in the support electronics. The requirements for the support electronics did not specify environmental testing.

All testing was conducted at Bendix except for the shock test which was accomplished at a testing laboratory in Massachusetts. Results of the testing indicate that the MMRDM is operational for the imposed limits of $\pm 15\%$ for the eight hour long term collection and $\pm 25\%$ for the fifteen minute short term collection.

B. Summary

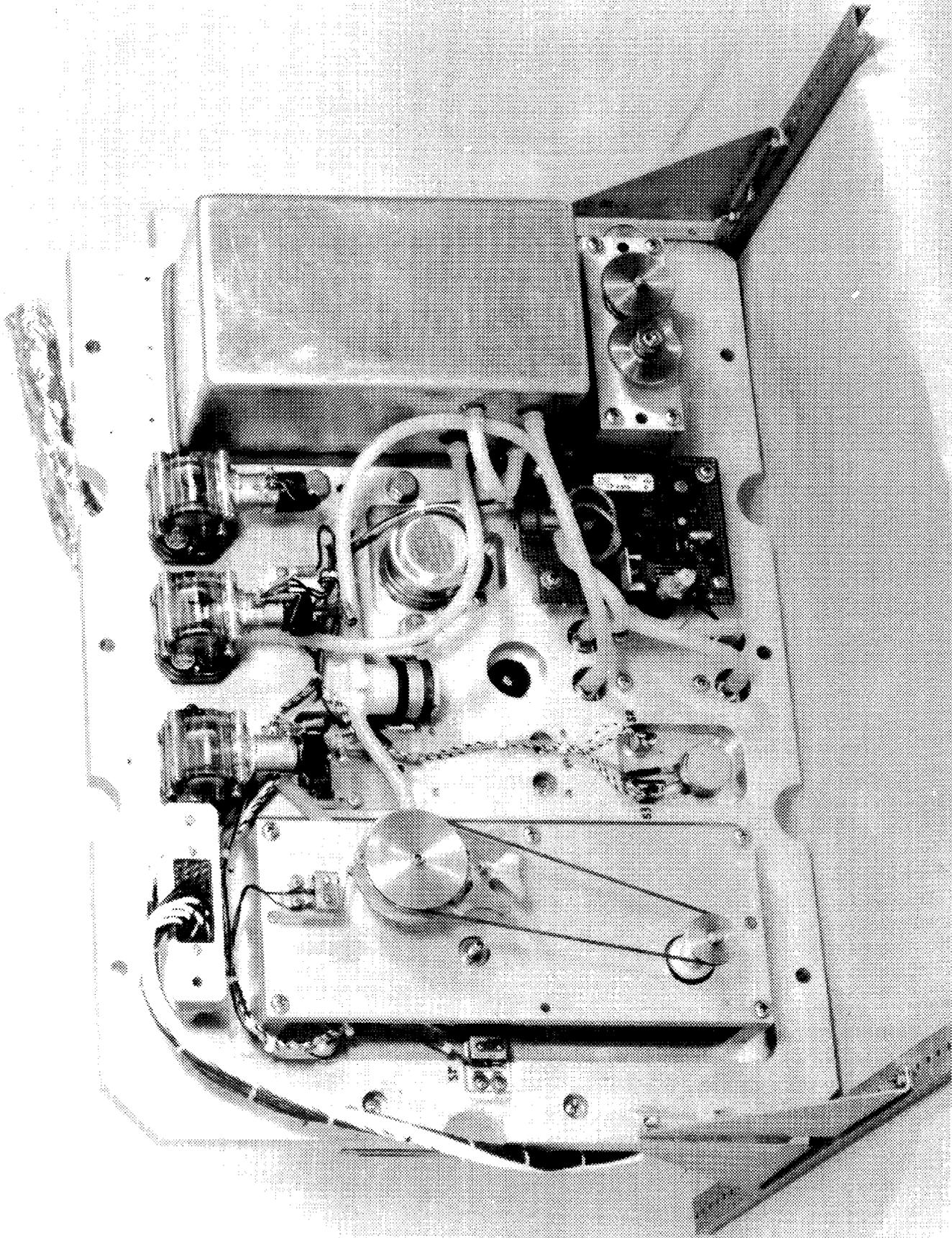
1. Mechanical Hardware

All mechanical hardware was mounted on a baseplate securely positioned in an armor clad housing and sealed with a cover of comparable strength and integrity. The housing and baseplate were necessary for testing the system as a unit and not as individual components. In missile environments, components that function very well individually occasionally fail as components



Reproduced from
best available copy.

**Figure 1. Prototype Respirable Dust Sampler/Detector Assembly
(Front View)**



**Figure 2. Prototype Respirable Dust Sampler/Detector Assembly
(Rear View)**

Reproduced from best available copy.



Figure 3. Support Electronics

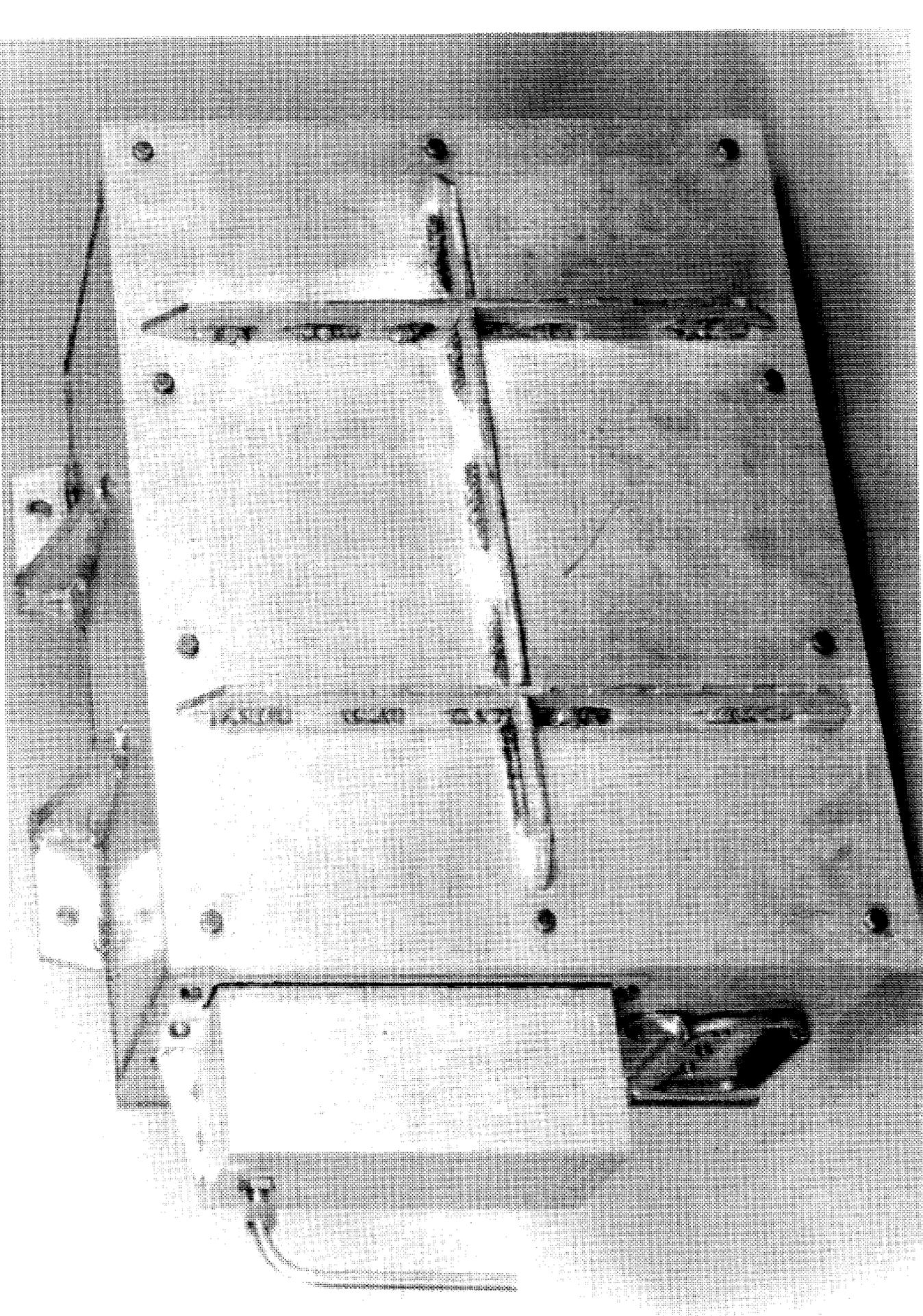


Figure 4. MMRDM Housing

in a system. The interactions of components and mounting structure can amplify the driving acceleration inputs to the individual components by many factors. For this reason it was believed necessary to investigate the compatibility of all the components when married as a common unit. The environmental testing results proved the hardware to be not only functional after many hours of testing, but also to be functional during testing.

All components were hard-mounted to a supporting structure. The mounting structural design philosophy can be approached from two different directions - one being a very soft-mounting system where the natural frequency of the loaded system is lower than the vibratory frequency - therefore, the structure will not follow the input. The second approach is where the loaded system natural frequency is above the vibratory frequency where attenuation or amplification is unlikely.

The design approach selected a stiff mounting system that would possess a natural frequency high enough not to affect the integrity of the mounted components.

The mechanical hardware fabricated for the MMRDM successfully met contract requirements. The contract stated that the hardware to be fabricated would consist of an air mover, a particle size selector, a filter, and a beta absorption detection system. The detailed mechanical hardware to satisfy this requirement consisted of the following:

- air mover
 - pump assemblies
 - fluidic capacitor (tank)
 - flow meters
 - fluidic flow controls
 - upper transitional head assembly
 - lower transitional head assembly
 - pneumatic system
 - upper head assembly lift mechanism (powered and manual)

- particle size selector
 - inlet tube
 - inlet plenum
 - two 10 mm *Dorr-Oliver nylon cyclones with oversized grit pots
 - mounting plate
 - heated pneumatic lines

*Reference to specific company names, products, or services is for information purposes only and does not constitute endorsement by the Bureau of Mines.

- filter
 - filter media
 - filter media drive, indexing, supply and take-up system
 - filter media dust spot punch and dust spot container
 - filter media dust encapsulation

2. Electronic Hardware

The electronic hardware consists of the beta absorption detection system and the electronic flow controller. The beta absorption detection system includes the following hardware:

- detectors (Geiger-Muller (G-M) tubes)
- high voltage power supplies
- solid state preamplifiers
- beta sources

The electronic flow control system encompasses the following hardware:

- motor control circuits
- differential pressure switch
- double diaphragm sampling pump
- pulsation dampener
- differential pressure inducer

The function of beta absorption detection system is to detect changes in the mass between the beta source and the window (sensor) of the G-M tube. The G-M tube output is a function of the beta radiation penetrating the mass between the G-M tube and beta source. Since the penetration of beta radiation decreases with an increase in mass in the path of the radiation, the beta absorption detection system is a satisfactory sensor for determining dust mass and it is not sensitive to composition or particle size, at least for those materials found in underground coal mines.

The electronic flow control system monitors the action of a differential pressure switch and adjusts the pump motor to keep the switch action nearly constant. The differential pressure switch is connected pneumatically across a differential pressure inducer and is located in the inlet side of the pump.

3. Support Electronics

The support electronics for the MMRDM provides the vital functions listed below:

- +12V to the unit.
- Control signals to the motors that advance the tape.
- Control signals to the head lift mechanisms.
- Stable time base for exposure and counting.
- Display and hold the count data.
- Safety interlock functions.
- Allow for operator time interval selection.
- Allow for manual period termination and tape advance.

All the necessary support electronics was built into a desk top control console. It contains the system power supplies; one for the MMRDM and another to power the microprocessor control electronics. Six multifunction counters-timers are used. Four counters are used for, short term-clean tape count, short term-dirty tape count, long term-clean tape count, long term-dirty tape count, and two counters provide short term clock and long term clock functions.

Thumb wheel switches permit the operator to select the short term time interval (where both the tape reading time and sample collection time are the same), the long term sample time, and the long term tape reading times.

Since the short term counters are in almost constant use, a display module was added to hold the count between tape advance intervals. The long term counters are programmed to store the count during the long term sample exposure time since the counters are not operational during this time.

A microprocessor was programmed to control the operation of the MMRDM. The sequence of operations is basically as follows:

- Sense the need for advancing tape either from the termination of the time interval or the manual switch.
- Stop the clock and counter, holding the count.
- Start the head lift motor and run until the head is up.
- Start the tape advance motor and run the tape forward the proper amount.
- Let the head return to the fully down position.
- Transfer or store the count.
- Zero the clock and counter if required.
- Restart clock and counter if required.
- Return to wait state for next command.

A more detailed discussion of the support electronics is contained in the section on support electronics.

4. Testing

Testing of the MMRDM was grouped into functional testing, and environmental testing.

Functional testing and investigation of all components of the MMRDM were made to insure that the:

- Filter media will index accurately.
- Filter media will withstand being driven with a clogged drum.
- Filter media spool diameter changing will not be a problem.
- Inlet heaters will produce enough heat for evaporating water, etc.

Environmental testing consisted of only those tests specified in the contract such as:

- Temperature extremes (32^oF to 120^oF)
- Relative humidity extremes (10% RH to 95% RH)
- Vibration (4g's, up to 500 Hz, for 10.5 hours)
- Shock (20g's, 11ms, and 18 shocks)

Results of the environmental tests indicate that the MMRDM remained functional throughout the tests, was ruggedly designed, and refinements should be made in a succeeding phase.

II. AIR MOVER AND PNEUMATIC SYSTEMS

A. Introduction

The MMRDM contains two pneumatic systems: one for the long term sampling and one for the short term sampling. The air mover for both systems uses the Bendix double diaphragm pump, which is employed in the MESA-approved *Bendix Super Sampler Permissible Air Sampling Pump.

The pneumatic system of the MMRDM was changed during the environmental testing phase, when a contract modification required that an electronic flow controller be incorporated. See Figure 5 for Pneumatic System Block Diagrams.

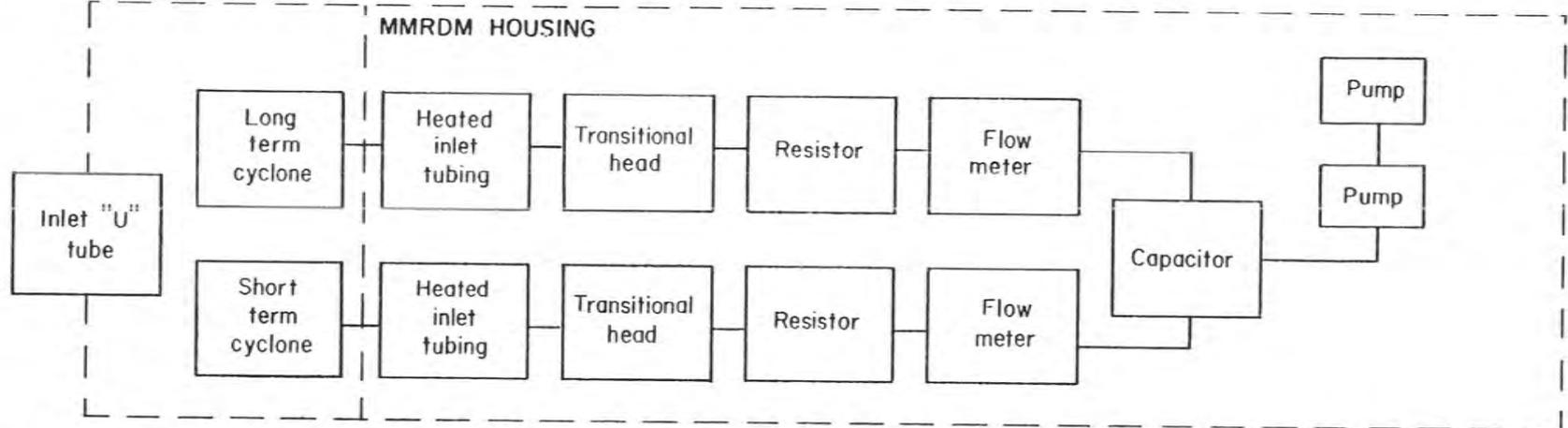
Prior to this requirement both long and short term pneumatic systems used a fluidic flow control based on a highly resistive system, where variations in the filter media resistances (clean filter versus maximum dust loaded filter) affect the flow less than 2.1% (See Appendix A). Both systems were fabricated and tested, and both systems will satisfy the flow control requirements.

The Phase I pneumatic system, which was first fabricated and tested, employed two double diaphragm pumps. Both pumps were connected pneumatically in series. The inlet of the second pump in the circuit was connected to the outlet of the first pump. Therefore, both pumps passed an equal volume of air. The second pump exhausted into the housing of the MMRDM. The first pump was connected on the inlet side to the fluidic capacitor (vacuum storage tank and system time constant). A pulsation dampener was not necessary because of the long system time constant. The fluidic capacitor was the common vacuum power source for both long and short term pneumatic systems. Cross talk was not experienced between the two systems; therefore, the two systems were compatible even though the transitional heads, where the dust spots are generated, are different in diameters.

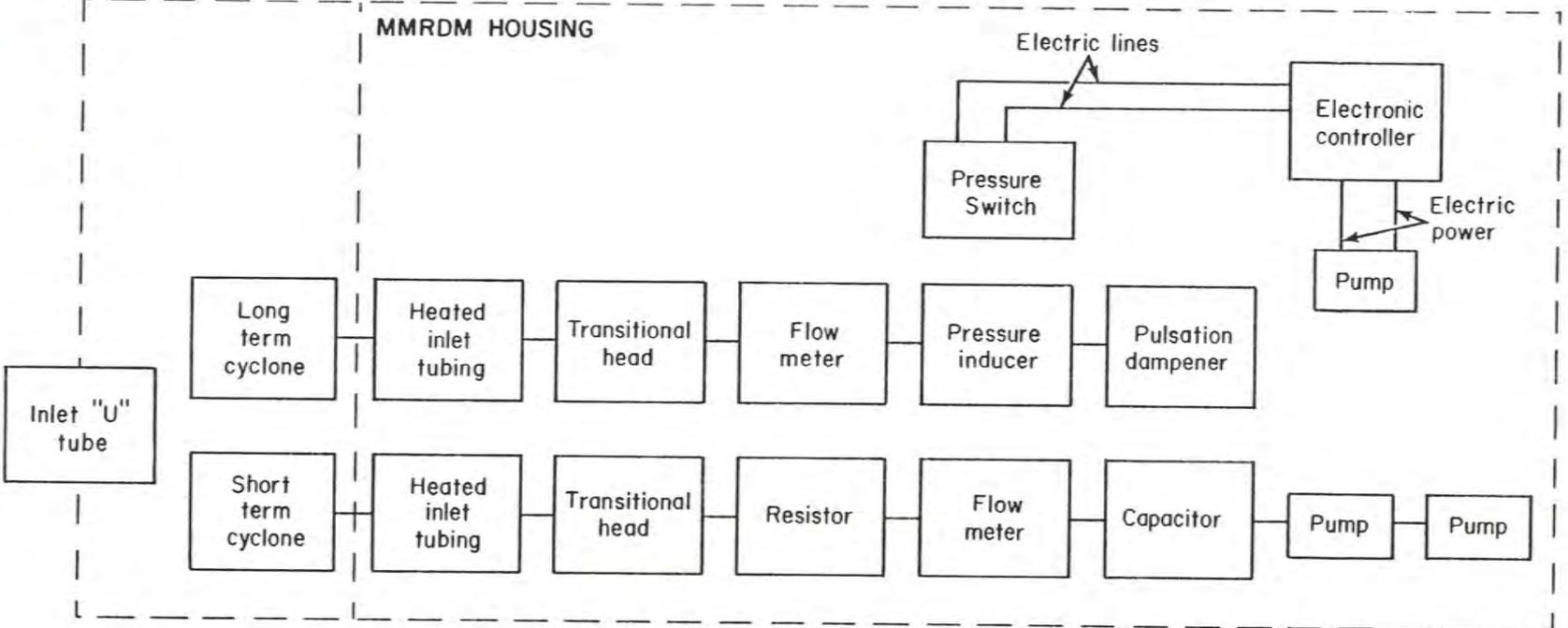
Two pneumatic lines came from the fluidic capacitor - one for the long term and one for the short term. The design of each system is essentially the same and are connected at the inlet plenum where they both use the same inlet tube.

*Reference to specific company names, products or services is for information purposes only and does not constitute endorsement by the Bureau of Mines.

PHASE I DESIGN



PHASE II MODIFIED DESIGN



18

Figure 5. Pneumatic System - Block Diagram

The phase I flow control system advantages are the following:

- No moving part controller
- Fewer parts
- Rugged mechanical system - shock and vibration resistant
- Will not cause electrical interference or electrical line transients
- Smooth air flow
- Not subject to electrical pulses
- Requires less skill to maintain or repair
- Reliable

The Phase II modification changed the pneumatic system as follows:

- Removed the long term in-line pneumatic resistor
- Removed the long term connection from the pneumatic capacitor
- Added to the long term pneumatic
 - a *Bendix double diaphragm pump
 - a pressure differential inducer
 - an electronic controller module
 - a pneumatic connection from the flow meter to the pressure differential inducer

The long term electronic flow controlled pneumatic system is well within the required flow of 2 ± 0.1 liters per minute, even when the inlet resistance increases ten times the resistance (less than 0.8 inches H_2O) of a maximum dust collection of 5 mgs. The electronic flow controlled approach will increase the life of the pump motor and will use less electrical power to operate.

Anticipated future requirements will make the electronic flow control the best approach since the MMRDM will be required to operate for a number of hours on the self-contained rechargeable battery. Since space on mining equipment is at a premium, the required battery volume will be of great concern and power justifications will be scrutinized. Therefore, it is anticipated that future phases of the long term and short term pneumatic systems will be identical.

*Reference to specific company names, products, or service is for information purposes only and does not constitute endorsement by the Bureau of Mines.

B. Air Mover

The air mover is a double diaphragm pump that is used in approved mine sampling equipment. The pump has proven to be reliable, and yet is easily repairable when necessary. The double diaphragm pump is a four-piece molded, high-impact plastic assembly containing a connecting rod, two diaphragms, and four flap valves, and is mechanically fastened with self-threading screws.

The pump motor powers the connecting rod through a low friction ball bearing/crank eccentric. The diaphragms are attached to the end of the connecting rod. As the connecting rod moves, one diaphragm pulls air into its chamber through two flap valves while the other diaphragm is expelling air from the opposite chamber through two other flap valves into an exhaust chamber. The pump exhausts into the MMRDM housing creating a slight positive pressure inside the assembly, thus, reducing the likelihood of external dust entering.

C. Pneumatic Capacitor

The pneumatic capacitor is an aluminum fabricated tank containing provisions for mounting and for attaching four pneumatic connections. The tank served two functions: first, as a fluidic capacitor which increases the pneumatic system time constant, and second as a continuous vacuum power source. It functioned as it was planned in Phase I. The pneumatic capacitor will be deleted in future designs when both channels use electronic flow controllers.

D. Fluidic Resistor

The fluidic resistor was necessary in the Phase I design and remains in the short term pneumatic system of Phase II, but it is not required with the electronic flow controller. The fluidic resistor is located in the bottom part of the short term flow meter. It functioned well in both the long term and the short term resistive capacitance fluidic network.

It serves the following function:

- Produces a significantly high resistive pneumatic circuit
- Reduces pump pressure ripples
- Minimizes the effect of pump speed variation

E. Flowmeter

The flowmeter used is a commercially available, *Dwyer VFA-23-55V. The scale is expanded so that a one liter-per-minute change is equal to a change in bead location on one half inch. The flowmeter was calibrated using a two liter bubble meter.

F. Transitional Plenums

Two sets of upper and lower stainless steel transitional plenums are used in the MMRDM. One set is for the long term pneumatic system and one set is for the short term pneumatic system. The upper and lower transitional plenums provide the necessary configuration to achieve a uniform dust deposition and not a center impact loader. The uniform deposition is very critical for accuracy since the Geiger-Muller (G-M) tube is smaller in diameter than the spot. Therefore, it is assumed in the mathematic ratio between the spot area and window area that the dust collected is of constant density throughout the spot.

The transitional plenums permit a 13-millimeter diameter spot to be deposited on the short term filter media and a 25-millimeter spot on the long term filter media.

G. Heated Pneumatic Lines

The heated inlet lines are teflon wrapped with *Clayborn heater tape, B-14-4, and insulated with an asbestos wrap covered with a reflective aluminum tape. The heater tape will raise the air temperature to more than 250°F during an air flow of 2 liters per minute. The air temperature varies depending on the location in the heated pneumatic lines. Temperatures were recorded from 150°F (3 inches into the heated lines) to 280°F (10 inches into the heated lines). The highest temperature recorded was 325°F at the end of the heated pneumatic line, yet the lines on the outside were not hot enough to be a hazard to personnel.

The heated inlet lines were needed to address the Phase I requirement of paragraph 1.4.1 " . . . contractor's design . . . shall consider the effect of liquid water in the collected sample on the accuracy and performance of the sampler/detector assembly". The major concern was to ensure that the water will pass through the filter media. If it were to collect on the filter media along

*Reference to specific company names, products, or services is for information purposes only and does not constitute endorsement by the Bureau of Mines.

with the dust, the beta absorption detection system is unable to discriminate which part of the total mass is dust. The mass of the water droplets influence the total calculated mass. The Bendix approach is to heat the air sample to a temperature where the water has to change in state from a liquid to a gas in a short time period.

Water in the gaseous state will pass through the filter media, therefore, not contributing to the total recorded dust mass. The reason for not just changing the relative humidity slightly so that the water droplets could more readily evaporate is that the time for the water to change state is short. The heat is also required since the transitional heads are effective heat sinks, thus, reducing the temperature considerably as the sample reaches the filter media. The sample temperature at the filter media should be kept as high as possible, but not higher than a safe temperature for the *Delnet backup membrane structure, a polypropylene scrim, when exposed for a total of eight hours.

*Reference to specific company names, products, or services is for information purposes only and does not constitute endorsement by the Bureau of Mines.

III. PARTICLE SIZE SELECTOR ASSEMBLY

A. Introduction

The contractual scope of work requires that the respirable fraction of the airborne dust shall be determined by one of the following methods:

- A 10 mm *Dorr-Oliver nylon cyclone operated at 2 liters/minute.
- A MRE elutriator operated at 2.5 liters/minute.
- A size classifier operated at some other flow rate but having penetration characteristics comparable to the MRE elutriator.

It also requires the design to consider the effect of liquid water in the collected sample and its effect on the accuracy and performance of the sampler/detector assembly.

The Bendix MMRDM employs the following features to meet the requirements as stated:

- A 10 mm *Dorr-Oliver nylon cyclone is used.
- A chamber traps the liquid water if present with the sample.
- Pneumatic inlets minimize accepting liquid water.
- Heated pneumatic lines prior to the filter media but inside the sample/detector assembly vaporize water droplets when present.

B. Particle Size Selector Assembly

The particle size selector (Figure 6) is as close to the filter media as possible in order to minimize the possibility of residual dust dislodging and settling on the filter media. Whenever a remote pneumatic inlet is required, obstruction to the operators vision will be minimized by installing a simple protected tube. The simplicity of installation for remote inlets greatly increases the flexibility of the design from one mining machine to another.

The particle size selector assembly consists of the following:

- Two 10 mm *Dorr-Oliver nylon cyclones with modified traps
- Mounting plate
- Sealing cover
- Inlets

*Reference to specific company names, products, or services is for information purposes only and does not constitute endorsement by the Bureau of Mines.

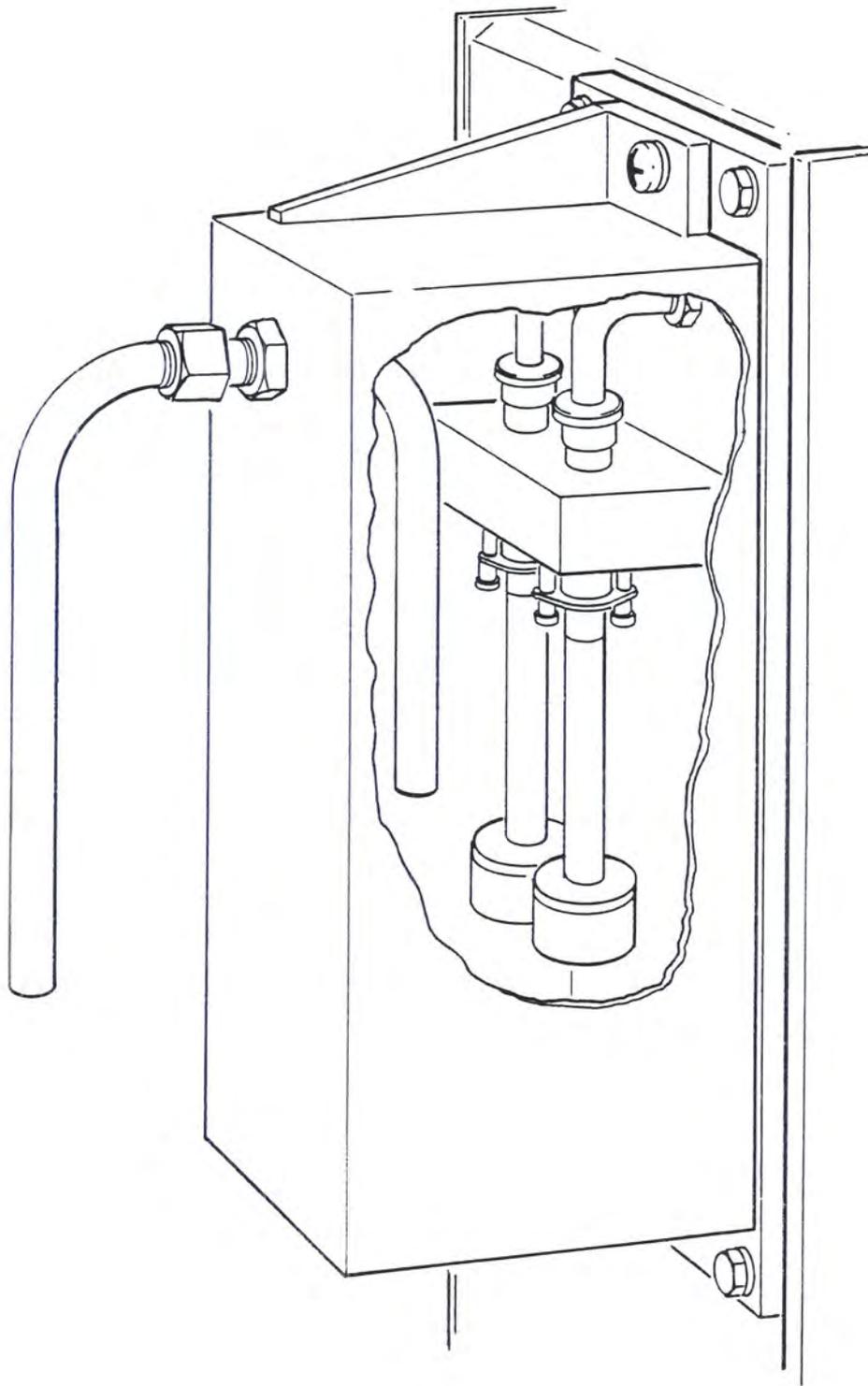


Figure 6. Particle Size Selector Assembly

Two 10 mm *Dorr-Oliver nylon cyclones are used to separate the respirable dust from the airborne dust. The cyclones are proven products and enhance the confidence level that only respirable dust will be collected and monitored. Both cyclones extract respirable dust from the sensing volume which is created by the sealing cover. The cyclone inlets are adjacent to each other for increasing the correlation between the short term sampling and the long term sampling. The sensing volume serves as a liquid water separator and a collector of dirt mischievously induced into the sensing inlet.

A volumetric modification to the cyclone dust traps entailed replacement of the current trap with a bushing and a cup. The size of the cup is adequate for a two month operation and was scaled from the existing trap.

The base plate contains the cyclones and the sealing cover and is secured to the MMRDM housing. The cyclone assemblies are well protected with a rugged sealing cover and should provide adequate service without malfunctioning.

The sealing cover contains a pneumatic fitting which serves as an inlet to the sensing chamber or as a connector for remote pneumatic inlets. A typical remote pneumatic inlet is shown in Figure 7. The recommended orientation of all inlets is typical of a man breathing air with the flow in an upward direction at an inlet velocity that is comparable to man. A single inlet diameter of 1.4 cms simulates this condition for the proposed dual channel system.

*Reference to specific company names, products, or services is for information purposes only and does not constitute endorsement by the Bureau of Mines.



Figure 7. Remote Inlet Location

IV. FILTER MEDIA

A. Introduction

During Phase I a search was conducted for filter media candidates that would satisfy the following requirements:

- Nonhygroscopic
- A membrane filter
- Retains 99 percent of one micron and larger dust particles
- Alpha quartz content of less than five micrograms per 1,000 square millimeters of filter area.
- An infrared window with respect to transparency at the 800 reciprocal centimeter region
- High heat resistance
- Suitable structural durability
- Available in tape form

Of the many vendors searched, only three materials found became candidates:

- A polycarbonate membrane, N500C PR203-01, from *Nuclepore, Inc.
- A polyvinylchloride (PVC) membrane, 50-50 PVC, from the *Amicon Corp.
- A teflon/polypropylene membrane, L10475, from *Gore, Inc.

A variety of filter sizes of the three candidate filter media was subjected to a maximum dust loading to determine the optimum operational filter parameters such as:

- Filter size
- Pressure drop
- Dust retentive characteristics

After the above was investigated, only two candidates remained; *Amicon and *Gore. The *Gore filter media was selected for the long term system since it was structurally more durable and could withstand a large unsupported area, which was required for the long term media. The short term system required a low mass filter but a strong filter media. The *Amicon media appeared to be a good choice. Low mass was needed to develop better discrimination between the mass of very light dust deposits and the mass of the filter media.

*Reference to specific company names, products, or services is for information purposes only and does not constitute endorsement by the Bureau of Mines.

The light dust loadings range from 60 micrograms to 625 micrograms distributed uniformly across a 13-millimeter diameter dust spot.

Phase II started with the filter media candidates being:

- A teflon/polypropylene membrane, L10475, *(Gore, Inc.) for the long term filter.
- A polyvinylchloride membrane, 50-50 PVC, *(Amicon Corp.) for the short term filter.

B. Phase II Status at the Beginning

During a 7 March 1977 meeting with the Technical Project Officer, it became apparent that the *Gore filter media did not possess an adequate infrared (IR) window even though the vendor had indicated that it was obtainable through two methods:

- A hot press treatment of the dust spot filter media (See Appendix B) or
- By adding Nujol to the support side of the filter media.

The above methods of obtaining acceptable results became less satisfactory. The problem was serious since the success of the MMRDM depended on obtaining an acceptable customer-approved filter media.

C. Meeting with the Two Vendors

Bendix met with two vendors and shared the problem with them and asked for suggestions. There was a strong feeling the the *Gore material possessed a satisfactory IR window when processed by one of the two methods. The only recommendation at this time was to continue with the existing material.

When talking with *Amicon, another concern arose and that was whether or not the material could be powered via a cogged drum and the fact that the material was not readily available in tape form.

D. New Filter Media Search

1. Vendor Search

Although not part of this Phase II contract, Bendix pursued a filter media search. Approximately sixty vendors were solicited for candidate

*Reference to specific company names, products, or services is for information purposes only and does not constitute endorsement by the Bureau of Mines.

filter media. The list of contacts was established from the Thomas Register and from filter media vendors.

2. Functional Tests Conducted on Sample Specimens

Thirty-one different kinds of filter media from twelve vendors were tested for compliance with the following specifications:

- The material shall not dissolve or decompose when emerged in ethyl or isopropyl alcohol.
- The flow resistance through a filter area of 1.3 square inches shall not be more than 1 inch-of-water at an airflow rate of 2 liters-per-minute.
- The strength and surface characteristics of the filter shall be such that dust deposited on its surface may be removed ultrasonically without tearing or degrading of the filter media.
- The filter media shall be a self-supporting membrane type.
- The filter media shall be ultrasonically weldable to polyethylene.
- The filter media shall be capable of being pulled with a cogged drum.

3. Filter Media That Met Bendix Requirements

Thirteen of the best candidates were selected and sent to MESA for further testing.

4. Results of the MESA Tests

MESA tested each specimen for the following:

- Dust Penetration
- Hygroscopic property of the media
- Flow resistance
- Solubility
- Possibility of degradation of the media by ultrasonic activity

Only two filter media were acceptable. Both are products from the same vendor, *Hollingsworth and Vose Company. The remaining eleven specimens failed one to three of the tests. See Appendix C for the test results.

The *Gore-Tex plus *Delnet failed only the penetration test. The vendor was contacted, and it was believed that the material should have passed the penetration test if the material was of the quality the vendor believed that

*Reference to specific company names, products, or services is for information purposes only and does not constitute endorsement by the Bureau of Mines.

it was and assuming that the material was not damaged between the vendor, Bendix and MESA.

A new lot of material was procured from *Gore Associates and a sample was sent to MESA requesting another set of penetration tests. The test results were favorable.

5. Selected Candidate

The selected candidate was the *Gore-Tex laminated with *Delnet. The density of this filter is less than the original *Gore-Tex used for the long term channel. Therefore, the filter media may be used for both the long term and short term channels. There has been preliminary infrared testing conducted at the U.S. Bureau of Mines and these results indicate that the filter media has an adequate infrared window.

*Reference to specific company names, products, or services is for information purposes only and does not constitute endorsement by the Bureau of Mines.

V. BETA ABSORPTION DETECTION SYSTEM

A. Introduction

The beta absorption detection system consists of a beta source, a G-M tube, a high voltage supply for the tube, and a solid state preamplifier. The dust monitor operation requires the use of four beta sources and four G-M tubes. In the short term sampling system, one beta source and one G-M tube read the clean tape and a second source and tube read the dust sample after the collection cycle has been completed. In the long term sampling system, a beta source and G-M tube read the clean tape and a second source and tube read the dust sample after the collection cycle has been completed.

B. Detector

The detector G-M tube size was chosen to be compatible with the spot size which was deposited. The spot size was chosen by computer analysis. For the long term sample, an end window G-M tube with an effective window diameter of 1.98 cm was used. For the short term sample, an end window G-M tube with an effective window diameter of 0.917 cm was procured.

The main objective of the detector selection was to obtain an effective window diameter that approached the diameter of the spot to be measured.

Laboratory tests on an experimental detection system showed that measurement accuracy by the beta absorption technique improved as the total area of the deposit sensed by the G-M tube increased.

*LND, Inc., 3230 Lawson Blvd., Oceanside, NY 11572, tube type 7242 was used for the long term sampling system and the tube type 711 was used for the short term sampling system.

C. Beta Source

The primary considerations in the selection of the beta source were areas of the source, activity of the source, and source material. The area of the source was selected to be greater than the effective window size so that source and tube alignment would not be critical. A gap spacing of 0.08 inch between the source and the tube was selected to minimize the effects of air density changes and focusing effects.

*Reference to specific company names, products, or services is for information purposes only and does not constitute endorsement by the Bureau of Mines.

In the short term measurement system, a nickel 63 source of approximately 0.8 cm^2 was used for the clean tape and the sampled tape sources. The specified activity was $80000 \text{ } \beta/\text{min}/\text{cm}^2$. The short term source is supplied by *Monsanto Nuclear Products, Dayton, Ohio 45407. The source is mounted on a nickel foil strip.

The long term measurement system utilized a carbon 14 source of approximately 5.06 cm^2 . The specified activity was $1.8 \times 10^6 \text{ } \beta/\text{min}/\text{cm}^2$. The long term source is supplied by *Amersham/Searle, Arlington Heights, IL. The beta source is mounted on a polymer film which is bonded to a holding fixture.

D. High Voltage Source

Each of the four G-M tubes is powered by separate power supply modules which convert the 12 volt dc to 700 volt dc. Individual supplies are used to prevent cross talk between channels and to ensure that the current levels are low enough to preclude spark hazards. The 700 volt dc sources have a potentiometer so the output count from the clean tape source can be adjusted to equal the output count from the sample counter tube when no dust sample is present by adjusting the voltage supplied to the tube and the tube to source spacing.

Many manufacturers of power supplies were investigated and it was found that the requirements could be satisfied by several. The (power supply) PN C-8T was procured from *Venus Scientific, Inc., Farmingdale, NY 11735.

E. Solid State Preamplifier

Due to the high impedance circuitry associated with a G-M tube, care was exercised in the circuitry layout and in the choice of input circuits. To provide counting accuracy and to limit stray capacitances and parasitic effects, the input resistors for each G-M tube are mounted close to each tube and the anode of each resistor is physically mounted on the tube. The output from each G-M tube is fed to a field effect transistor (FET) connected as a source follower. The output of the source follower is of a sufficiently low impedance that the output signal can be distributed by shielded wire to the signal conditioning and counting circuitry.

*Reference to specific company names, products, or services is for information purposes only and does not constitute endorsement by the Bureau of Mines.

VI. ELECTRONIC FLOW CONTROL

In the long term dust collection system, air flow through the collecting media is maintained constant by using an electronic flow control system to regulate the sample pump speed.

The main elements of the control system are:

- Differential pressure inducer
- Pressure switch
- Pulsation dampener
- Double diaphragm sampling pump
- Motor control circuits

The theory behind the electronic flow control states that by using a differential pressure inducer with a constant flow through the inducer, a constant differential pressure will be produced on each side of the inducer. If the flow changes, this pressure will change. Using this principle and a differential pressure switch connected across the inducer, an electronic flow control system may be made. A schematic of the electronic flow control is shown in Figure 8.

The opening and closing of the pressure switch contacts impress a voltage on an integrating capacitor. This voltage is sensed by a high input impedance FET amplifier stage which controls a series pass regulator circuit that supplies power to the pump motor.

As the flow attempts to change, the pressure switch detects the resulting pressure change and the voltage on the integrating capacitor is shifted. This voltage change is amplified causing the series regulator to supply more or less power to the motor as required to correct the air flow and return it to its preset value. Circuit values are chosen to provide smooth operation and not respond to pump pulsation. Tests have shown that the flow rate remains in tolerance while operating even with a varying inlet fluidic resistance.

To improve reliability and reduce dissipation in the pump motor pass transistor, a regulated voltage is supplied to the electronic flow control. This also helps reduce interaction with the rest of the system electronics.

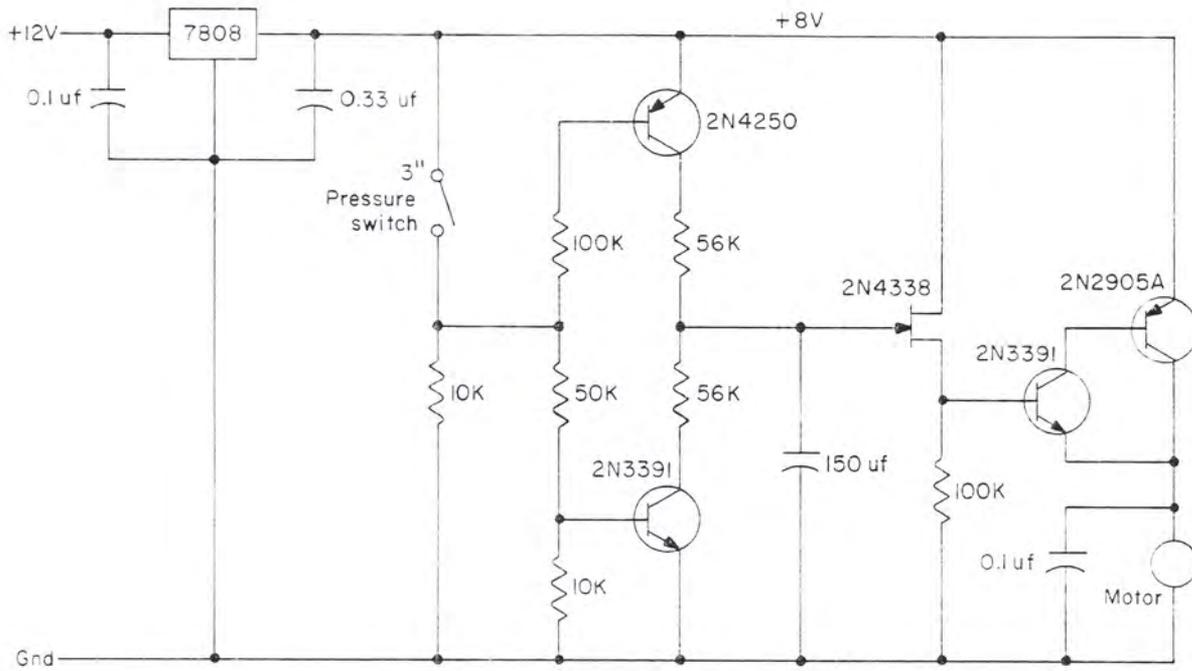


Figure 8. Electronic Flow Control Schematic

VII. SUPPORT ELECTRONICS

A. Control System

The approach to the control system design began as a study effort to identify the tasks that must be accomplished. This effort also provided necessary information to perform effective comparison among three methods. One system used motor driven cam switches. Another system used discrete electronic components. The third system incorporated a microprocessor.

The system using a microprocessor was selected. A simplified block diagram is shown in Figure 9.

A one card system, *Pro-Log Corporation, PLS-881, using the 8080A microprocessor was selected. A relay interface card controls the motors, and another card contains miscellaneous buffers and interface circuits.

Two sets of digital display modules were added for the short term tape counters, since the data is held on the counters for only a few seconds while the tape is advancing. The additional display modules hold the count of the last period during the current counting period.

B. Counters

The *Data Precision Corporation, Model 5740 counter was selected for each G-M tube to allow maximum flexibility and simplicity of operation. The major features in the clock/counter are:

- Readable display
- Event range of 9,999,999 plus overflow
- Remote control of operation
- Parallel data outputs
- TTL compatibility

C. Clock

A separate *Data Precision Corporation, Model 5740 Multifunction Counter is used as the system clock for each tape channel. These instruments, the same as used for the frequency counters, provide a time range of 0 to 99,999.99 seconds (27.77 hours).

*Reference to specific company names, products, or services is for information purposes only and does not constitute endorsement by the Bureau of Mines.

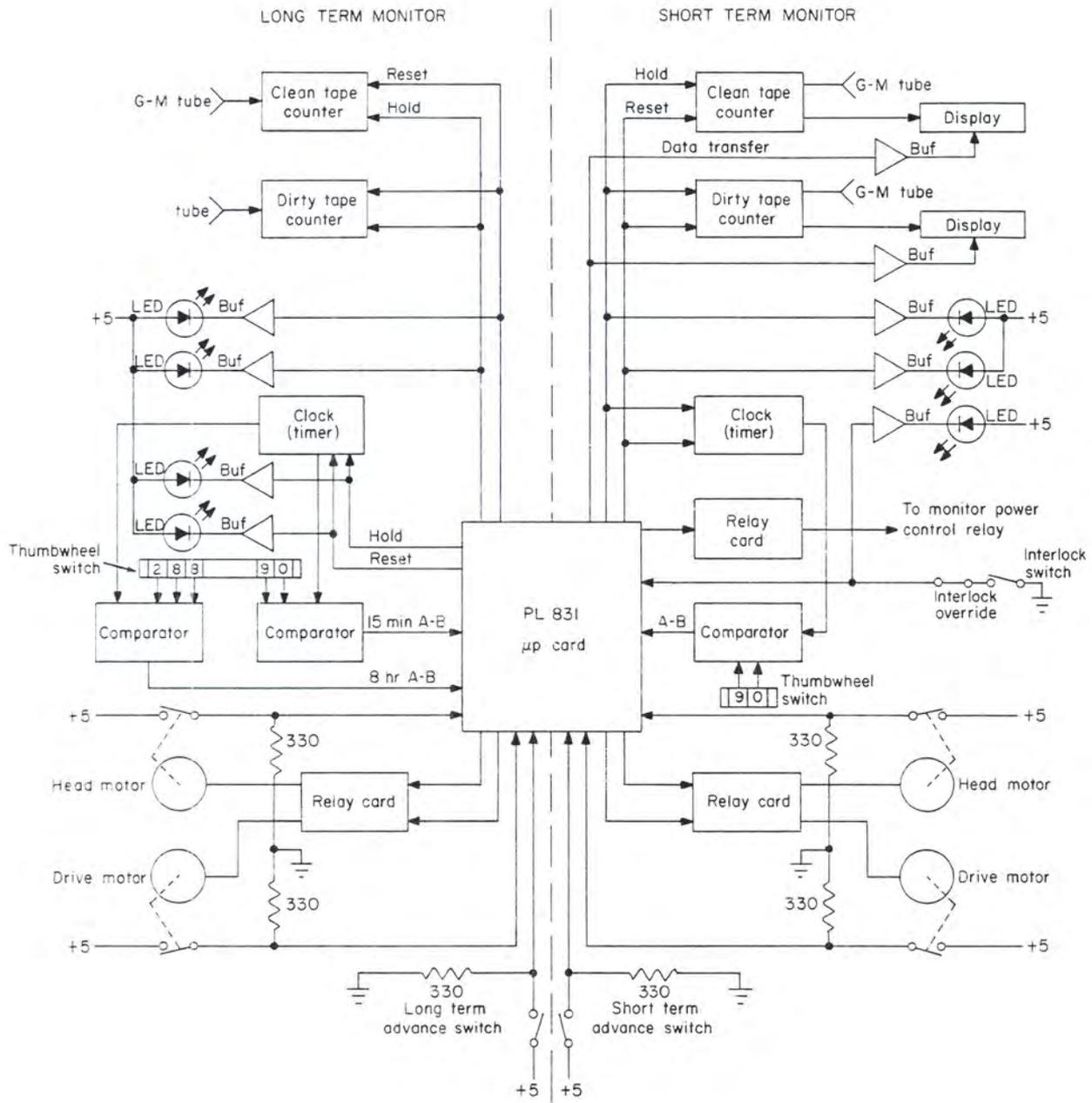


Figure 9. Support Electronics Simplified Block Diagram

D. Internal Timing

To allow maximum flexibility in test and operation, the operator selects the time period used for dust collection and tape reading.

In the case of the short term sample, sample collection and sample readout times are the same. As each sample is being collected, a section of clean media is being read and the previously collected sample is being read. A thumbwheel switch on the control panel allows interval selection from 10 to 990 seconds (16.5 minutes).

The long term channel has two sets of thumbwheel switches allowing readout times from 10 to 990 seconds (16.5 minutes) and exposure times from 100 to 99,900 seconds (27.75 hours).

The desired times are dialed in seconds x 10 for reading time and seconds x 100 for long term exposure time.

Three sets of bit comparators are used to combine the clock output data with the time desired.

The result is a group of 3 lines to the microprocessor that represents (1) the short term clock start signal, (2) the long term clock signal for start of exposure, (3) the long term clock signal for start of the reading period.

In each case, after the start signal has been recognized and processed, the clock is reset to zero by the microprocessor before the next sequence is started.

E. Manual Switch

A manual switch initiates tape movement cycles for the short term tape and the long term tape on both the chassis of the dust monitor and the control console.

Operation of any manual switch will cause the operating channel to be terminated, the tape to advance and a new period to start. If there is a tape advance cycle in progress, it must be completed before the switch signal will be accepted.

F. System Power Supplies

The dust monitor system is operated from standard 115V 60 Hz power. The control chassis contains the main system power supplies.

A +12V supply furnishes power to the dust monitor chassis for the pumps, heaters, motors and G-M tube power supplies.

A triple output power supply furnishes +12V, +5V, -5V to the micro-processor and its associated circuits.

Separate G-M tube power supplies were used to reduce interaction between the system elements and for transient protection.

A single circuit breaker switch on the control chassis applies power to the system.

G. Interlock Action

Removal of the dust monitor case cover causes the interlock switch to operate. This switch controls a relay that turns off the +12V power supply that feeds the dust monitor. The removal of the 12V will turn off the G-M tube source, and shut down the motors and heaters.

The unit will not operate until the cover has been replaced or the interlock override switch on the control console is operated. When either condition has been satisfied, all circuits will be reset to zero awaiting a new manual start.

H. Indicators

To assist in following the system operation, several indicator lamps are provided.

The short term system has a reset and hold indicator over the short term interval thumb wheel switches. The reset lamp is on when the reset to zero signal is supplied to the counters. The hold lamp indicates that the values on the clocks and counters are being held. When both lamps are out, the clock is running and the counters are operating. Data from the short term counters is transferred to the data storage displays at the end of each interval and held until the end of the next interval to allow for manual copying of the exposure data.

The long term reset and hold indicator operates in the same manner, except there are separate reset and hold lines for the clock and counters. This allows the count to be held and displayed during the time a sample is being exposed to the air flow.

There are indicators in the card cage (Figure 3). On board 1, the interface board, there are four lamps that light when a switch closure is made. The top lamp is the long term tape head switch that operates when the modified head is in the up position. The second lamp is the long term tape drive switch which lights once for each increment of tape motion. The third lamp is the short term tape head position and the bottom lamp is the short term tape drive. They are operated the same as in the long term channel.

The #4 card (Figure 3) is the relay interface card between the microprocessor and the motors. A light on indicates that power is being fed to the motor. The lights and their function are listed from top to bottom.

1. Long Term Tape Head Motor
2. Long Term Tape Drive Motor
3. Not Used
4. Short Term Tape Head Motor
5. Short Term Tape Drive Motor
6. Interlock Relay Operated
7. Not Used
8. Not Used

I. Operating Sequence

1. General

The microprocessor, after the power on sequence which resets the clocks and counters, looks for start signals from either the clocks or the manual switches. Since the clocks have been reset to zero, the manual start must be used for initial operation.

As soon as the start signal is received, data in the clock and counters is held and the tape head motor is started. This lifts the head until the limit switch showing the head is up has been actuated. The head motor turns off and the tape drive motor is started. The tape is pulled forward until the tape drive limit switch is actuated by the Geneva drive indicating the tape has advanced the proper amount. The drive motor turns off and the head motor is restarted. The head lowers and when it is down, the head motor is stopped and the clocks and counters are reset and started.

The microprocessor searches for the next start signal from either the clocks or manual switches.

There are a few minor differences between the channels. The short term program stores the counter data in the display before resetting and starting a new time interval.

In the long term channel, the microprocessor is programmed to alternate between two programs; one moves the tape one increment, and the other moves the tape two increments. Also, the counted exposure data is held in the counter display while the next air sample is being taken.

2. Long Term Tape Movement Sequence

- Recognize start signal, either clock or manual switch
- Determine if tape is to be moved 1 position or 2 positions
- Stop clock and counters
- Hold data
- Raise tape head
- When head is up, start tape drive
- Advance tape the correct amount
- Lower tape head when tape drive is turned off
- Reset clock to zero
- Reset counters to zero if required to start count sequence next
- If exposure sequence next - hold counter data
- Start clocks
- Start counters if count interval is next
- Await next start signal

3. Short Term Tape Movement Sequence

- Recognize start signal either manual or clock
- Stop clock and counters
- Hold data
- Latch data in display module
- Raise tape head
- When head is up start tape drive motor
- Index tape 1 position and stop drive motor
- Lower tape head
- Reset clock and counters to zero
- Start clock and counters
- Await next start signal

J. Microprocessor System

1. General

To implement the control functions, a single card microprocessor system was chosen. It has more than adequate memory, speed, and input-output capability. The relay interface card takes the low level microprocessor signals and uses them to control the relays to turn the motors in the MMRDM on or off.

A listing of the input-output port assignments for the logic system follows.

2. Input Assignment

Port 0

1. Long Term Manual Switches
2. Long Term Exposure Clock Signal
3. Long Term Read Clock Signal
4. Short Term Manual Switches
5. Short Term Clock Signal
6. Not Used
7. Not Used
8. Not Used

Port 1

1. Long Term Head Position Switch
2. Long Term Tape Drive Switch
3. Short Term Head Position Switch
4. Short Term Tape Drive Switch
5. Not Used
6. Not Used
7. Not Used
8. Not Used

3. Output Assignment

Port 0

1. Long Term Clock Reset Line to Buffer
2. Long Term Clock Hold Line to Buffer
3. Long Term Tape Head Motor to Relay
4. Long Term Tape Drive Motor to Relay

5. Not Used
6. Long Term Counter Reset Line to Buffer
7. Long Term Counter Hold Line to Buffer
8. Not Used

Port 1

1. Short Term Clock Reset Line to Buffer
2. Short Term Clock Hold Line to Buffer
3. Short Term Tape Head Motor to Relay
4. Short Term Tape Drive Motor to Relay
5. Data Transfer to Buffer
6. Not Used
7. Not Used
8. Not Used

Port 2

1. Interlock Relay to Relay
2. Not Used
3. Not Used
4. Not Used
5. Not Used
6. Not Used
7. Not Used
8. Not Used

4. Program

The processor program is arranged in functional groups:

1. System Initialization
2. Interlock Program
3. System Reset
4. Main Scan
5. Long Term Manual Switch or exposure clock - 1 step
6. Long Term Read Clock - 2 step
7. Short Term
8. Three Second Delay

Room has been left in the microprocessor to allow growth potential. Room for expansion is also present since only one PROM has been used. As an example, only one-quarter of the PROM has been utilized. Further, there is space for three additional PROMS on the single microprocessor board. A copy of the program used may be found in Appendix D.

VIII. TESTING

A. Introduction

Two types of testing were conducted. First the MMRDM was functionally tested under room environment to determine whether or not the mechanical and electrical hardware functioned in accordance with the design intent. Second, the MMRDM was functionally tested while exposed to environmental conditions similar to mine environments.

B. Functional Testing

The MMRDM was functionally tested as each component was assembled. It was found that modifications were required in some areas before continuing. This critical investigation of components, interfaces and interactions of this multi-component system was necessary to ensure a higher probability of success during the environmental testing phase. The following major assemblies were evaluated for adequacy of design and operation.

- Air mover and pneumatic system
- Particle size selector assembly
- Filter media
- Beta absorption detection system
- Support electronics
- Electronic flow controller

The following are problem areas that arose during functional testing the defective unit.

- The 12 volt power supply failed; vendor replaced the defective unit.
- The tape drive and transistional head lift motors were underpowered for the tasks required. It appears that the motor assembly was overrated. A gear pressed onto a shaft inside the motor assembly would slip causing a malfunction. Vendor stated that it would take a minimum of four months for another shipment and none were available from off-the-shelf. Bendix recovered by adding a speed reducer to develop the necessary torque for reliable operation.
- The material for Phase I long term filter media required a change since it possessed a customer unacceptable infrared window (not required by contract). Another filter media was found after a lengthy search which may be used for either the short term or long term channel.

- An unpredictable problem occurred with the coal dust that was used in the airborne dust generator. The problem caused considerable delay since it was assumed to be a hardware problem. The coal dust was oily, and airborne dust was difficult to generate and control. Once the cause of the problem was recognized, a new supply of coal dust was obtained, and the operation was back to normal.
- A contract modification required the flow to be electronically controlled and not mechanically controlled. Bendix proposed using a thermal type of flow sensor for this modification, but before ordering the hardware for the MMRDM, Bendix experienced malfunctions with the thermal type flow indicator used in laboratory test equipment. The thermal sensor(s) is very sensitive to the cleanliness of the air flowing through the sensor. Bendix changed its approach by utilizing a differential pressure inducer monitored by a differential pressure switch. The pressure switch duty cycle is monitored and controlled by an electronic package that controls the pump motor speed.
- The Scotch Tape roller bracket pivot point was redesigned to obtain more contact force when rolling the Scotch Tape onto the filter media.
- Punch structure was reinforced to prevent binding, and the filter material slot was increased to prevent the filter material from getting caught in the die.
- The manual and powered head lifting mechanism was modified to function easier.
- Excessive cross-coupling and erroneous counting were found when using a single high voltage power supply and amplifier circuits. The problem was corrected by using separate power supplies and separate shielded amplifiers.

C. Environmental Testing

The environmental test plan was designed to conduct one environment attribute at a time for those environments specified in paragraph 1.4.1 of the Phase I Scope of Work. The environments considered were as follows:

- Temperature (32, 70, 120°F)
- Relative humidity (10 to 95%)
- Dust concentrations: (Long term: 0.2 to 5 mg/m³)
(Short term: 2 to 20 mg/m³)
- Type of dust (coal, limestone, Arizona road)

- Vibration [MIL-STD-810B, METHOD 514, Procedure 1, Part 3, Curve W(4g)]
- Shock [MIL-STD-810B, METHOD 516, Procedure 1, saw tooth shock pulse amplitude (20g's), time duration-C (11 min)]

The environment test plan is located in Appendix F.

Environmental test data may be found in Appendix G. The recorded raw data was taken from the supporting electronic counters. The "clean tube count" is that data recorded for the clean filter media where the dust is about to be deposited. The "dirty tube count" is that data recorded for both the filter media and a percentage of the dust spot.

D. Dust Mass Calculations

The dust mass concentration is calculated by using the following formula and assuming the flow rate of the collected sample is 2 liters/minute

$$MC = \left[\frac{\ln \left(\frac{N_1}{N_2} \right)}{M} \right] D_d^2 \left[\frac{22619}{T_s} \right] = \text{mg/m}^3$$

- Where:
- MC = dust mass concentration in mg/m^3
 - N_1 = clean filter media beta count
 - N_2 = dirty filter media beta count
 - M = beta source mass absorption coefficient
 - D_d = diameter of the dust spot in cm.
 - T_s = dust collection time in seconds

The "factor to be multiplied by the log of the count ratio" is developed from the following factors:

- GM tube window area
- Dust spot area
- Mass absorption coefficient

The factor varies as the dust spot area varies or when the mass absorption coefficient changes, i.e. nickel₆₃ for the short term and carbon₁₄ for the long term. The long term calculation based on a handbook mass absorption coefficient value and verified in the laboratory is reasonably accurate. The short term calculation was in error about +90% based on a handbook mass absorption coefficient.

It can be noticed that the values in "factor to be multiplied by the Log of the Ratio" column change for both long and short term. The changes reflect the dust spot area changes.

At one of the meetings with the Technical Project Officer (TPO) during Phase II, there was an expression of great desire that Bendix conduct a mathematical study of the data for determining whether or not the Phase II data is in tolerance with confidence level of 95 percent (not required by contract).

Bendix conducted a study and the results are as follows:

● Long Term:

- Data used may be found in Appendix G
- The average of all data is -2.202% (See Appendix H)
- There is a 95% confidence level that all data will be within +13.05% and -17.46%
- There is a 97.28% confidence level that all data will be +15% or less
- There is a 90% confidence level that all data will be -15% or more
- If the average had been zero and the constant factor adjusted to create a normal distribution about zero, then a 95% confidence level will indicate all data would be encompassed between $\pm 15.25\%$.

● Short Term:

- Data used may be found in Appendix G
- The average of all data is -5.2664%
- There is a 95% confidence level that all data will be within +13.32% and -23.86%
- There is a 99.84% confidence level that all data will be +25% or less

- There is a 96.25% confidence level that all data will be -25% or more
- If the average had been zero and the constant factor adjusted to create a normal distribution about zero, all data would be within $\pm 18.59\%$ with a 95% confidence level.

See Appendix H for data study computer program.

See Appendix I for Shock Test Report from Associated Testing Laboratories, Inc.

IX. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The Phase II MMRDM hardware was fabricated in accordance with the Phase I design with improvements. The equipment described in this report meets the Phase I requirement for measuring variable levels of airborne respirable dust concentrations while exposed to laboratory simulated mining environmental conditions.

B. Recommendations

Recommendations listed below are based on the fact that the prototype hardware functioned as originally proposed.

- Another phase should be initiated to design machine-mounted electronic hardware that will meet the mining environment described in Phase I and the refinement of the prototype design.
- Packaging approach should be a modular concept instead of one container housing all hardware.
- Short term G-M tubes and long term G-M tubes should be the same to aid in logistics and to be more cost effective.
- Short term filter media and long term filter media should be the same width to aid in logistics and to be more cost effective.
- Short term and long term pneumatic systems should be the same.
- Short term and long term monitoring systems should be independent modules.
- The G-M window area and the dust spot area should be approximately the same in size to increase accuracy of dust deposition.
- The material used for the upper transitional heads should be investigated to reduce the heat sink effect.

APPENDIX A

TEST DATA OF THE ORIGINAL
FLOW CONTROL SYSTEM

Test Data of the Original Flow Control System
(A Highly Resistive Fluidic System)

Started Conditions:

Filter resistance	Actual Flow	
1.7 inches of H ₂ O	2.01 1/m	long term
	2.03 1/m	short term
2nd Reading:		
1.9 inches of H ₂ O	2.00 1/m	long term
	2.02 1/m	short term
3rd Reading:		
2.18 inches of H ₂ O	1.98 1/m	long term
	2.03 1/m	short term
4th Reading:		
2.27 inches of H ₂ O	1.98 1/m	long term
	2.02 1/m	short term
5th Reading:		
2.42 inches of H ₂ O	1.99 1/m	long term
	2.03 1/m	short term
6th Reading:		
2.6 inches of H ₂ O	1.99 1/m	long term
	2.04 1/m	short term
7th Reading:		
2.7 inches of H ₂ O	1.97 1/m	long term
	2.04 1/m	short term
8th Reading:		
2.75 inches of H ₂ O	1.97 1/m	long term
	2.03 1/m	short term
9th Reading:		
2.94 inches of H ₂ O	1.97 1/m	long term
	2.01 1/m	short term

The long term flow changed less than 2.1% when collecting more than 5 mgs of dust. During this time the short term varies less than 1%. Therefore, the resistive fluidic system can maintain the flow for each channel, long and short term, well within the 5% variation that is permitted even though both channels use the same common vacuum source.

APPENDIX B

FILTER MEDIA

INFRARED SCAN PREPARATION

IR SCAN SAMPLE PREPARATION - GORE-TEX LAMINATE L10475

- MATERIALS REQUIRED:
- (1) Carver Press (temperature-controlled platens)
 - (2) Heavy Aluminum Foil
 - (3) 2" x 2" polished metal plates
(2 required)

- PROCEDURE:
- (1) A "sandwich" is prepared as follows:

2" x 2" plate
foil
Laminate L10475
foil
2" x 2" plate
 - (2) The "sandwich" is placed between the Carver Press Platens (preheated to 350^oF), and allowed to heat 3-4 minutes.
 - (3) 5000 - 10000 lbs. pressure is applied to the laminate for 1 minute. (This is gage pressure; effective pressure depends upon the surface area of the ram in the cylinder).
 - (4) Release pressure, remove sample, let cool and remove metal plates and foil.

APPENDIX C

MESA FILTER MEDIA TEST DATA

RESULTS OF THE FILTER MEDIA TESTING CONDUCTED AT MESA

<u>Material</u>	<u>No.</u>	<u>P/N</u>	<u>Manufacturer</u>	<u>Press. Drop</u>	<u>Weldability</u>	<u>MESA Test Results</u>
Strips	11	-	Pallflex	0.2" of H ₂ O	Excellent	Failed: Penetration and Degradation
Zitex	13	H662-123	Chemplast	1.0" of H ₂ O	Excellent	Failed: Penetration Solubility and Degradation
Ramay	16	2470	DuPont	0.2" of H ₂ O	Good	Failed: Penetration Solubility and Degradation
P10FEJOH	21	77386	Pallflex	0.5" of H ₂ O	Excellent	Failed: Solubility
TX40A30	23	3389A	Pallflex	0.6" of H ₂ O	Fair	Failed: Hygroscopic and Degradation
E70-2075W	24	3353B	Pallflex	0.8" of H ₂ O	Good+	Failed: Solubility
Glass & Polyester	25	LD-2131	Hollingsworth & Vose	0.5" of H ₂ O	Good	PASSED
Glass & Polyester	26	HD-21-41	Hollingsworth & Vose	0.5" of H ₂ O	Good	Failed: Solubility
Glass & Polyester	27	LD-2151	Hollingsworth & Vose	0.5" of H ₂ O	Good	Failed: Solubility
Glass & Polyester	28	LD-2161	Hollingsworth & Vose	0.5" of H ₂ O	Good	PASSED
Glass & Polyester	29	LB-5211	Hollingsworth & Vose	1.0" of H ₂ O	Good	Failed: Solubility
Nuclepore	30	N500CPR	Nuclepore	0.8" of H ₂ O	Fair	Failed: Penetration
Gore-Tex plus Delnet	35	RB0707	Gore	0.2" of H ₂ O	Very Good	Failed: Penetration

APPENDIX D

MMRDM COMPUTER PROGRAM

MMRDM COMPUTER PROGRAM

G-2

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

HEX/DECIMAL			MNEMONIC		TITLE	DATE
PAGE ADR	LINE ADR	INSTR	LABEL	OPERATION	OPERAND	COMMENTS
0	0	00	INITL:	NOP		
	1	31		LXI		INITIALIZE STACK POINTER RAM
	2	F0		-		
	3	12		-		
	4	F3		EI		ENABLE INTERRUPT
	5	C7		JMP		JUMP TO RESET
	6	40		-		
	7	00		-	RESET:	
	8					
	9					
	A					
	B					
	C					
	D					
	E					
	F					
0	1	0				
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	A					
	B					
	C					
	D					
	E					
	F					

100001 8/74

G-2

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

HEX/DECIMAL			MNEMONIC		TITLE	DATE
PAGE ADR	LINE ADR	INSTR	LABEL	OPERATION	OPERAND	COMMENTS
0	2	0				
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	A					
	B					
	C					
	D					
	E					
	F					
0	3	0				
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8	F3	INTLOCK:	DIV		RST INTERRUPT ADR.
	9	3E		MVI	A	Set up Interlock Relay
	A	FF		-		
	B	D3		OUT	2	
	C	02		-		
	D	C7		JMP		JUMP TO INITL:
	E	00		-		
	F	00		-	INITL:	

100001 8/74

MMRDM COMPUTER PROGRAM

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

G-2

HEXADecimal			LABEL	Mnemonic	INSTRUCTION		TITLE	DATE
PAGE	LINE	INSTR			OPERATION	OPERAND		
0	40	00	RESET:	NOP			MMDM	10-4-77
	1	F8		LI				
	2	3E		MVI	A			ENABLE INTERRUPT
	3	1E		-				OPEN INTERLOCK RELAY
	4	D3		OUT	2			
	5	02		-				
	6	3E		MVI	A			SET UP LT C+C RESET TO 0
	7	A1		-				
	8	D3		OUT	0			
	9	00		-				
A		3E		MVI	A			SET UP ST C+C RESET TO 0
B		F1		-				
C		D3		OUT	1			
D		01		-				
E		C7		JMP				JUMP TO SCAN
F		60		-				
0		00		-	SCAN:			
1		00						
2								
3								
4								
5								
6								
7								
8								
9								
A								
B								
C								
D								
E								
F								

10001 8/74

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

G-2

HEXADecimal			LABEL	Mnemonic	INSTRUCTION		TITLE	DATE
PAGE	LINE	INSTR			OPERATION	OPERAND		
0	60	DB	SCAN:	IN	0		MMDM	10-4-77
	1	00		-				PORT 0 → A
	2	2F		CMA				COMPLEMENT
	3	47		MOV	BA			LOAD B WITH A
	4	78		MOV	AB			LOAD A WITH B
	5	E6		ANI				MASK - TEST FOR MAN SW. LT.
	6	01		-				
	7	C2		JMB				JUMP TO LTape IF TRUE
	8	A0		-				
	9	00		-	LTape			
A		78		MOV	AB			LOAD A WITH B
B		0F		RRC				ROTATE SHIFT RIGHT
C		E6		ANI				MASK TEST FOR LT EXP. CLOCK
D		01		-				
E		C2		JMP				
F		A0		-				
0	70	00		-	LTape			
	1	78		MOV	AB			
	2	0F		RRC				
	3	0F		RRC				
	4	E6		ANI				MASK TEST FOR ST MAN SW.
	5	01		-				
	6	C2		JMB				
	7	E0		-				
	8	00		-	LLAPE:			
	9	78		MOV	AB			
A		0F		RRC				
B		0F		RRC				
C		0F		RRC				
D		E6		ANI				MASK TEST FOR ST MAN SW
E		01		-				
F		C2		JMB				JUMP STAPE IF TRUE

10001 8/74

MMRDM COMPUTER PROGRAM

G-2

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

HEXADECIMAL			MNEMONIC		TITLE	DATE
PAGE ADR	LINE ADR	INSTR	LABEL	OPERATION	OPERAND	COMMENTS
0	80	40		-		
	1	01		-	STAPE:	
	2	78		MUO	AB	
	3	0F		RRC		
	4	0F		RRC		
	5	0F		RRC		
	6	0F		RRC		
	7	E6		ANI		MAY- TEST ST CLK
	8	01		-		
	9	C2		JMB		
	A	40		-		
	B	01		-	STAPE:	
	C	C3		JMP		
	D	60		-		
	E	00		-	SCAN:	
	F					
09	0					
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	A					
	B					
	C					
	D					
	E					
	F					

100001 8/74

G-2

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

HEXADECIMAL			MNEMONIC		TITLE	DATE
PAGE ADR	LINE ADR	INSTR	LABEL	OPERATION	OPERAND	COMMENTS
0A	0	3E	LTAPE:	MVI	A	HOLD C+C
	1	C2		-		
	2	D3		OUT	0	
	3	00		-		
	4	3E		MVI	A	START HD MOTOR
	5	C6		-		
	6	D3		OUT	0	
	7	00		-		
	8	DB		IN	1	LOOK FOR SW Closure (head up)
	9	01		-		
	A	3E		CMC		
	B	E6		ANI		
	C	01		-		
	D	C2		JMB		
	E	AB		-		
	F	00		-		
0B	0	3E		MVI		STOP HD - START DRIVE
	1	CA		-		
	2	D3		OUT		
	3	00		-		
	4	CD		CALL		WAIT 3 SEC
	5	90		-		
	6	01		-	DELAY:	
	7	DB		IN		LOOK FOR SW ON DRIVE
	8	01		-		
	9	3F		CMC		
	A	0F		RRC		
	B	E6		ANI		
	C	01		-		
	D	C2		JMB		
	E	B7		-		
	F	00		-		

100001 8/74

MMRDM COMPUTER PROGRAM

G-2

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

HEXADECIMAL			MNEMONIC		TITLE	DATE
PAGE ADR	LINE ADR	INSTR	LABEL	INSTRUCTION OPERATION OPERAND		
0	C	3E		MUI	A	STOP DR, ST HD Reset C+C
	1	A5		-		
	2	D3		OUT		
	3	00		-		
	4	CD		CALL		WAIT 3 SEC
	5	90				
	6	01			DELAY	
	7	3E		MUI	A	STOP HD
	8	A1		-		
	9	D7		OUT		
	A	00		-		
	B	16		MVI	D	CLEAR D REG
	C	00		-		
	D	3E		MUI		START C+C
	E	80		-		
	F	D3		OUT		
0	D	00		-		
	1	C3		JMP		
	2	60		-		
	3	00		-	SCAN	
	4					
	5					
	6					
	7					
	8					
	9					
	A					
	B					
	C					
	D					
	E					
	F					

10001 8/74

G-2

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

HEXADECIMAL			MNEMONIC		TITLE	DATE
PAGE ADR	LINE ADR	INSTR	LABEL	INSTRUCTION OPERATION OPERAND		
0	E	7A	LLAPE	MOV	A,D	
	1	E6		ANI		CHECK IF FLAG SET
	2	01		-		
	3	C2		JNZ		
	4	60		-		
	5	00		-	SCAN	
	6	3E		MUI	A	C+C HOLD
	7	C2		-		
	8	D3		OUT		
	9	00		-		
	A	3E		MUI		START HD
	B	C6		-		
	C	D3		OUT		
	D	00		-		
	E	DB		IN		LOOK FOR HD SW
	F	01		-		
0	F	3F		CMC		
	1	E6		ANI		TEST
	2	01		-		
	3	C2		JNZ		
	4	EF		-		
	5	00		-		
	6	3E		MUI		STOP HD - START DR.
	7	CA		-		
	8	D3		OUT		
	9	00		-		
	A	CD		CALL		WAIT 3 SEC
	B	90		-		
	C	01		-	DELAY	
	D	DB		IN		LOOK FOR DR SW.
	E	01		-		
	F	3F		CMC		

10001 8/74

MMRDM COMPUTER PROGRAM

G-2

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

HEXADECIMAL			MNEMONIC		TITLE	DATE
PAGE	LINE	INSTR	LABEL	OPERATION	OPERAND	COMMENTS
ADR	ADR					
1	00	0F		RRC		
	1	E6		ANI		TEST
	2	01		-		
	3	C2		JNZ		
	4	FD		-		
	5	00		-		
	6	CD		CALL		DO 3 Sec - 2 nd step
	7	90		-		
	8	01		-	DELAY	
	9	DB		IN		LOOK FOR DR SW
	A	01		-		
	B	3E		CMC		
	C	0F		RRC		
	D	E6		ANI		
	E	01		-		
	F	C2		JNZ		
1	10	09		-		
	1	01		-		
	2	3E		MVI	A	STOP Dr. St. Hd. Reset CLK ONLY
	3	C5		-		HOLD COUNT.
	4	D3		OUT		
	5	00		-		
	6	CD		CALL		WAIT 3 SEC
	7	90		-		
	8	01		-	DELAY	
	9	3E		MVI		STOP Hd Motor
	A	C1		-		
	B	D3		OUT		
	C	00		-		
	D	16		MVI	D	SET D FLAG
	E	01		-		
	F	3E		MVI		START CLOCKS

100001 8/74

G-2

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

HEXADECIMAL			MNEMONIC		TITLE	DATE
PAGE	LINE	INSTR	LABEL	OPERATION	OPERAND	COMMENTS
ADR	ADR					
1	20	C0		-		
	1	D3		OUT		
	2	00		-		
	3	C7		JMP		Return to SCAN
	4	60		-		
	5	00		-	SCAN:	
	6					
	7					
	8					
	9					
	A					
	B					
	C					
	D					
	E					
	F					
1	30					
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	A					
	B					
	C					
	D					
	E					
	F					

100001 8/74

MMRDM COMPUTER PROGRAM

G-2

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

HEXADECIMAL			MNEMONIC		TITLE	DATE	COMMENTS		
PAGE ADP	LINE ADP	INSTR	LABEL	OPERATION				OPERAND	
1	40	3E	STAPE:	MUI	A	MM DM	10-4-77	C+C HOLD	
	1	E2		-					
	2	D3		OUT					
	3	01		-					
	4	3E		MUI					LATCH DATA
	5	E2		-					
	6	D3		OUT					
	7	01		-					
	8	3E		MUI	A				ST HO.
	9	E6		-					
	A	D3		OUT					
	B	01		-					
	C	DB		IN					LOOK FOR HD SW
	D	01		-					
	E	2F		CMA					
	F	0F		RRC					
15	00	0F		RRC					
	1	E6		ANI		TEST			
	2	01		-					
	3	CA		JZ					
	4	4C		-					
	5	01		-					
	6	3E		MUI		STOP HD, START DR - Reloc Data latch.			
	7	EA		-					
	8	D3		OUT					
	9	01		-					
	A	CD		CALL		WAIT 3 Sec			
	B	90		-					
	C	01		-	DELAY:				
	D	DB		IN		LOOK FOR DR SW			
	E	01		-					
	F	2F		CMA					

100001 8/74

G-2

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

HEXADECIMAL			MNEMONIC		TITLE	DATE	COMMENTS		
PAGE ADP	LINE ADP	INSTR	LABEL	OPERATION				OPERAND	
1	60	0F		RRC		MM DM	10-4-77		
	1	0F		RRC					
	2	0F		RRC					
	3	E6		ANI					TEST
	4	01		-					
	5	CA		JZ					
	6	5D		-					
	7	01		-					
	8	3E		ANI					STOP DR, start HD Reset C+C
	9	E5		-					
	A	D3		OUT					
	B	01		-					
	C	CD		CALL					WAIT 7 SEC
	D	90		-					
	E	01		-	DELAY				
	F	3E		ANI					STOP HD start C+C
17	00	E0		-					
	1	D3		OUT					
	2	01		-					
	3	C3		JMP		Return to SCAN			
	4	60		-					
	5	00		-	SCAN:				
	6								
	7								
	8								
	9								
	A								
	B								
	C								
	D								
	E								
	F								

100001 8/74

MMRDM COMPUTER PROGRAM

G-2

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

HEXADECIMAL			MNEMONIC		TITLE	DATE
PAGE ADR	LINE ADR	INSTR	LABEL	INSTRUCTION		
				OPERATION	OPERAND	
1	80					
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	A					
	B					
	C					
	D					
	E					
	F					
1	90	3E	DELAY	MUI	A	LOAD A 0C 3 sec.
	1	0C		-		
	2	01		LXI	Bc	LOMO B E0 C 05
	3	05		-		
	4	E0		-		
	5	3D		DCR	A	DEC A
	6	C2		JNZ		
	7	95		-		
	8	01		-		
	9	05		DCR	B	DEC B
	A	C2		JNZ		
	B	95		-		
	C	01		-		
	D	0D		DCR	C	DEC C
	E	C2		JNZ		
	F	95		-		

100001 8/74

G-2

PRO-LOG CORPORATION

PROGRAM ASSEMBLY FORM

HEXADECIMAL			MNEMONIC		TITLE	DATE
PAGE ADR	LINE ADR	INSTR	LABEL	INSTRUCTION		
				OPERATION	OPERAND	
1	A0	01		-		
	1	C9		RET		RETURN
	2	00				
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	A					
	B					
	C					
	D					
	E					
	F					
1	B0					
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	A					
	B					
	C					
	D					
	E					
	F					

100001 8/74

APPENDIX E

MMRDM DRIFT DATA

MMRDM Drift Data

LONG TERM:

<u>Date</u>	<u>Clean Tube</u>	<u>Dirty Tube</u>
Nov. 3	3015828 > 30181395 3020451 > avg.	3002542 > 3005166.5 (Min.) 3007791 > avg.
Nov. 9	3020173	3020571
Nov. 11	3011801 Min. -0.21%	3017848
Nov. 17	3027836	3017577
Nov. 18	3031239	3022575
Nov. 28	3032759	3013903
Dec. 2	3033208 Max. +0.499%	3011147
Dec. 8	3026573	3025491
Jan. 3, 1978	3016469 > 3019700.5 avg. 3022932 > +0.052%	3042908 > 3037755 avg. (Max.) 3032602 > +1.08%

SHORT TERM:

Nov. 3	46921 > 467794 avg. 46667 >	46610 > 46541 avg. 46472 >
Nov. 5	47050	46825
Nov. 8	46870	46688
Nov. 9	47356	47459 Max. +1.97%
Nov. 11	45968	46200
Nov. 17	47394 Max. +1.28%	47373
Nov. 18	46445	46732
Nov. 28	44993 Min. -3.85%	45241 Min. -2.79%
Dec. 2	46386	45330
Dec. 19	45849	45782
Jan. 3, 1978	46041	46115
	46078	46061
Feb. 14	46950 +0.33%	46727 +0.399%

APPENDIX F

ENVIRONMENTAL TEST PLAN

ENVIRONMENTAL TEST PLAN
for the
Machine Mounted Respirable Dust Monitor (MMRDM)

A. Room Temperature and Room Relative Humidity

Long Term Correlation	[5.0 mgs (coal dust)] [0.2 mgs (coal dust)]
Short Term Correlation	[0.625 mg (coal dust) equivalent to 20 mg/m ³] [0.0625 mg (coal dust) equivalent to 2 mg/m ³]
Long Term Correlation	[Between 0.2 and 5.0 mgs-limestone dust]
Short Term Correlation	[Between 0.0625 mg and 0.625 mg-limestone dust]
Long Term Correlation	[Between 0.2 and 5.0 mgs-Arizona Road Dust]
Short Term Correlation	[Between 0.0625 mgs and 0.625 Arizona Road Dust]

B. 120°F and Temperature Box Relative Humidity

Long Term Correlation	[Between 0.2 mg and 5.0 mgs-coal dust]
Short Term Correlation	[Between 0.0625 and 0.625 mg-coal dust]

C. 32°F and Temperature Box Relative Humidity

Long Term Correlation	[Between 0.2 mg and 5.0 mgs-coal dust]
Short Term Correlation	[Between 0.0625 mg and 0.625 mg-coal dust]

D. Room Temperature and 10% Relative Humidity

Long Term Correlation	[Between 0.2 mg and 5.0 mgs-coal dust]
Short Term Correlation	[Between 0.0625 and 0.625 mg-coal dust]

E. Room Temperature and 95% Relative Humidity

Long Term Correlation	[Between 0.2 mg and 5.0 mgs-coal dust]
Short Term Correlation	[Between 0.0625 mg and 0.625 mg-coal dust]

F. Vibration Test at Room Temperature and Room Relative Humidity

Vibratory Spectrum:	5 to 500 to 5 hertz
Acceleration	: 4 g's
Duration	: 3 hours each axis

Long Term Correlation [Between 0.2 mg and 5.0 mgs-coal dust]
Short Term Correlation [Between 0.0625 mg and 0.625 mg-coal dust]

Dust determination shall be recorded before, during, and after the vibratory input to the MMRDM.

Comparisons shall be made.

G. Shock Test at Room Temperature and Room Relative Humidity

Acceleration : 20 g's
Duration : 11 ms
Number of Shocks: 3 shocks per axis - total of 18 shocks

Long Term Correlation [Between 0.2 mg and 5.0 mgs-coal dust]
Short Term Correlation [Between 0.0625 mg and 0.625 mg-coal dust]

Dust determination shall be recorded before and after the shock input to the MMRDM. Comparison shall be made.

APPENDIX G

ENVIRONMENTAL TEST DATA

Raw Test Data and Calculated Dust Levels

Factor to be Multiplied by the Log of the Ratio	Clean Tube Count	Dirty Tube Count	Weighed Dust (mg)	Calculated Dust (mg)	% Of ERROR	Channel
----------------------------------------------------------	------------------------	------------------------	-------------------------	----------------------------	------------------	---------

A. Room Temperature and Room Relative Humidity

19.339396	3011395	2766392	1.721	1.641	-4.65%	Long
19.339396	2999981	2572351	3.396	2.974	-12.4%	Long
19.339396	3137759	2999985	0.885	0.868	-1.89%	Long
19.339396	2963431	2882056	0.455	0.5383	+18.3%	Long
19.339396	3026871	3008016	0.122	0.1208	-0.95%	Long
19.339396	3108847	3039234	0.441	0.438	-0.686%	Long
19.339396	3117077	2489128	4.638	4.351	-6.19%	Long
0.8491633	17858	16836	0.047	0.050	+6.47%	Short
0.8491633	17646	13069	0.259	0.225	-1.55%	Short
0.8491633	17731	5086	0.966	1.060	+9.78%	Short
0.8491633	16303	15533	0.050	0.0411	-17.83%	Short
0.8481633	15638	8828	0.502	0.4856	-3.28%	Short
0.8481633	17434	14690	0.119	0.145	+22.2%	Short
0.8481633	15953	15001	0.055	0.0523	-4.96%	Short

30% Relative Humidity - Room Temperature

19.339693	3160026	2400155	5.189	5.3193	+2.55	Long
-----------	---------	---------	-------	--------	-------	------

CHANGE SPOT SIZE

1.05766822	43141	30912	0.359	0.353	-1.80%	Short
1.05766822	44703	30913	0.383	0.390	+1.86%	Short
1.05766822	42444	27404	0.467	0.463	-0.92%	Short
1.05766822	45849	29274	0.501	0.475	-5.28%	Short
1.05766822	42522	34136	0.259	0.232	-10.29%	Short
1.05766822	43234	34009	0.280	0.254	-9.34%	Short
24.632542	7623711	7365284	0.822	0.849	+3.34%	Long
24.632542	7617642	7421802	0.655	0.642	-2.05%	Long

Raw Test Data and Calculated Dust Levels

Factor to be Multiplied by the Log of the Ratio	Clean Tube Count	Dirty Tube Count	Weighed Dust (mg)	Calculated Dust (mg)	% Of ERROR	Channel
----------------------------------------------------------	------------------------	------------------------	-------------------------	----------------------------	------------------	---------

A. Room Temperature and Room Relative Humidity

Ariz. Road Dust

24.632542	7777310	7542903	0.738	0.754	+2.14%	Long
24.632542	7617807	6867875	2.41	2.553	+5.9%	Long
1.05766822	43236	32973	0.340	0.287	-15.7%	Short
1.05766822	44988	23093	0.851	0.7053	-17.12%	Short

Limestone Dust

24.632542	7883134	7729138	0.504	0.486	-3.58%	Long
1.05766822	41083	33438	0.231	0.218	-5.63%	Short
1.05766822	40578	37436	0.099	0.085	-14.14%	Short

After Vib & Before Shock

24.632542	7638752	7466256	0.535	0.562	+5.0%	Long
1.05766822	41223	31207	0.328	0.294	-10.4%	Short

After Shock

1.05766822	43398	33595	0.305	0.271	-11.21%	Short
------------	-------	-------	-------	-------	---------	-------

After Shock

24.632542	7678150	7515850	0.555	0.526	-5.2%	Long
-----------	---------	---------	-------	-------	-------	------

After Shock

1.05766822	44511	36307	0.275	0.216	-21.6%	Short
24.632542	7508229	7247089	0.972	0.872	-10.3%	Long
1.05766822	44442	38851	0.179	0.142	-20.9%	Short
24.632542	7697476	7447361	0.821	0.813	-0.09%	Long

Raw Test Data and Calculated Dust Levels

Factor to be						
Multiplied	Clean	Dirty	Weighed	Calculated	%	
by the Log	Tube	Tube	Dust	Dust	Of	
of the Ratio	Count	Count	(mg)	(mg)	ERROR	Channel

B. Temperature: 120°F and Temperature Box Relative Humidity

19.339693	2969089	2820075	1.213	0.996	-17.89%	Long
0.8491633	42813	31456	0.294	0.262	-10.97%	Short
19.339693	3079608	2946624	0.900	0.8537	-5.15%	Long
0.8491633	43699	26578	0.404	0.422	+4.52%	Short

C. Temperature: 32°F and Temperature Box Relative Humidity

19.339693	2969540	2784887	1.441	1.242	-13.84%	Long
0.8491633	34468	17176	0.601	0.5915	-1.59%	Short
19.339693	3042936	2837822	1.234	1.3496	+9.37%	Long

D. 12% Relative Humidity - Room Temperature

19.339693	7676267	6711793	2.688	2.597	-3.4%	Long
0.8491633	42746	17976	0.834	0.73553	-11.81%	Short

E. 95⁺% Relative Humidity - Room Temperature

0.8491633	46722	33691	0.283	0.278	-1.77%	Short
19.339693	7326188	7012760	0.929	0.8456	-8.98%	Long

Raw Test Data and Calculated Dust Levels

F. Vibration Test Data

Room Temperature and Room Relative Humidity

	<u>Long Term</u>		<u>Short Term</u>	
	<u>Clean Tube</u>	<u>Dirty Tube</u>	<u>Clean Tube</u>	<u>Dirty Tube</u>
Before:	7428369	7455842	39427	39447
During:	7381367	7443714	39322	39583
	7419089	7450462	39483	39518
	7341105	7419132	38162	38679
	7361776	7418771	38420	38865
	7391093	7433945	39264	39147
	7401766	7434062	41893	39197
	7405772	7433378	44301	39267
	7418525	7445291	44157	39433
	7345373	7415560	38978	38851
	7346040	7429830	38445	38643
			38594	39318
After:	7396851	7439041	39003	38984
	7404394	7432953	39064	38986
	7375061	7447245	39079	39196
	7409469	7464052	39663	40015
	7422138	7464316	39649	40068
	7392016	7439831	38842	39695

Before Vibration
Limestone Dust

24.632542	7883134	7729138	0.504	0.486	-3.58%	Long
1.05766822	41083	33438	0.231	0.218	-5.63%	Short
1.05766822	40578	37436	0.099	0.085	-14.14%	Short

After Vibration

24.632542	7638752	7466256	0.535	0.562	+5.0%	Long
1.05766822	41223	31207	0.328	0.294	-10.4%	Short

Raw Test Data and Calculated Dust Levels

G. Shock Test Data

Room Temperature and Room Relative Humidity

	<u>Clean Tube</u>	<u>Dirty Tube</u>		<u>Clean Tube</u>	<u>Dirty Tube</u>	
Before						
<u>Readings:</u>	7421839	7508368		38928	44862	
				<u>38193</u>	<u>44895</u>	
				77121	89757	
				Avg. 38560.5	Avg. 44878.5	
After						
<u>Readings:</u>	7381924	7524493		38618	45154	
	7400171	7534559		38699	45434	
	7435469	7553179		39062	45477	
	7440617	7551840		39039	45540	
	Avg. 7414545	7541018		38855	45401	
	Δ 7294	Δ 32650		Δ 295	Δ 522	
Percentage						
<u>Change</u>	-0.098%	+0.434%		+0.765%	+1.16%	
<u>Before Shock</u>						
24.632542	7638752	7466256	0.535	0.562	+5.0%	Long
1.05766822	41223	31207	0.328	0.294	-10.4%	Short
<u>After Shock</u>						
1.05766822	43398	33595	0.305	0.271	-11.21%	Short
24.632542	7678150	7515850	0.555	0.526	-5.2%	Long
<u>1.05766822</u>	44511	36307	0.275	0.216	-21.6%	Short
.632542	7508229	7247089	0.972	0.872	-10.3%	Long
.05766822	44442	38851	0.179	0.142	-20.9%	Short
24.632542	7697476	7447361	0.821	0.813	-0.09%	Long

APPENDIX H

DATA STUDY - COMPUTER PROGRAM

MMRDM DATA STUDY - COMPUTER PROGRAM

```
100 OPEN 'LP:' FOR OUTPUT AS FILE #1
110 READ N1
120 S=0
130 FOR N=1 TO N1
140 READ E
150 S=S+E
160 NEXT N
170 A=S/N1
180 PRINT #1:'AVERAGE IS'A
190 RESTORE
200 READ N1
210 V=0
220 FOR N=1 TO N1
230 READ E
240 D=E-A
250 V=V+D*D
260 NEXT N
270 R=SQR(V/N1)
280 PRINT #1:' RMS IS 'R
290 STOP
1000 DATA 23,-4.65,-12.4,-1.89,18.3
1010 DATA -.95,-.686,-6.19,-17.89,-5.15
1020 DATA -13.84,9.37,2.55,-3.4,-8.98
1030 DATA 3.34,-2.05,2.14,5.9,-3.58
1040 DATA 5,-5.2,-10.3,-.09
2000 END
```

LONG TERM

```
AVERAGE IS-2.202
RMS IS 7.7805
```

```
1000 DATA 25,6.47,-1.55,9.78,-17.83
1010 DATA -3.28,22.2,-4.96,-10.97,4.52
1020 DATA -1.59,-11.81,-1.77,-1.8,1.86
1030 DATA -.92,-5.28,-10.29,-9.34,-15.7
1040 DATA -17.12,-5.63,-14.14,-10.4,-11.21
1050 DATA -20.9
2000 END
```

SHORT TERM

```
AVERAGE IS-5.2664
RMS IS 9.48463
```

Reproduced from
best available copy.



APPENDIX I

SHOCK TEST REPORT

Test Report No. T-6360-11

No. of Pages 5

Report of Test on

DUST MONITOR

SHOCK TEST

for

RENDIX CORPORATION

Associated Testing Laboratories, Inc.

Date February 13, 1978

	Prepared	Checked	Approved
By	M. Linszner	E. Kulcsar	D. Jarmv
Signed	<i>M. Linszner</i>	<i>E. Kulcsar</i>	<i>D. Jarmv</i>
Date	<i>2/14/78</i>	<i>2-14-78</i>	<i>2/15/78</i>

Administrative Data

1.0 Purpose of Test:

To determine the effects upon the submitted Dust Monitor when subjected to the shock test specified in this report.

2.0 Manufacturer: Bendix Corporation
Environmental Sciences Division
1400 Taylor Road
Baltimore, Maryland 21201

3.0 Manufacturer's Type of Model No.: MMRDM

4.0 Drawing, Specification or Exhibit: Written and verbal instructions from a representative of Bendix Corporation

5.0 Quantity of Items Tested: One (1)

6.0 Security Classification of Items: Unclassified

7.0 Date Test Completed: January 26, 1978

8.0 Test Conducted By: Associated Testing Laboratories, Inc.

9.0 Disposition of Specimens: Returned to Bendix Corporation

10.0 Abstract:

The submitted Dust Monitor was subjected to shock testing in accordance with the written and verbal instructions from the Bendix Corporation representative. No damage was incurred to the Dust Monitor as a result of this test. The unit was returned to Bendix for further evaluation.

Report No. T-6360-11

Page 1

Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470
Burlington, Massachusetts 01803

LIST OF APPARATUS

ITEM	MANUFACTURER	MODEL NO.	ACCURACY	CALIBRATION DATE	CALIBRATION DUE
Accelerometer	Endevco Corp.	2215	<u>+5%</u>	12-8-77	3-8-78
Charge Amplifier	Unholtz-Dickie	11MGS	<u>+1%</u>	12-28-77	3-28-78
Vibration System	Linco Electronics	335	<u>+5%</u>	12-28-77	3-28-78
Oscilloscope	Tektronix, Inc.	503	<u>+3%</u>	1-17-78	4-17-78
Digital Vibration Control System	Hewlett-Packard	5425A	<u>+0.1%F</u> <u>+1%A</u>	9-7-77	3-7-78

Report No. T-6360-11

Page 2

Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470
Burlington, Massachusetts 01803

SHOCK TEST

TEST PROCEDURE

The Dust Monitor was subjected to a shock test in accordance with customer instructions, as follows.

The unit was mounted to the shock machine. The shock machine was previously calibrated to produce a shock pulse of 20g peak amplitude and 11 milliseconds time duration. The shock pulse wave form approximated that of a sawtooth. The Dust Monitor was subjected to a total of 18 blows, three in each direction of three mutually perpendicular axes.

Following the test, the unit was removed from the fixture and examined for evidence of physical damage.

TEST RESULTS

There was no visible damage incurred to the unit as a result of the shock test. The Dust Monitor was returned to Bendix Corporation for further evaluation.

Report No. T-6360-11

Page 3

Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470

Burlington, Massachusetts 01803

1/26/78 BENDIX DUST MONITOR



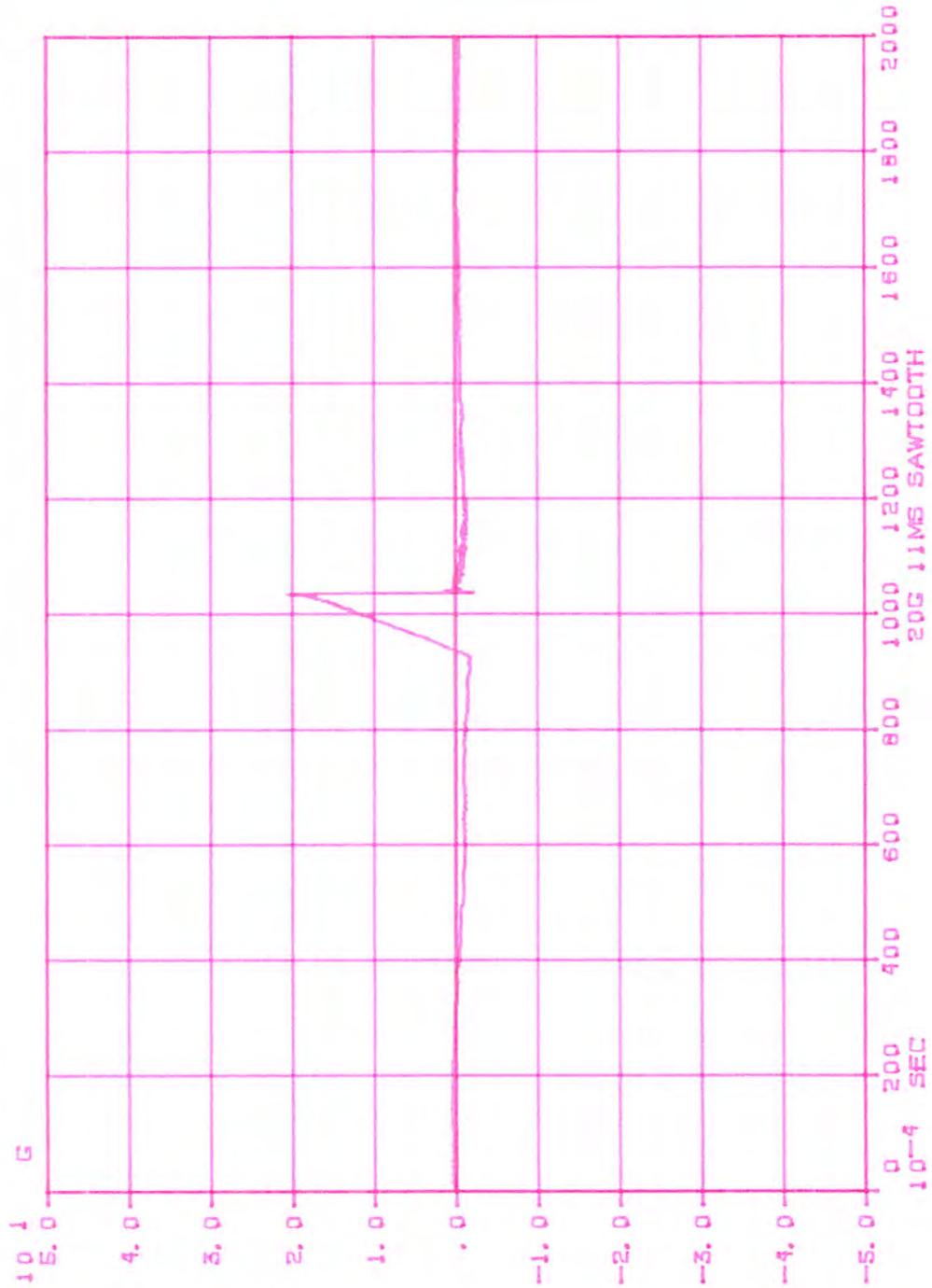
Report No. T-6360-11

Page 4

Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470
Burlington, Massachusetts 01803

1/26/78 BENDIX DUST MONITOR



Report No. M-6360-11

Page 5

Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470
Burlington, Massachusetts 01803

