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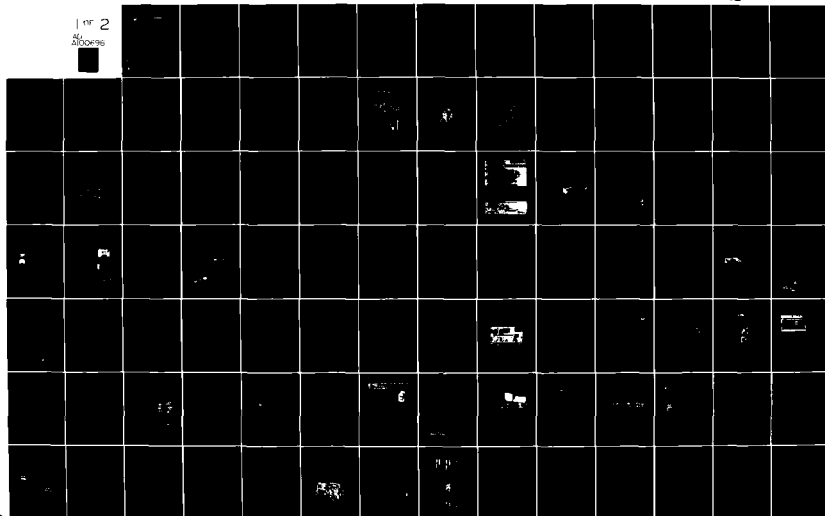
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## NAVAL AIR ENGINEERING CENTER

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APPLICATION OF AN IN-LINE CONTAMINATION  
MONITORING UNIT TO THE AHT-64  
HYDRAULIC TEST STAND

Handling and Servicing/Armament Division  
Support Equipment Engineering Department  
Naval Air Engineering Center  
Lakehurst, New Jersey 08733

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Final Report for Period 13 Mar 1978 - 30 Sep 1980

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APPLICATION OF AN IN-LINE CONTAMINATION  
MONITORING UNIT TO THE AHT-64  
HYDRAULIC TEST STAND

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| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)<br>Hydraulic Test Stands      Aircraft Hydraulic Systems<br>Oil Contamination Monitors      Ground Support Equipment<br>In-line Fluid Monitors      Particulate Measuring Equipment<br>Vibration Sensitivity      Sensors<br>Vibration Signatures      Analyzers                                                                                                                              |                                     |                                                                     |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>This report documents a support engineering analysis establishing parameters, including vibration environment, for development and application of an in-line contamination monitor on the Portable Hydraulic Test Stand AHT-64 to indicate attained degree of particulate decontamination of return hydraulic fluid. Approaches are evaluated, concepts presented and recommendations made. |                                     |                                                                     |

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## PREFACE

Vibration sensitivity, which appeared as a major shortcoming of in-line hydraulic system monitors in a previous RDT&E 6.2 program, is a new design parameter to be included in the development of a procurement specification for hydraulic contamination monitors. The report NAEC-GSED-105 (Development of a Procurement Specification for an In-line Contamination Monitoring Unit) proposed a free-standing, two-wheeled cart for the contamination monitor; however, because of a desire to avoid further proliferation of Ground Support Equipment (GSE), the NAVAIRSYSCOM opted for a test-stand-mounted in-line contamination monitor. Mounting on a hydraulic test stand requires the monitor to withstand the vibration signature of the test stand making vibration sensitivity of monitors a critical factor.

This report establishes vibration parameters for contamination monitors which will withstand the vibration levels experienced on the AHT-64 hydraulic test stand. In comparison with other current inventory test stands, the AHT-64 emits the highest levels of vibration because it is a diesel-powered pump unit. Vibration tests of the AHT-64 indicate normal vibration amplitude to be 2 G at a critical frequency of 360 Hz.

A search of available commercial in-line contamination monitors and subsequent testing of candidate models at the vibration signature levels of the AHT-64 revealed a monitor which functions with no distortion. The concept of employing an in-line contamination monitor on a hydraulic test stand is feasible and vibration sensitivity data for the report NAEC-GSED-105 is established.

Consideration is given to application of the contamination monitor to the AHT-64 test stand. This consideration examines requirements for the physical package, location on the stand, piping, electrical and structural changes to accommodate the monitor package plus incorporates portability to allow movement from stand to stand. A listing of drawings affected in the application of the monitor to the test stand is included plus a general statement of changes to these drawings.

This report recommends development of the in-line contamination monitor concept in its application to the Portable Hydraulic Test Stand, AHT-64.

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## I. INTRODUCTION

A. BACKGROUND. NAEC-GSED-105 (reference (a)) established the feasibility of an in-line hydraulic system contamination monitor to provide a "go-no go" type indication of hydraulic fluid particulate contamination for aircraft hydraulic systems. Vibration sensitivity, indicated as a shortcoming in NAEC-GSED-105, became a critical factor when the Naval Air Systems Command (NAVAIRSYSCOM) rejected the free-standing, two-wheeled cart concept proposed for the monitor and opted for an AHT-64 hydraulic test stand (reference (b)) mounted monitor. An in-line monitor thus mounted must withstand the vibration of the AHT-64, a diesel powered test stand with a nine-piston axial hydraulic pump experiencing high levels of vibration.

B. OBJECTIVE. This report provides engineering data establishing the vibration signature of the AHT-64 hydraulic test stand. The report also provides data indicating the ability of candidate contamination monitors to operate satisfactorily at the vibration signature levels of the test stand. Further objectives are the examination of locations on the test stand for an in-line contamination monitor, selection of the optimum location and investigation of the various factors involved in the development, fabrication and application of a monitor package to the test stand. This application objective is to provide a suitable monitor with simple operation and "go-no go" indication of hydraulic fluid particulate contamination. The application also examines the feasibility of interchange of the monitor package from one test stand to another.

### C. APPROACH.

1. In order to fulfill the foregoing objectives, the feasibility for locating an in-line monitor on the test stand was investigated. When NAVAIRSYSCOM opted for a hydraulic test stand mount for the contamination monitor, a study of possible locations on the test stand was initiated. Evaluation of possible locations on the AHT-64 hydraulic test stand, the selected test vehicle for a stand-mounted contamination monitor, indicated a rear-mounted monitor location to be most feasible. Rough sketches of a proposed concept for this location are included in the body of this report.

2. Examination of requirements to satisfactorily locate the monitor on the rear of the AHT-64 indicates a modification of the test stand piping, electrical system and support structure is necessary. Modifications are detailed in Section II.

Ref: (a) NAVAIRENGCEN Technical Report NAEC-GSED-105 of 14 Jun 1977:  
Development of a Procurement Specification for an In-line  
Contamination Monitoring Unit, Final Report (Prepared by  
J.J. Coyle for NAVAIRENGCEN).

(b) NAVAIRSYSCOM Technical Manual NAVAIR 17-15BF-66 of 1 Nov 1977:  
Portable Hydraulic Test Stand, Diesel Engine Driven, Operation  
and Maintenance Instructions with Illustrated Parts Breakdown  
(Teledyne Sprague Engineering).

3. A literature search of available commercial particle contamination monitors was conducted and characteristics compared and evaluated. Support requirements for these monitors revealed the necessity for providing a motor pump unit, an inverter to provide 120 VAC of sufficient wattage to power both motor pump unit and monitor, and a debubbler to extract entrained air from the return line of the aircraft prior to passage through the monitor transducer or sensor.

4. With required components established, selection and packaging of these components in a minimum size package was investigated. Component arrangement was developed, and a package design concept formulated. A listing of primary components of the monitor package is as follows:

- a. Transducer
- b. Electronic Signal Analyzer
- c. Hydraulic Oil Pump
- d. Electric Motor
- e. 28 VDC to 120 VAC Inverter
- f. Debubbler Unit

Assembling these components into a package 18 inches wide by 18 inches high by 12 inches deep appears feasible. Figure 1 is a representation of the contamination monitor concept as applied to the rear location of the AHT-64 hydraulic test stand.

5. The package concept requires hydraulic quick-disconnect type fittings and flexible hoses and an electrical harness with Cannon-type connectors in order to be readily removed and reconnected to another test stand. All of the six primary components are contained within the 18" x 18" x 12" package.

a. External hydraulic connections to disconnects on the test stand, which effect a bypass from the return line from the aircraft (within the piping in the stand directly behind the suction return connection port) to the package oil pump, thence through the debubbler, to the transducer, and then return through flexible hose to the test-stand disconnect and into the return line downstream from the pickup point.

b. The external electrical connections from the contamination monitor package to the test stand employ flexible cable with Cannon plugs on each end. This cable brings in the 28 VDC from the test-stand alternator to the inverter, the 120 VAC output of which operates the transducer light source, electronic signal analyzer, and the pump motor. An output signal from the signal analyzer operates a "go-no go" indicator light when desired hydraulic decontamination level is achieved. The "on-off" switch for the monitor and the "go-no go" light may either be located adjacent to each other on the test-stand control panel or elsewhere within clear view of the operator. Both "on-off switch and "go-no go" light may be mounted directly on the monitor package as long as the view path and access is clear from the test-stand control panel.

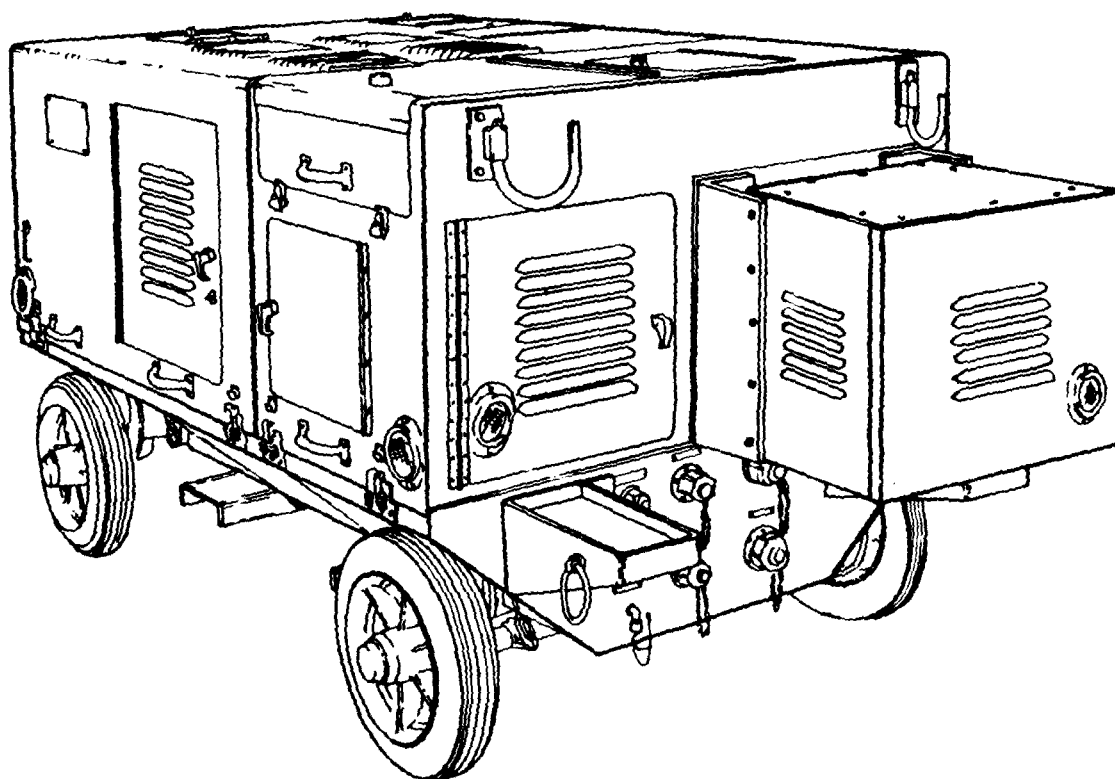


Figure 1. In-line Contamination Monitor Unit on AHT-64 Hydraulic Test Stand

6. A search of available oil contamination monitors adaptable to in-line monitoring has been made and a tabulation compiled indicating features such as size, weight, adaptability for this application, estimated cost per unit and chronological data. Discussions of the various monitors appear in Section II and brochures of specifications for each are included in Appendix A. The candidate in-line monitors from Table I, Page 12, have individually varying characteristics. Generally, they are sensitive to entrained particulate contaminants ranging on the small end of the scale between 10.0 and 0.5 microns, sense entrained air as particulates, and because they use light attenuation and reflection as a means of measure, do not provide a good indication of the presence of water in the oil-based fluids. Monitors having very small flow passages in the sensing area of the transducer are subject to blockage by large particles and require reverse flow capability to clear the transducer. For this reason, only those monitors capable of exceeding a minimum flow rate of 3 gpm through the transducer appear to be suitable for the "go-no go" type indication and for providing the relatively low maintenance desired. The Mean Time Between Failures (MTBF) due to contaminants in transducers is unknown and would need to be determined for the candidate monitors selected.

7. Resolution of the critical factor of vibration sensitivity raised in NAEC-GSED-105 has been accomplished by a two-step effort. These investigative steps are detailed in Section II.

a. The first step, determination of the vibration signature of the equipment on which the in-line monitor is to be mounted, has been established and is reported in Appendix B. The AHT-64 hydraulic test stand, during operation, has a normal amplitude of 2 G at a critical frequency of 360 Hz as determined by test.

b. With vibration levels of the test-stand platform for a monitor established, the second step required is to find a monitor capable of satisfactory operation in such a vibrational environment. An in-line contamination monitor has been found which does operate satisfactorily in the AHT-64 vibration environment. A test report of this determination is included in Appendix C.

## II. EQUIPMENT AND PROCEDURES

A. LOCATION OF MONITOR ON AHT-64 TEST STAND. Subsequent to a NAVAIRSYSCOM decision to locate a contamination monitor on the AHT-64 hydraulic test stand, occasioned by a desire to avoid proliferation of Ground Support Equipment (GSE) in aircraft environments, investigation into location possibilities for a typical monitor package revealed five possible locations on the test stand: three on the top, one aft within the hose stowage area, and one below between the fork pockets in a heavy steel enclosure.

1. TOP LOCATIONS. The three top locations were eliminated primarily because of the undesirable feature of added height to the test stand but also because of structural complexity required to provide adequate support, plus the disadvantage of relatively long hydraulic lines through areas where the lines will hamper maintenance. For some models of the available contamination monitors, hydraulic lines must be as short as possible because monitor response lags with increase of line length.

2. BETWEEN FORK POCKETS LOCATION. Investigation of the space between the fork pockets eliminated same as a location for a monitor for the following reasons:

- a. Insufficient depth to accommodate components of the monitor package.
- b. Vulnerability to fork tines even with a relatively heavy steel closure to the monitor package space between the test-stand fork pockets.
- c. If sealed against road dirt and water, heat dissipation of motor, pump, inverter and electronics would be a problem.
- d. Difficult access to the monitor for maintenance.
- e. Such a location would greatly impair ease of transfer of the monitor to another test stand.

3. REAR PANEL LOCATION

a. The location aft within the hose stowage area is most advantageous for the following reasons:

- (1) Easy access to the monitor package.
- (2) Easily mounted onto aft pipe frame and bedplate of trailer chassis.
- (3) Readily configured for short hose quick disconnects for both hydraulic and electric lines, thus simplifying the change kit for adapting AHT-64 stands to receive a contamination monitor.
- (4) The high visibility of this location from the operator's position at the control panel allows both "on-off" switch for the monitor and the "go-no go" light indication of state of oil decontamination to be mounted directly on the contamination monitor package.

b. A disadvantage appears for this rear location - vulnerability to damage by having the monitor package extend aft beyond the chassis of the test stand. This disadvantage may be resolved by either extension bumpers in the area of each rear tie-down ring or by stiffening all support structure members for the monitor package. The extension bumpers appear to be the most feasible resolution.

## B. INVESTIGATION OF AVAILABLE MONITORS.

1. MONITOR SEARCH. A search of available particle contamination monitors revealed eight companies that produce monitors of varying degrees of applicability for contaminant monitoring on hydraulic test stands. Of these, two monitors were actually subjected to tests and only one of these operated satisfactorily.

a. Cost Range, Volume and Weight. Known costs of monitors investigated ranged from a low of \$3,500.00 to a high of \$17,000.00. There is also a rather large variance in the size and weight, the smallest and lightest of these with a volume and weight of 0.37 cubic foot and 10.5 pounds respectively. The other extreme is over 12 cubic feet and approximately 150 pounds and has the highest cost. Because of a desire to assemble the smallest possible contamination monitor package, only those units on the low end of the size scale were tested.

b. Equipment Presentations. Representatives of the following monitor suppliers have brought their equipment to the Naval Air Engineering Center (NAVAIRENGCEN) and/or discussed the application with NAVAIRENGCEN Support Equipment Engineering Department (SEED) and Sanders and Thomas personnel at the NAVAIRENGCEN: Environment/One Corp.; Leeds and Northrup Co.; Gam Rad, Inc.; Micro Pure Systems, Inc.; and Millipore Corp.

c. Monitor Suppliers. The eight monitor suppliers contacted for data applicability to the AHT-64 are as follows (those who gave equipment presentations are preceded by an asterisk):

- \* (1) Environment/One Corp.  
2773 Balltown Road, Schenectady, NY 12309  
Attn: W. W. Aker (518) 346-6161
- \* (2) Leeds and Northrup Co., Microtrac Division  
Dickerson Road, North Wales, PA 19454  
Attn: F. Dempsey/R. Snyder (215) 643-2000
- \* (3) Gam Rad, Inc.  
46101 Grand River, Novi, MI 48050  
Attn: W. E. Helke (313) 348-1005
- \* (4) Micro Pure Systems, Inc.  
2 Oakwood Place, Scarsdale, NY 10583  
Attn: Tonis Oja (914) 723-0896/(401) 231-9429
- (5) HIAC Instrument Division, Pacific Scientific Co.  
4719 W. Brooks St., Montclair, CA 91763  
Attn: G. Shinbrot (516) 543-1310/(714) 621-3965

(6) Spectrex Corp., 3594 Haven Ave., Redwood City, CA 94063,  
Attn: J.M. Hoyte (415) 365-6567

\*(7) Millipore Corp., Ashby Rd., Bedford, MA 01730,  
Attn: R.W. Schaefer (800) 225-1380/(617) 275-9200

(8) Royco Instruments, Inc., 141 Jefferson Drive, Menlo Park, CA  
94025, Attn: S.P. LaVallee (617) 891-5320/(415) 325-7811

2. MONITOR PARTICULARS. Table I lists the eight contamination monitor manufacturers, physical characteristics, model data, cost where known, and pertinent chronological data relating to the investigation.

a. HIAC Particle Counter Availability. HIAC Instrument Division, Pacific Scientific Company particle counter PC-120 is owned by NAEC and used at the Franklin Institute and NAEC Tribology Laboratory. HIAC PC-120 was made available for consideration as a test stand application. Model PC-120 has been replaced by Model PC-320 which is readily adaptable to a "go-no go" type indication of oil contamination.

b. Static Bottled Fluid Particle Counter. Spectrex Corporation laser particle counter is configured to detect particulates in bottled fluids (such as beer), laser scans a static fluid. Spectrex did not appear interested in modification of their product to suit this application, however, did furnish literature on their product.

c. Extreme Vibration Sensitive. Royco Instruments Inc. manufacture very sensitive particle counters capable for particulates as small as .5 microns, capable of determining particle concentrations, and providing digital readout for simultaneous automatic counting of multiple particle size ranges. The Royco unit is extremely sensitive to vibration as evidenced by the experience at NAEC in the Tribology Laboratory, and could not be adapted to an AHT-64 mounted monitor package. Vibration sensitivity of the Model 220 required mounting on a vibration isolation table even within the Tribology Laboratory because of structure-borne disturbance by machinery located at a considerable distance but in the same hangar building.

C. SIZING OF CONTAMINATION MONITOR COMPONENTS. NAEC-GSED-105 indicated that the contamination monitor proposed for the wheeled-cart concept would have dimensions of 18" by 18" by 43" high including handles, wheels and storage space for connecting electric cable and hydraulic hoses. By locating a contamination monitor on the AHT-64 test stand, the electric cable and hydraulic hoses are reduced to a minimum, requiring either a very small or no internal stowage space and the steering handle and wheels are eliminated. With these reductions in required volume and by optimum arranging of the components, a package 18" x 18" x 12" deep appears feasible, with both the electrical cable and hydraulic hoses normally remaining connected to the test stand. Individual components are examined for size, weight and compatibility in the following paragraphs.

TABLE I. COMMERCIAL PARTICLE CONTAMINATION MONITOR SEARCH

| COMPANY                                                                | MONITOR                                                                                                                                                      | COST    | CHRONOLOGICAL DATA                                                                                                                                                                                                                                                     |
|------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Environment/One Corp.<br>Schenectady, NY 12309                         | Transducer<br>Cat #D-1012N-007, S/N 130<br>2.38" x 2.38" x 4.50", 2.0 Lb<br>Signal Conditioner<br>Cat #B-101-00002G2, S/N 00013<br>6.5" x 8.5" x 11", 8.5 Lb | \$3,500 | Displayed equipment in Trib Lab<br>12 Jun 1979. Equipment on loan to<br>Franklin Institute for test Nov 1979.                                                                                                                                                          |
| HIAC Instrument Div.,<br>Pacific Scientific Co.<br>Montclair, CA 91763 | Analog Particle Counter<br>Model PC-120<br>6" x 8" x 14", 20 Lb<br>Sensor Cat CMB-1.0<br>2" x 2" x 5.8", 2 Lb                                                | \$ -    | NAVAIRENGCEN-owned Model PC-120 on<br>loan to Franklin Institute for test<br>Nov 1979.                                                                                                                                                                                 |
| Leeds & Northrup Co.<br>No. Wales, PA 19454                            | L&N Microtrac SSM<br>Cat #C4.7123-DS<br>25" w x 11" h x 7-1/4" d, 50 Lb                                                                                      | \$4,600 | 19 Dec 1978 meeting in Trib Lab dis-<br>played and discussed Microtrac SSM -<br>Principle applicable to AHT's but<br>package is much too large. 3 Oct<br>1979, Demo and seminar at Travel<br>Lodge, Mt Laurel, NJ - same conclu-<br>sions prevailed as on 19 Dec 1978. |
| Millipore Corp.<br>Bedford, MA 01730                                   | Millipore Micro Scan-2<br>7" x 10" x 14", 12 Lb                                                                                                              | \$8,000 | 28 Mar 1979 meeting at Trib Lab dis-<br>cussed adaptation of Millipore monitor<br>to in-line monitoring and degree of<br>sensitivity. No info as of Nov 1979.<br>At best 4 micron detection in H2O -<br>Sensing reaction to hyd fluid unknown.                         |
| Royco Instruments Inc<br>Menlo Park, CA 94025                          | Sensor & Flow Controller<br>Model 220<br>10-1/2" h x 16-3/4" w x 18-1/2" d<br>32 Lb<br>(Optics too vibration-sensitive<br>for this application)              | \$ -    | Royco construction too sensitive to<br>vibration per experience in Trib Lab<br>with Model 220 - Optical system is<br>not rigid enough for any but Lab<br>conditions.                                                                                                   |

TABLE I. COMMERCIAL PARTICLE CONTAMINATION MONITOR SEARCH (CONTINUED)

| COMPANY                                         | MONITOR                                                                                                                                                                                  | COST     | CHRONOLOGICAL DATA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Spectrex Corp.<br>Redwood City, CA 94063        | Laser Particle Counter<br>Model ILI 1000<br>Cat #67000<br>18" h x 12" w x 24" d,<br>31 Lb                                                                                                | \$7,600  | Unit configured to monitor contaminants in bottled fluids or transparent pipes. Laser light source not employed as continuous monitor.                                                                                                                                                                                                                                                                                                                                                                                   |
| Gam Rad, Inc.<br>Novi, MI 48050                 | Enviro Monitor Fluid Analyzer<br>Model 260<br>FA-128A Sensor, PN 2576<br>11" x 11" x 9" (approx), 12 Lb<br>FA-166 Control Station<br>PN 2575<br>8" x 8" x 12" (approx)<br>15 Lb (approx) | \$3,150  | Demo in pit at Trib Lab 1 May 1979, returned unit 23 May 1979. Model 260 fluid analyzer with control station was demonstrated by Bill Helke on setup with small pump. Sensitivity of unit was immediately evident with introduction of 2 mg/l AC fine dust into system. If light source will withstand vib levels of AHT-64, can adequately monitor oil contamination from aircraft - readily adaptable to "go-no go" type indication for use on stand. Light source is incandescent. Vibration characteristics unknown. |
| Micro Pure Systems, Inc.<br>Scarsdale, NY 10583 | Micro Contaminant Monitor<br>Model 1100 - \$16,000<br>Fluid Line Inspection<br>Chamber - \$1,000                                                                                         | \$17,000 | Units displayed and described in Trib Lab Nov 1979. Indications are that this equipment is satisfactory for Laboratory use only.                                                                                                                                                                                                                                                                                                                                                                                         |

1. SIGNAL ANALYZER. Of the eight monitors listed in Table I, three appear to be suitable for possible application to the AHT-64 package. These are:

- a. Environment/One Corp.  
Signal Conditioner Cat # B-101-00002G2, S/N 00013  
Dimensions 6.5" x 8.5" x 11"  
Weight 8.5 Lb
- b. HIAC Instrument Div., Pacific Scientific Co.  
Analog Particle Counter, Model PC-120  
Dimensions 6" x 8" x 14"  
Weight 20 Lb
- c. Gam Rad, Inc.  
Enviro Monitor Fluid Analyzer, Model 260  
FA-166 Control Station PN 2575  
Dimensions 8" x 8" x 12"  
Weight 15 Lb

2. TRANSDUCER OR SENSOR. The pickup sensor or transducer for use in conjunction with each of the above three models follow. Of these the Gam Rad Inc., FA-128A Sensor PN 2576 is least desirable because of size and weight, requiring more volume and weighing nearly as much as its matching electronic control station. It can, however, be made to fit into a projected monitor package.

- a. Environment/One Corp.  
Transducer Cat #D-1012N-007, S/N 130  
Dimensions 2.38" x 2.38" x 4.50"  
Weight 2.0 Lb
- b. HIAC Instrument Div., Pacific Scientific Co.  
Sensor Cat CMB-1.0  
Dimensions 2" x 2" x 5.8"  
Weight 2 Lb
- c. Gam Rad, Inc.  
Enviro Monitor Fluid Analyzer, Model 260  
FA-128A Sensor PN 2576  
Dimensions 11" x 11" x 9"  
Weight 12 Lb (Approx)

3. MOTOR PUMP FOR HYDRAULIC FLUID. Of the three remaining candidate monitors, the Environment/One Corp. unit requires the greatest flow rate, a minimum of 3 gpm. The pump unit selected for the monitor package for sizing purposes will deliver 5.46 gpm at 100 psi and 1,200 rpm. Typical pumps operating in this range can be purchased flange mount coupled directly to end cap of motor. A typical motor for this pump requirement is 1/3 hp, 1,200 rpm and provides a package within the limiting dimensions of the proposed monitor package size. If the motor is 28 VDC, frame size would have to be larger to accommodate the additional copper in windings but the inverter requirement would not then need be sized to accommodate the motor load. Motor pump size projection of 9" x 9" x 18" is predicated on use of Vickers Pump Model No. V210-5-1C-12-5214, flange mounted on a motor of NEMA frame size 182 or 184.

Estimated weight of this motor pump unit is 45 pounds. See Appendix A for reprints of pump and motor data extracted from the Vickers Catalogue.

4. 28 VDC TO 120 VAC INVERTER. Sizing of the inverter required to operate the monitor package is based on a demand for 115 VAC by three units in the monitor: the circulator pump motor, the signal analyzer and the transducer or sensor. In each case of the three candidate monitors the transducer or sensor is powered through the signal analyzer. The maximum wattage is 150 for Gam Rad's "Enviro Monitors", the minimum 10 watts for Environment/One. Allowance for the 115 VAC pump motor and the analyzer transducer package of 500 watts total, with a 2-to-1 surge capability for starting the motor, is planned. For planning purposes a DC-to-AC inverter, Model 1172 heavy-duty 500-watt square-wave inverter, manufactured by Wilmore Electronics Co. Inc. (see EEM/1980, 81 p. 3495, Vol. 2), is selected with dimensions of 7" x 8-1/2" x 11" and weighing 32 pounds. A reprint from the EEM catalog is included in Appendix A.

5. DEBUBBLER. During particulate decontamination of an aircraft hydraulic oil system, entrained air in the return line is read as particulate matter by contamination monitors; thus any gasses must be removed before the oil passes through the transducer or sensor. To accomplish this, a debubbler installed in the line upstream between the return line and the sensor will vent trapped gasses. A typical debubbler or deaerator requires a vertical cylinder approximately 4 inches in diameter by 14 inches high and weighs approximately 14 pounds (with system full).

D. SIZING AND ARRANGEMENT OF CONTAMINATION MONITOR PACKAGE. An estimated size for the monitor of 18" x 18" x 12" deep appears reasonable based on the size of commercially available components. Packaging of these components within this space is tight; however, by mounting units on bottom and back only, with front, sides, and cover removable, access to components will be adequate. All vertical faces of the container, including the door, will be louvered in order to dissipate heat buildup from motor, pump, inverter, and debubbler. Figure 2 shows an arrangement whereby the components may be contained in the proposed package as well as a representation of the monitor package as applied to the AHT-64 test stand.

E. REMOVAL AND REPLACEMENT CAPABILITY. In order to provide a monitor package that can be easily removed and replaced on the AHT-64 test stand, a change kit needs to be developed for attachment to the test stand. A typical change kit provides a mount for the monitor package which rests on and is bolted to the bedplate of the chassis and is bolted to mounting lugs welded to the component assembly bridge. Figure 3 shows the location for the mounting lugs on the component assembly bridge and the area for bolting the support to the chassis bedplate. In order to provide ventilation from the pump and filter area of the test stand, the mount employs vertical angles as stand-offs to allow for this ventilation and also to provide space to bring out lines for electrical and hydraulic connections. Figure 4 shows a conceptual arrangement of this mounting method on the AHT-64.

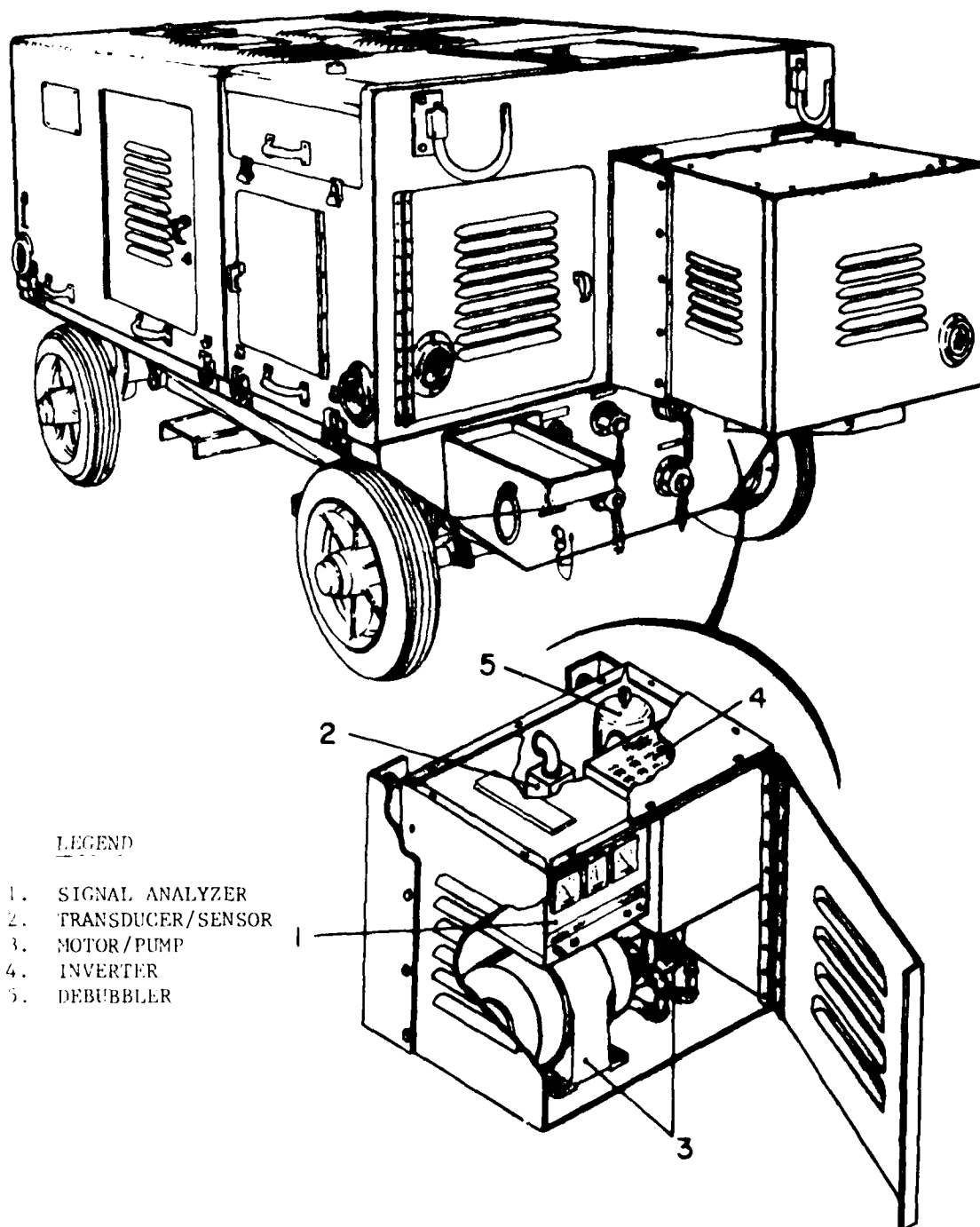


Figure 2. Contamination Monitor Arrangement on AHT-64 Test Stand

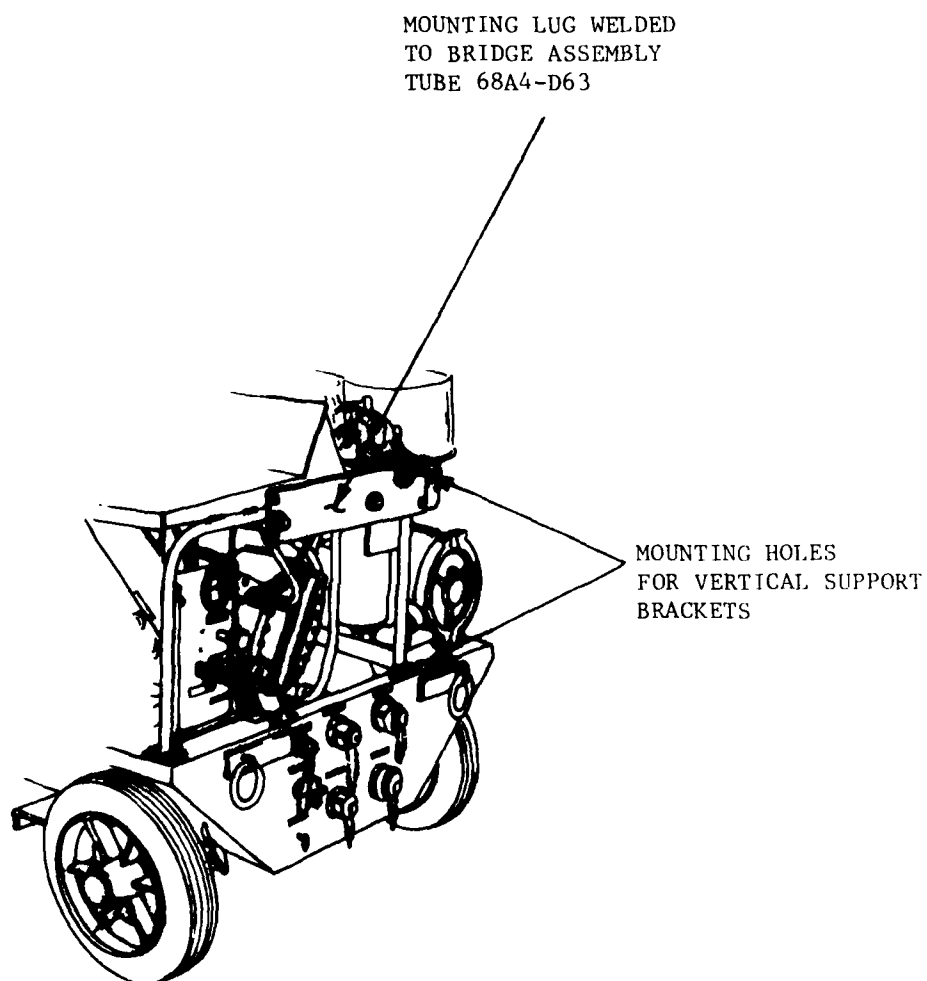


Figure 3. Mounting Lugs and Attachment Points to AHT-64 Chassis

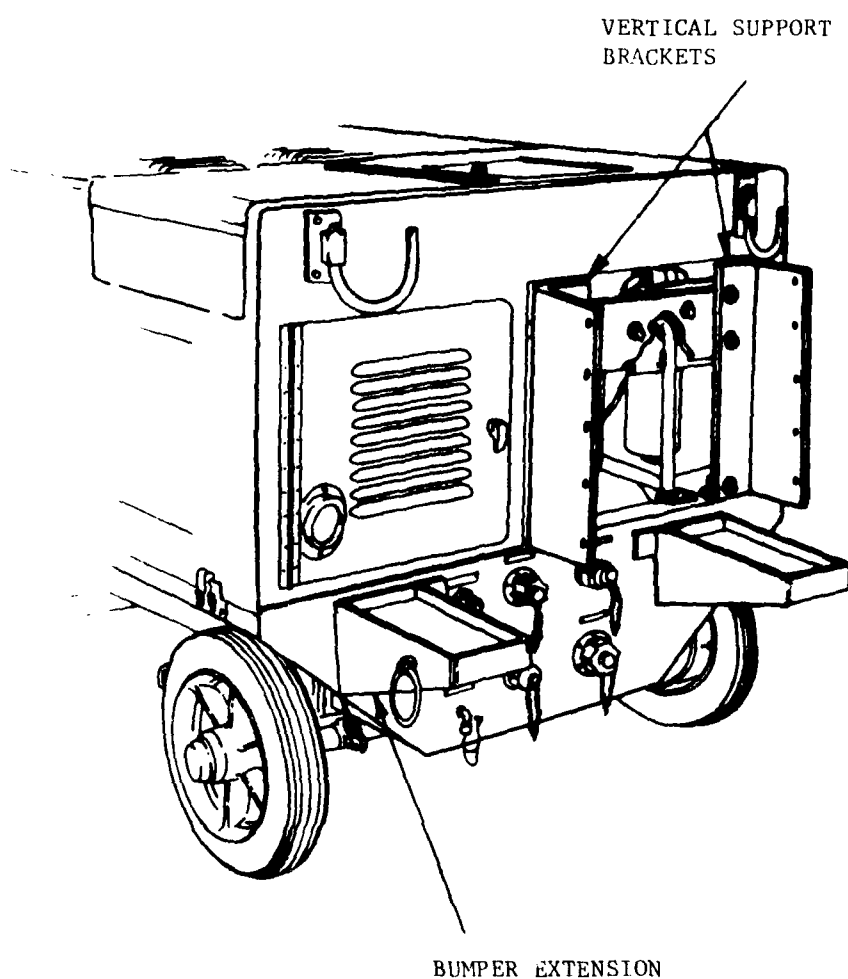


Figure 4. Mounting Arrangement for Monitor on AHT-64 Test Stand

1. ELECTRICAL CONNECTION. The change kit necessarily includes a wire harness to connect the 28 VDC output from battery/alternator system to a Cannon plug on the exterior of the stand behind the location of the contamination monitor. A mating connector from the contamination monitor then connects the monitor to the stand.

2. MONITOR-STAND HYDRAULIC CONNECTION. Hydraulic connections from the test stand to the monitor include two hydraulic lines tapped from tees in the hydraulic return line within the test stand (behind the return connector from the aircraft) to quick disconnects on the stand behind the monitor package. Short flexible lines extend from the monitor couple to these disconnects for the pickup and return flow through the transducer. The return flow from the monitor transducer is to the downstream tee in the low-pressure return line.

#### F. ELECTRICAL INTERCONNECTION WITH TEST STAND

1. 28-VDC POWER SOURCE. Electrical power needed for the contamination monitor is provided by a line from the positive side of the battery and alternator as shown on electrical schematic diagram, Figure 1-10 of NAVAIR 17-15BF-66; the line runs through the ignition switch to a Cannon plug on the back of the test stand, thence to an "on-off" switch in the monitor package. The monitor "on-off" switch is connected to the 28-VDC to 120-VAC inverter and thence to ground. The 120-VAC 500-watt output from the inverter connects to the pump motor and signal analyzer. An interconnection from the signal analyzer powers the transducer or sensor.

2. POWER CABLE. To provide an easy electrical disconnect capability, a short flexible cable extends from the rear of the monitor package for connection to the Cannon plug on the test stand. When the monitor package is removed from its mount on the hydraulic test stand, the connecting electrical cable may be stowed within the package.

G. HYDRAULIC INTERCONNECTION WITH TEST STAND. Interconnection with the test stand may be made by incorporating a pickup tee and tube in tube assembly-5 of piping installation Part No. 68A4-J800-1 (Figure 9-4 of NAVAIR 17-15BF-66). This pickup tube extends to a point behind the mounting area of the monitor and terminates in a coupling half. The mating half to this coupling connects with the inlet side of the monitor package pump through appropriate hose, couplings, fittings and tubing. After passage through the components in the monitor package, a discharge line passes through appropriate tubing, fittings, and hose back to another coupling half on the test stand. The mating coupling half on the test stand discharges into tube assembly-6 of Part No. 68A4-J800-1 through appropriate tube and fittings. The interconnecting hoses may be removed from respective couplings on the test stand and monitor package and stowed with the monitor package when the monitor is to be transferred to another test stand.

H. PHYSICAL ADAPTATION TO STAND STRUCTURE. Previous discussion and evaluation has established the location on the rear of the test stand as optimum for the monitor package. Paragraphs II.E.1 and II.E.2, when considering removal and replacement capability from the rear location, refer to mounting the monitor

package on the tube (68A4-D63-1) of the bridge assembly (68A4-J614 or 68A5-J610) and to the rear panel-assembly top surface (68A4-F31 or 68A4-J607) of the chassis assembly (68A4-J20 or 68A4-J903). Lugs welded to the tube (68A4-D63-1) will absorb horizontal forces imposed at the top of monitor mounts, and vertical loads will be absorbed by the top flange of the rear panel assembly (68A4-F31 or 68A4-J607). A mounting structure as represented in Figure 4 will be bolted to the lugs on the bridge assembly tube and to the rear panel assembly. This mounting structure is fabricated from structural angles and steel plate. A cutout in the rear end housing (68A4-F17) will enable the end housing to be removed without removal of monitor mounts. The cutout portion will be secured to the monitor mount to maintain present closure and ventilation. An external box shown on some models of the rear panel assembly, presumably added for stowage of the fill system outlet hose, will be removed. Other stowage for this hose may be readily accomplished.

1. MAINTENANCE CONSIDERATIONS. The foregoing modification and structural additions to the AHT-64 test stand will not impair any operations of the stand, and added structural members for the monitor may be readily removed if disassembly is required. Mounting lugs welded to the bridge assembly tube do not interfere with any assembly/disassembly procedures of the stand. Other supports are bolted to the chassis. Unions at the connection points to the hydraulic suction return line tube assemblies will make added piping above the chassis bedplate removable if required during any major teardown of the test stand.

2. OPERATION AND MAINTENANCE CHANGES. Maintenance and operations are less convenient with the addition of the monitor package to the stand. The high-pressure filter will be more difficult to change and attachment of the coupling end to the suction return connection port will require the operator to secure same from a squatting position. The present stowage arrangement on the test stand for pressure outlet and suction return hose is not compromised by the addition of the monitor package. The hose storage manifold and valve will be more convenient to use if rotated 90° with the valve handle extended aft rather than down. Provision of bumpers on the aft panel of the chassis and location of the monitor package will negate vulnerability occasioned by this valve rotation.

3. TEST-STAND PARTS AFFECTED. A listing of test-stand components requiring change to accommodate the in-line monitor and a description of the change is indicated in Table II. The part number column lists those part numbers for Teledyne Models 68A4-J600 and 68A4-J800. Where duplication items appear in the description column, these are to accommodate the differences between models.

TABLE II. TEST-STAND PARTS CHANGES FOR MONITOR

| DESCRIPTION                    | TELEDYNE<br>PART NO. | CHANGE TO DRAWING                                                                                                     |
|--------------------------------|----------------------|-----------------------------------------------------------------------------------------------------------------------|
| Bridge Assembly*               | 68A4-J54             | Add welded lug for monitor support                                                                                    |
| " " *                          | 68A4-J55-1           | " " " " " "                                                                                                           |
| " " *                          | 68A4-J614            | " " " " " "                                                                                                           |
| Chassis Assembly               | 68A4-J20-9           | Show added holes for support brackets                                                                                 |
| " "                            | 68A4-J607            | " " " " " "                                                                                                           |
| " "                            | 68A4-J903-1          | Show reqd holes for support structure                                                                                 |
| Component Assy Bridge          | 68A4-J613            | Show welded mounting lug on drawing                                                                                   |
| " " "                          | 68A4-J902            | " " " " " "                                                                                                           |
| Component Assy Rear<br>Housing | 68A4-F612            | Show cutout, remove reflector and<br>hose storage                                                                     |
| Hyd Test Stand Assy            | 68A4-J600/<br>-J800  | Modify sheets of assy to show monitor                                                                                 |
| Internal Component Assy        | 68A4-J2              | Change view sheets 4, 5 and 6                                                                                         |
| " " "                          | 68A4-J601            | " " " 2, 4, 5, 6 and 7                                                                                                |
| " " "                          | 68A4-J901            | Change B/M and view sheets 3, 4, 5 and 6                                                                              |
| Piping Installation            | 68A4-H731            | Add tee in tube 68A4-D404-29 for pickup                                                                               |
| " "                            | 68A4-H731            | " " " " 68A4-D571-23 for return                                                                                       |
| " "                            | 68A4-H913            | Change elbow MS51521820 to tee for pickup                                                                             |
| " "                            | 68A4-H913            | Add tee in tube 68A4-C921-1 for return                                                                                |
| Rear End Housing               | 68A4-F17-1           | Make cutout for clearing supports, remove<br>hose storage box 68A4-C16-1, remove right<br>hand reflector from housing |
| Rear Housing Assy              | 68A4-F610            | Change view to show changes on 68A4-F17-1                                                                             |
| Rear Panel Assy                | 68A4-F31-1           | Add bolt hole for mounting bracket on<br>top flange of -11, add bumper extension<br>brackets and relocate tie-downs   |
| Right-Hand Side Panel<br>Assy  | 68A4-F21-1           | Add mounting bolt hole to 68A4-608-1<br>top rear                                                                      |
| Wiring Installation            | 68A4-D741-1          | Add connecting cable to monitor switch                                                                                |
| " "                            | 68A4-D586            | " " " " " "                                                                                                           |

\* These 3 assemblies have lug welded to tube, bridge assy 68A4-D63.

## I. EVALUATION OF CANDIDATE MONITORS

1. GENERAL. In paragraphs II.B and II.C, investigation of the eight candidate monitors revealed in a data search eliminated all but three models. Details of all eight candidates are listed in Table I and reasons for rejecting five discussed. The remaining three were considered for their size, weight and compatibility in a proposed monitor package. Of the three candidate monitors, the Environment/One Corp. signal conditioner and transducer were the only units which had been flight certified and had seen service in the Navy's A-7 aircraft. Also the Environment/One unit is the smallest and lightest. Pertinent data of these three candidate monitors appear in Table III.

2. AUXILIARY COMPONENTS AND PARAMETERS. Each of the three monitors require an auxiliary circulator pump, a 28-VDC to 120-VAC inverter, and a debubbler to extract entrained air from the hydraulic fluid in order to be adaptable to the AHT-64 test stand.

a. Power requirements for each of these monitors is of relatively slight significance in light of the fact that the pump motor starting torque demands an inverter capable of providing an estimated 500 watts at 120 VAC.

b. Contamination monitor package size and weight are very nearly the same for each of these three monitors since the motor pump unit, debubbler and inverter account for approximately 65% of the package volume and approximately 85% of the weight.

c. Operating pressure for these monitors in the AHT-64 aircraft return line environment will always be less than the lowest rated pressure of the three monitors.

d. Shock will not be a critical factor for this application because the mass of the test stand will effectively attenuate imposed shocks below critical levels of monitor components. Any revealed sensitivity to shock may be readily cushioned for such small components as employed in the monitor package. Vibration as a factor influencing performance of in-line contamination monitors is discussed in the following paragraphs.

J. VIBRATION SIGNATURE DETERMINATION OF TEST STAND. The vibration sensitivity pointed out as a deficiency of in-line contamination monitors in report NAEC-65ED-105 has been overcome through a two-step process. The first step of the process is determination of the vibration signature of the vehicle on which the contamination monitor will be mounted. The second step is determining the capability of candidate monitors to withstand the vibration levels of the carrying vehicle. The following paragraphs present the findings of the vibration signature investigation of the AHT-64 hydraulic test stand. The AHT-64 was selected as the vehicle on which to mount an in-line contamination monitor because, of all the mobile hydraulic test stands, it appears to experience the highest level of vibration. This high level of vibration is caused primarily by the diesel engine drive of its 3,000-psi, 28-gpm, nine-piston pump. Also the AHT-64 is a high inventory test stand.

TABLE III. CANDIDATE MONITOR EVALUATION

| TYPE DATA -<br>COMPONENT | ENVIRONMENT/ONE<br>SIGNAL CONDITIONER/<br>TRANSDUCER | HIAC<br>PC 120                  | GAM RAD<br>ENVIRO<br>MONITOR |
|--------------------------|------------------------------------------------------|---------------------------------|------------------------------|
| Volume: Analyzer         | 0.352 Cu Ft                                          | 0.390 Cu Ft                     | 0.445 Cu Ft                  |
| Sensor                   | 0.015 Cu Ft                                          | 0.002 Cu Ft                     | 0.631 Cu Ft                  |
| Total                    | 0.367 Cu Ft                                          | 0.392 Cu Ft                     | 1.076 Cu Ft                  |
| Weight: Analyzer         | 8.5 Lb                                               | 18 Lb                           | 15 Lb (Approx)               |
| Sensor                   | 2.0 Lb                                               | 2 Lb                            | 12 Lb (Approx)               |
| Total                    | 10.5 Lb                                              | 20 Lb                           | 27 Lb (Approx)               |
| Pressure: Operating      | 100 Psig                                             | 85-3,000 Psi                    | 250 Psi (Approx)             |
| Test                     | 600 Psig                                             | -                               | 325 Psi                      |
| Operating Temperature:   |                                                      |                                 |                              |
| Analyzer                 | 200° F                                               | -                               | 190° F                       |
| Sensor                   | 350° F                                               | 200° F                          | 190° F                       |
| Input Power              | 117 V                                                | 110-240 VAC                     | 117 VAC                      |
|                          | 47-400 Hz                                            | 50-60 Hz                        | 50-60 Hz                     |
|                          | 10 W                                                 | 40 W                            | 150 W                        |
| Sensor: Shock            | 15 G                                                 | -                               | -                            |
| Vibration                | 50 G at 2,000 CPS                                    | -                               | -                            |
| Analyzer: Shock          | 15 G (on board<br>model only)                        | -                               | -                            |
| Vibration                | 2.2 G at 3,600 CPS                                   | -                               | -                            |
| Particulate Range        | 2 + PPM                                              | 0-100, 0-300,<br>0-1K, 0-3K PPM | 50 PPB to 50K PPM            |
| Flow-Rate Range          | 3-20 Gpm                                             | Uniform flow rate               | 0-75 Gpm                     |
| Cost Per Unit            | \$3,500                                              | \$10,000 (PC-320)               | \$3,150                      |

1. COMMERCIAL TEST COMPANY SELECTION. A number of commercial companies were contacted to provide monitoring equipment for use by NAVAIRENGCFN laboratory personnel. Response was extremely varied in cost both for purchase and rental of equipment with lead times extended and costs high. The NAVAIRENGCFN Test Department Electronic Division and a number of commercial testing companies were requested to quote on performing vibration signature analysis of candidate AHT-64 test stands. This service was provided by:

Vibration Specialty Corporation  
100 Geiger Road, Philadelphia, PA 19115

The vibration signature analysis is reprinted in Appendix B.

2. VIBRATION SIGNATURE ANALYSIS. A vibration signature analysis of two AHT-64 hydraulic test stands was performed, one at Naval Air Engineering Center, Lakehurst, and one at Naval Air Station, Willow Grove, PA, (stand 143 and 117 respectively), to determine existing vibration amplitudes and frequencies.

a. Vibration energy was monitored at seven locations on the test stand as shown in Figure 5. Signatures were recorded in the horizontal, vertical, and axial directions under idle (1,000 rpm), full-speed (2,400 rpm), loaded (3,000 psig), unloaded and transient conditions. Each signature (see Appendix B) shows vibration amplitude in G acceleration versus frequency in Hz. The amplitude (vertical scale) is logarithmic with full-scale equal to 1 G or 10 G as indicated. The frequency (horizontal scale) is linear from zero to 2,000 Hz with 4 Hz resolution. Described in the heading are test stand number, test position, total overall vibration level, various instrument settings, and test stand operating conditions.

b. Vibration amplitude response varied by a factor of two or more between the two test stands due to structural integrity differences, not input energy differences. Vibration frequency response was consistent on both test stands - that is, 360 Hz was the major source and response frequency.

c. Basically all input energy was measured at positions 6 and 7, Figure 5. Test position 6, Figure 5, was the hydraulic pump, where loaded (3,000 psig) and unloaded (zero gauge) pressure variations were tested. Measured and recorded were the change in vibration energy levels produced by the two conditions.

d. Stand 143 showed a considerable increase in vibration (almost double) with load (see Appendix B, Figures 20 and 41). Stand 117 showed very little increase (about 10 percent), as seen in Figures 60 and 77 of Appendix B. The major vibration frequency was 360 Hz, or nine times the operating speed (2,400 rpm = 40 Hz). It was determined that the pump had nine pistons working axially, which explains the high ninth harmonic response in all test positions, predominantly in the axial direction.

e. Test position 7, Figure 5, was the diesel engine on both stands, rotating at 2,400 rpm, with or without pressure load on the pump. The engine vibration levels recorded on each stand were very similar, and there were no appreciable changes with pump loading (Appendix B, Figures 22, 43, 62 and 78). The major frequency source from the diesel was the 40 Hz signal and the associated harmonics.

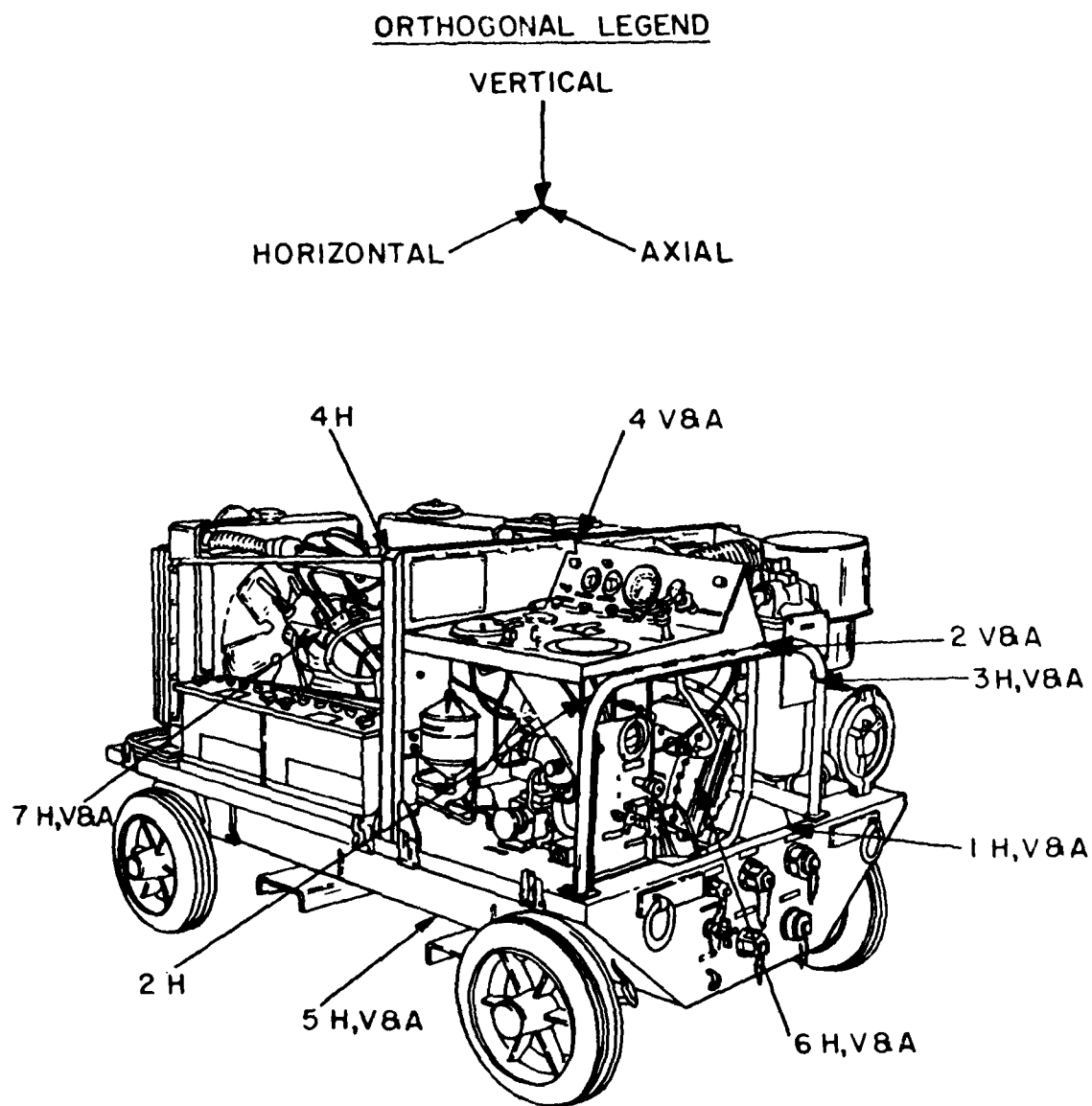


Figure 5. AHT-64 Vibration Test Positions

f. Structural vibration response was measured and its frequency spectra signature recorded at five different locations on the AHT-64 structure. Remember, the major frequency on all signatures on both test stands was 360 Hz.

g. The highest amplitude response (2.2 G) on stand 143, was at position 5, Figure 5 (Appendix B, Figure 36), which is the underside of the base structure of the stand. A level almost equal to this (2 G) was recorded in the axial direction at positions 1 and 3, Figure 5 (Appendix B, Figures 26 and 32). Positions 2 and 4, Figure 5, showed levels around 1.5 G (Appendix B, Figures 29 and 35).

h. In comparison, test stand 117 had the highest response (7 G) at position 4, Figure 5 axial (Appendix B, Figure 73). The next highest response on stand 117 was 3 to 4 G's (still higher than 143) at positions 2 and 3, Figure 5 (Appendix B, Figures 67 and 68). Positions 1 and 5, Figure 5, had levels around 1 to 2 G.

i. The only explanation for this drastic difference in response between these two test stands would be the way the control panel is connected to the rib structure at those points. In other words, stand 143 is stiffened by the ribs being rigidly connected together by the control panel, and stand 117 is less rigid by being loose or possibly not connected at all, thereby allowing this center point to vibrate excessively. Upon examination, bridge-assembly mounting bolts were found to be loose and several welds on the bridge cracked.

### 3. ANALYSIS SUMMARY

a. The excitation energy on each test stand was similar, producing a similar frequency response. However, the amplitude response was different by a factor of two or more. Therefore, the instrument package which is to be mounted on the AHT-64 structure must be able to withstand vibration frequencies around 360 Hz. However, the amount of vibration energy it must withstand is still in question.

b. If we assume that test stand 143 had "good" structural integrity and needs no further reinforcements, etc., and we assume that test stand 117 could be fixed and/or reinforced enough to respond similar to 143, then the amount of vibration energy which must be withstood by the instrumentation would be 2 G's if mounted on the rear of the stand below the control panel (positions 1, 2 and 3 on Figure 5).

### 4. VIBRATION TOLERANCE OF MONITORS

1. After determination of the vibration signature of the AHT-64 test stand, a nondestructive test-bench setup was devised which would allow candidate contamination monitor components to be gradually subjected to increasing amplitudes at the critical frequency of the AHT-64. This test bench enables monitors to be tested for their ability to perform satisfactorily in the simulated vibration environment of the AHT-64.

2. These tests indicate that an in-line contamination monitor does exist which will operate satisfactorily at the AHT-64 hydraulic test-stand

vibration signature. Procedures, results and illustrations of this test-bench setup are included in their entirety in Appendix C. Of the three monitors selected as applicable, two were made available for tests. Of the two which were tested, one proved satisfactory and the other could not be tested adequately because it was determined to be inoperable prior to any vibration excitation. This model, the HIAC PC-120, is no longer manufactured and has been replaced by a Model PC-320 which can be provided with a signal closure device for automatic shut-off at a predetermined degree of fluid particulate decontamination. Vibration sensitivity of PC-320 is unknown.

### III. CONCLUSIONS

- A. Determination of the vibration signature of the AHT-64 hydraulic test stand provides amplitude and frequency data required to complete the hydraulic contamination monitor specification in NAEC-CSED-105, Development of a Procurement Specification for an In-Line Contamination Monitoring Unit.
- B. A commercial in-line contamination monitoring unit has been satisfactorily tested for operation at the critical frequency and amplitude of the AHT-64 hydraulic test stand.
- C. A contamination monitor package concept has been developed which is adaptable to the AHT-64 hydraulic test stand.
- D. The modification of AHT-64 test stands to incorporate an in-line contamination monitor is compatible with present operation and maintenance procedures of the test stand.

#### IV. RECOMMENDATIONS

A. Development of an in-line contamination monitor package is recommended. This will include assembly of primary components in a common enclosure, mounting on a test stand and operating for an engineering evaluation.

B. It is recommended that concurrent with development of the in-line contamination monitor a modification kit be developed for adaptation of the monitor to the AHT-64 hydraulic test stand.

C. The vibration signature data contained herein should be added to the procurement specification NAEC-GSED-105, Development of a Procurement Specification for an In-Line Contamination Monitoring Unit.

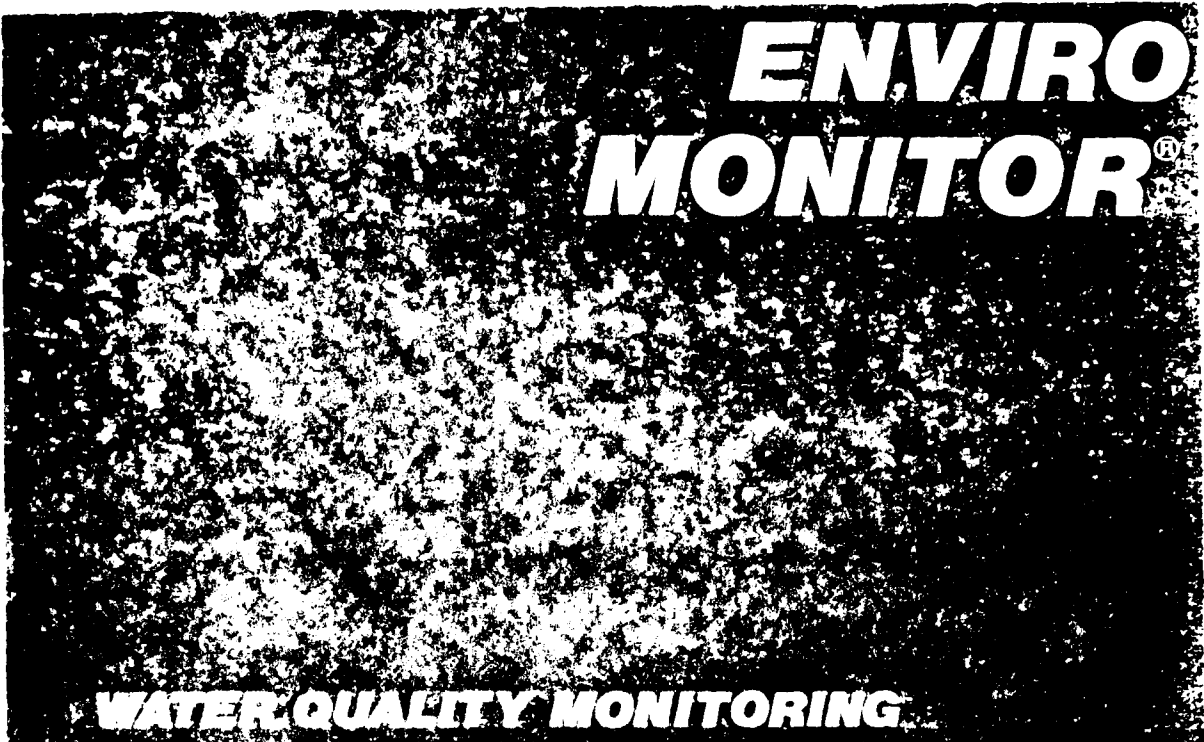
V. REFERENCES

- (a) NAVAIRENGCEN Technical Report NAEC-GSED-105 of 14 Jun 1977:  
Development of a Procurement Specification for an In-Line  
Contamination Monitoring Unit, Final Report (Prepared by  
J.J. Coyle for NAVAIRENGCEN)
- (b) NAVAIRSYSCOM Technical Manual NAVAIR 17-15BF-66 of 1 Nov 1977:  
Portable Hydraulic Test Stand, Diesel Engine Driven, Operation  
and Maintenance Instructions with Illustrated Parts Breakdown  
(Teledyne Sprague Engineering)

APPENDIX A  
MANUFACTURERS' DATA FOR CANDIDATE  
IN-LINE CONTAMINATION MONITORS

The manufacturers' data is presented in the following order:

|                                           |    |
|-------------------------------------------|----|
| Gam Rad, Inc.....                         | 32 |
| Environment/One Corp.....                 | 38 |
| HIAC Division, Pacific Scientific Co..... | 48 |
| Leeds & Northrup Co.....                  | 55 |
| Micro Pure Systems Inc.....               | 62 |
| Royco Instruments Inc.....                | 67 |
| Spectrex Corp.....                        | 72 |
| Vickers Inc.....                          | 78 |
| Wilmore Electronics Co., Inc.....         | 80 |



# **ENVIRO MONITOR<sup>®</sup>**

**WATER QUALITY MONITORING**

**over 20 different parameters and 40 models**

**GamRad, Inc.**

# Introduction to Enviro Monitors

Enviro Monitor describes a series of water quality instruments that are divided into three major categories:

|                  |             |
|------------------|-------------|
| Single Parameter | Series 500  |
| Multiparameter   | Series 1000 |
| Wet Chemistry    | Series 2000 |

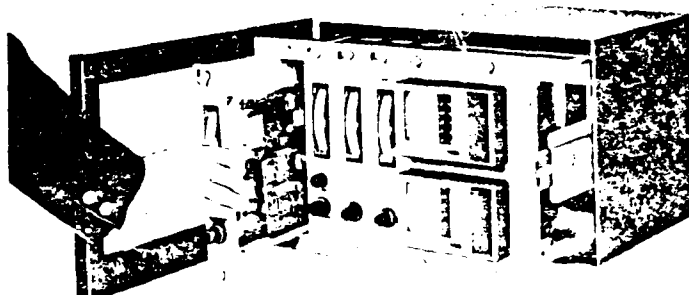
This partial list of parameters indicates the many instrument systems available in the Enviro Monitor line. If your particular requirement is not listed, don't hesitate to contact the factory for recommendations.

AMMONIA  
CALCIUM  
CHLORIDE  
CHROMIUM, HEXAVALENT  
CONDUCTIVITY  
COLOR  
DISSOLVED OXYGEN  
DISSOLVED SOLIDS  
FLOW  
HARDNESS  
NITRATE  
NITRITE  
ORP  
ORTHOPHOSPHATE  
pH  
POTASSIUM  
RESIDUAL CHLORINE  
SELECTIVE ION  
SODIUM  
SULFIDE  
SULFUR DIOXIDE  
SUSPENDED SOLIDS  
TEMPERATURE  
TURBIDITY\*

\* Meets EPA design criteria.

A single Series 500 and each channel of the Series 1000 Enviro Monitor provides the same total capacity. These separate series are available to fulfill the need for single or multiparameter monitoring. The Series 2000 Wet Chemistry Enviro Monitors are available for applications that require complex sample treatment prior to measurement.

Enviro Monitors offer single-source capability for monitoring all water quality parameters. This means total instrument requirements for measurement and/or control of influent, effluent, or process water quality can be satisfied by a single source. Gam-Rad, Inc. Enviro Monitors utilize state of the art electronics and proven technology to provide the best optimum system.

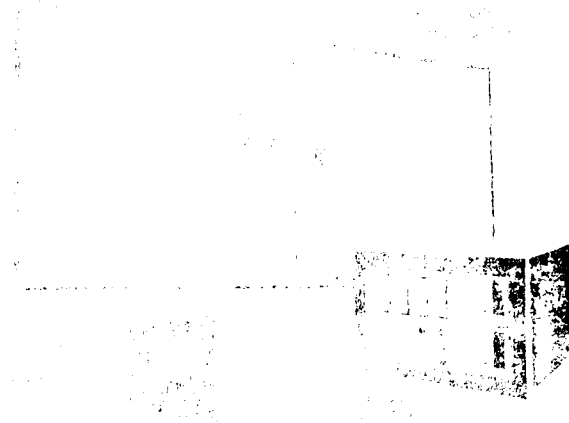


## Enviro Monitor Benefits

Shopping around to mix and match instruments is a thing of the past. By specifying Enviro Monitors you benefit in many ways. For example, single source capability also means single source responsibility. You no longer have to be bothered with incompatible instruments.

Further benefits are derived from continuity in packaging, electronics, materials, construction, power requirements, readout and output standardization, instruction and service manuals, and most of all by integrated technical assistance. In keeping with this concept, we offer engineering specifications and application data sheets.

For over ten years Gam-Rad has manufactured instruments to meet customers' needs. That service is yours for the asking. You don't have to settle for off-the-shelf instruments to meet special requirements. Enviro Monitors have been designed to offer custom instruments at off-the-shelf prices.



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### GAM RAD IS . . .

a diversified, multi-product company that has been producing water quality monitoring instrumentation for over a decade. With the expanded ENVIRO MONITOR line, we are now prepared to solve all of your water quality monitoring needs.

Our business is building these instruments, at competitive prices, to meet the needs of our customers.

### ENVIRO MONITOR BENEFITS . . .

Single source capability also means single source responsibility, and that means benefits like these:

Compatible instruments, physically and electronically

Continuity in packaging, electronic materials and construction

Standardized readouts and outputs

Standardized input power requirements

Integrated technical assistance

IF YOU'RE IN NEED OF OUR EXPERTISE IN WATER QUALITY MONITORING,  
CONTACT OUR LOCAL REPRESENTATIVE OR FACTORY PERSONNEL.

*represented by*

46101 Grand River  
Novi, MI 48050  
313/348-1005

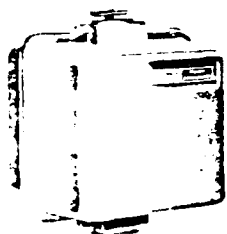
Printed in U.S.A. 5/71 550000001

# Fluid Analyzers



## GAM RAD, INC.

Monitor suspended solids (turbidity) in process streams with these accurate, dependable instruments. Designed to meet modern process application requirements. Ultra-pure materials to slurries. Monitor and control your process with assurance.



### Model 370-A Fluid Analyzer

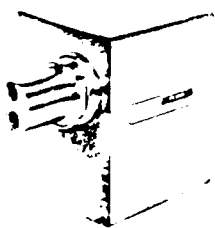
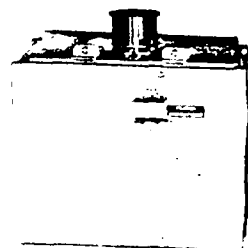
1 PPM to 50,000 PPM, total range

The Model 370-A is designed for applications demanding the utmost accuracy, particularly with ultra-pure materials down to **one part per billion** concentrations. Optical system incorporates unique dual light beam, dual detector arrangement for extreme sensitivity. Measures 90° scattered light from suspended solids with almost instantaneous response. BULLETIN T-200

### Model 260 Fluid Analyzer

50 PPM to 50,000 PPM, total range

The Model 260 incorporates a single light beam, single detector optical system to measure 90° scattered light. Low end sensitivity is **50 parts per billion**. May also be set up to measure transmitted light (absorbance) when needed. Designed for applications where less sensitivity and range is required. BULLETIN T-100



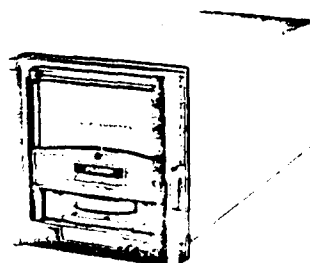
### Model 150 Fluid Analyzer

10 PPM to 150,000 PPM, 15% total range

The Model 150 is particularly suited for heavier concentrations — up to **15% total solids**. There are no limitations on flow rate because of probe type. Measure light scattered at 130° (back-scattered) from suspended solids. May be installed in process lines of any size or in tanks or vessels. BULLETIN T-300

### Control Station

The Control Station provides readout, measuring and control circuitry, power supply and output signal connections for each of the above sensing stations. It can be located adjacent or remote (up to 500 feet away). Standard panel mounted style shown. Table top styles also available. Features all solid state circuitry, 5" readout meter and 0-100 millivolt output along with control switches and calibration controls.



PATENTS PENDING

## General Features

The Models 260 and 370-A are "flow thru" instruments rated at 75 GPM with less than 2" water pressure drop. 2 1/2" sanitary fittings are standard and flange fittings are optional. The Model 150 has no flow limitation. This is determined by the line size into which it is installed. It, also, is available with 2 1/2" sanitary or flanged fitting.

All Fluid Analyzers are rated at 250 PSIG pressure. Temperature maximums are 140° F for Model 260 and Model 150 and 190° F for Model 370-A. All may be equipped for up to 450° F service.

All models feature condensation proof windows, electronically controlled light source and temperature stabilized detector cells.

All wetted components are made of type 304 stainless steel. In addition, the flow chambers on the Model 370-A and 260 are "Teflon coated". Alternate materials and coatings are available.

All Sensing Stations are suitable for indoor or outdoor installations. Explosion proof housings are available for hazardous locations.

Power requirements are 117 VAC, 50-60 HZ, 150 watts max. Output signal is 0-100 millivolts DC-adjustable. Milliamperage or pneumatic outputs are available.

Other options and accessories to meet most process requirements.

## Typical Uses

*monitor and control -*

FILTER EFFLUENTS  
CENTRIFUGES  
CLARIFIERS  
DEMINERALIZERS  
SCRUBBERS  
POLISHERS  
THICKENERS  
MIXERS

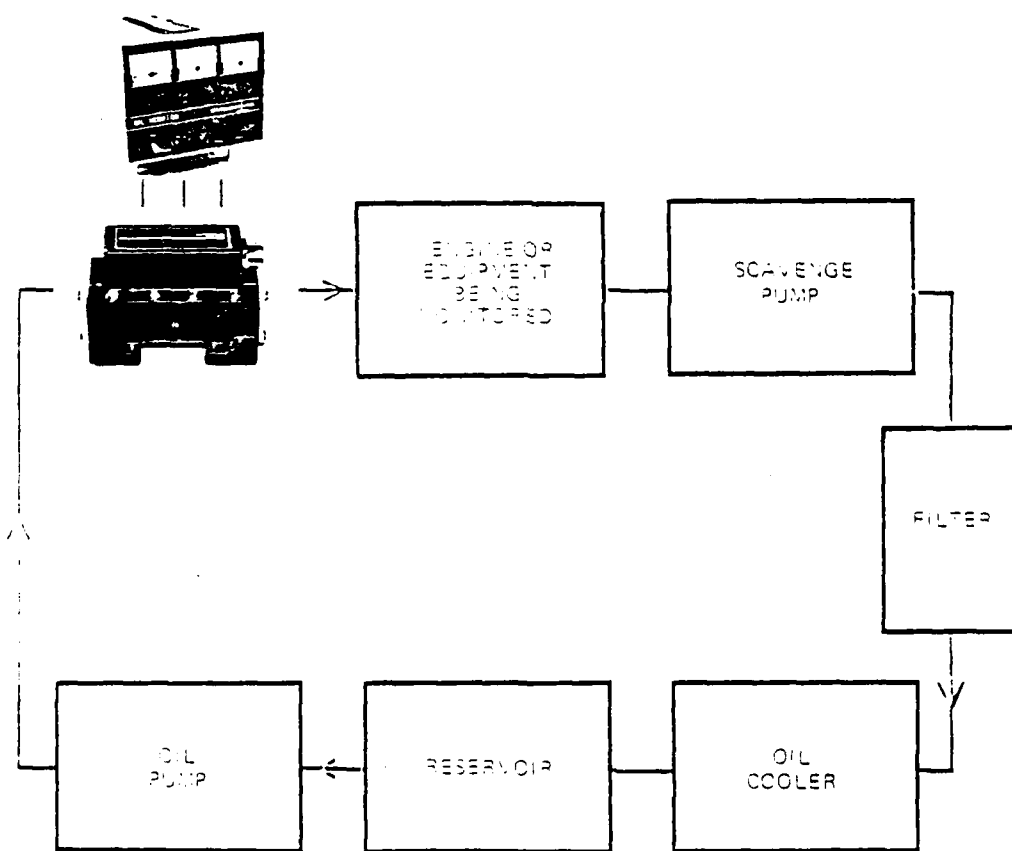
CLARITY  
EMULSIONS  
CLOUD AND FOG POINTS  
PRECIPITATIONS  
REACTIONS  
SLURRIES

BOILER FEEDWATER  
HYDRAULIC OIL  
BEER  
FRUIT JUICES  
POLYETHYLENE  
RAW WATER  
SPENT PICKLED LIQUOR  
ALUMINUM SILICATE  
PLATING ELECTROLYTE  
INDUSTRIAL WASTES  
SILICON  
SUGAR  
SOLVENTS



**GAM RAD, INC.**  
46101 Grand River  
Novi, Michigan 48050  
Area Code 313-348-1005

# EQUIPMENT CONDITION MONITOR (OIL MONITOR)



environment | one  
CORPORATION

PROTECTING MAN'S ENVIRONMENT

AN IN-LINE MONITOR WHICH PROVIDES  
REAL TIME DETECTION AND  
MEASUREMENT OF METALLIC AND  
NON-METALLIC PARTICULATE  
CONTAMINATION AND CHEMICAL/  
THERMAL DEGRADATION OF  
LUBRICATING OILS AND OTHER FLUIDS

## FEATURES

- In-line, real time indication of metallic and non-metallic particulate presence and chemical/thermal degradation in oil or other fluids
- Detects ferrous and non-ferrous particulates and dissolved impurities introduced from within or from outside the equipment
- Provides early warning and trending of equipment malfunction
- Automatically and continuously self-calibrating
- Long term, maintenance free, automatic operation
- Individual outputs for particulate presence, chemical/thermal degradation and flow rate

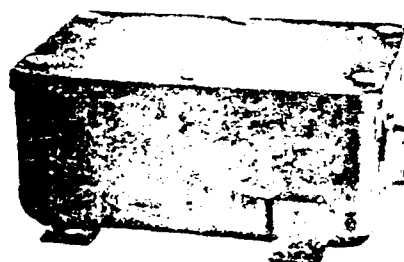


## SPECIFICATIONS

### PRODUCER

Cat. #D-1012N-007

- Operating temperature to 350°F
- Operating pressure to 100 PSIG\*
- Pressure drop 5 PSIG at 18 GPM
- Flow rate 3 to 20 GPM
- Shock 15 g's
- Vibration 50 g's at 2000 CPS
- Size 2.38" x 4.50"
- Weight 2.0 lbs.
- \*Tested to 600 PSIG



### AMPLIFIER/OUTPUT DRIVER ON BOARD

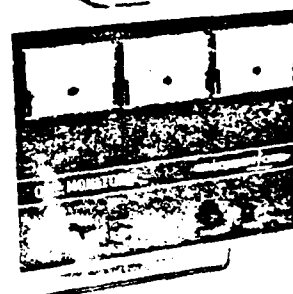
Cat. #D-1012B-010

- Operating temperature to 200°F
- Input Power 28 VDC at 0.3 Amps
- Output 0 to 5 VDC each channel
- Vibration 5 g's at 2000 CPS
- Shock 15 g's
- Size 5.25" x 7.25" x 3.3"
- Weight 3.0 LBS max
- \*Other configurations available

### FINAL CONDITIONER, TEST CELL REMOTE

Cat. #B-101-00002G2

- Visual output on panel meters, 0 to 5 VDC each channel
- Input power 117V, 47 to 400 Hz, 10 Watts
- Size 6.5" x 8.5" x 11"
- Weight 8.5 LBS



## INTRODUCTION

The Equipment Condition Monitor is a field proven in-line lubrication system monitor which provides real time incipient failure prediction and degradation rate of oil-wetted parts, oil overheating, excess aeration, inadequate flow, seal failures and other abnormal engine or equipment conditions.

The Equipment Condition Monitor's early warning and trending capabilities can effect genuine economies for the user by:

- reducing or eliminating expensive damage to capital equipment;
- minimizing equipment down time;
- reducing maintenance to an "as needed" basis;
- reducing sample frequency and analysis where S.O.A.P. or similar procedures are followed and
- predicting residual operational life of a component.

In addition to lubrication systems, the Equipment Condition Monitor is applicable for other fluids such as fuels, hydraulic or process fluids or others in a circulating system.

### SYSTEM SUB-ASSEMBLY

The Equipment Condition Monitor System consists of a Transducer mounted in the oil line and a Signal Conditioner located either on-board or at a remote station. For multi-point monitoring, if continual read-out is not required, one Signal Conditioner can accommodate several transducers on a time-share basis.

During operation the oil or fluid is monitored by measuring the light scattering caused by metallic particulates and light attenuation resulting from chemical, thermal degradation and non-metallic particulates. An output corresponding to flow rate is also provided. Unique design features which incorporate internal, stable references make the Monitor automatically and continuously self-calibrating over all system operating conditions.

Designed initially for aircraft gas turbine operation, the Equipment Condition Monitor can withstand adverse conditions of temperature, shock and vibration.

### TRANSDUCER

The Transducer, designed to accommodate a broad range of flow rates, is normally mounted directly in the high pressure side of the main oil line. In this location the effects of free air in the oil are minimized because most of the air is dissolved. As the oil passes through the Transducer, it causes a rotor to turn. The rotor contains fluid passages and optical references which are alternately placed in an optical system as the rotor revolves. The optical paths utilize sealed fiber optics to conduct the light into and out of the oil and to produce a light beam parallel to the axis of the rotor. One

photo sensor is mounted radially so that it views the light beam at 90° to provide the scattering output. The attenuation sensor views the axial component of transmitted light. The output of each sensor is a series of pulses alternating between reference and signal. These are fed to a signal conditioner which computes the ratio of signal to reference amplitudes.

### SIGNAL CONDITIONER

In the signal conditioner, outputs from the scattering and attenuation sensors are transmitted to their respective, variable gain, current amplifiers which pass only the light pulses and eliminate the DC component due to stray light and dark current. Reference channels compare incoming reference pulses with a fixed voltage reference and provide control signals to change the gain of the current amplifiers thereby providing a continuous and automatic self-calibrating condition.

The outputs of the flow, scattering and attenuation channels provide from 0 to 5 volts dc with a current output capability of 2 milliamperes. These outputs can be applied to condition monitoring multiplexers, A/D converters, recorders, cockpit indicators or other on-board or remote monitoring equipments.

Two additional features include a test mode and a malfunction indication. The test mode will cause the Signal Conditioner to read out the measured scattering and attenuations levels of the Transducer references. This provides a check of the Monitor circuits as well as the read-out equipment. The malfunction indication, which can activate a warning circuit, is initiated by component or power failure or low flow rate.

## APPLICATIONS

Designed initially for use as an on-board, real time indicator of the optical properties of lubrication oils in aircraft gas turbines, the Equipment Condition Monitor System can be similarly used for continuous or periodic, on-board or remote monitoring of stationary gas turbines, vehicular turbines, marine turbines, industrial machinery, gear boxes, fuel systems, transmissions, processing systems and other equipment using circulating fluid systems.

### AIRCRAFT



- Military Engines and Gear Boxes
- Commercial Airlines Engines
- Helicopter Gear Boxes and Transmissions
- Business and Private Jets

### MARINE



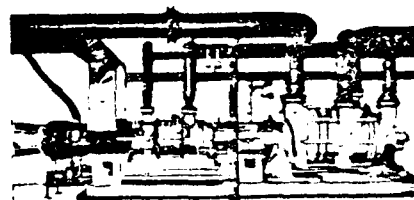
- Naval Turbines and Hydraulic systems
- Bearing Lube Systems
- Merchant Marine Equipment
- Passenger Ship Turbines
- Turbine Fuel Monitoring

### STATIONARY



- Gas Turbines for Power Generation
- Pipeline Engines and Compressors
- Off Shore Drilling Rigs
- Mining Equipment
- Stand-By and Peaking Turbines

### PROCESSES



- Flushing Cycle Monitoring
- Filter Evaluation
- Liquid Chemical Monitoring
- Liquid Food Monitoring
- Petroleum Evaluation

ALSO FOR GAS TURBINES AND ENGINES IN  
LOCOMOTIVES  
OFF THE ROAD EQUIPMENT  
TRUCKS AND BUSES

Since the Equipment Condition Monitor System uses optical techniques, factors such as fluid opacity enter into its feasibility for specific applications such as diesel engine lubricating systems or other reciprocating equipment. Contact us with your application requirements so that we can determine the Equipment Condition Monitor's suitability for your equipment. A simple test can make this determination toward the application of this cost saving system to your requirements.

ENVIRONMENTALITE CORP.  
2773 BALLTOWN RD.  
SCHENECTADY, N.Y. 12309  
(518) 346-6161

ECM-311M1-6/75

## THE IN-LINE OIL MONITOR AND ITS ROLE IN ENGINE CONDITION MONITORING

George F. Skala\*

Environment/One Corporation, Schenectady, N. Y.

### Abstract

An Equipment Condition Monitor for the continuous in-flight detection of abnormal conditions of oil-wetted engine components has been developed. The system employs the principles of light scattering for particulate debris detection and light attenuation for chemical/thermal degradation. Long-term stability is obtained by an automatic and continuous self-calibration feature using internal references. An output proportional to flow rate also is provided. The system can withstand the adverse temperature, shock, and vibration ambients associated with jet aircraft applications. Flight tests on passenger-type, multi-engine aircraft and on single-engine military aircraft have been conducted. A bearing failure on an endurance test engine was predicted by abnormal oil condition readings prior to any other indications of failure.

### Introduction

Until recently, an on-board real-time condition monitoring system has been a conspicuous missing link in airborne engine instrumentation systems. In addition to its functions of lubricating and cooling, the oil is a messenger carrying information which, if heeded, can help prevent some of the 30 to 35% of engine failures caused by oil-wetted components. Engine-installed oil monitoring at present generally is limited to the use of magnetic chip detectors and screens which are periodically examined for collected debris. In some cases, this is supplemented by the Navy pioneered Spectrometric Oil Analysis Program (S.O.A.P.). This can be effective as a preventive maintenance tool if all the human factors from sampling, to analysis, to reporting, to interpreting, and finally to taking corrective action are carefully controlled.

In recognition of the need for continuous oil monitoring, there have been several recent developments which utilize a form of trapping device, such as a magnet or screen, coupled with an arrangement to produce an electrical signal which is a function of the collected debris. The signal is usually generated by a change in resistance, capacitance, or magnetic properties produced by the collected material, or by a pressure transducer monitoring the drop across a filter.

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\* Manager.

## GEORGE F. SKALA

These can provide information only on what they have removed from the oil. Also, in order to produce an output which can indicate the start of an abnormal condition, it is necessary to know the rate at which the debris is being collected. This requires the use of some form of differentiating, or rate of change, circuit that would be difficult to design for sufficient accuracy on a real time basis. Finally, all forms of trapping device require regular maintenance in that they must be periodically cleaned or replaced.

Requirements

For sufficiently early warning, the oil-monitoring system must have adequate sensitivity and long-term stability to detect a significant departure from a long-term trend. For most jet engine applications, this minimum detection level should be no more than the equivalent of about 10 ppm.

To present a true "on-condition" indication, the detection capabilities should encompass all forms of undesirable oil conditions. These would include the detection of wear metals from the engine, dirt from outside the engine, and degradation of the oil. It also would be desirable if the source of contamination could be identified. However, the qualitative analysis techniques that this entails would, at the present state of the art, require an overly complex approach, or a severe limitation of the kinds of contamination that could be detected. For example, the use of radioactive isotope tagging would eliminate the detection of contamination originating from outside the engine. With a universal detector, once an "off-condition" situation develops, conventional ground-based analysis, such as S.O.A.P., can be used to identify the contamination. A truly effective oil-monitoring system also should require little or no maintenance or attention. Since one of the ultimate objectives of engine condition monitoring is to eliminate unnecessary maintenance, the components of such a system should not contribute to any required maintenance. Other, more obvious requirements are that it be reliable, small, lightweight, and reasonable in cost.

Design Approach

Because optical sensing is universal, and can be sensitive, this technique was selected for the oil monitoring system developed by Environment/One Corporation. Scattered light is used to detect particulates, and the attenuation of a direct beam detects dissolved impurities.

Optical methods have been in use for some time as sensitive fluid monitors, one example being the measurement of water turbidity. The instruments employed for this purpose are relatively large and often fragile, or mechanically complex, so that a new design concept was developed to meet aircraft requirements.

The major considerations in obtaining stability are to correct for the large temperature coefficients of solid-state photo detectors, and the changes in illumination due to light source variations and window deposits. An optimum

## IN-LINE OIL MONITOR

configuration is to use a single optical path, with means to introduce alternately the oil and an optical reference. This is done by mounting the optical references on a rotor which is turned by the flowing oil. In addition to providing the reference function, this causes the light received by the photo sensors to be chopped, so that a.c. amplification, which eliminates effects of stray light and dark current, can be employed.

The references are of glass, designed to duplicate the scattering and attenuation characteristics of partially contaminated oil. Fiber optics are used to transmit light into and out of the oil and to change its direction by  $90^\circ$ . The fiber optics are sealed, so that conventional windows are eliminated. Also, because of the collimating properties of the fiber, lenses are also eliminated.

The light beam is parallel to the axis of the rotor. One photo sensor is mounted radially so that it views the light beam at  $90^\circ$  to provide the scattering output. The attenuation sensor measures transmitted light. The output of each sensor is a series of pulses alternating between reference and signal. These are fed to a signal conditioner which computes the ratio of signal to reference amplitudes. Since the same light source, fiber optics, and sensor are used for the reference and signal, all variations in these components are canceled out.

The transducer, shown in a cutaway view in Fig. 1, is 2.4 in. wide, 4.5 in. long, and weighs 2 lb. In addition to scattering and attenuation photo-transistors a third one is used to generate a gate signal that is used by the signal conditioner to separate the measuring and reference pulses. Because the photo-transistors' peak response is in the near infrared region of the spectrum, the effect of normal oil color variations on the attenuation output is minimized.

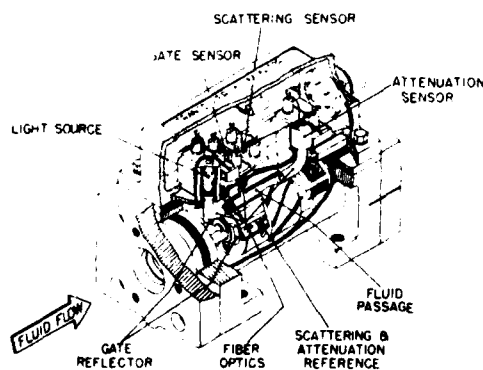


Fig. 1 Transducer.

The transducer is normally mounted directly in the high-pressure side of the main lube supply line. In this location, the effects of free air in the oil usually are eliminated because the air is dissolved in the oil. In one engine installation, in which aeration in the high-pressure line was evident in ground tests, it disappeared at altitudes above 18,000 ft where the air separator was more effective.

The signal conditioner can be mounted

GEORGE F. SKALA

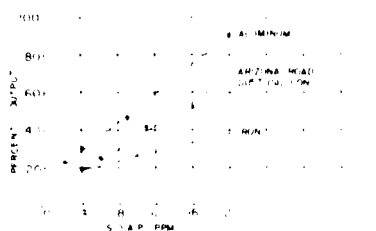


Fig. 2 Equipment condition monitor scattering output; oil temperature, 180°F. Flow = 9 GPM.

correct operation of the oil monitor and its associated read-out equipment can be checked automatically. The signal conditioner circuits also can be supplied on two circuit boards about 3 1/2 x 7 in. for incorporation in the same enclosure with other condition monitoring circuits.

in any convenient location. Its size is about 5 x 7 x 3 in., and it weighs 2.5 lb. It provides separate 0- to 5-v.d.c. outputs proportional to scattering and attenuation. Also, because the rotor frequency is directly related to oil flow rate, a third output of flow also is provided.

The circuit presents a malfunction indication in the event of a component failure in the transducer or signal conditioner: power failure, cable failure, or loss of oil flow. There is also a self-test feature by which the

### Results

A typical calibration of the scattering channel vs S.O.A.P. is shown in Fig. 2. This does not imply a unique relationship between scattering and ppm content because the size and shape of the particles determine the relative amounts of optical scattering. Another difficulty in correlating with S.O.A.P. is the question of its sensitivity to particles vs dissolved materials. For example, it was necessary to add about 250 ppm of the Arizona Road Dust to obtain a S.O.A.P. reading of 16 ppm, although some of this could have been due to settling out of the large particles in the test oil loop. Figure 2 does not represent

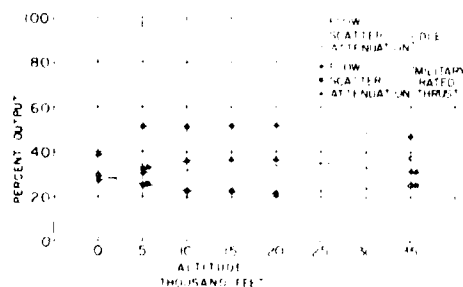


Fig. 3 Equipment condition monitor output; aircraft A7A No. 2658, NATC Patuxent River, Md., Flight No. 1, April 27, 1971.

the maximum sensitivity of which the system is capable. A several-times increase in sensitivity is possible for applications in hydraulic systems when complete airframe condition monitoring becomes a reality.

Figure 3 represents the data on the first flight of a series conducted on an A-1A aircraft at NATC Patuxent River, Md. Tests were at altitudes from sea

## IN-LINE OIL MONITOR

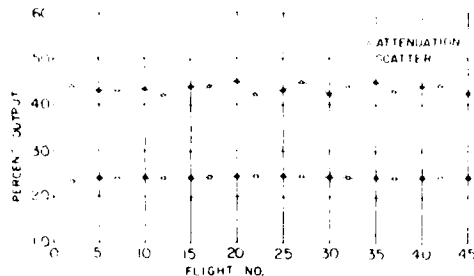


Fig. 4 NADS computer output; equipment condition monitor, aircraft type A7A No. 2658, NATC Patuxent River, Md.

level to 35,000 ft, and at engine speeds from idle to military rated thrust (MRT). The data show no significant altitude effect but only a change in flow at different engine speeds.

Data at MRT at 5000 ft from other flights of this series are shown in Fig. 4. Most of the flights were of 2- to 3-hr duration, al-

though some were longer, representing cross-country flights to California. Considerable oil was added, although data on how much and when are not available. The flight program was continued for a total of 163 flight hours, with no unusual readings except when oil foaming was deliberately induced by subjecting the aircraft to negative g loads. Carrier arrest landings were also part of the test program. After completion of the flight tests, the oil monitor was removed, and its calibration checked in a test loop. No shift in calibration was detected.

A similar series of tests is now being conducted in which the oil monitor is part of a complete engine condition monitoring system (IECM). In this installation the oil-monitor circuits have been incorporated into the Signal Analyzer Unit of the IECM system.

Figure 5 represents data on a TF41 endurance test engine. This engine experienced an LP compressor thrust bearing failure that was accompanied by high attenuation and scattering readings that occurred prior to other evidences

of malfunction. The S.O.A.P. analysis showed an increase in iron content from 8 to 29 ppm when the engine was shut down. The engine was repaired, and a second endurance run of 1065 hr was completed. Again the oil monitor system was removed and checked on a test loop, with no evidence of degradation or calibration shift.

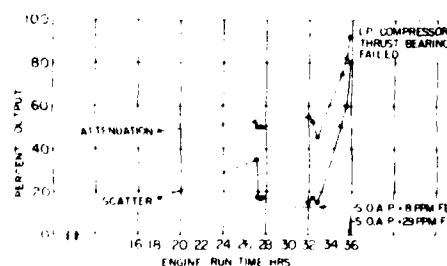


Fig. 5 Equipment condition monitor output; TF41 endurance test, engine S/N 141050 BU9, Oil MIL-L-7808, May 20, 1971.

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To date, an estimated minimum of 5000 hr of engine running time has been accumulated by Environment/One's oil-monitoring systems. Except for some problems due to faulty commercial power supplies in early signal conditioners, there have been no reported failures, malfunctions, or false alarms of properly installed systems. In addition to the TF41, the engines on which the monitor has been tested include the TF30, CF6, GE4, F101, and J57. Evaluation testing on the HLH engines, LM2500, TF39, and others is being planned.

Conclusions

A field proven on board real-time oil monitor for use on jet engines, either by itself or as part of an over-all engine monitoring system, is now available. In addition to warning of incipient failure of oil-wetted components, other benefits include:

- 1) Early detection of failure modes, on development engines or component test rigs, before complete destruction of the failed components. This will allow better analysis of the cause of failure.
- 2) Because of the ability of the monitor to detect excess air under flight conditions, it can be an aid in the development of air separators.
- 3) Possible warning of low oil supply by the resultant increase in trapped air.
- 4) Engine oil changes only when needed, instead of on arbitrary time schedule.
- 5) Extension of time between overhauls.

# Model PC-120 Contamination Monitor & Analog Particle Counter

For continuous on-stream measurement of particles per second, with high or low concentration limit alarm. Four push button ranges: 0-100, 0-300, 0-1000, and 0-3000 particles per second.

## Typical applications:

### Monitoring

Hydraulic systems clean-up  
Ultra clean solvents  
Deionized water supplies  
Intravenous liquids  
Turbine lubricating oils  
JP-4 manufacturing

### Testing

Filter units: systems (one sensor upstream, one downstream)  
Lubricating oils  
Hydraulic fluids  
Solvents  
Bill cards, flush stands, and test stands

## Description:

The PC-120 is a single-channel particle counter with an adjustable particle size threshold and a continuous analog output proportional to particles-per-second through the sensor. Outputs can be used for analog meter display, strip chart recorder, automated data acquisition system, and the alarm system (panel lamp or remote device). The automatic alarm circuit signals when upper or lower pre-set concentration limits have been exceeded.

Input may be from the standard HIAC "CM" sensor powered by the PC-120 (with sensor as remote as 1,000') or by other HIAC counters (PC-305, PC-320 or PC-420). Four pushbuttons on the panel face select particle concentration range.

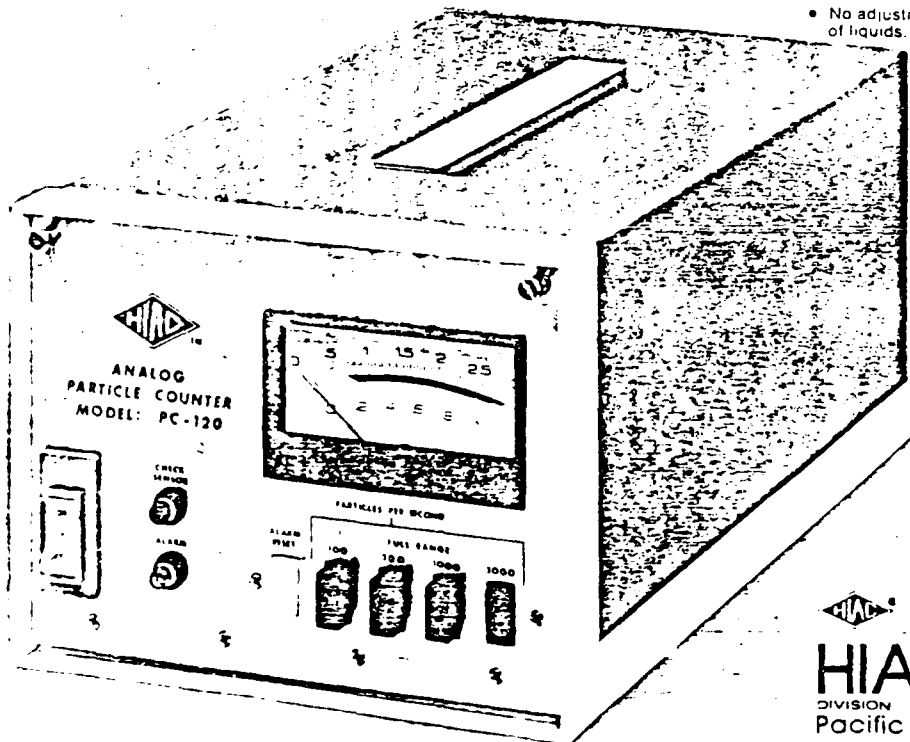
The PC-120 is portable and can be half-rack mounted.

## Features:

- Read and plot (with recorder accessory) particle concentration continuously.
- Automatic concentration limit alarm.
- Direct dialing of particle size threshold.

## PC-120 Flexibility:

- Connected to the PC-305, PC-320 or PC-420 (short BNC to BNC coaxial cable), it receives the signal from their sensor and provides analog output. Also can be used with 420 "SB" Series sensor through PC-120 sensor cable.
- Can be "prime calibrated" in the field.
- Digital count equivalent on strip chart recorder very close to actual, if flow rate and elapsed time are known.
- Selected interval recording: leave PC-120 on; connect strip chart recorder through ordinary percentage timer.
- Multiple sensor selector switches are available.
- Sensor can be remote to 1,000'. Standard cable is 6' long.
- Sensors rated to 3000 psi and 200°F.
- No adjustment required for varying colors of liquids.



**HIAC**  
DIVISION  
Pacific Scientific Company

# Model PC-420 Analog Particle Counter & Contamination Monitor

## SPECIFICATIONS:

### Input

- From standard HIAC 15M Mono sensor.
- From ENC connector at rear of PC-305, PC-320 or PC-420 particle counters.

### Output

- Analog needle display.
- 0-1V for external strip chart recorder.
- 0-5V for automatic data acquisition system.
- Alarm signal when contamination is greater or less than pre-set limits.

### Range, particles per second

0-100  
0-300  
0-1000  
0-3000

### Calibration

Runtime electronic

### Power

100-240 V AC 50-60 Hz

### Size

6" x 8" x 14"  
20 lbs approx

### NOTE

A special cable (AO-1) is required for a remote alarm.

For strong acids or caustic solutions, special sapphire windows and shields are available.

Demonstration units are available at many HIAC Division offices.

|    |   | Pin          | Function     |
|----|---|--------------|--------------|
| *A | 1 | 5V supply    | 5V supply    |
|    | 2 | Common       | Common       |
|    | 3 | Signal       | Signal       |
|    | 4 | Signal       | Signal       |
| *B | 1 | 100-120 V AC | 100-120 V AC |
|    | 2 | 200-240 V AC | 200-240 V AC |

### Accessories

#### ITEM

- Recorder, Strip Chart
- Recorder, Roll Paper
- Service Kit (See manual)
- Chart Paper, Single Run, 10 Rolls
- Chart Paper, Dual Run, 10 Rolls
- Recorder Pens, Black, 10 each
- Additional Sensor, 2.50 micrometers
- Additional Sensor, 3.00 micrometers
- Additional Sensor, 4.00 micrometers
- Additional Sensor, 5.00 micrometers
- Additional Sensor, 10.00 micrometers
- Spares Kit (See manual)
- Sensor Mounting Stand
- Additional Segment (see Sensor Manual)
- Beaker and tubing with flow meter (see manual)
- Extra length Sensor cable
- Additional length of cable



**HIAC**  
DIVISION

Pacific Scientific Company

P.O. Box 3007  
4719 West Brooks Street, Montclair, California 91763

Pacific Scientific International

227 Finchley Road  
London N.W. 3

HIAC INSTRUMENTS DIVISION  
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MOUNTAIN VIEW, CALIFORNIA 91763  
PACIFIC SCIENTIFIC INTERNATIONAL  
HAUPTSTRASSE 132  
CH-4450 SIBSACH, SWITZERLAND

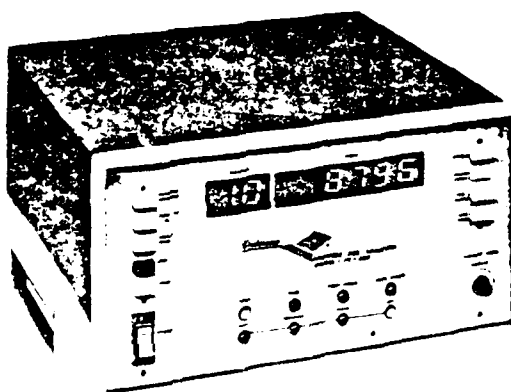


Bulletin 7633

PC-320 SERIES "CRITERION"  
LAB or FACTORY USE

## "CRITERION", MODEL PC 320 PARTICLE COUNTING AND SIZING ANALYSIS SYSTEM

### EXCLUSIVE FEATURES



- Designed to be the nucleus of an integrated particle analysis system
- Six full channels may be expanded to nine or even twelve channels
- "Direct Dial" size thresholds
- Full range calibration in every channel
- Six digit display with built-in timer
- Sample may be defined by volume, time, or pre-set particle count
- All solid state construction including photo detector
- Samples may be run wet or dry with no electrolyte needed
- Data is available in print out form if required
- Total/Delta operation with the flip of a switch.

The PC 320 "Criterion" particle size analyzer is the most advanced instrument of its type available on today's market.

It not only measures particles by size and counts them in as many as twelve different size groups, but does it all automatically.

The PC 320 will operate with full efficiency on liquids of different viscosity and color without any special adjustments. In addition, it has an integral monitor which warns of any change in sensor operation due to particle window blockage or change in the fluid system.

The "Criterion" analyzer has a BCD output which will interconnect with data processing equipment or for analog displays.

Sensors are compact (2" x 2" x 5") with ultra linear calibration. Sensors can be located as far as 1000 feet from the counter if necessary. In addition, multiple sensors with selector switch can be used. Special sensors for use with corrosive liquids are also available.

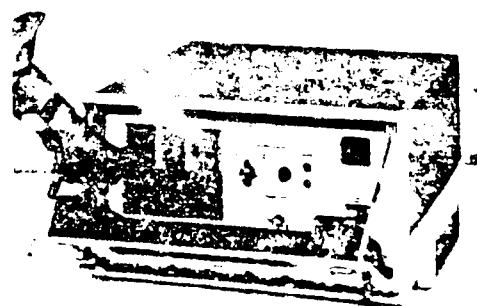
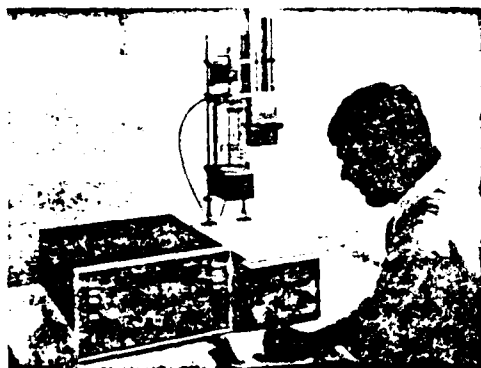
In addition to these features the Model PC 320 is suited to either sample bottle or on stream analysis. Every unit is factory calibrated and electronic and reference standards are available.

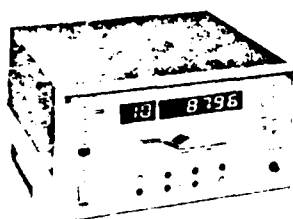
Particles from 1 to 3000 microns can be accurately counted and sized (with the proper sensor). Circuits are of modular construction for easy "plug-in" replacement or service.

LABORATORY PC-320 SERIES "CRITERION"

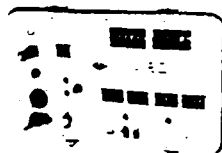
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## ACCESSORIES

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## BASIC HIAC INSTRUMENTS



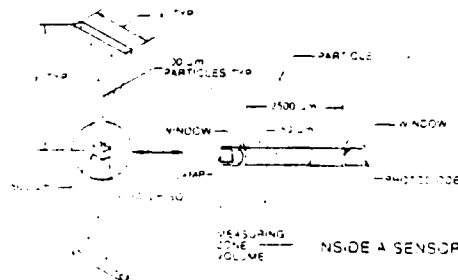
HIAC instruments categorize particles suspended in a carrier medium held in sample containers or flowing in an on-stream system by size and number. They are categorized in from one to six size ranges, with an optional capability of up to twelve channels. These ranges are selected by the operator. Particles are measured accurately regardless of their makeup, size or color characteristics. The instruments count very rapidly approximately 4,000 particles per second and can analyze particles per fluid volume or size distribution alone.

Liquid containing the particles to be measured is passed through a sensor where the particles'

size and number are sensed and sent along a cable to the counter to be displayed. Each sensor has a size measurement ratio of 1:60 from smallest to largest particle. Therefore, a 1 through 60 micrometre sensor can measure particles from 1 to 60 micrometres; a 2.5 through 150 micrometre sensor from 2.5 to 150 micrometres. The instrument operator programs the display channels for any size distribution within the capability of any one sensor. For example using a 2.5-150 Sensor the operator could select the following size distribution:

| Channel | 1              | 2             | 3             | 4              | 5               | 6            |
|---------|----------------|---------------|---------------|----------------|-----------------|--------------|
| Size    | 2.5-10 $\mu$ m | 10-25 $\mu$ m | 25-50 $\mu$ m | 50-100 $\mu$ m | 100-125 $\mu$ m | >125 $\mu$ m |

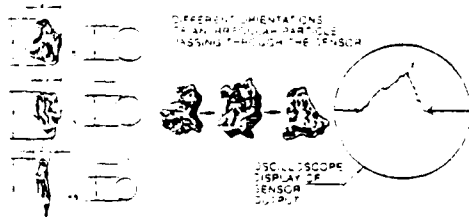
HIAC instruments operate on the principle of light blockage. A constant output from the photodiode is maintained by passing a light through a passageway on to a photodiode. As a particle passes an amount of light proportional to its size is blocked. If recommended concentration levels are not exceeded (4,000 particles/second) there is only one particle in every ten measuring zone volumes so that each particle is sized individually.



HLAC measures the maximum area of the particle exposed as it passes through the measuring zone.

The area is equated to spheres in the HLAC calibration tables for a single dimensional reference.

### THE HLAC METHOD



As you can see, the microscope measures all these particles as being the same, whereas the HLAC measures them as being different by the ratio of their areas. The HLAC method gives more information about the particle and is certainly a more realistic approach to measuring the actual size of the particle.

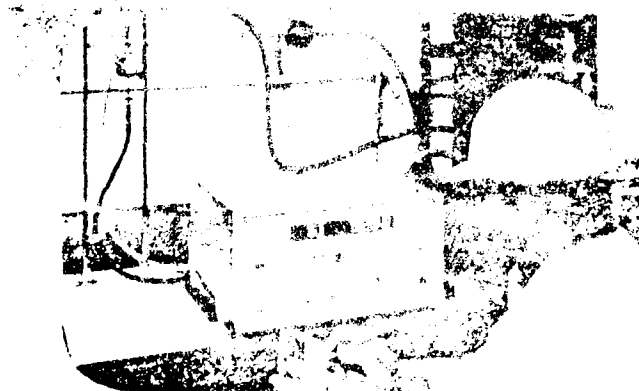


The operator places the bottle sample to be analyzed into the sample holding cylinder. The analysis is initiated by pushing the reset button. Filtered air is automatically pumped into the holding cylinder and forces the sample through the sensor and into a metering device which does the test when the tested sample has been analyzed. The sensor is cleaned and sized the particles and the analysis results appear at the test conclusion on the automatic particle counter display. Typical test time, one minute.

#### Flow Control

The in-stream sampler is attached to the flow line to be tested. The pressure from this line is used to force the liquid through the sensor and inline fittings with the meter. The operator sets the flow meter to a given flow rate and pushes the reset button on the counter. This starts the one minute timing and analysis. At the end of that time, the analysis results are displayed on the counter.

The operator attaches the in-line system with flow controller by means of quick disconnects to the equipment to be tested. The pressure from the system forces liquid through the sampler at approximately 500 cc/min. Of that 50 cc/min is directed through the sensor (located on the back of the sampler). This flow rate is adjusted by the operator using the flow control adjustment in conjunction with the Delta P gage. The reset button on the counter is pressed and a one-minute analysis begins. At the conclusion the numbers are recorded and the quick disconnects removed.



Air Gun Hydraulics • Film Emulsions • Parenteral Solutions • Hypodermic Syringes, Vials and Ampoules • Rubber Stoppers and Capsules • Manufactured Petroleum Products • Hydraulic Fluids • Micro-Circuits Manufacturing • Missile Systems • Fuel Systems • Hydraulic Test Stands • Trucks, Tractors, Hydraulic Systems • Synthetic Fibers • Nickel Plating Baths • Deionized Water • Construction Vehicles Hydraulic Systems • Magnetic Memory Hydraulic Systems • Pumps and Valves • Turbine Bearings • Aircraft Engines • EHC Fluids • Freon Flush Solvents • Jet Engine Fuel • NC Machinery Hydraulic Systems.

**Size Control Of**  
Dental Polymers • Latex Films • Titanium Dioxide (paint & white wall tiles) • Dye Stuff Manufacturing

Seed and Spore • Rust Nodules (salt water corrosion research) • Algae • Nuclear Fuel Granules • Oyster Spat • Shrimp Spawns • Powders

Parenteral Solutions • Foods & Beverages • Manufactured Silicon Oils

Monitoring D.I. Water and Solvents • Cancer Cell Studies • Oil-Water Separation Research • Filter Test Evaluation • Corporeal Blood Filter Evaluation

- (1) No electrolyte or special sample preparation necessary
- (2) Light blockage principle
- (3) Built-in Timer
- (4) Manual or automatic control, remote or local.
- (5) Indicator lamps
- (6) Total solid state construction including photo detector.

- a) Printout system
- b) Calibration kit
- c) Sensor selector switch
- d) Spares kits

## MODEL P-1000 (PARTS) 3300 P-1000-13

An automatic system for counting and sizing particles in fluids with a memory to store 5 or 12 channels of information and with a single 8 digit display.

- A. From CMB Series Sensors
- B. From CMH Series Sensors
  - A. BSN - 40 volt base level sensor analogue
  - B. Sensor - For sensor
  - C. ABS - Automatic Bottle Sampler
  - D. Lamp Voltage - For lamp adjustments, replacement
  - E. Printout - 1-1V BCD for Printer or TTL Logic Circuitry
  - F. Accessories
    - (a) Remote Display
    - (b) Remote Control
    - (c) Computer data acquisition
    - (d) Simultaneous display

Direct dial electronic threshold size adjustment to set each channel anywhere within the size limits of the sensor.

Factory prime calibrated using spherical standards with calibration chart provided.

1-99 seconds

1-99 minutes

OFF, 100, 1K, 10K, 100K

To indicate blockage, lamp malfunctions, optical density changes.

115-230 VAC ± 10%, 47-63 HZ, 40 Watts

Size: 13 1/2" W x 9 1/2" H x 13 1/2" D

Weight: 40 lbs.

**HIAC INSTRUMENTS DIVISION**  
Pacific Scientific Company

P. O. Box 3007 • 4719 W. Brooks St.  
Montclair, California 91763  
Telephone: (714) 621-3965



- [illegible]

[illegible]

## OPERATION

A liquid stream to be monitored is passed through an integral sample cell which is illuminated by a continuous laser source. Suspended solids in the stream scatter light as they pass through the cell; the scattered light is collected by a lens which focuses the light on a proprietary Compumask™ optical filter. The optical filter passes a selected portion of the light which is then focused by another lens onto a photodetector.

The light received by the detector is proportional to the volume of particles in the liquid stream. The instrument automatically corrects for the attenuation of the laser due to light scattering and normalizes the output signal to the incident intensity. These automatic corrections permit reading a true linear volume response independent of light absorption by the host liquid.

Initiating operation is extremely simple. A zero adjustment is made with clean water flowing through the cell. The sample stream is then switched to the instrument which continuously measures the amount of suspended solids.

A one-time single-point calibration using gravimetric data taken on a process sample from the instrument out-

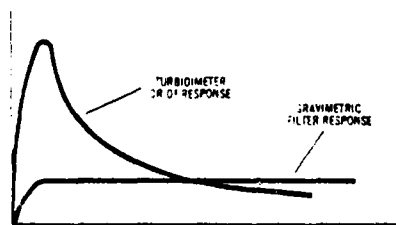
let is used to adjust for true mass loading. Routine operation consists of checking the zero with clean water (usually once a day) and cleaning the sample cell with the plunger provided (usually once a week). Cell cleaning and zero adjustment are both accomplished without entry into the instrument and take only a few minutes to accomplish.

Compared to other monitoring techniques, the SSM offers significant advantages including:

- Direct measurement of volumetric concentration or mass loading after a single one-point calibration.
- Linear dynamic response independent of particle size in the suspended-solids range.
- True continuous analog of the gravimetric method, avoiding the inconsistent relationships between turbidity and suspended solids.
- No routine calibration—only an occasional zero check required.
- Optional output signal representing average particle size can be provided, often useful in checking performance of control or process equipment.
- Automatic compensation for variations in transmission unaffected by color of liquid.

## TURBIDITY AND SUSPENDED SOLIDS

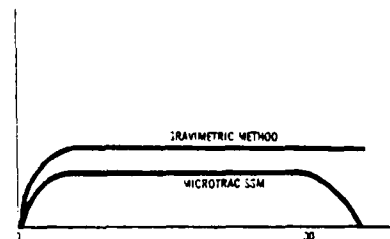
These two measurements are widely used in water and wastewater processes. Turbidity is related to the visual clarity of a sample and depends upon the cross-sectional area of the particles, the concentration of particles, and the color of the host liquid. Suspended solids is a measurement of particle concentration in the range between colloidal and settleable solids. The measurement is referenced against the gravimetric filtration technique and must therefore be independent of size distribution over this range.



This figure illustrates the response for a turbidity/particle-area instrument with constant loading and variable particle size. While differing in level, this general response is obtained whether the turbidimeter uses back-scatter, forward-scatter, or 90° scatter nephelometry.

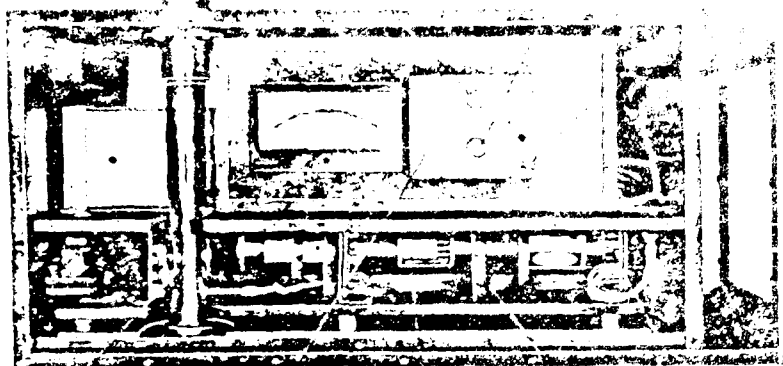
Prior to the introduction of a true suspended-solids monitor, turbidimeters were employed to imply suspended solids, sometimes having scales marked in parts per million. The relationship between turbidity and true suspended solids is consistent only if particle-size distribution and host liquid color are constant and if colloidal particles are low in concentration compared to the suspended solids level.

Turbidity and suspended solids are each useful, but are measurements with different uses, and correlation between them should not be attempted.



This figure illustrates the similarity of the Microtrac SSM volume of response to the gravimetric method. After a one-time single-point calibration, these curves would be found over a range of about 100 microns.

AMPLE 1000 is a portable, rugged, and reliable instrument designed for the detection and measurement of airborne particulate matter. It is suitable for use in a wide range of environments, including industrial, commercial, and residential areas. The instrument is designed to be easy to operate and maintain, and it provides accurate and reliable results.



AMPLE 1000 PARTICULATE MEASUREMENT INSTRUMENT. (1) SAMPLE INLET, (2) SAMPLE FLOW, (3) FLOW METER, (4) FILTER, (5) FLOW METER, (6) SAMPLE OUTLET, (7) CONTROL PANEL, (8) POWER SWITCH, (9) BATTERY, (10) CARRYING CASE.

## SPECIFICATIONS

**Concentration Range** 0.01 to 10.0 mg/m<sup>3</sup> (0.001 to 1.0 g/m<sup>3</sup>)

**Particle Size Range** 0.3 to 10.0 µm (0.01 to 1.0 mm)

**Sensitivity** 0.01 mg/m<sup>3</sup> (0.001 g/m<sup>3</sup>)

**Accuracy** ± 10% (± 1.0 mg/m<sup>3</sup>)

**Precision** ± 5% (± 0.5 mg/m<sup>3</sup>)

**Ambient Temperature Range** 0 to 50°C (32 to 122°F)

**Sample Temperature Range** 0 to 50°C (32 to 122°F)

**Typical Flow Rate** 1.0 L/min (0.028 gpm)

**Output Signals** 0 to 10 VDC (0 to 1.0 g/m<sup>3</sup>)

**Controls** On/Off switch, Flowmeter, Filter, Sample Inlet, Sample Outlet

**Indicators** Meter, Flowmeter, Filter, Sample Inlet, Sample Outlet

**Power Requirements** 1.5 VDC (0.043 gpm)

**Enclosure** 10.0 L/min (0.28 gpm)

## Weight

## OPTIONS AVAILABLE

AMPLE 1000 is available with a variety of options, including a carrying case, a power supply, and a flowmeter.

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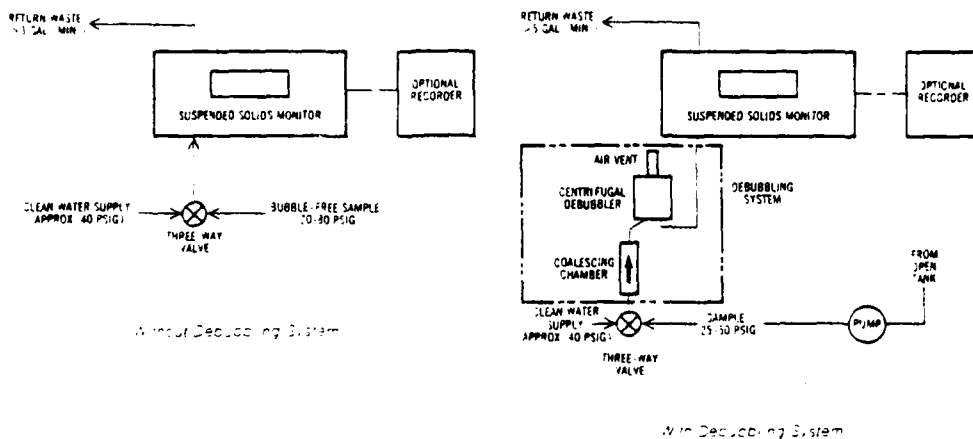
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Leeds & Northrup

## Typical Plumbing Connections for Microtrac SSM



Also available

### 7991 MICROTRAC Particle-Size Analyzer

for particle-size analysis in the laboratory

- Designed for plant and quality-control lab analysis
- Available for wet slurries and dry powders suspended in water, with optional ability to measure dry powders in air
- Particle-size range: 0.2 to 175 or 0.2 to 300 microns
- On-line optical system, sample cell and processing electronics offering the following features:
  - 13-channel histogram output via integral digital printer
  - Operator independent, insensitive to sample concentration or density, factory calibrated
  - Summary data on size distribution and surface area
  - Repeat analyses every 3 to 300 seconds, new sample every 2 minutes

Ask for Data Sheet D4-1124-TP

### 7981 MICROTRAC Particle-Size Monitor

- Designed for on-line, real-time process monitoring and control
- Available in two standard configurations: wet slurry or dry powder
- Uses same optical system, sample cell and processing electronics as Microtrac Analyzer, plus:
  - On-line sample-conditioning system
  - Digital or analog outputs with local digital display
  - Rugged NEMA 12 industrial enclosure
  - Internal security system to permit remote, unattended operation
- Provides same data output forms as the 7991 Microtrac Analyzer, digital or analog, plus any three customer-specified percent-passing channels, analog current outputs or printer optional
- Usable on-line in process monitoring, or off-line in routine analysis

Ask for Data Sheets D4-1122-TP and D4-1126-TP

Questions about applications should be directed to the Advanced Business Development Department, Leeds & Northrup Company, North Wales, PA 19454



**LEEDS & NORTHRUP** North Wales, PA 19454

1. AN OUTSTANDING AGES (21773)  
 2. AN OUTSTANDING AGES (21773)  
 3. AN OUTSTANDING AGES (21773)



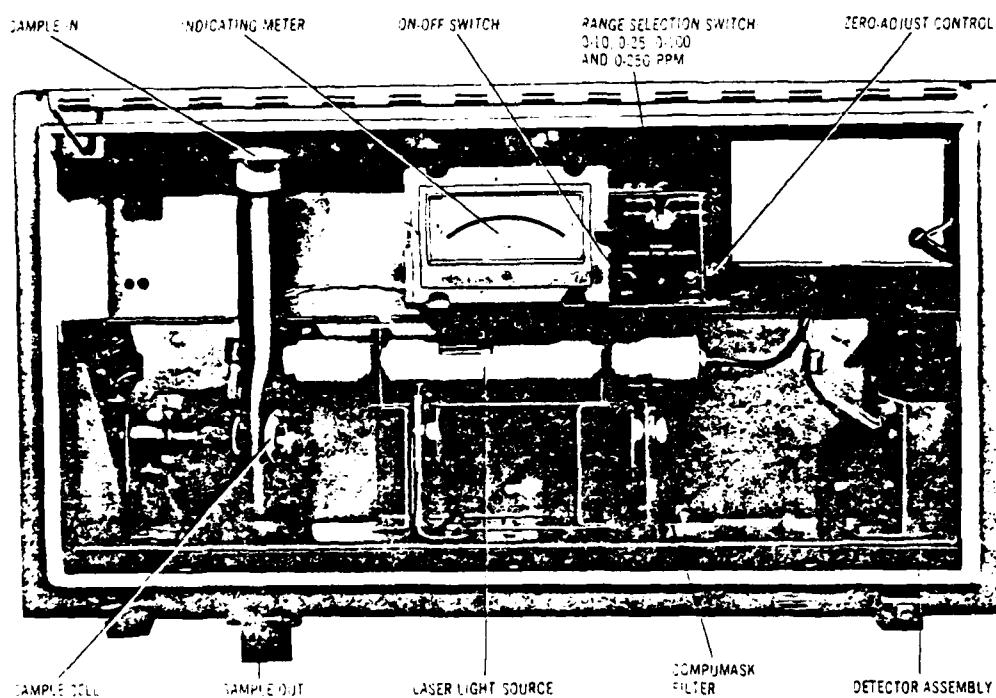


Figure 9: Interior of Suspended Solids Monitor

## 7982

|    |            |        |       |                  |
|----|------------|--------|-------|------------------|
| 1. | 0-250 ppm  | \$3880 | (-10) | Delivery 8 weeks |
| 2. | 0-2000 ppm | \$3880 | (-20) | Delivery 8 weeks |

|     |                 |          |       |            |
|-----|-----------------|----------|-------|------------|
| 1.  | Brass/Copper    | Standard | (-10) |            |
| *2. | Stainless Steel | \$300    | (-20) | Add 1 week |

|                                                |                                                  |
|------------------------------------------------|--------------------------------------------------|
| 1. Optical Crown Glass (0° -60°C)              | <input type="checkbox"/> Standard (-10)          |
| *2. Fused Silica (Hi Temperature) (0° - 120°C) | <input type="checkbox"/> \$370 (-20) Add 2 weeks |
| *3. Sapphire (Hi Abrasion)                     | <input type="checkbox"/> \$240 (-30) Add 3 weeks |

\*1. Debubbler Std Mt1 ☐ \$450 (-10)SS ☐ \$750 (-11)  
☐ \*2. External Sample Pump Cast Iron ☐ \$450 SS ☐ \$1150  
☐ \*3. Laboratory Sample Conditioner ☐ \$3950 (-40) Add 2 weeks

\*1. Mean Volume Diameter. 0-10V, 0-100mV Output ☐ 5660 (-10)

☐ 1. Analog Meter ☐ Standard (-10)  
☐ \*2. Digital Meter ☐ \$180 (-20)  
☐ \*3. Remote Meters (Analog or Digital) See Catalog

\*1. Non-isolated analog current and voltage (internal) 4-20 mA, 1-5V ☐ \$150  
\*2. Isolated Analog Current (separate package) See Cat. ☐ \$150  
3. Recorder outputs 0-10V, 0-100 mV ☐ Standard (-00)

1. Remote Window Service Indicator Output ☐ Standard (-00)  
\*2. Alarms, Indicators and Controls. See Catalog

|                          |                                    |                          |                |
|--------------------------|------------------------------------|--------------------------|----------------|
| <input type="checkbox"/> | 1. Remote Manual Zero Adjust Inout | <input type="checkbox"/> | Standard (-00) |
| *2.                      | Remote Range Selection             | <input type="checkbox"/> | \$55 (-10)     |
| *3.                      | Automatic Zero Adjust. See Catalog |                          |                |

\*1. 6-foot Line Cord and Plug ☐ 120V, 60Hz ☐ \$15 (-66)  
☐ 2. Conduit Entry, 120V, 60Hz ☐ Standard 220-50 ☐ 120-50 ☐ 220-50 ☐  
 (-16) (-26) (-15) (-25)

|                          |                         |
|--------------------------|-------------------------|
| 1. Wall Mount            | Standard (-10)          |
| *2. Bench Mount          | \$100 (-20) Add 2 weeks |
| *3. Floor Stand Mounting | \$100 (-30) Add 2 weeks |

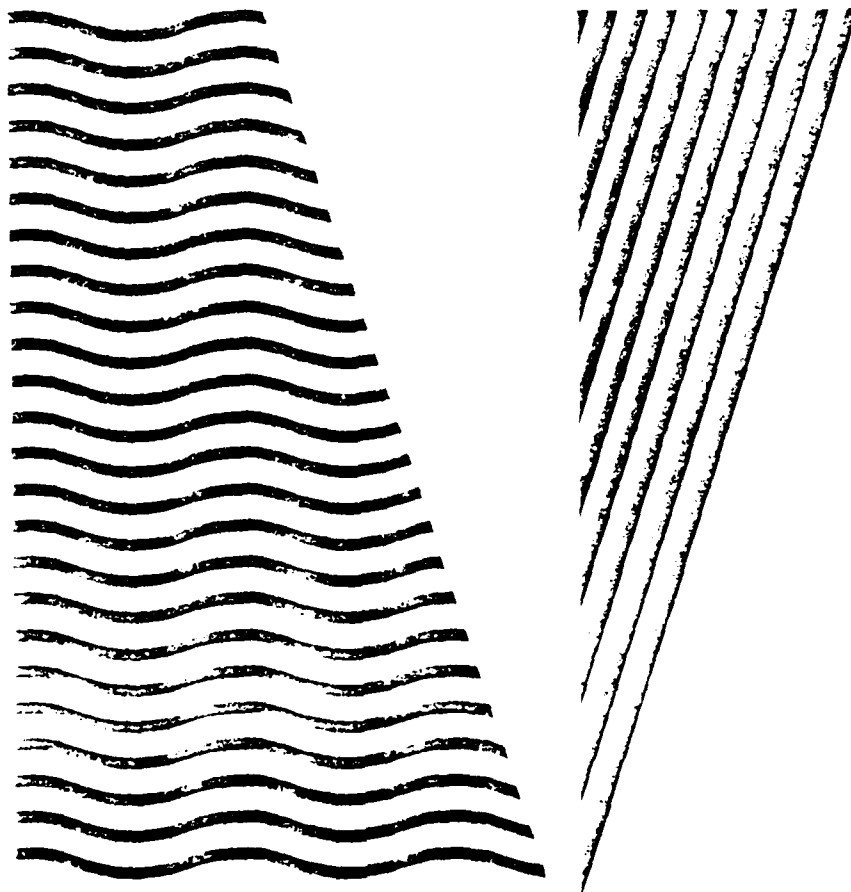
Spares - ☐ None (-00) Recommended Spares (See Catalog).

TELEPHONE 215 643-2000 • CABLE ADDRESS LEEDS/INTL

NAEC-92-146

MICRO PURE SYSTEMS INC.

Monitoring Contaminants  
in Closed Systems



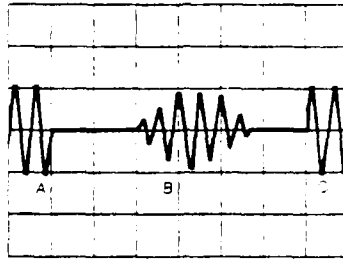
### The Versatile System

Due to the nature of ultrasonics and the unique design of our discriminator and chamber, the Micro Pure system can be used for the monitoring of most liquids. The system operates independently of the fluid's thermal or electrical conductivity, viscosity or optical properties. Included are: Water, oil, latex, acids, dyes, inks, paints, hexane and a variety of food stuffs. These applications would apply to the chemical, food, photographic, waste water, hydraulic and pharmaceutical industries as well as the manufacturing of integrated circuits and printing inks.

### The Operating Principle

The micro-contaminant monitor, Model 1100, uses ultrasonic wave reflection to detect microscopic particles and bubbles in a flowing liquid. This is accomplished by the use of two separate components, an in-process flow-through ultrasonic chamber and a pulser-receiver module or monitor.

A piezo-electric transducer element mounted in a chamber external to the fluid flow, receives electrical pulses from the MCM-1100 and converts them into acoustic waves. These waves are focused and passed into the flowing stream. Particles or bubbles in the liquid will reflect sound back to the transducer where the sound is reconverted to an electrical signal. This signal is then coupled to the receiver module.



Oscillogram A: Source wave from transducer  
B: Reflection from contaminant  
C: Reflection from chamber wall

The MCM-1100 amplifies and converts the return signal into a series of digital impulses which are processed to determine the size and number of contaminants measured. A separate logic function discriminates between microparticles and microbubbles above 50 microns.

### The Chamber

One of the most innovative aspects of the Micro Pure System is its process capability. The in-process chamber design is a technique that the fluid is monitored and analyzed. Use the advantage of ultrasonic wave reflection monitoring. The need for random sampling and laboratory analysis is eliminated. This inspection technique allows the monitoring of relative solid content, impurities as well as the degree to which a chemical reaction has progressed.



Steel chamber

The fact that the transducer element does not directly contact the monitored fluid and that the chamber material can be matched to the process, line, eliminate wear and tear. The inspection system is suitable for a wide range of contaminant levels. The chamber can be adapted to the flow rate, diameter and downward velocity desired. Modifications are used to suit flow system performance for design and operation requirements. Some examples of chamber materials are: glass, stainless steel, aluminum, polystyrene and plexiglas.

### The Pulsar-Receiver Modules

The Pulsar-Receiver Modules Pure Systems have used these electronic components necessary to cause the detector to function and receive the resulting signals. The Pulsar-Receiver Modules are integrated over a set number of samples and saved separate using LED readouts. An collected information is also made available on the readout panel. The instrument for monitoring and digital recorders. In addition to the constant monitoring of the level of contamination, the operator can set an upper limit for either particles or bubbles. When this is exceeded a front panel light is activated and an audible signal is sent to the rear panel that may be adapted as a distress or high signal to shut the device off from the production process.

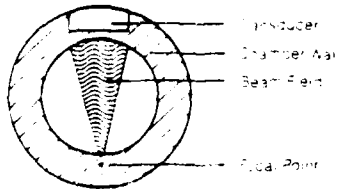


Figure 1 - Chamber Section



### The People Behind the Technology

#### Leigh R. Abts

Mr. Abts has served as Bio-Medical Engineer for the Department of Cardiovascular Surgery at Rhode Island Hospital since 1973. A member of the Acoustical Society of America and Sigma Xi, he has numerous publications in the field of ultrasonic detection of microemboli and microbubbles. He has served as a consultant to many major manufacturers of blood oxygenator devices. His investigation in the field of extracorporeal monitoring for microemboli led to his developing the patented technique used in the ultrasonic measurement of particles in flowing liquids.

Presently, Mr. Abts serves as President of Micro Pure Systems and is actively involved in the further development of our technology.



#### Robert T. Beyer, Ph.D.

Professor Beyer has been a member of the Physics Department of Brown University since 1945 and served as its Chairman between 1968-74. He holds two U.S. patents, is the author of several books and over one hundred articles, principally in the field of ultrasonics. He has supervised 20 Ph.D. theses in this field. In 1968-69, he served as President of the Acoustical Society of America and is currently Chairman of the International Commission on Acoustics. He has been an advisor to the Micro Pure Research Program since 1974 and is a member of the Board of Directors.

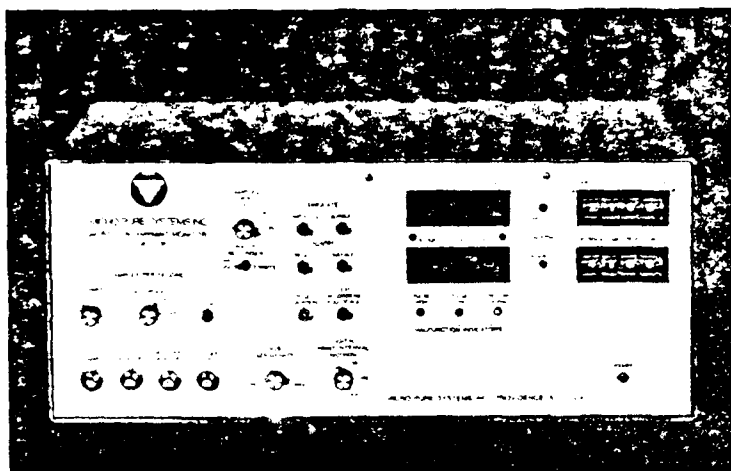


#### Karl E. Karlson, M.D., Ph.D.

Dr. Karlson has been a member of the staff at Rhode Island Hospital since 1971 and now serves as Surgeon-in-Charge, Division of Cardiovascular and Thoracic Surgery. He has had teaching appointments at three universities. Currently, he is Professor of Medical Sciences at Brown University and Adjunct Professor of Biomedical Engineering at the University of Rhode Island.

He has had an interest in extracorporeal circulation for many years, particularly with the function of blood oxygenators and the production of microemboli by these devices. His interest in this field provided the impetus for the development of the ultrasonic methods of detection employed by Micro Pure.

In August 1979, he was the U.S. representative in Cardiovascular Surgery for a National Council for U.S.-China trade delegation to the Peoples Republic of China. Presently, Dr. Karlson serves as Chairman of the Board of Micro Pure Systems, Inc.



704-112

### Manufacturer's Specifications for Model 1100 Micro-Contaminant Monitor

**PULSER** Spike-type output with maximum 1000 negative pulses at 50 chips per second. With an external time divider of spike interval from 1 to 100 seconds, the 50 transients depending on 1000 chips.

**RECEIVER** Broadband with a low gain in the band and fast recovery from noise and background transiently 10-12 MHz.

Controls:

**Controls:**  
**SAMPLES PER SECOND** - number of samples per second to be averaged  
**PERIOD** - number of samples per second to be averaged  
**PERIOD** - number of samples per second to be averaged  
**PERIOD** - number of samples per second to be averaged  
**SAMPLES PER DISPLAY** - number of samples per display  
**PERIOD** - number of samples per second to be averaged  
**PERIOD** - number of samples per second to be averaged  
**RESET COUNTERS** - when COUNT mode is selected, the counters may be reset by the user using push button controls.

**TEST RECORDERS FULL SCALE** 1000  
 over 1000 hours for testing battery  
 and log outputs and the digital recorder  
 can store up to 1000 and 10000  
**DIGITAL PRINT INTERVAL** 10, 30, 60, 120, 180, 240, 300, 360, 420, 480, 540, 600 seconds may be selected  
**ALARM RESET** This over current alarm  
 can be reset by pressing the reset button

ALARM DISABLE - 1.5. DE DESACTIVAR O  
TIRAR SISTEMA DE ALARMA. 1.5.1. DE  
DESEMPENHAR O DESEMPENHAR O DESEMPENHAR O  
DESEMPENHAR O DESEMPENHAR O DESEMPENHAR O

## SIMULATE PARTICLES &amp; BUBBLES

[illegible]

SIZE SENSITIVITY: The size of the paper must be larger than the photo image to be printed (e.g., 8 1/2" x 11" paper for 4" x 6" photo). Postscript 1.5 and 2.0 are not supported. Postscript 3.0 and 3.0c are recommended. Windows 3.11 and higher are required. Windows 95 and higher are recommended.

[illegible]

### Indicators and Outputs

BUBBLE AND PULSE RATE, PART 1  
 After the initial start-up, the bubble and pulse rates are monitored and recorded. The bubble rate is measured by counting the number of bubbles that pass through the flow cell in a given time interval. The pulse rate is measured by counting the number of pulses that pass through the flow cell in a given time interval. The bubble and pulse rates are then compared to the theoretical values and the results are recorded.

OUTPUT MONITOR - This monitor is used to observe the output of the system.

RECEIVED MONITORING UNIT 10-11-64  
 10-11-64 10-11-64 10-11-64  
 10-11-64 10-11-64 10-11-64

TRIGGER CLIP

ANALOGOUS RESULTS HAVE BEEN OBTAINED FOR THE  
POLYMERIZATION OF VINYL MONOMERS IN THE PRESENCE OF  
CATIONIC POLYMERIZATION CATALYSTS.

DIGITAL PRINTED BY ...  
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 ...  
 ...

100-443887-1000



### **A Breakthrough in Technology.**

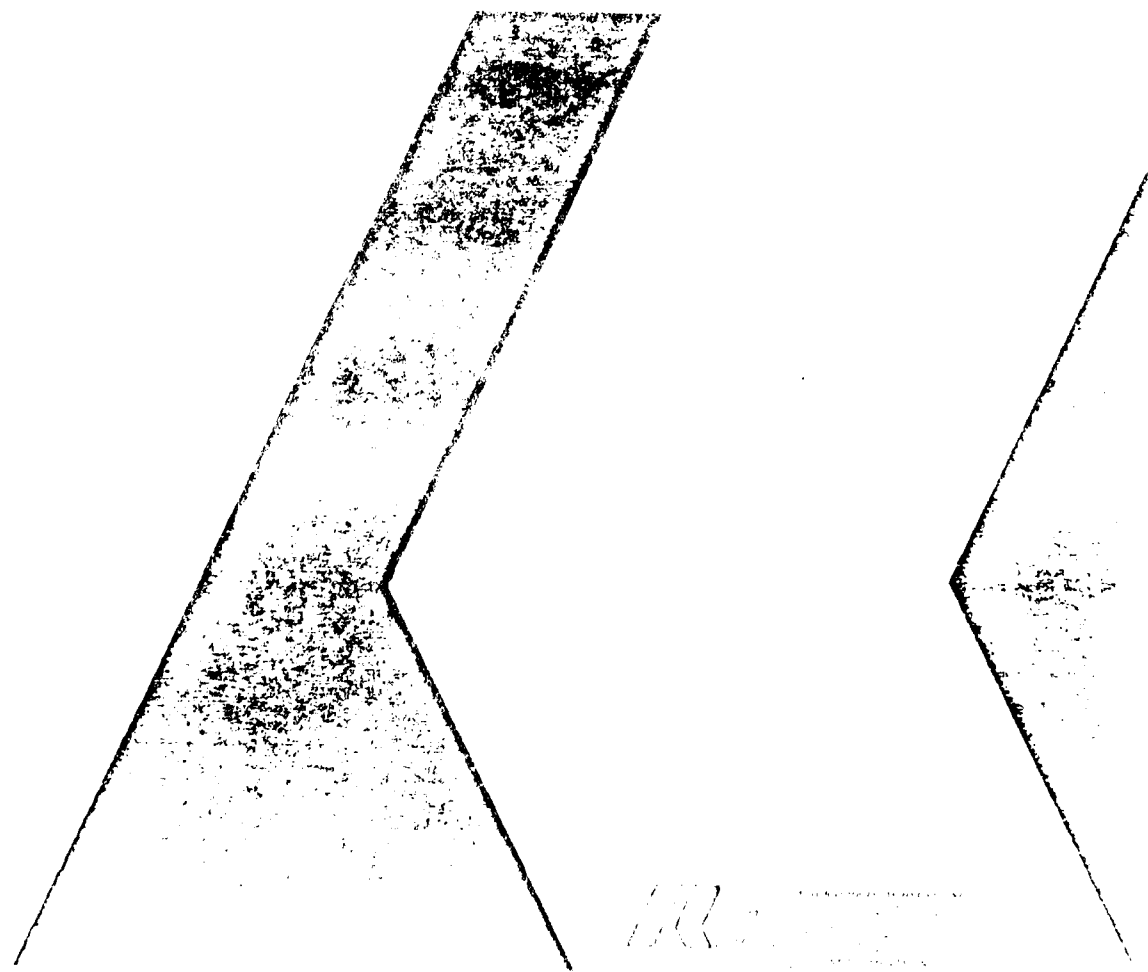
Micro Pure Systems, Inc. introduces a new era in the monitoring of micro-contaminants in fluids. The employment of new techniques in focused ultrasound has led to the development of a patented system for the in process detection of particles and bubbles below 1 micron in diameter. Discrimination between microsolids and microbubbles is achievable down to 50 microns.

This innovative technology is the culmination of years of research by an outstanding team of engineers, physicists and physicians at Brown University and Rhode Island Hospital. The MCM-1100, featured here, evolved through an effort to monitor gaseous and particulate contaminants in the heart-lung bypass circuit utilized in open heart surgery.

The combination of the research and development endeavors of the scientists at Micro Pure with our high quality of manufacturing, has resulted in products of high integrity. As a result of its adaptability and capacity, the range of applications is substantial. The MCM-1100 is the most reliable, accurate and versatile micro-contaminant monitor available today.

Micro Pure is interacting with numerous Fortune 500 companies and is actively engaged in responding to their quality control needs. Micro Pure's scope of activity and dedication to your quality control functions will assure the success of your efforts to maximize product reliability.

THE UNIVERSITY OF CHICAGO  
ADMINISTRATIVE SERVICES  
HOBBS BUILDING, CHICAGO, ILL.



RECEIVED  
JAN 10 1964

## INSTRUMENTATION

### UNIQUE TOTAL CAPABILITY IN PARTICLE COUNTING TECHNOLOGY

#### THE CAPABILITY

At Royco, there is a total capability in systems and instrumentation for every type of particle counting. Counting particles in both dusts and aerosols is possible. Our material particle measuring equipment is available for use in a wide range of applications including: near forward, total, light absorption, total scatter, and light absorption total scatter systems for process control, air pollution, and environmental monitoring.

#### THE FACILITY

Royco's entire staff and facilities are located in the heart of the San Francisco Peninsula's Silicon Valley. The complex covers 27,500 square feet and includes the manufacturing, administrative, scientific and engineering facilities. It is a fully equipped laboratory for the study of industrial and environmental processes that involve detection and measurement of particles in liquids and gases.

This facility permits Royco to produce instruments with the precision and quality that are the hallmarks of the company. The facility also allows for the development of new instruments and the testing of existing ones. The facility is equipped with the latest in particle counting technology, including: light scattering, light absorption, total scatter, and light absorption total scatter systems.



#### THE TECHNOLOGY

Particles in suspension, liquid suspension, scatter and/or absorb light in quantities that vary with their size and concentration. This light-scattering phenomenon can be used to detect, measure and count particles in suspension. Royco's particle counting systems are designed to measure particle size and concentration data by optical systems developed for this purpose.

The total capability in particle size and concentration measurement technology is provided by Royco's systems in a broad spectrum of applications in both industrial and environmental monitoring.

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To facilitate and implement the technology of particle counting, Royco has developed and offers the automatic systems, instrumentation and accessories listed on the following pages. In addition to the broad range of standard instruments shown, our catalog Royco also has the capability for special instruments for special applications. You are invited to discuss your needs with us at Medio Park, California, or with your local Royco sales engineer.

### INSTRUMENTATION FOR GAS ANALYSIS

Particle counting systems are available for the detection and measurement of particles in both dusts and aerosols. The total capability in particle size and concentration measurement technology is provided by Royco's systems in a broad spectrum of applications in both industrial and environmental monitoring.

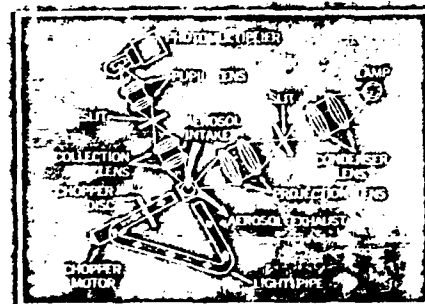


Figure 1: Right Angle (90°) Scatter Optical System

When monitoring large volumes of ambient gases where suspended particles can vary widely in composition, size and optical properties, a Near Forward Scatter Optical System as shown in Figure 2 will produce best results.

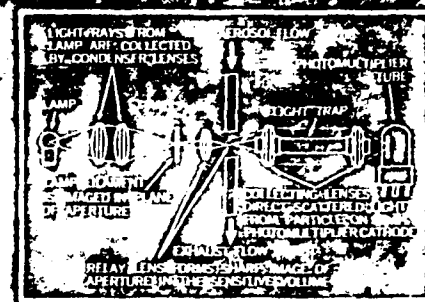


Figure 2: Near Forward Scatter Optical System

## SUMMARY OF SPECIFICATIONS MODEL 203

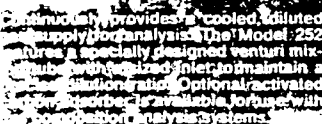
SUMMARY OF SPECIFICATIONS--MODEL 220

### SUMMARY OF SPECIFICATIONS, MODEL 218

**Standard Accessories.** A complete family of tools and expanding accessories is available for Power Right Angle, 90° Swivel and Non-Swivel Swivel configurations. Please see Page 7 and 8 for a full listing of available tools.

1. The first step is to identify the problem. This involves understanding the situation and the goals that need to be achieved.

100-102512

[illegible]

**MODEL 253**  
Smoke Generator

Provides a high-volume smoke output in accordance with ANSON 101, 1-17.2. Also uses a special deep-solvent filtered exhaust evaluation. Output smoke volume is variable. Collection efficiency is 99.9%.



**CONFIDENTIAL**

The standard accessories shown on this page are for use with either Royco instrumentation for gas analysis or liquid analysis as indicated. See Page 2 for a complete list of all general purpose accessories common to both gas and liquid instrumentation.

APPLICATIONS: Standard Atmosphere  
for Gas Analysis, Interpolation

[illegible]

Ar. gni 100-150, 14 kg.

Model 200 Aerosol Generator  
 Aerosol Output: 1500 cc per hour  
 Operating Period: 90 minutes  
 Particle Size Range: 0.1 to 10 micrometers  
 Filter: HEPA type  
 Deisicant: Inert liquid  
 Power: 1000 watts  
 Controls and Gauges: Nebulizer, pressure, temperature, flow  
 Dimensions: 18 inches high, 12 inches wide, 12 inches deep  
 Weight: 25 lbs.

### Accessory Pumps

Model 13 Output 2 (30.5 cm) D  
AC at 59/50 Hz Size 5 1/2" (13.9 cm) D  
W x 12" (30.5 cm) D

MODEL 258 Smoke Generator

Unfiltered smoke output: 150 to 200 feet per minute (fpm) at 25 PSI, depending on the type of filter. The number of filters employed in combination can be increased to 10 for higher flow rates.

Test: Smoke produced by the test cigarette is drawn through a 20 PSI standard air supply and can be used for:

- Power:** Compressed air or other gas supply to deliver gas at 25 PSI or greater. Air supply connector, air hose, filter and pressure regulator included.
- Controls and Gauges:** Light gauge to monitor fuel level. Thermometer to measure fluid temperature.

Dimensions: 18 inches (45.7 cm) x 11 inches (30.5 cm) x 2 inches (5.1 cm) tall

Weight: 25 lbs. (11.3 kg)

**SPECIFICATIONS - Standard Accessories**  
for Liquid Analysis Instrumentation

MODEL 363 Liquid Batch Sample Feeder

**MODEL 366 Volumetric Match Sample Feeder**  
 Sample Volume 100 cc  
 Sample Size 500 g  
 Sample Range 100 cc  
 Sample Rate 100 cc/min  
 Sample Height 100 mm  
 Sample Diameter 100 mm  
 Sample Power 100 W  
 Sample Dimensions 100 mm

## MODELS 273 In-Line Sampling System

**MODEL 373 In-Line Sampling Section**  
Sample Flow Rate: 100-1000 ml/min  
Operating Pressure: 0-100 psig  
Dimensions: 10 1/2" x 10 1/2" x 10 1/2"

MODEL 146 Contamination Control Center

**Dimensions: Overall Size** 10.5 in. (267 mm) H x 10.5 in. (267 mm) W x 10.5 in. (267 mm) D

**Work Surface Size** 5.5 in. (140 mm) x 14 in. (355 mm) x 12 in. (305 mm)

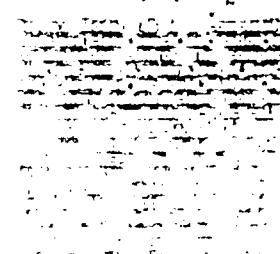
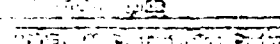
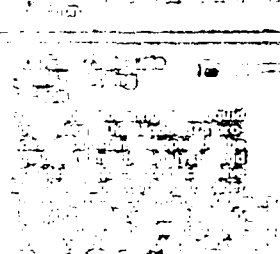
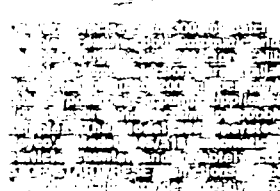
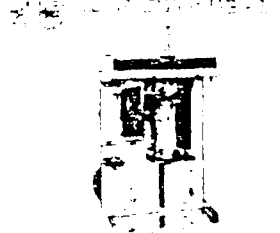
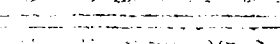
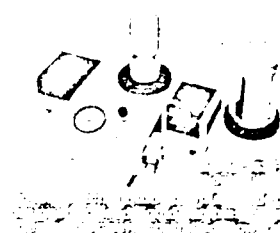
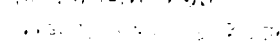
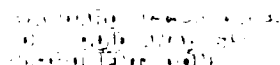
**Air Filtration** HEPA, 99.99% efficiency, 0.3  $\mu$ m

**Power Requirements** 115 VAC, 60 Hz, 15 A

**Particle Analyzer** Real-time, 0.5  $\mu$ m to 10  $\mu$ m, 100% efficiency

**Digital Printer** 100% efficiency, 0.5  $\mu$ m to 10  $\mu$ m, 100% efficiency

**Batch Sample Handler** 100% efficiency, 0.5  $\mu$ m to 10  $\mu$ m, 100% efficiency



## GENERAL PURPOSE ACCESSORIES COMPATIBLE WITH ALL ROYCO INSTRUMENTATION

The accessory equipment described on this page is compatible with Royco's full family of particle counting and sizing instrumentation for both gas and liquid analysis.

### MODEL 107 Alarm Module

Analog Alarm Module for audible signal and meter reading indication that a pre-set particle count level has been exceeded. Reset and audible cut-off controls are provided. Operates on 115/230 VAC at 50/60 Hz. 6½ inches (16.5 cm) H x 8 inches (20.3 cm) W x 11 inches (27.9 cm) D. Weighs 9 lbs. (4.1 kg).



### MODEL 145 Instrument Cart

The Model 145 instrument cart is designed to provide a movable multi-level mounting for Royco particle counting systems. The unit is furnished with 5 AC convenience outlets and full width storage drawer.



### MODEL 129 and 129C Digital Printers

Royco's Model 129 digital printers are medium speed, parallel entry units that scan and print out data stored in multi-channel memories. Operation uses reliable inked ribbon and standard paper. Optional clock (Model 129C) time dates printed data.



### SPECIFICATIONS — Model 129 and 129C Digital Printers

**Printing Speed:** 2.5 lines per second; 9 characters per line.  
**Print Format:** 8421 BCD format.  
**Power:** 115/230 VAC at 50/60 Hz.  
**Dimensions:** 5½ inches (14.0 cm) H x 7¾ inches (19.1 cm) W x 14½ inches (36.8 cm) D.  
**Weight:** 20 pounds (9.1 kg)

## GENERAL INFORMATION

### Terms of Sale and Shipment

Royco particle counting instruments and systems are priced F.O.B. Menlo Park, California. All prices are subject to change without notice. Terms are Net 30 days.

### Leasing Agreements

Leases with option to purchase are available to meet the specific requirements of each user. You are invited to contact our Menlo Park Headquarters for full details.

### Warranty

All Royco products are warranted against defects in materials and workmanship. This warranty applies for 1 year from date of delivery, or in the case of certain major components listed in the operating manual, for the specified period. We will repair or replace products which prove to be defective during the warranty period provided they are returned to Royco. No other warranty is expressed or implied. Royco is not liable for consequential damages.

### Maintenance and Service

Royco recognizes its responsibility to provide each user with the technical support required to assure the full eco-

nomie life of each Royco product. Royco service centers provide repair and replacement service to users of Royco equipment both during and after the new equipment warranty period. Each service center maintains a fully trained staff and an inventory of tested replacement parts.

Repair labor and parts are charged at the current catalog rates then in effect for all out-of-warranty service performed at a Royco service center. Field service for on-site repairs will be charged at the current catalog rates in effect for all out-of-warranty repair labor and parts. All travel, meals and lodging will be charged at cost for both in-warranty and out-of-warranty service.

### Preventive Maintenance and Calibration Service and Contracts

Routine preventive maintenance and calibration will greatly extend the useful out-of-warranty instrument life. This service is available on a "demand" basis or under service contracts. For detailed information, contact your local Royco Sales office.

## FIELD ENGINEERING OFFICES AND SERVICE CENTERS ROYCO U.S.A.

**Boston**  
Telephone: 617/891-5320

**Chicago**  
Telephone: 312/428-7794

**Los Angeles**  
Telephone: 213/257-5340

**San Francisco**  
Telephone: 415/325-7811  
Telex: 34-8323

## ROYCO INTERNATIONAL

Gelman Hawksley, Ltd.  
12 Peter Road  
Lancing, Sussex BN15 9TN England  
Telephone: 2815-6  
Telex: 37134

Royco Instruments, Inc.  
Dennis Haslop, European Marketing Mgr.  
9 Cambridge Rd.  
Brighton, Sussex BN3 1DF, England  
Telephone: 774238  
Telex: 87323 HASLOP

Royco Instruments, Inc.  
Uwe Jessen, European Sales Manager  
Hertigstrasse 51  
7250 Leonberg-2, W. Germany  
Telephone: 07152-47375

Beckman Instruments, Lapsco Division  
P.O. Box 3100  
Tulleton, California 92634 U.S.A.

London Industries Ltd.  
10-13 Higashi-Minamachi  
Ohta-Ku, Tokyo, Japan  
Telephone: 404/8781-5  
Telex: 0242-3320

**Royco**  
A SUBSIDIARY OF HYCEL, INC.  
INSTRUMENTS, INC.

141 Jefferson Drive  
Menlo Park, California U.S.A. 94025  
Telephone: 415/325-7811 • Telex: 34-8323



# PROTOTRON PARTICLE COUNTER MODEL ILI 1000



## FEATURES

- Makes in-situ, quantitative particle counts of bottled liquids
- Reads any bottle with a 20 to 200 mm inside diameter
- Uses scanning laser beam with all solid state electronics
- Provides automatic digital readout after a scan of 10 cc in approximately 15 seconds
- Detects the number of particles above a manually set threshold between 1 and 100  $\mu\text{m}$
- Can be used to count particles in liquids flowing through transparent pipes

## APPLICATIONS

- Quality control of hydraulic fluids & oils
- Particle count of air filters
- Monitoring continuous flow operations through glass pipe
- Inspection of pharmaceutical solutions
- Water quality testing for semiconductor industry
- Quality control for bottled beverages
- .... and many other applications.

## GENERAL DESCRIPTION

The standard Prototron Particle Counter includes both diffuse vertical illumination for visual identification of large particulates, and a scanning laser beam for detection of small particulate matter.

The 31 pound, compact unit (12" X 24" X 18") houses the laser tube, scanner and photo detection electronics. A front panel knob allows setting of a particle size threshold limit between 1 and 100  $\mu\text{m}$ . Particle counting and illumination are controlled by front panel pushbuttons. A simplified schematic of the instrument is shown in Figure 1. The laser beam focuses inside the bottle in a 2 cm long "sensitive zone" as shown in Figure 2.

The secondary lens picks up scattered light (in the annulus around the target) from all particles in the path of the scanning laser beam. However, the photo detection electronics only registers those particles in the "sensitive zone", which are larger than the size specified by the threshold setting. Usually, dust particles on the bottle wall do not affect the count, as long as the wall is not in the sensitive zone. However, optical discontinuities should be avoided.

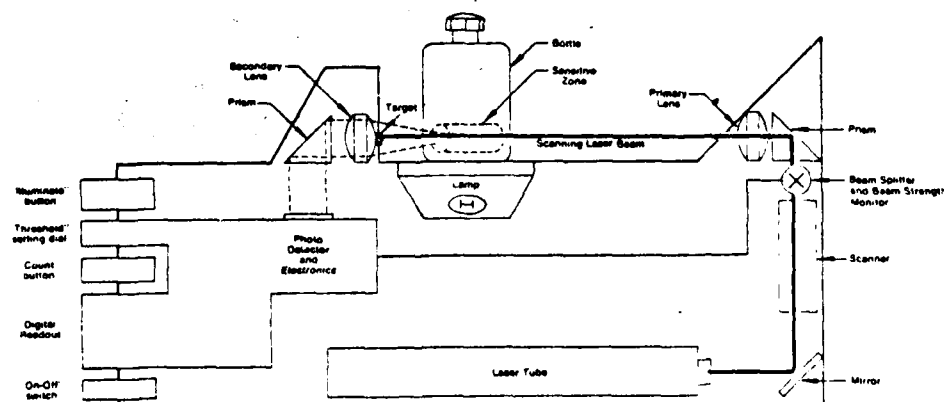


Fig. 1 Schematic of Particle Counter

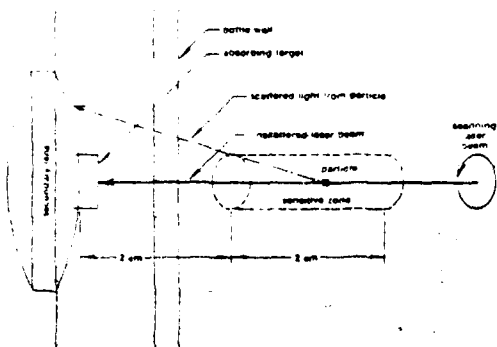


Fig. 2: Laser Beam Optics.

Once the count button is pushed, the revolving laser beam scans a total volume of 10 cc in 15 seconds, and the digital readout displays the average number of particles with sizes above the threshold limit in one cc of liquid.

By taking sequential measurements, qualitative size distribution data can be developed, or the threshold selector can be locked to provide statistical quality control data at one setting.

## MAINTENANCE

The Prototron Particle Counter is fully covered by a one year warranty and the laser life is rated at 10,000 hrs. The warranty includes replacement of the illumination lamp and the laser tube. Other than such normal replacement, the unit is virtually maintenance free.

## OPERATION

The operation of the Prototron Particle Counter consists of three steps: (1) Gently agitate the sample of bottled liquid to produce a uniform suspension; (2) Place bottle in the "V" notch and rotate to a point where the laser beam enters and leaves unobstructed; (3) Press the "Count" button. Within 15 seconds, the total particle count per cc is displayed on the digital readout.

In addition, by pressing the "Illuminate" button, a light table may be used to visually detect particles larger than 40 microns. The light table goes off when the "Count" button is pressed.

## SAFETY

The laser used in the Prototron Particle Counter is rated at one milliwatt and emits a very low energy beam through the primary lens. Virtually all laser beam energy is absorbed by the target. The Electrical Safety Association has recommended that the 30,000 watt laser beam and OSHA accept lasers with energies of 5 milliwatts or less, for relatively unrestricted usage. Therefore, the Prototron Particle Counter is well within the specified safety regulations.

## SPECIFICATIONS

Size: 18" (45.72 cm) high, 20" (50.8 cm) wide, 24" (60.96 cm) deep

Weight: 31 pounds (14.06 kg)

Power: 115 volts, 60 Hz (can be modified to 230 volts, 50 Hz on special order)

Display: 3 digits

Outputs: Connections provided for external alarm, printer, oscilloscope or pulse height analyzer

Bottle Size: 20 to 200 mm inside diameter

Bottle Material: Transparent, scratch-free glass or plastic

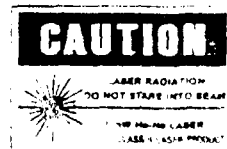
Read-Out Volume: 1 cubic centimeter

Detectable Particle Size: Continuously adjustable from 1 to 100  $\mu$ m

Warranty: One year on unit

## ORDERING INFORMATION

The Prototron Particle Counter may be ordered direct from Spectrex Corporation. It may also be leased, with an option to buy plant. To arrange a lease, call collect (415) 365-6567. Quantity discounts are available. For more information, write or call Spectrex Corporation.



3594 HAVEN AVENUE, REDWOOD CITY, CALIFORNIA 94063

NAEC-92-146

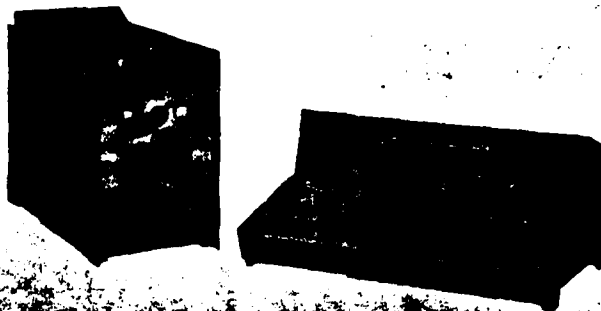
## SPECTREX

CORPORATION

3594 HAVEN AVENUE, REDWOOD CITY, CALIFORNIA 94063, (415) 365-6567

### PRICE QUOTATION

### LASER PARTICLE COUNTER and ACCESSORIES



| ITEM<br>NO. | QUAN-<br>TITY | DESCRIPTION                                                                                                                            | CAT<br># | PRICE     |
|-------------|---------------|----------------------------------------------------------------------------------------------------------------------------------------|----------|-----------|
| 1           | 1             | ILI 1000 Particle Counter (110V) including: (1) carrying case; (2) 3 bottles; calibrated check suspensions (3) neutral density filter. | 67000    | \$8200.00 |
| 2           | 1             | Particle Profile Attachment Model 3. (Microprocessor with "mass distribution" and "settling scan" modes.).                             | 67008    | \$5500.00 |
| 3           | 1             | Opacity Meter.                                                                                                                         | 67012    | \$ 350.00 |

F.O.B. REDWOOD CITY, CALIFORNIA

THIS QUOTATION IS VALID FOR 60 DAYS

8/1/79 jmh/amk

# PROTOTRON PARTIAL COUNTER

3534 HAVEN AVENUE  
REDWOOD CITY CALIF  
94063 (415) 365-6887

## APPLICATION NOTES

### CLASSIFICATION OF HYDRAULIC FLUIDS

Several standard classification systems have been established for hydraulic fluids based upon their particulate content. A typical one recommended by SAE is NAS 1638 which specifies maximum concentration limits for particles ranging in diameter from 5 micrometers to over 100 micrometers. The Prototron ILI-1000 provides a quick method of establishing the class number of an unknown fluid.

First a 200 ml sample of the unknown is placed in a 250 ml beaker and stirred to establish a uniform particulate distribution. The sample is allowed to remain quiet for approximately 20 seconds so that bubbles can escape. It is then placed upon the ILI-1000 and five readings are taken, resetting the instrument threshold level between each reading. These readings would for example give the number of particles per milliliter greater than 100 micrometers, the number greater than 50, the number greater than 25, the number greater than 15, and the number greater than 5. By subtracting the second reading from the first, the number of particles in the range between 50 and 100 can be determined. In a similar fashion each of the other specified size ranges can be determined. These values are then compared with the maximum limits keeping in mind that many limits are given on the basis of 100 milliliters.

For very clean fluids an averaged series of readings at each level can be used to increase the statistical significance of the determinations. This is possible because the test is non-destructive. This represents a significant advantage over other available automatic particle counting systems.

If the fluid is very dirty it may contain more than 1000 particles greater than 1 micrometer per milliliter. This should be checked and if it is the case the sample should be diluted with a well filtered clean solvent and the measured particle concentration corrected for this dilution ratio. Keeping the count less than 1000 will prevent excessive co-incidence counting from destroying the accuracy of the determination.

An example of a test of MIL-H-5606 hydraulic fluid which has been added 0.5 mg/liter of AC FINE test dust) follows:

| Size Threshold | Reading | Differential<br>part/ml | Class 8 Max Limits<br>part/ml |
|----------------|---------|-------------------------|-------------------------------|
| 5              | 227     |                         |                               |
| 15             | 35      | $227 - 35 = 192$        | 640                           |
| 25             | 11.5*   | $35 - 11.5 = 23.5$      | 114                           |
| 50             | 2.4*    | $11.5 - 2.4 = 9.1$      | 20                            |
| 100            | 0.5*    | $2.4 - 0.5 = 1.9$       | 3.6                           |
|                |         | $0.5 - 0.0 = 0.5$       | 0.6                           |

\* These readings are average of 10 counts to increase the statistical significance.

Because the differential values are all less than the Class 8 Max Limits we can conclude that this test fluid corresponds to Class 8 of NAS 1638.

**SPECTREX**

COMPANY

3594 HAVEN AVENUE, REDWOOD CITY, CALIFORNIA 94063, (415) 365-6567

**COMPARISON OF THE SPECTREX "PROTOTRON" TO OTHER PARTICLE COUNTERS**

The Coulter Counter is designed to count blood cells and does an excellent job for this specialized application. It works on the principle that blood cells do not conduct electricity but blood plasma does. A diluted sample flows through an insulating orifice, and the electrical resistance of the liquid column within the orifice is measured. Passage of a blood cell will change the resistance, and these resistance changes can be counted. The orifice must be very small, and the flow rate must be very slow. The range of particle sizes is therefore severely limited. The flow rate is also very small.

The Ilse and the Nucleo Particle Counters use optical light scattering in a flow cell to count particulates. The optical light scattering overcomes the dynamic range limitation of the Coulter method, and liquids other than electrolytes can be examined. The flow cell still limits the flow rate but not as severely as does the Coulter orifice. The largest disadvantage of these optical particle counters is that the flow cells require windows and these windows become dirty with use. Dirt on the windows effects the accuracy of the calibration and usually forces the user to frequently clean the cell and re-calibrate the instrument. The rapidly moving liquid in the cell generates pressure waves which usually limit the smallest detectable particle to 2 microns.

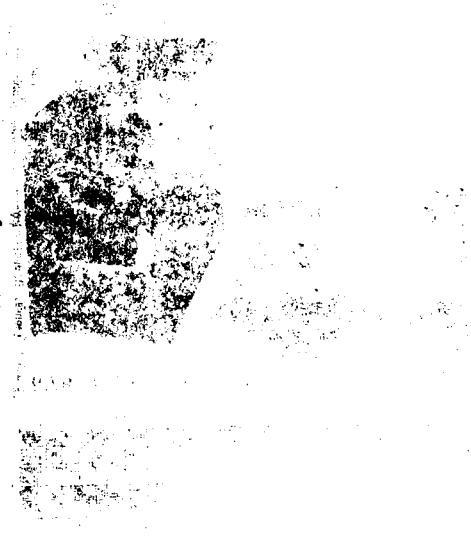
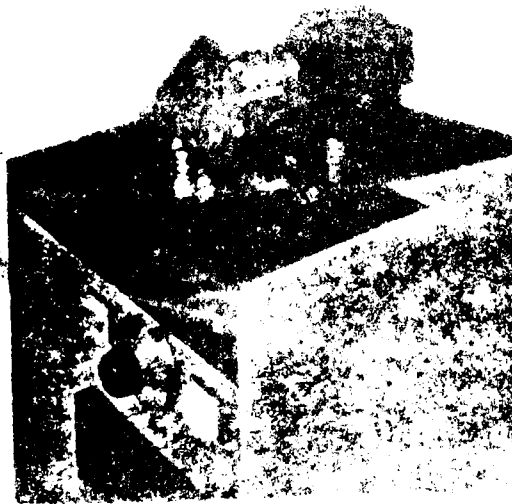
The Prototron also uses optical light scattering but its method is unique in that the liquid is moving very slowly and therefore contains no pressure waves. The laser beam is moving rapidly to produce the necessary scanning. This accounts for the greater sensitivity of the ILI-1000 and permits measurement of particles as small as one micron. The time required for a single determination of these small particles is substantially faster than with any other counting method. The other unique feature of this instrument is the optical system which keeps the sample container walls out-of-focus and, therefore, counts only the particles suspended in the liquid. This feature permits the measurement of particulates in sealed containers.

When flow cells are used, a flow measuring system is also required, and the count accuracy is limited by accuracy of this flow measuring system. The ILI-1000 electronically times the scan period and, therefore, avoids inaccuracies in flow measurement associated with all other automatic particle counters.

9/24/74 amk

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# CALIBRATION OF OPACITY AND TRANSMITTANCE



The purpose of this paper is to describe a method for calibrating the opacity and transmittance of a turbidity meter. The method is based on the use of a laser beam and a series of standard particles. The particles are suspended in a liquid and the laser beam is directed through them. The amount of light that is scattered by the particles is measured and compared to the amount of light that is scattered by a known particle. The results of the calibration are used to determine the opacity and transmittance of the sample.

When the opacity of a sample is measured, the amount of light that is scattered by the sample is compared to the amount of light that is scattered by a known particle. The results of the calibration are used to determine the opacity and transmittance of the sample.

The purpose of this paper is to describe a method for calibrating the opacity and transmittance of a turbidity meter. The method is based on the use of a laser beam and a series of standard particles. The particles are suspended in a liquid and the laser beam is directed through them. The amount of light that is scattered by the particles is measured and compared to the amount of light that is scattered by a known particle. The results of the calibration are used to determine the opacity and transmittance of the sample.



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## SOLID-STATE POWER CONVERSION EQUIPMENT

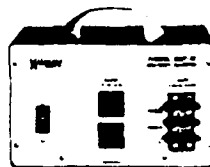
STANDARD    CUSTOM    INDUSTRIAL    MILITARY

### DC-TO-AC INVERTERS

### UPS/STANDBY POWER

#### MODEL 1057 300-WATT INVERTER

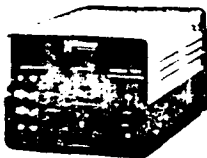
Economically priced and ideally suited for waveshape sensitive electronic equipment such as oscilloscopes, chart recorders and video tape recorders, the frequency stable 300 VA Model 1057 inverter is an inexpensive alternative to sine wave power. The switching-mode wave-shaping technique yields a three-level step wave-shape which has approximately the same peak-to-rms voltage ratio as a true sine wave. The Model 1057 inverters are protected against overloads, short circuits and reversed polarity of dc input line. Versions for input voltages of 12 Vdc, 24 Vdc, 32 Vdc and 36 Vdc are standard. Outputs of 115 Vac/60 Hz or 230 Vac/50 Hz are also standard. All models are approximately 80% efficient from one-half to full load and have a frequency stability of  $\pm 0.25\%$ . The Model 1057 is packaged for portable or stationary use, with a convenient carrying handle. All versions are 8 1/2" high x 11" wide x 8 1/2" deep and weigh 25 pounds. Units are shipped from stock. Single piece price for all versions is \$374.00 each. Resale, OEM, and quantity discounts are available. Request bulletin 9091C.



MODEL 1057

#### MODEL 1172 HEAVY-DUTY INVERTER

The Model 1172 is an inexpensive, rugged, 500-watt square-wave inverter designed to power heavy duty loads. This inverter will provide a 2 to 1 surge, approximately 1000 watts, for high-inrush loads such as small power tools, refrigerator compressors and incandescent lights. The Model 1172 is a modular inverter and two units may be easily paralleled in the field for added continuous and surge power. Versions for input voltages of 12 Vdc, 24 Vdc and 32 Vdc are standard. Output voltages of 115 Vac or 230 Vac and 50 Hz or 60 Hz are also standard. All versions are more than 80% efficient for most of their output load range. The frequency stability is  $\pm 2$  Hz and the output voltage is proportional to the input voltage. All Model 1172 inverters are 7" high x 8 1/2" wide x 11" deep and weigh 32 pounds. The single piece price of all versions is \$335.00 each. Resale, OEM, and quantity discounts are available. Units are normally shipped from stock. Request bulletin 1011A.

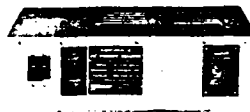


MODEL 1172

Wilmore Electronics manufactures other inverters in the 15-watt to 500-watt power range. Other square-wave-output inverters are available, and for those loads that are extremely wave-shape and frequency sensitive, regulated stepped-wave or sine-wave inverters are also available. Please contact our sales department for information.

#### MODEL 1252 AUTOMATIC STANDBY AC POWER SUPPLY

Serious problems may result when commercial ac power is unexpectedly interrupted to sensitive loads, such as point of sale terminals, communication systems or monitoring equipment. Such interruptions are becoming more commonplace and many people are exploring point of use uninterruptible power supplies like the Wilmore Model 1252 to keep their systems operating. When commercial ac power fails, this standby ac power source continues to supply needed power to your load by switching to inverter operation. Upon restoration of ac power, the Model 1252 automatically returns to normal line operation, and the internal battery charger recharges the batteries. Two basic versions are available, one providing a three-level-stepped wave approximation to a sine wave output and 250 watts of power, and the other supplying 500 watts of square-wave power. Standard battery input voltages are 12 Vdc and 24 Vdc. All units are 5 1/2" high x 17" wide x 14" deep and weigh 45 pounds. They can be installed in a standard 19" rack or they may stand alone. The Model 1252 system consists of inverter, battery charger and switchover/protection circuitry. The battery is not included. The user has the flexibility to size and specify a battery to fit his particular system and desired back-up time. Single piece price is \$575.00 each. Resale, OEM, and quantity discounts are available. The Model 1252 is normally shipped from stock. Request bulletin 6021.



MODEL 1252

#### NEW INVERTER AND UPS PRODUCTS

With models ranging in power rating from 50 VA to 1 KVA, the Series 1400 inverters considerably broaden Wilmore's dc-to-ac product line. To be introduced in mid-1980, these conservatively designed inverters represent rugged, reliable, cost-effective solutions to a wide variety of needs for frequency stable ac power. Their improved output waveshape, surge-handling capability, and ability to handle a wide range of load power factors ensures compatibility with most loads, even those normally considered to be "troublesome" for solid-state inverters.

Concurrently with the introduction of the Series 1400 inverters, Wilmore is introducing the Series 1401 Uninterruptible Power Supplies. As with the Series 1400 inverters, on which this UPS line is based, models

within the Series 1401 range in power rating from 50 VA to 1 KVA. Normally sold without a battery, Series 1401 models feature a self-contained battery charger, frequency stable inverter, and line-to-inverter

**Wilmore** ELECTRONICS CO., INC.  
P.O. Box 1329, Hillsborough, N.C. 27278 U.S.A.  
Telephone (919) 732-9351

APPENDIX B  
VIBRATION SIGNATURE ANALYSIS OF  
AHT-64 HYDRAULIC TEST STAND

NOTE: The 19 figures presented  
in this appendix were ex-  
tracted from a total of  
78 charts. These are dis-  
cussed in the analysis.



VIBRATION SPECIALTY CORPORATION

100 Geiger Road Philadelphia Pa 19115  
215/698-0800

March 30, 1979

Mr. Edwin Roberts  
Sanders & Thomas  
1000 Box 5  
Lakewood, CO 80501

Dear Mr. Roberts:

As per your letter with purchase order C-26024, our engineer  
and I visited Lakewood and Willow Grove Naval Air Stations  
on March 29, 1979. Our purpose was to perform a  
vibration analysis of two AHT-64 hydraulic test stands  
operating at various amplitudes and frequencies.

Vibration was monitored at seven locations on the test  
stands as shown in the enclosed diagram. Signatures were recorded  
in both radial and axial directions under idle  
conditions (3000 RPM), loaded (3000 psig), unloaded  
conditions. Each signature (see Figure A) shows  
vibration acceleration versus frequency in hertz.  
The scale is logarithmic with full scale equal  
to 100 g. The frequency (horizontal scale) is  
linear with 412 resolution. Described in the  
enclosed report, test position, total overall vibration  
level, test position, and test stand operating

Vibration response varied by a factor of two or more  
between the two test stands due to structural integrity differences,  
input energy differences. Vibration frequency response was con-  
stant on both test stands - that is, 360 hertz was the major  
vibration and response frequency.

#### DISCUSSION

Basically all input energy was measured at positions 6 and 7.  
Test position 6 was the hydraulic pump, where loaded (3000 psig)  
and unloaded (zero gauge) pressure variations were tested. Measured  
and recorded were the change in vibration energy levels produced by  
the two conditions.

Stand #143 showed considerable increase in vibration (almost  
double) with load (see Figures 20 and 41). Stand #117 showed very

Mr. Edwin Roberts  
Sanders & Thomas

March 30, 1979

Page Two

little increase (about 10 percent), as seen in figures 69 and 77. The major vibration frequency was 360 hertz, or nine times the operating speed (2400 RPM = 40 hz). It was determined that the pump had nine pistons working axially, which explains the high ninth harmonic response in all test positions, predominantly in the axial direction.

Test position seven was the diesel engine on both stands, rotating at 2400 RPM, with or without pressure load on the pump. The engine vibration levels recorded on each stand were very similar, and there were no appreciable changes with pump loading (Figures 22, 43, 62 and 78). The major frequency source from the diesel was the 40 hz signal and the associated harmonics.

Structural vibration response was measured and its frequency spectrum signature recorded at five different locations on the AHT-64 structure. Remember, the major frequency on all signatures on both test stands was 360 hertz.

The highest amplitude response (2.2g) on stand No. 143, was at position 5 (Figure 36) which is the underside of the base structure of the stand. A level almost equal to this (2g) was recorded in the axial direction at positions 1 and 3 (figures 26 and 32). Positions 2 and 4 showed levels around 1.5g (Figures 29 and 35).

In comparison, test stand No. 117 had the highest response (7g) at position 4 axial (Figure 73). The next highest response on stand No. 117 was 3 to 4 g's (still higher than No. 143) at positions 2 and 3 (Figures 67 and 68). Positions 1 and 5 had levels around 1 to 2 g's.

The only explanation for this drastic difference in response between these two test stands would be the way the control panel is connected to the rib structure at those points. In other words, stand No. 143 is stiffened by the ribs being rigidly connected together by the control panel and stand No. 117 is less rigid by being loose or possibly not connected at all, thereby allowing this center point to vibrate excessively.

#### CONCLUSION

The excitation energy on each test stand was similar, producing a similar frequency response. However, the amplitude response was different by a factor of two or more. Therefore, the instrument package which is to be mounted on the AHT-64 structure must be able to withstand vibration frequencies around 360 hertz. However, the amount of vibration energy it must withstand is still in question.

If we assume that test stand No. 143 had "good" structural integrity and needs no further reinforcements, etc., and we assume that test stand No. 117 could be fixed and/or reinforced enough to respond similar to No. 143, then the amount of vibration energy which

Mr. Edwin Roberts  
Sanders & Thomas

March 30, 1979

Page Three

must be withstood by the instrumentation would be 2 g's if mounted on the front of the stand below the control panel (positions 1,2 and 3).

#### RECOMMENDATION

Assumptions were made in the last paragraph which we recommend be eliminated through further testing, inspections, and modifications. The future tests would not have to be as detailed in terms of frequency response, only amplitude response. Amplitude can be measured and recorded more easily than the previous tests using a transducer and an overall vibration meter capable of displaying at least two of the three engineering parameters - acceleration, velocity, and displacement.

I would estimate four to six test stands could be monitored in one day, obtaining the orthogonal amplitude responses at the same seven locations on the stand operating in the pressure loaded condition. It would be advisable to inspect the test stands closely for loose bolts, cracked welds or structural members. This can be done with the same vibration meter with a strobe light attachment. If differences were found through this inspection, I would suggest corrective measures be performed if possible. In this way we would be assured of similar structural integrity between test stands.

Our charges for the engineering testing and analysis would be \$500 per day of on-site services. There would be no additional charge for analysis completed in our engineering center. Travel and per diem expenses incurred during the test program are also included in the above price.

We thank you for the opportunity to provide our service. If you have any questions, please do not hesitate to contact us.

Very truly yours,

  
WILLIAM D. KEELEY  
Field Service Manager

WCK/cem

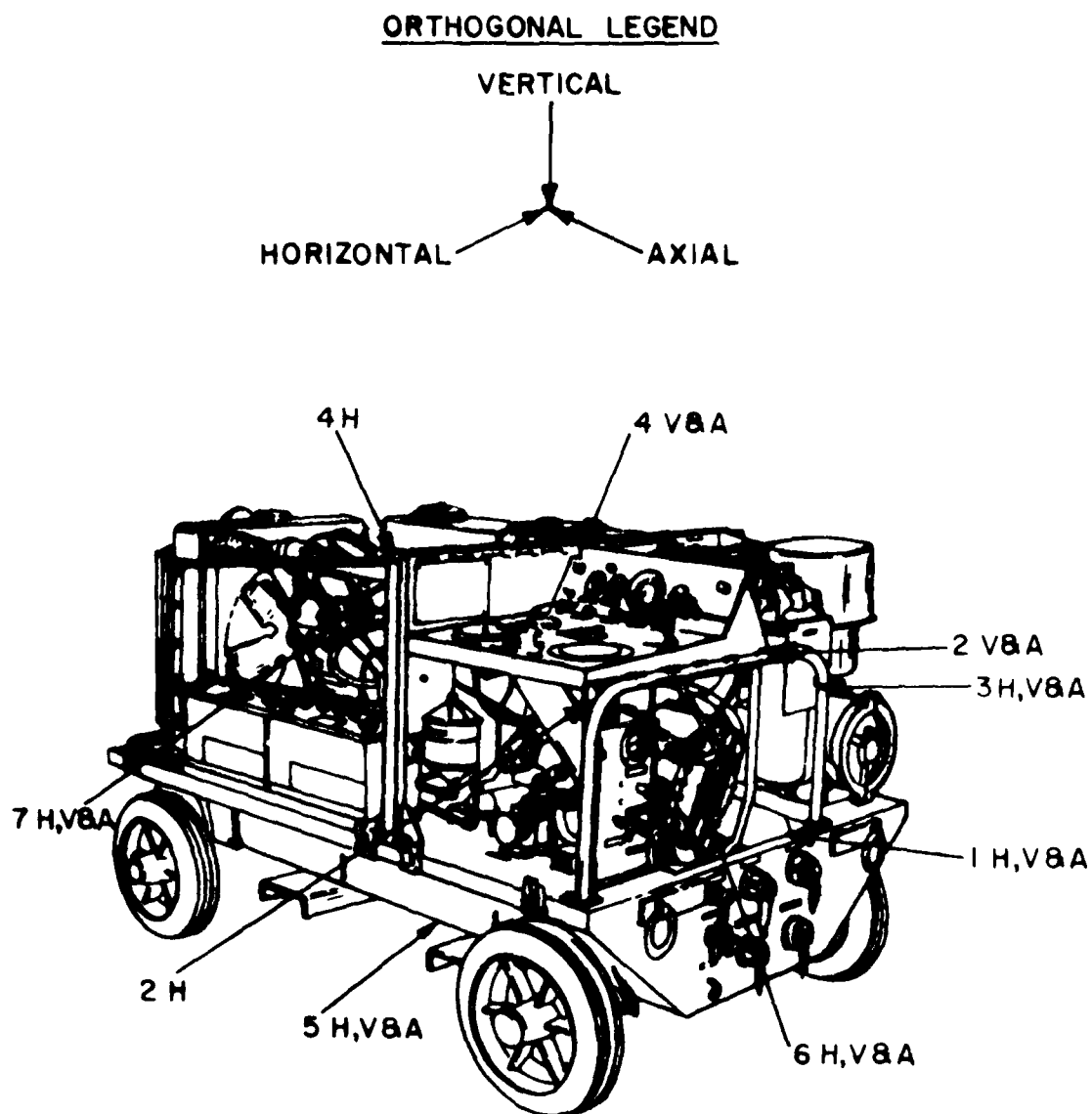
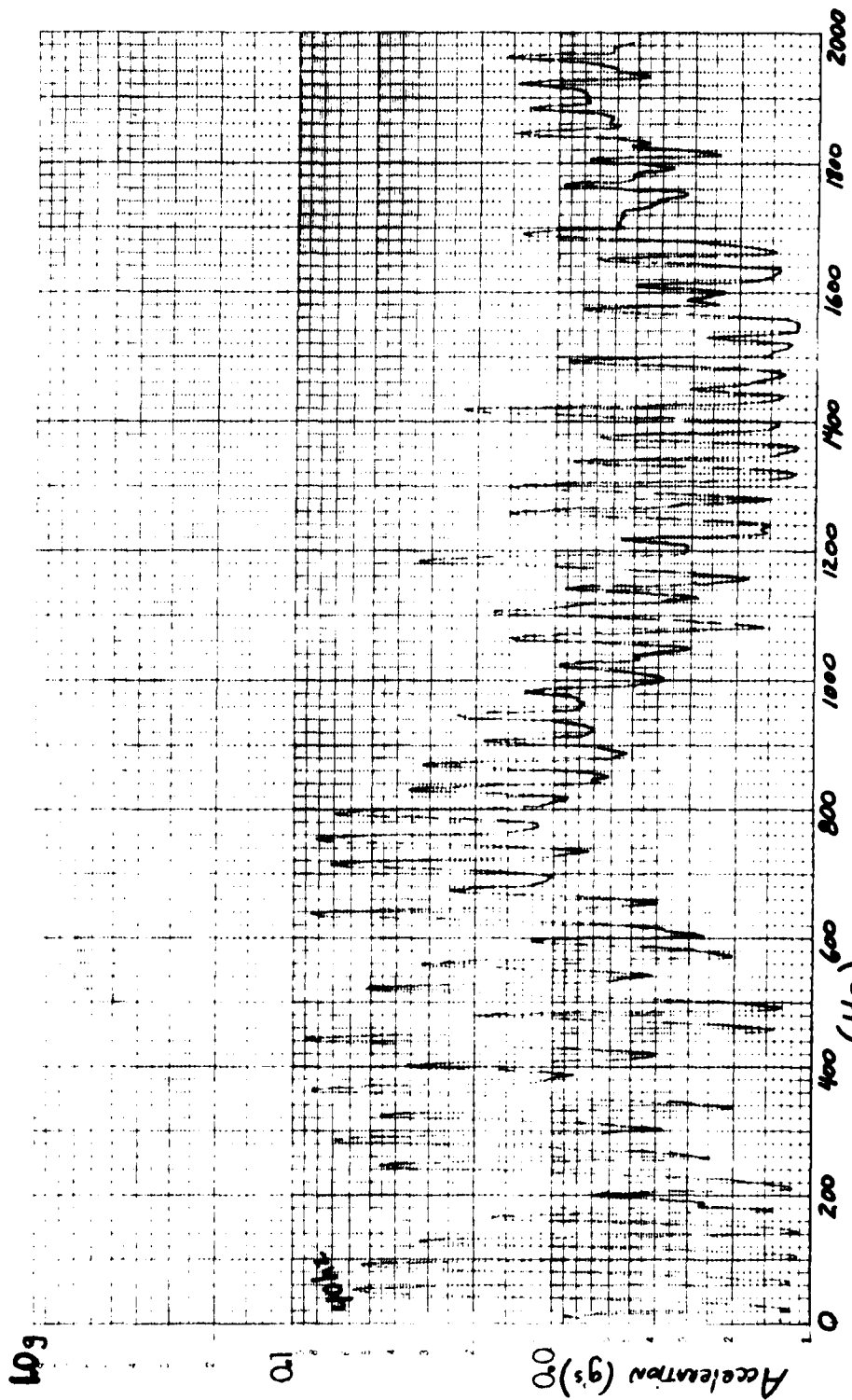


Figure A - Vibration Signature Positions

SAMPLES a - 40.000S  
 20414 3/12/79  
 Wulgarid - 2400 RPM = 40 Hz  
 ANT 64  
 X 32  
 1H  
 -10  
 38g  
 2000 Hz  
 40500

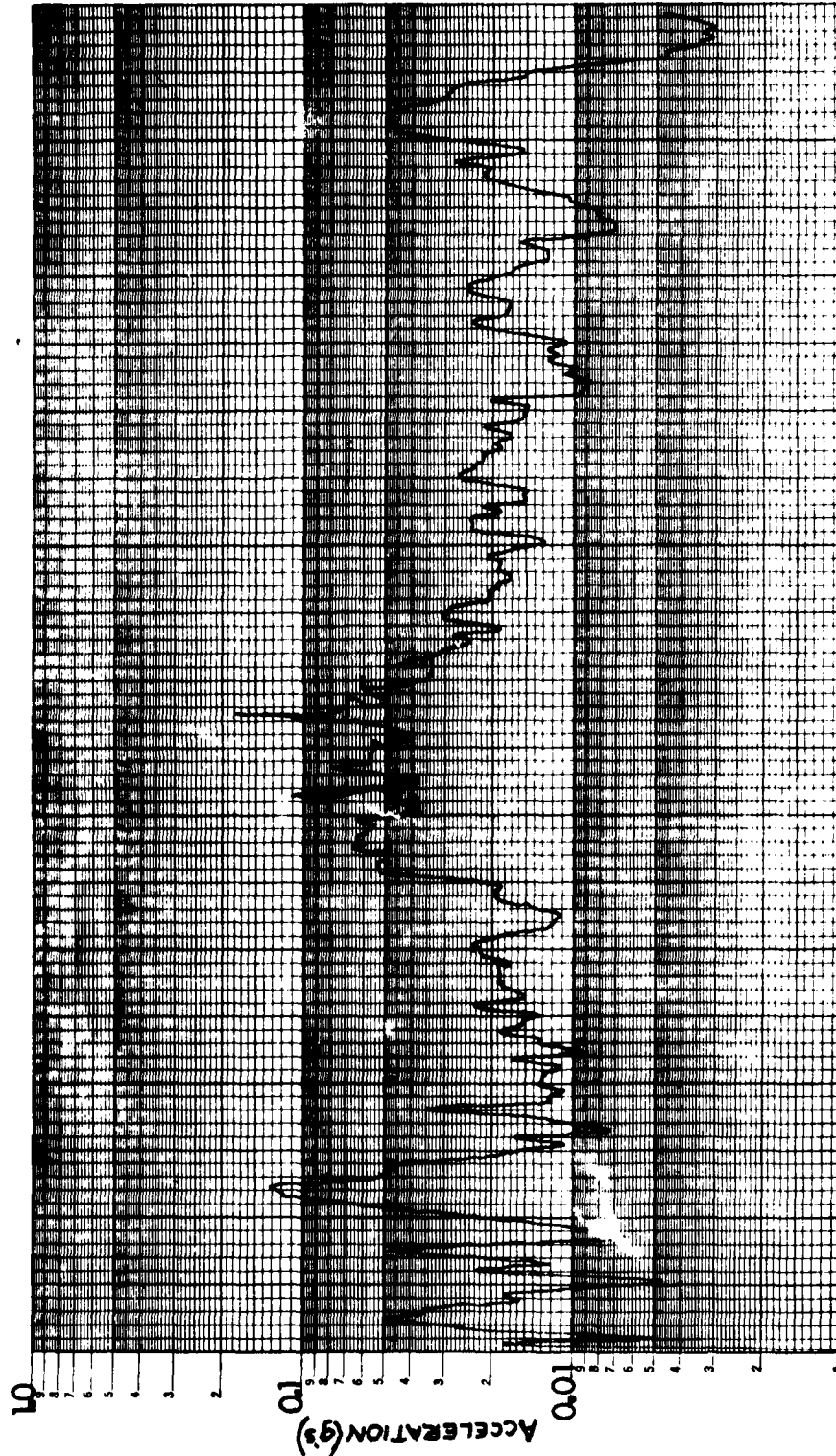


VIBRATION SPECIALTY CORPORATION  
 100 Gager Road, Channahon, IL 61015, 215 494-1111

FREQUENCY (Hz)  
 NOTE: FREQUENCY RANGE SAME  
 FOR ALL SUBSEQUENT FIGURES  
 IN APPENDIX B.

figure 1  
 X No. of samples looked at/analyzed over 0-2000 Hz Range  
 XX Summation of G's over 32 sample points (in 0-2000 Hz Range)

CUSTOMER SANDERS + THOMAS PROJECT AHT-64 #143 FREQUENCY RANGE 2000 Hz  
 JOB NO. 20419 DATE 3/22/79 ANALYST W.A. AVERAGE 3.2 DO -16 INPUT FROM 4R50  
 TEST CONDITIONS Transient - Idle to Full Speed - Unbalanced



87 (B-7)

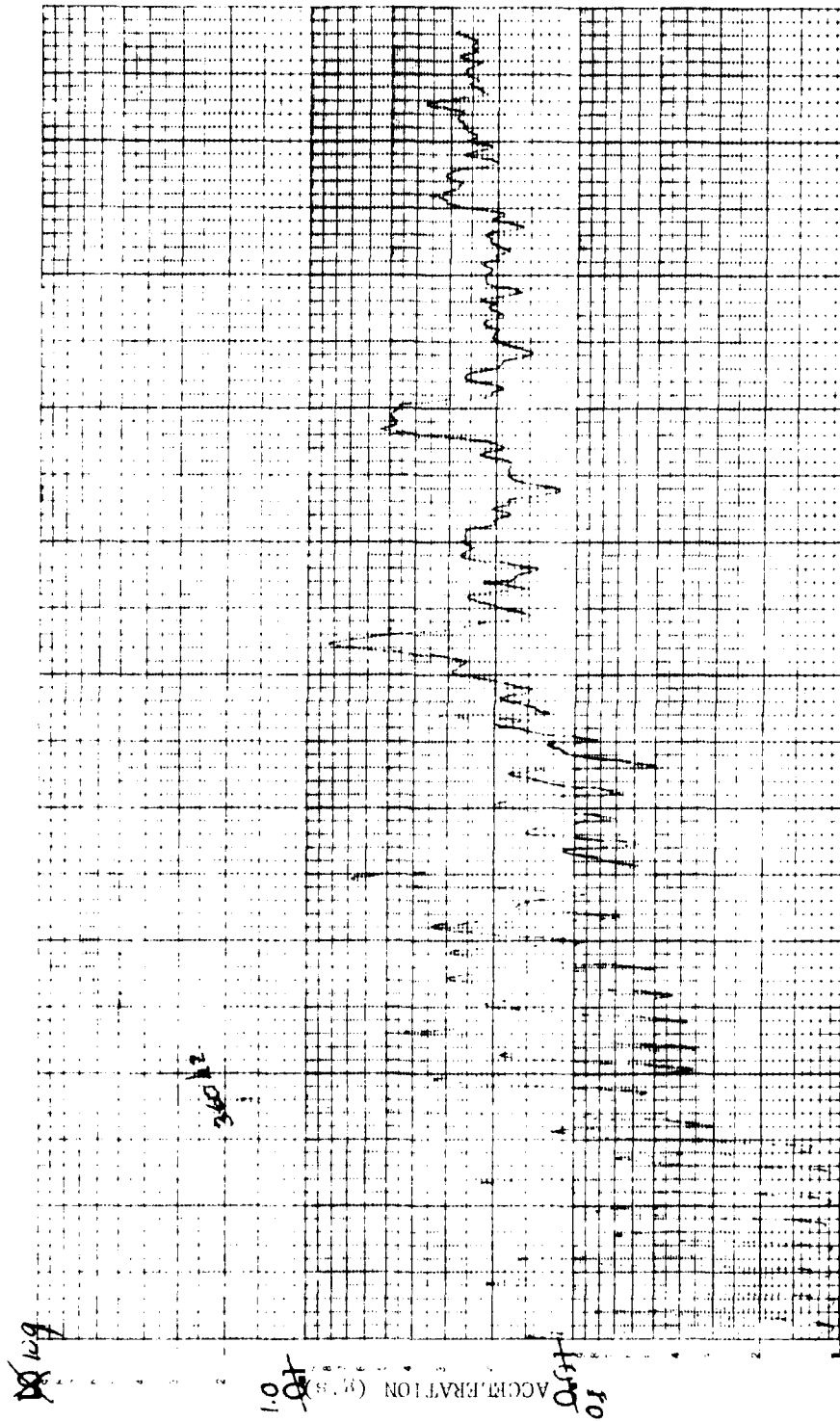
VIBRATION SPECIALTY CORPORATION  
 100 Geiger Road Philadelphia, Pa. 19115 (215) 598-1850

FREQUENCY

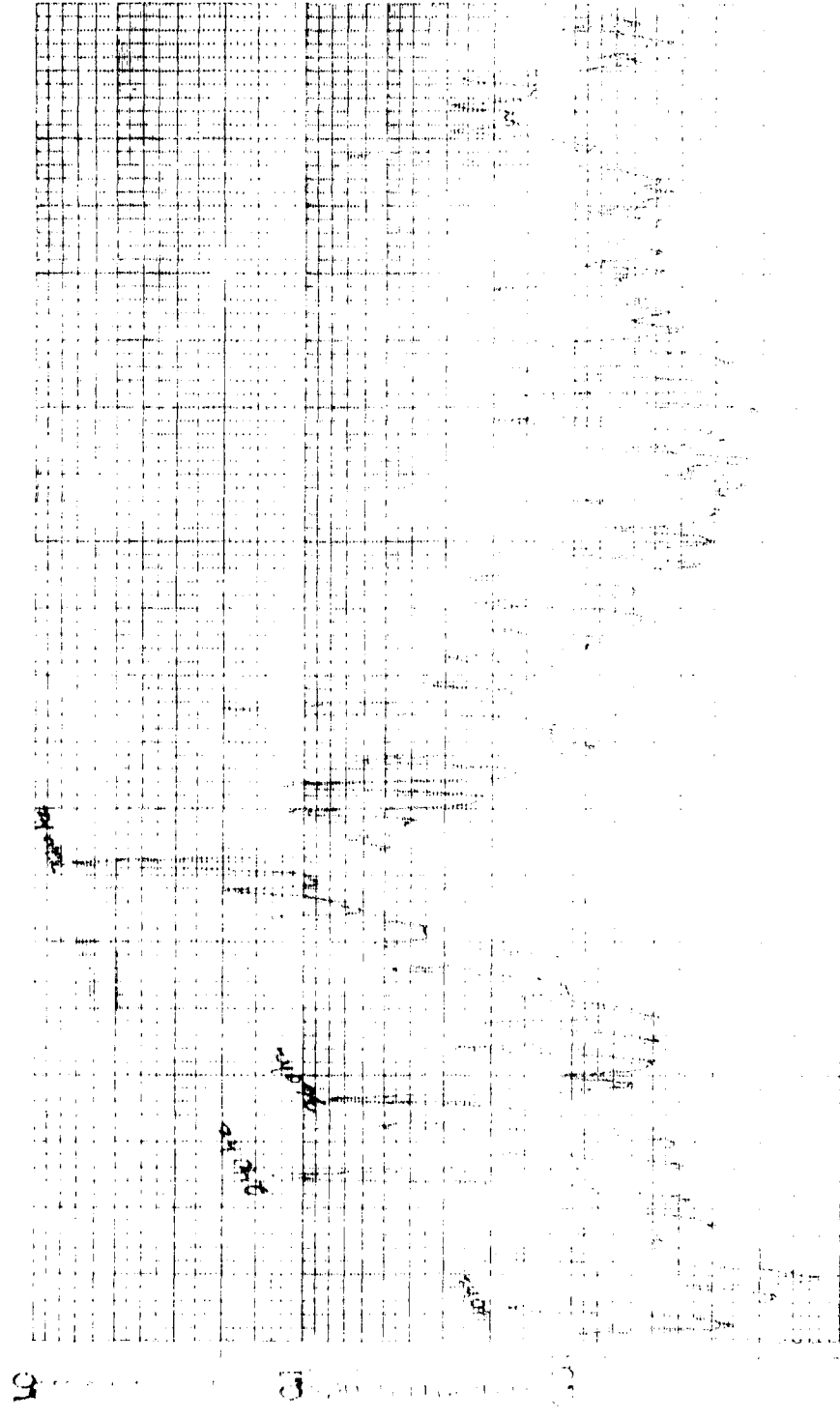
figure 3

NARC-92-146

Saunders & Thomas  
 26419 3/22/79  
 TRANSIENT FROM LOAD TO UNLOADED PRESSURE  
 AHT-64 #143 CA - 200012  
 -16 40500



SPARKS - 7400000  
 2040 3120000  
 100 32 200 2000 42  
 100 32 200 2000 42

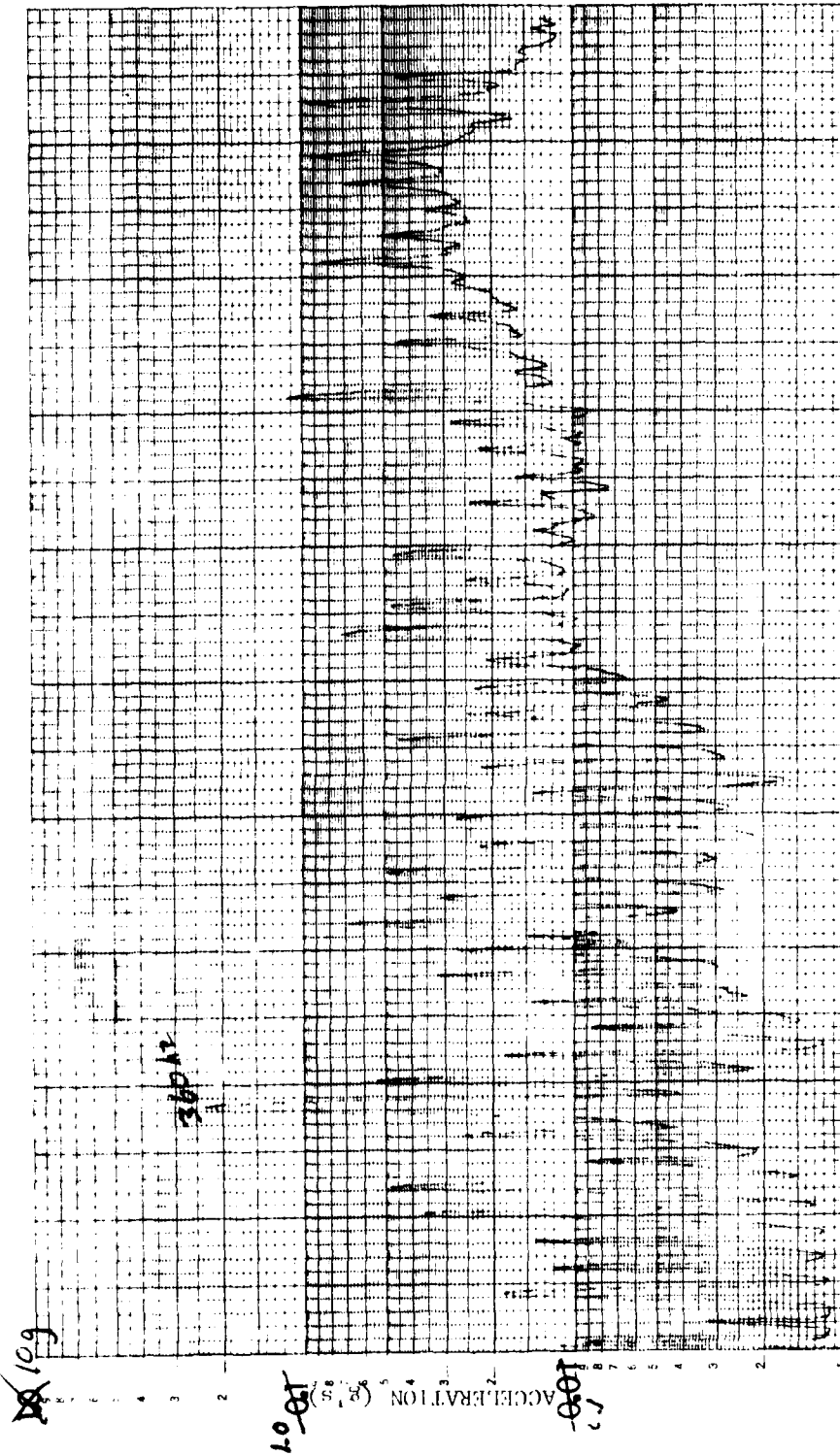


CONCENTRATION

FREQUENCY

Figure 5

SANCER & THOMAS  
 20419 3/22/74  
 Unloaded  
 AMT-04 140 32  
 6A 6.8g 2000 Hz  
 -16 48500

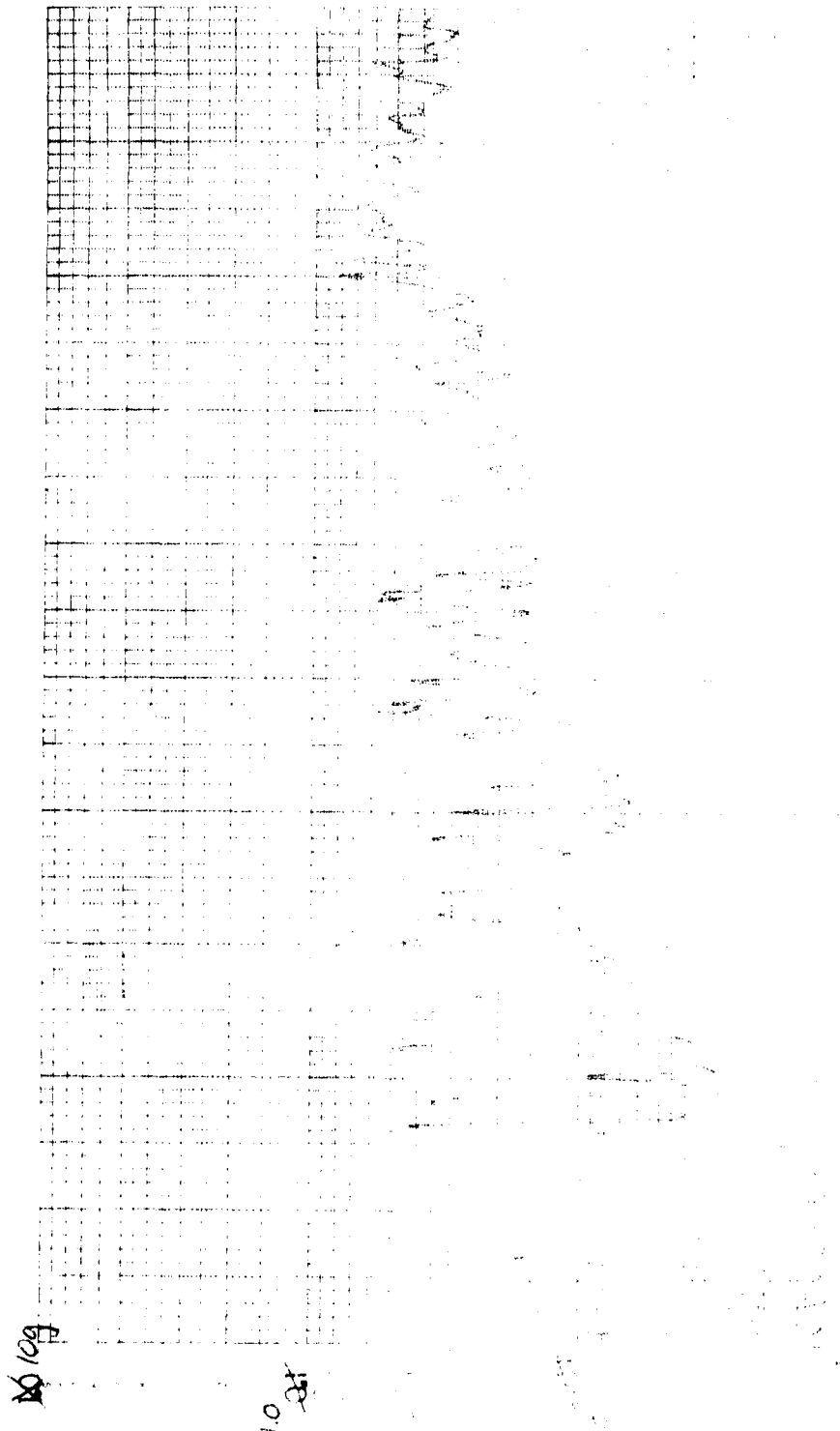


VIBRATION SPECIALTY CORPORATION  
 1701 W. 10th St. Oklahoma City, OK 73106

FREQUENCY

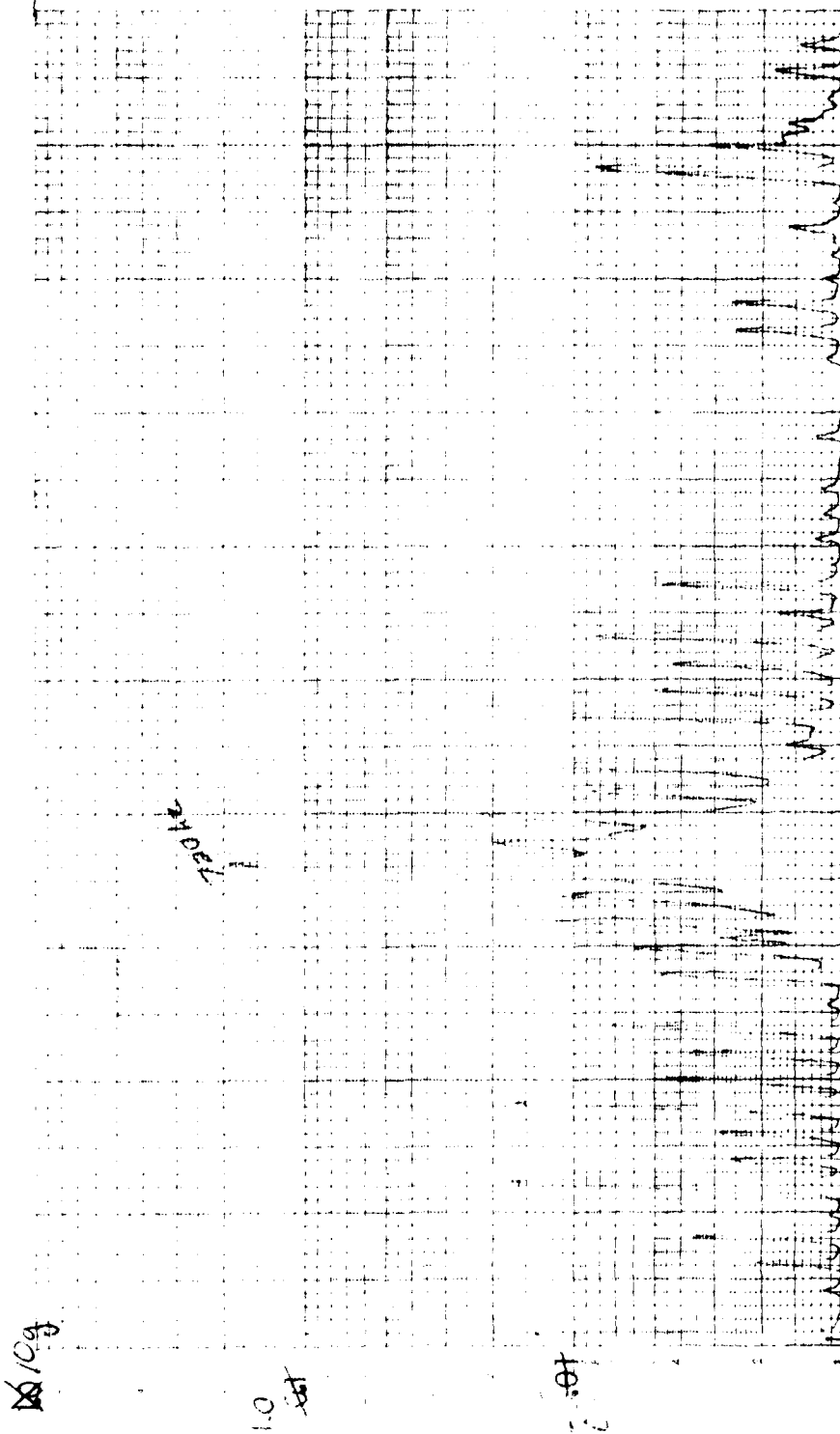
Figure 20

SANDERS & THOMAS  
 20419 3/22/79  
 A.T-64 143 32  
 7V 9.5g 2000 Hz  
 -16 4950  
 Unloaded



FREQUENCY  
 VIBRATION SPEED ALL IN UNITS PER MIN  
 Page 23

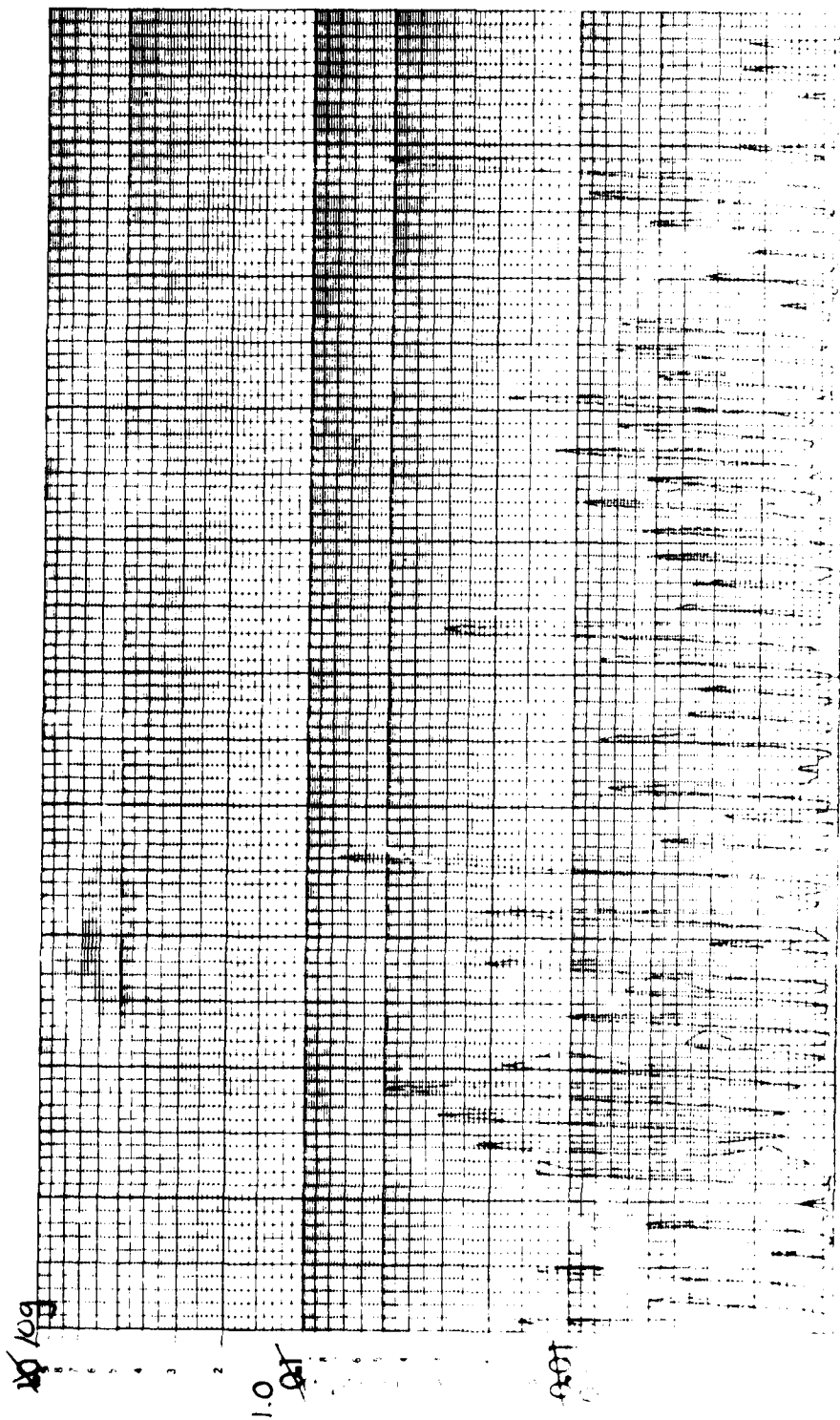
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 11A 2g Dec 02  
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VIBRATION SPECIALTY CORPORATION  
 100 Gager Road, Philadelphia, PA 19104, 215-381-0000

FREQUENCY  
 figure 26

|                    |              |            |            |      |     |               |      |           |        |
|--------------------|--------------|------------|------------|------|-----|---------------|------|-----------|--------|
| SANDERS & THOMPSON |              | AHT-64     |            | #143 | 2A  | OVERALL LEVEL | 159  | FREQUENCY | 20m 02 |
| 20418              | DATE 3/22/79 | ANALYST WK | AVERAGE 32 | 00   | -16 | INPUT FROM    | WASH |           |        |
| Loaded             |              |            |            |      |     |               |      |           |        |



VIBRATION SPECIALTY CORPORATION

figure 29

AD-A100 696

SANDERS AND THOMAS INC POTTSTOWN PA

F/G 14/2

APPLICATION OF AN IN-LINE CONTAMINATION MONITORING UNIT TO THE --ETC(11)

JUN 81 P M O'DONNELL, E W ROBERTS

N00140-80-C-0053

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NAEC-92-146

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|---------|------------------|-----------|--------|----------|----|---------------|-----|-----------------|---------|
| NAME    | SANDERS & THOMAS | EQUIPMENT | AHT-64 | POSITION | 3A | OVERALL LEVEL | 2g  | FREQUENCY RANGE | 2000 Hz |
| DATE    | 204/19           | ANALYST   | WK     | AVERAGE  | 32 | QU.           | -16 | INPUT FROM      | 4050    |
| Labeled |                  |           |        |          |    |               |     |                 |         |

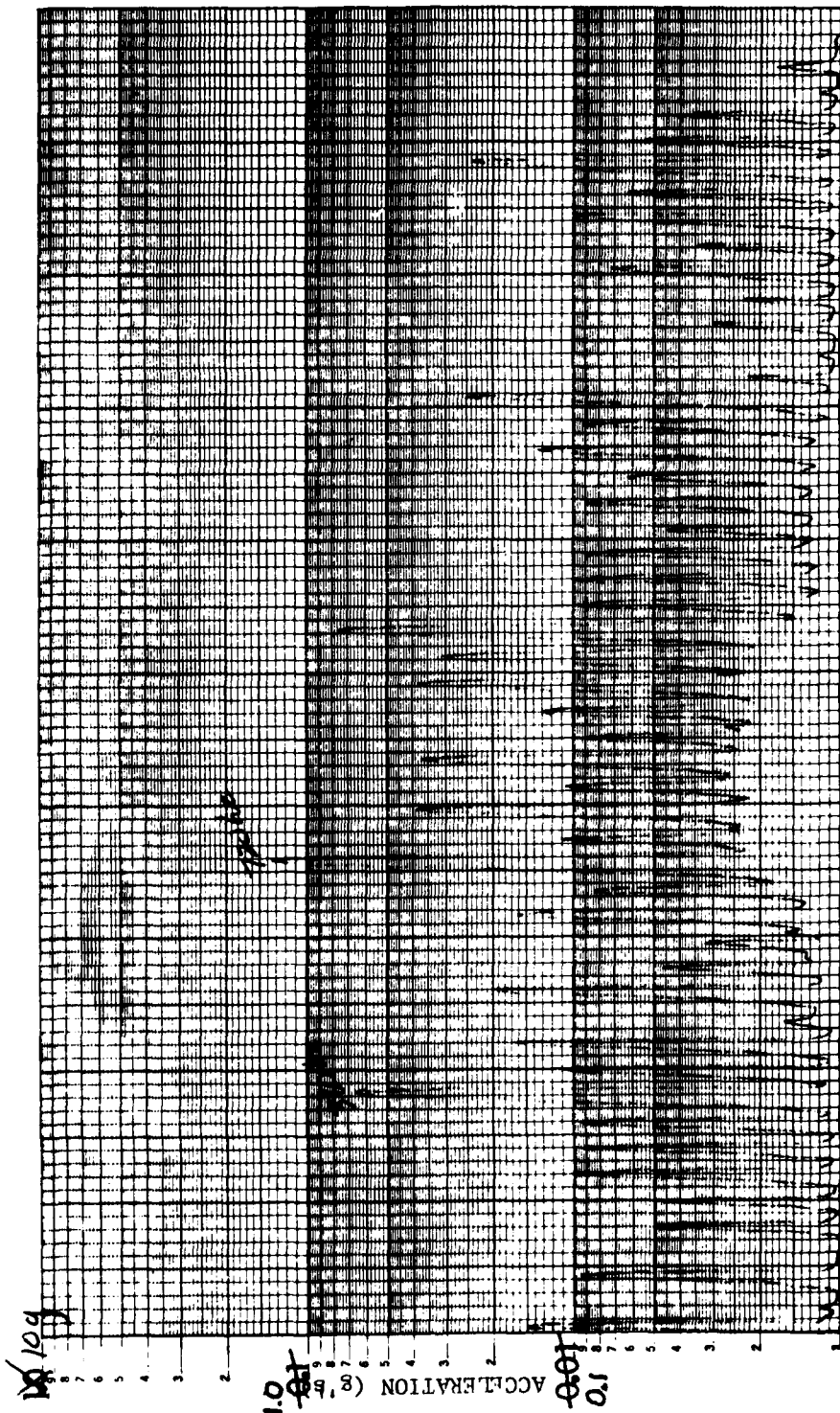
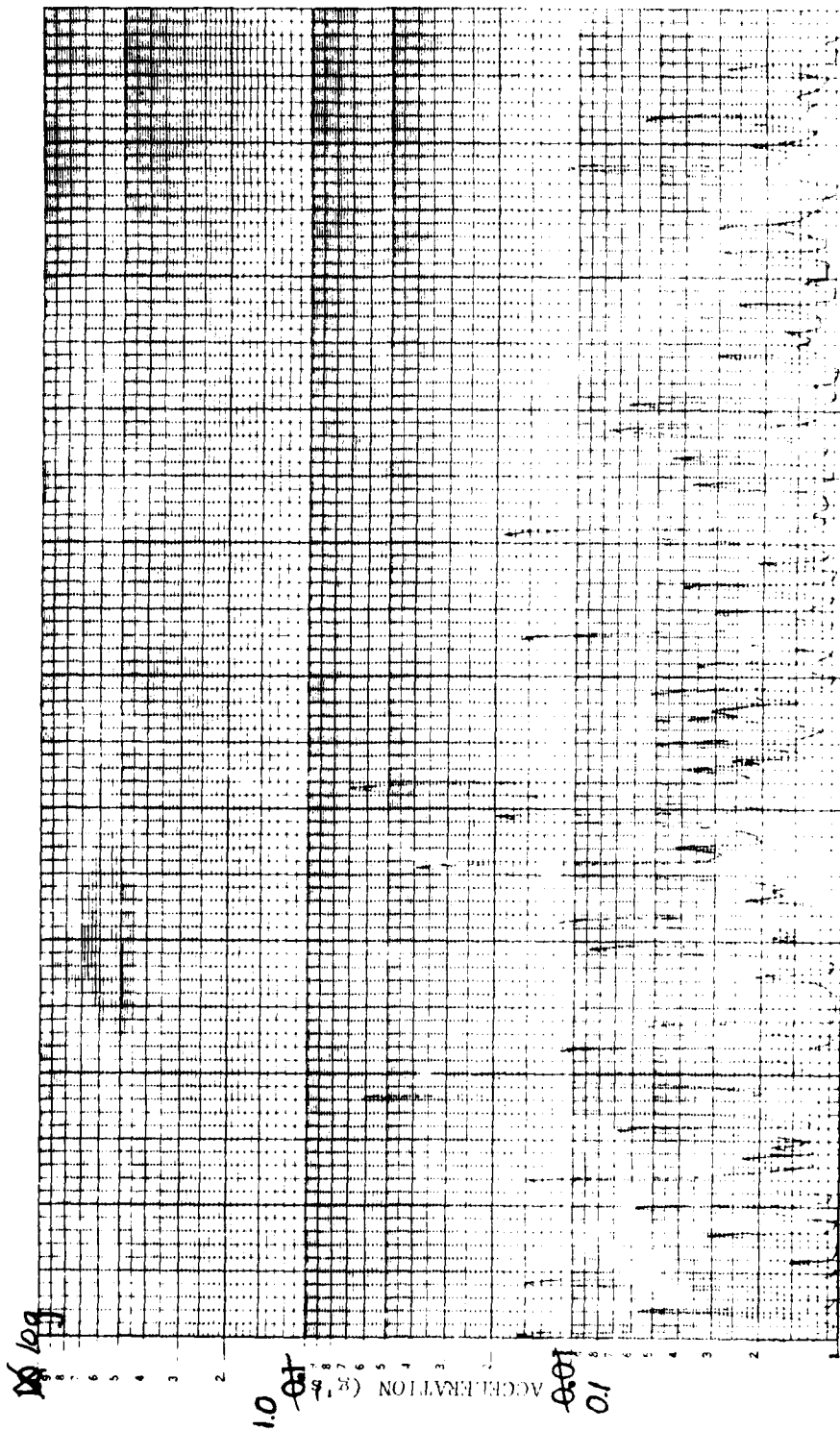


figure 32

VIBRATION SPECIALTY CORPORATION  
100 Geger Road / Philadelphia Pa 19115 (215) 698 0800

FREQUENCY

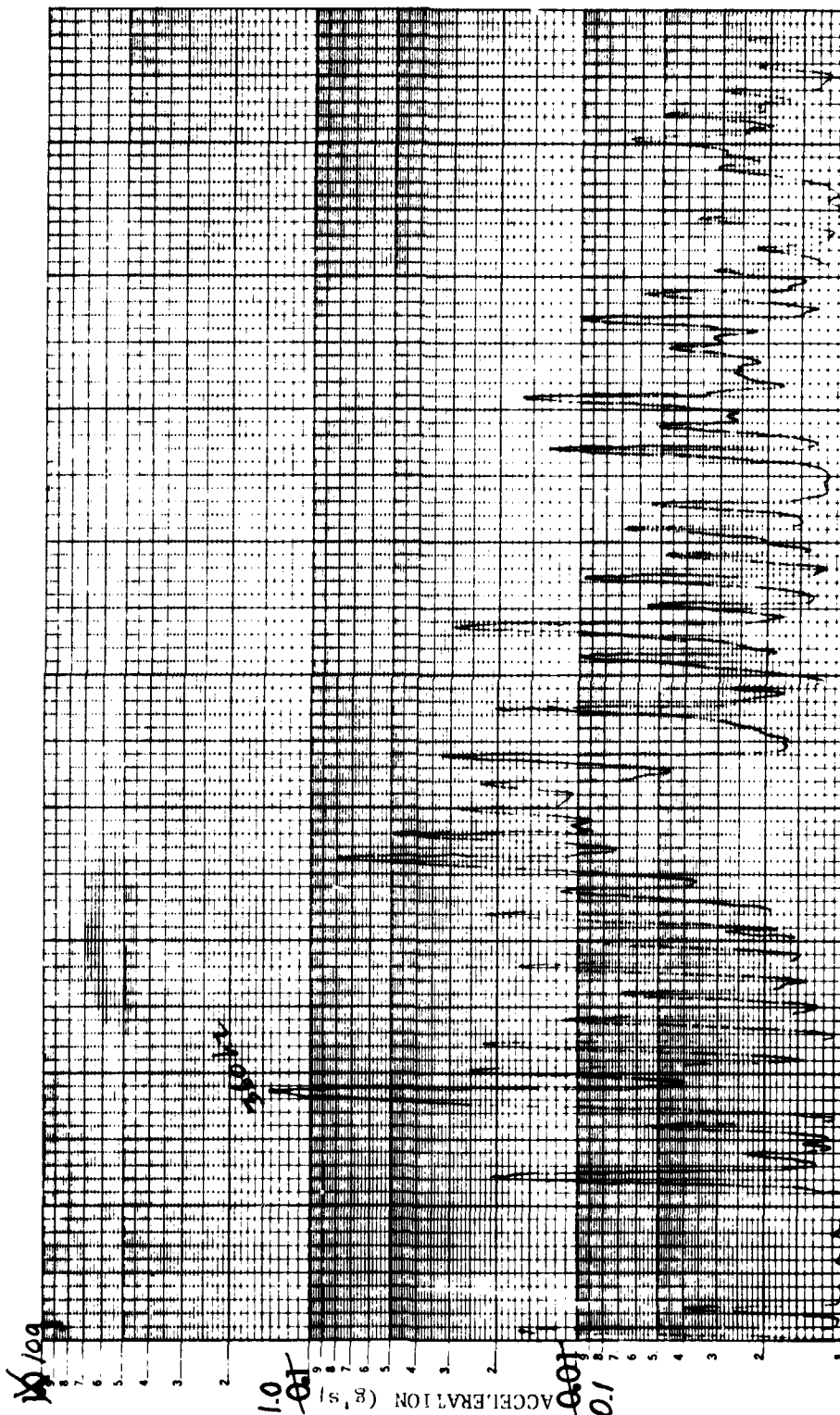
JOB NO. SANDERS & THOMAS EQUIPMENT AHT-64 "143" POSITION 4A OVERALL LEVEL 149 FREQUENCY RANGE 2000 Hz  
 JOB NO. 20419 DATE 3/22/78 ANALYST WK AVERAGE 32 00 -16 INPUT FROM 4950  
 TEST CONDITION Loaded



VIBRATION SPECIALTY CORPORATION  
 ONE 16th Street Philadelphia, PA 19103

Figure 35

SANDERS & THOMAS  
 JOB NO. 20419 DATE 3/22/79 ANALYST WK  
 FREQUENCY 2000 Hz  
 5H 2.2g 143  
 -16 32  
 INPUT FREQ. 49500  
 LOAD



96 (B-16)

VIBRATION SPECIALTY CORPORATION  
100 Geiger Road Philadelphia, Pa. 19115

figure 36

|                  |  |              |  |      |         |                   |
|------------------|--|--------------|--|------|---------|-------------------|
| SANDERS & THOMAS |  | AHT-64       |  | #143 | OVERALL | FREQUENCY         |
| 20419            |  | DATE 3/22/79 |  | W.K. | LEVEL   | RANGE             |
| Loaded           |  | AVERAGE      |  | 32   | 6A      | 13g               |
|                  |  |              |  |      | IF      | INPUT FROM 4A 500 |



VIBRATION SPECTROGRAPH

FREQUENCY

Figure 4

SANDERS & THOMAS  
 20419  
 DATE 3/22/79  
 ANALYST WK  
 PROJECT BHT-64  
 TEST # 143  
 AVERAGE 32  
 OVERALL 7V  
 SCALE 119  
 INPUT FROM 49500  
 FILE NO. 2000 k2  
 ANALYST  
 TEST #  
 AVERAGE  
 OVERALL  
 SCALE  
 INPUT FROM

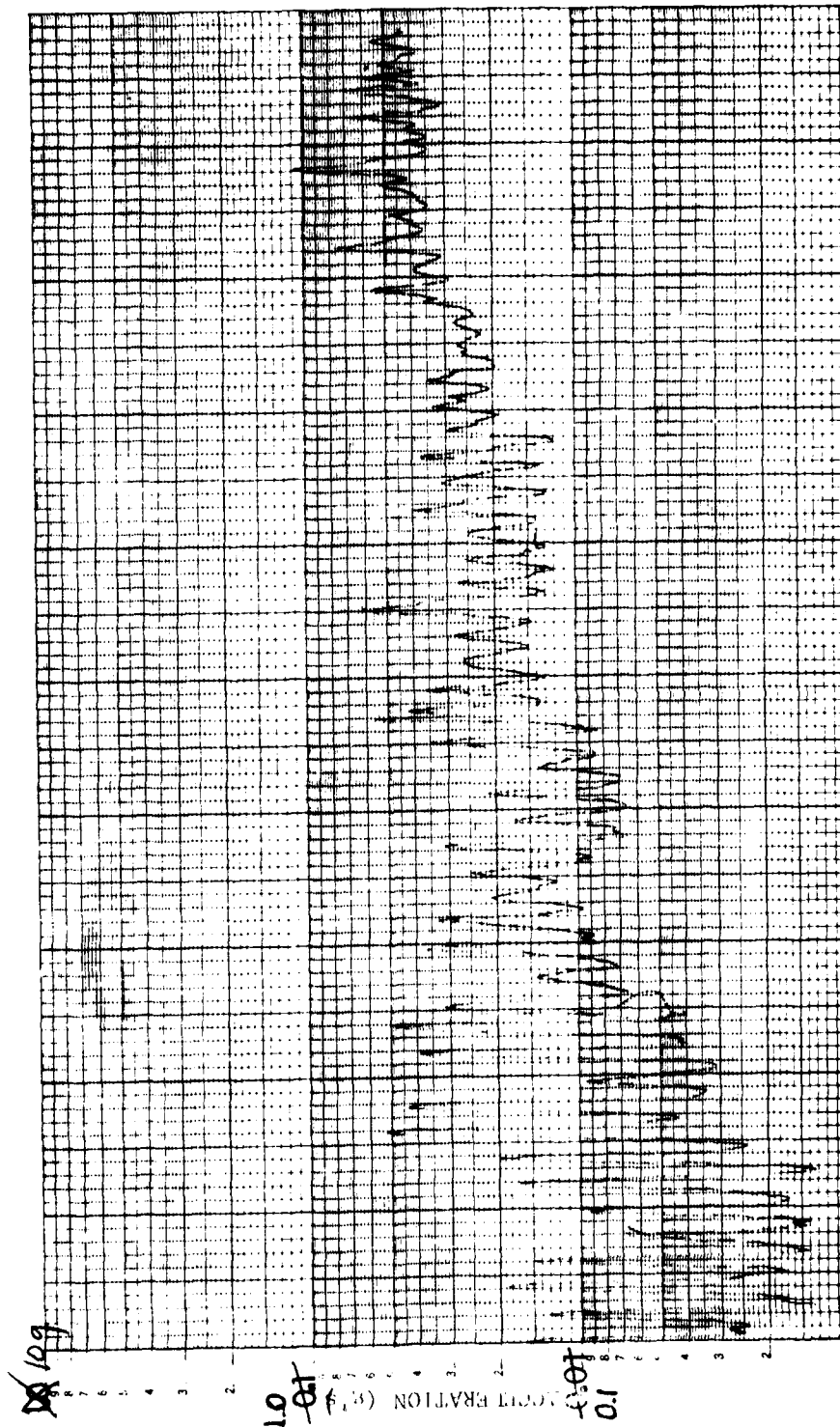
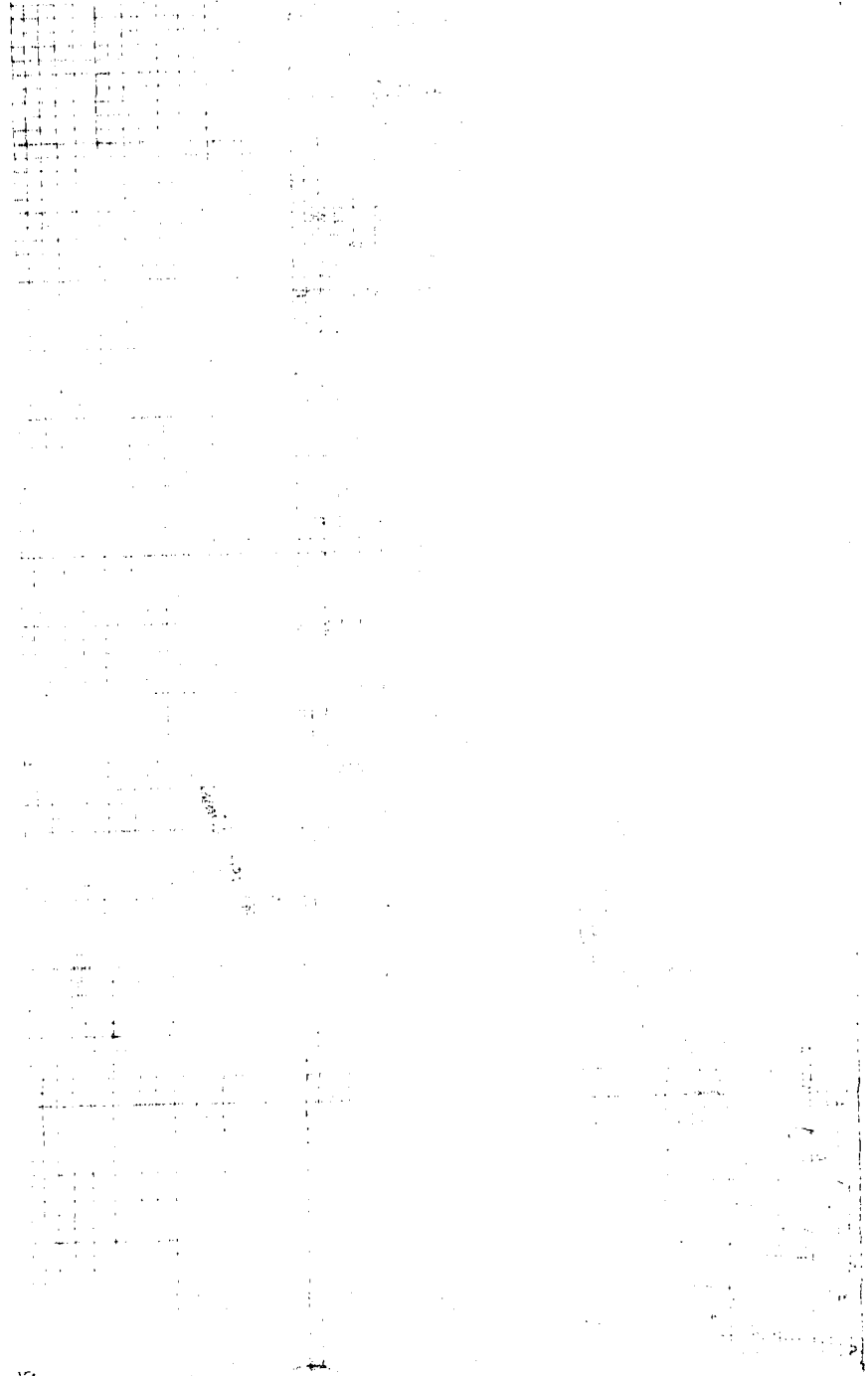


figure 43

VIBRATION SPECIALTY CORPORATION  
 100 Geger Road Philadelphia, Pa. 19115 (215) 698-0800

FREQUENCY

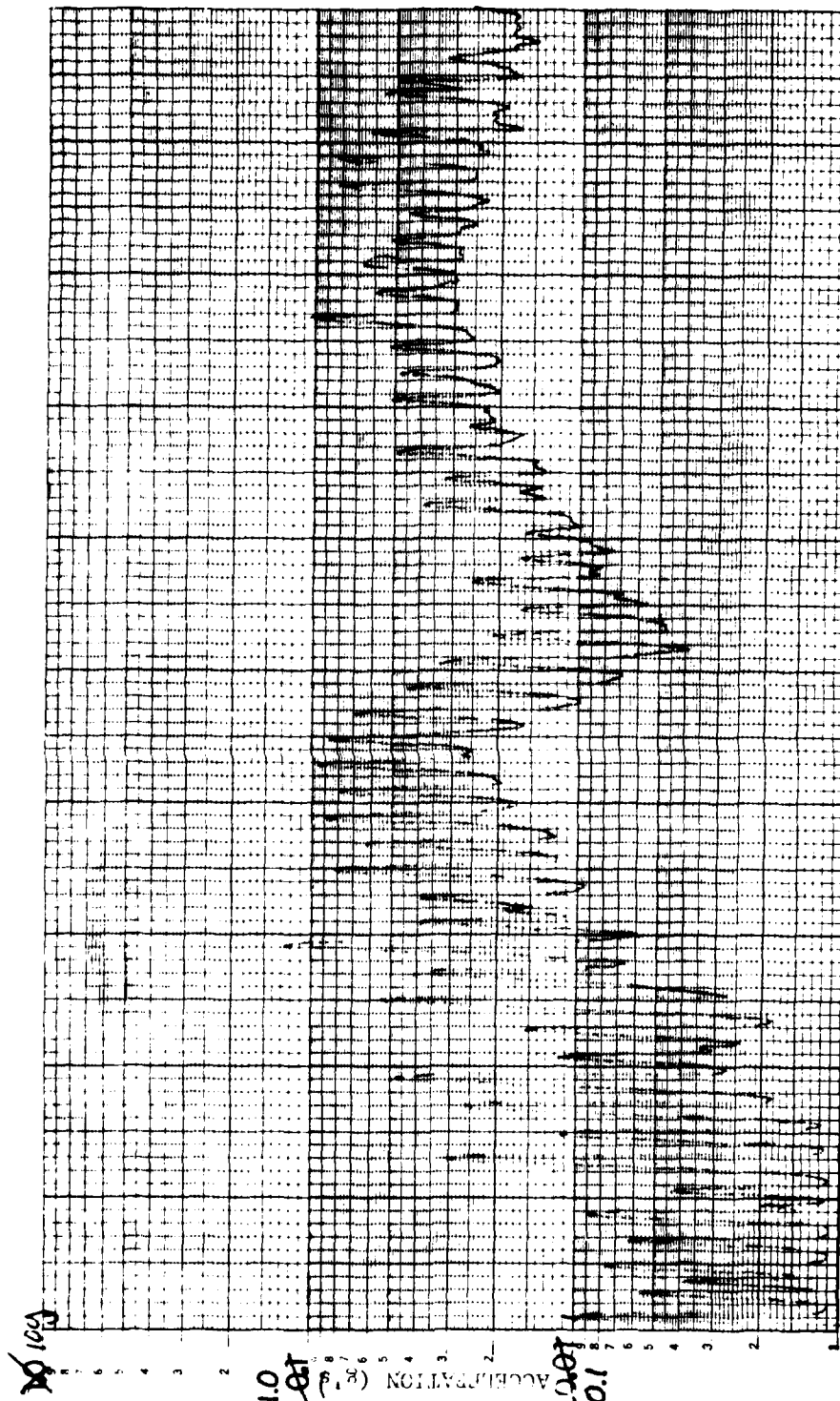
SANDERS - HIMA  
 20410 3/19/94  
 NO LOAD  
 10.83 10.83 2000 12  
 14 14 14 14



1093

1093

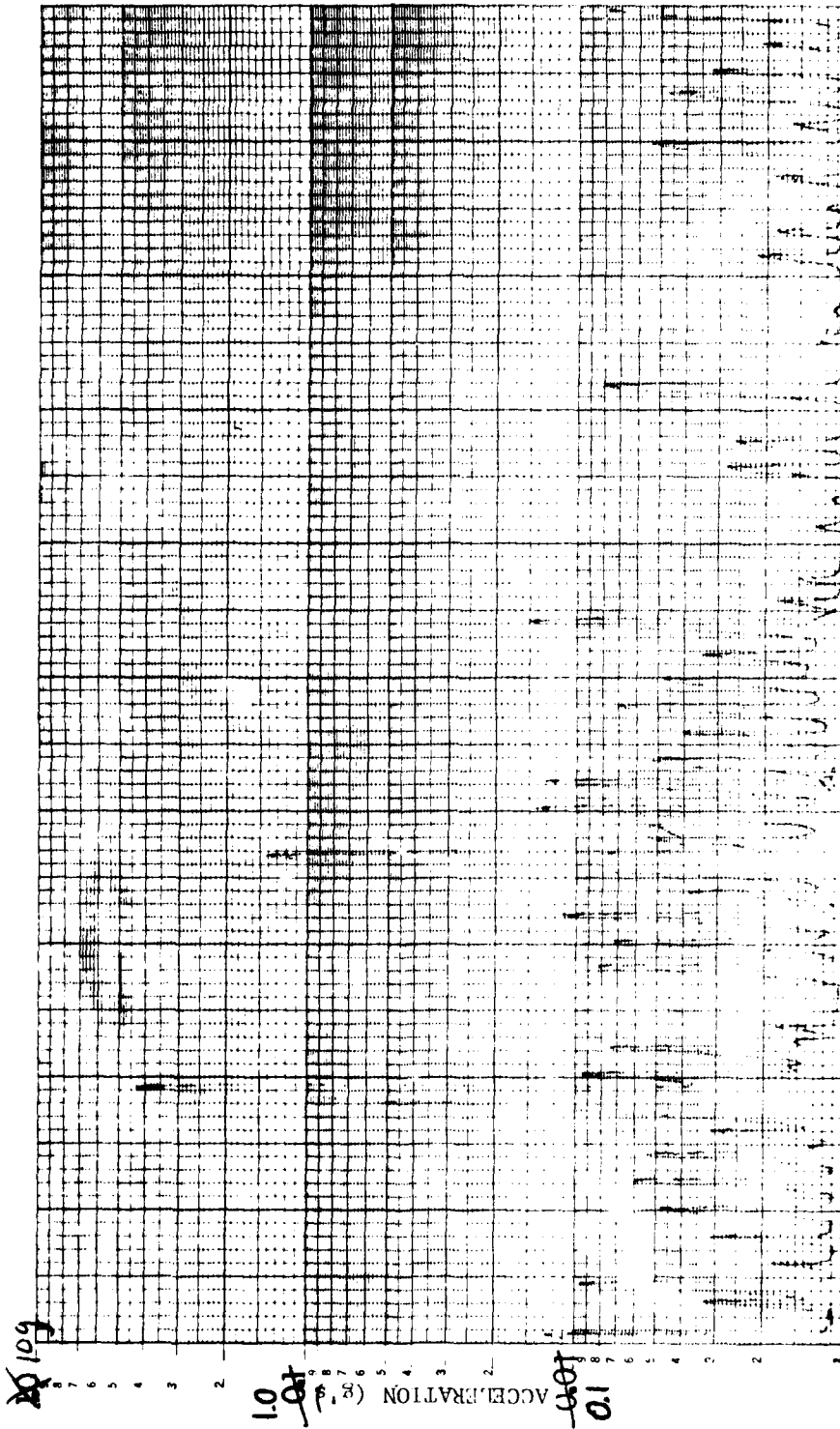
SANDERS & THOMAS  
20419 3/19/79 WK  
7A 9g's 2000k  
-16 32 4850



VIBRATION SPECIALTY CORPORATION  
100 Gager Road Philadelphia Pa 19115 (215) 698-0800

Figure 62

SANDERS & THOMAS  
 20419 3/19/74  
 Loaded  
 AHT-64 WK  
 112  
 2A SERIAL 449  
 -16 INPUT SUM 4950



VIBRATION SPECIALTY CORPORATION

figure 67

FREQUENCY

SANDERS & THOMAS  
20419 3/19/78  
Lead  
AHT-64 WK 32 3H -16 3.2 200012 14500

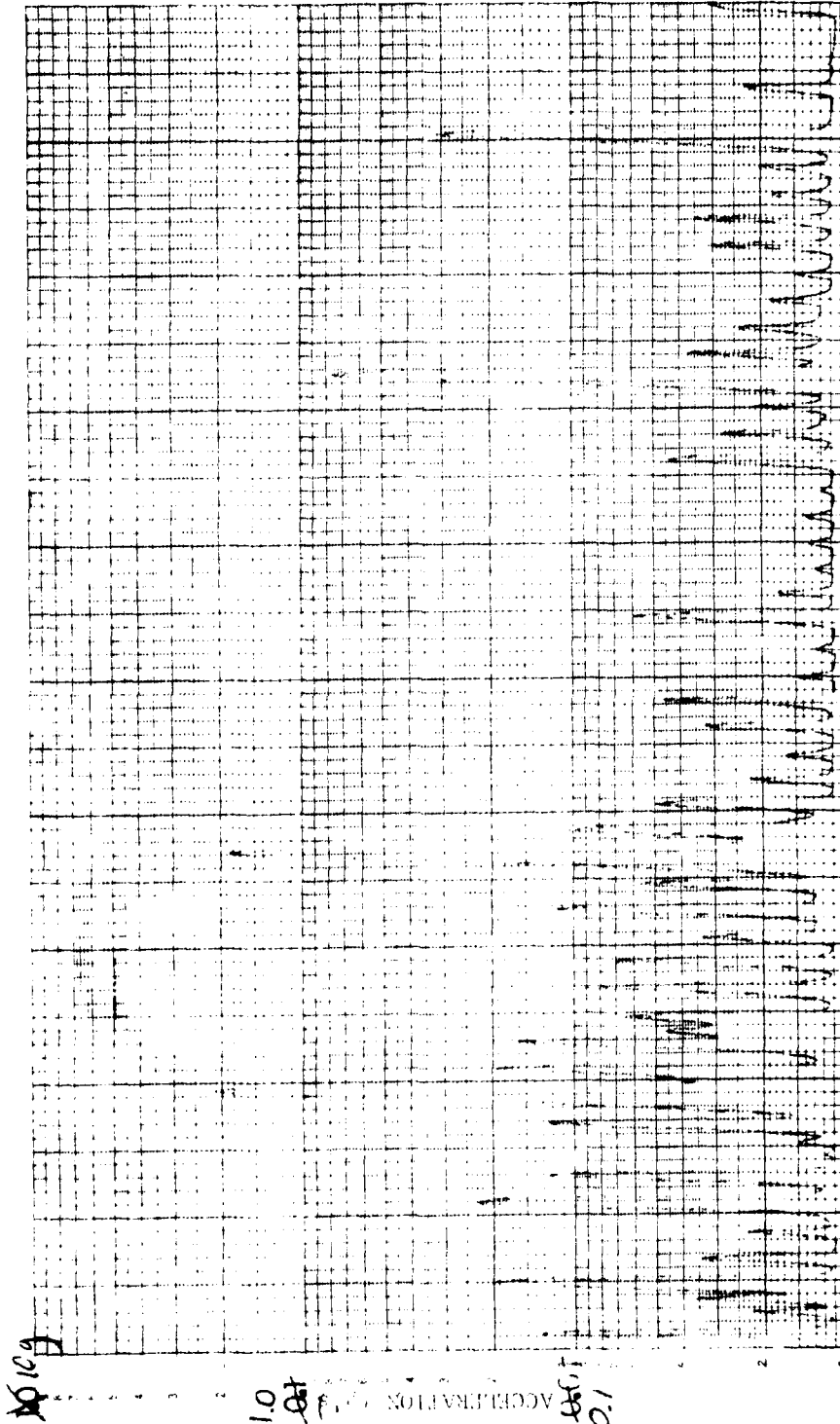
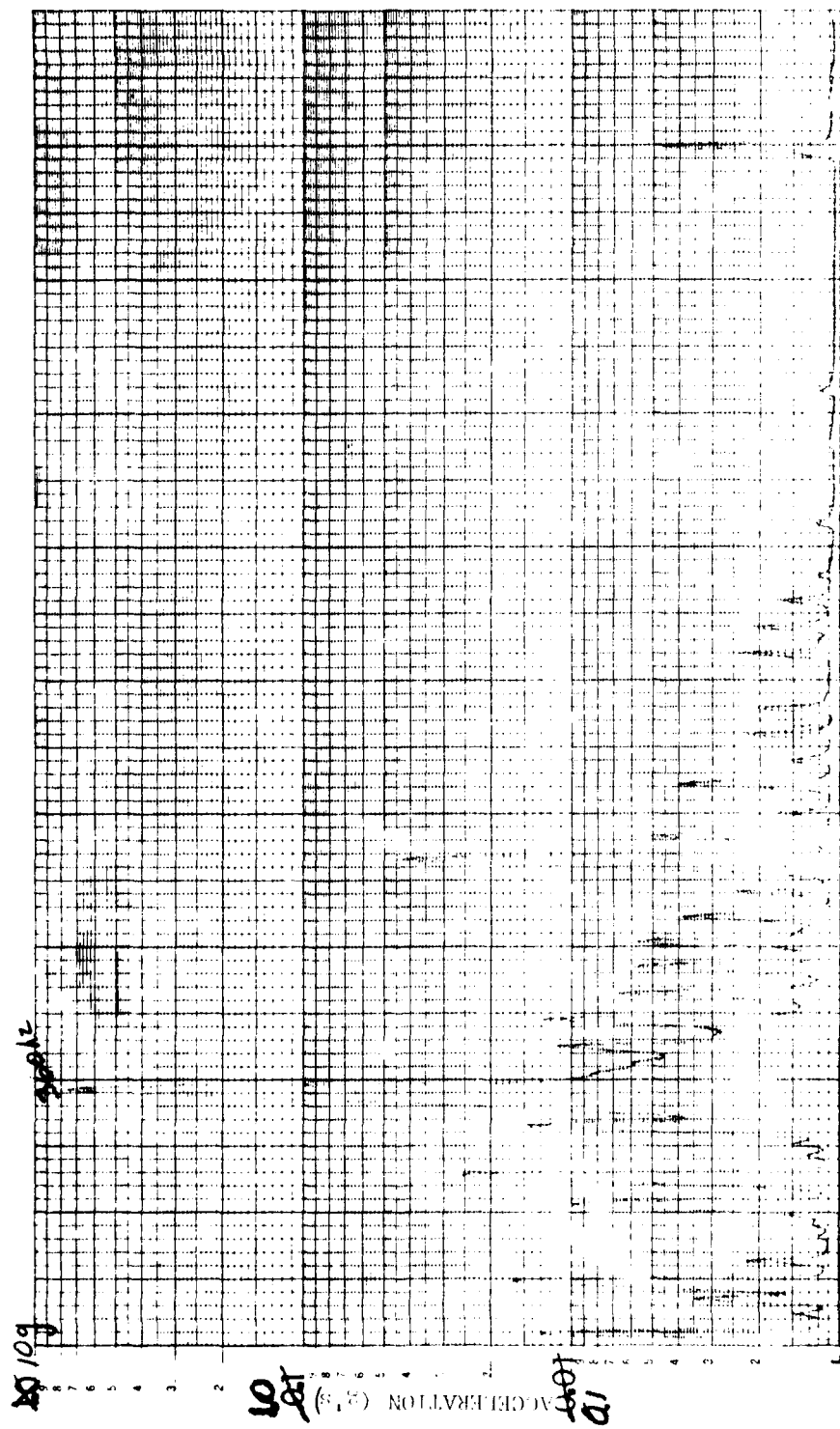


figure 68

VIBRATION SPECIALTY CORPORATION  
100 Geiger Road Philadelphia, Pa 19115 (215) 698 0800

FREQUENCY

SANDERS & THOMAS      AHT-64      #117      4A      795      2000 Hz  
 20412      3/19/77      4X      32      -16      INPUT FREQ.      49500  
 LOADED

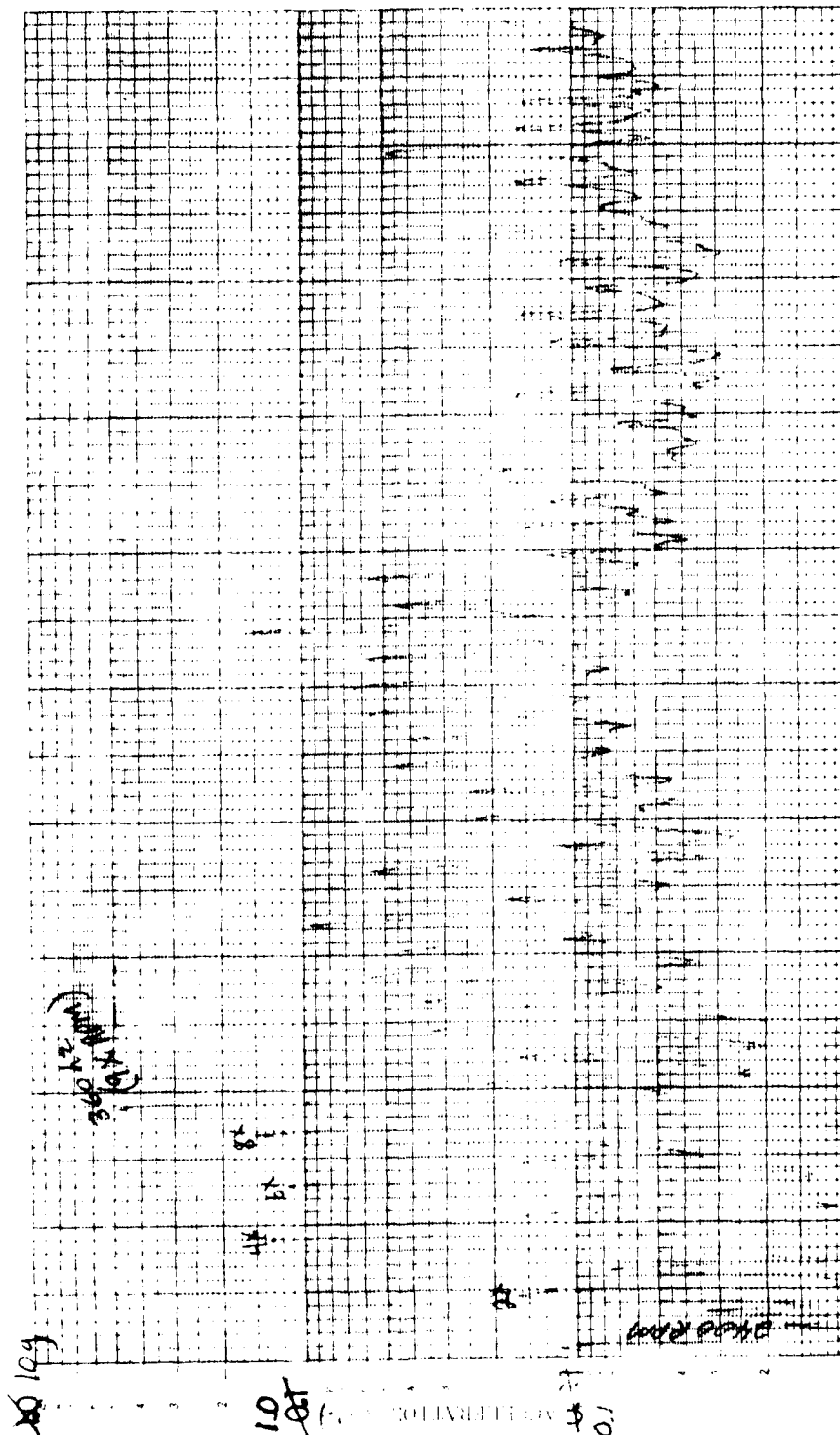


VIBRATION SPECIALTY CORPORATION

Figure 73

SANDERS & THOMAS  
20419 3/19/79  
banded

AHT-64 #117  
WX 32  
6A 8.7  
-16 200012  
40500

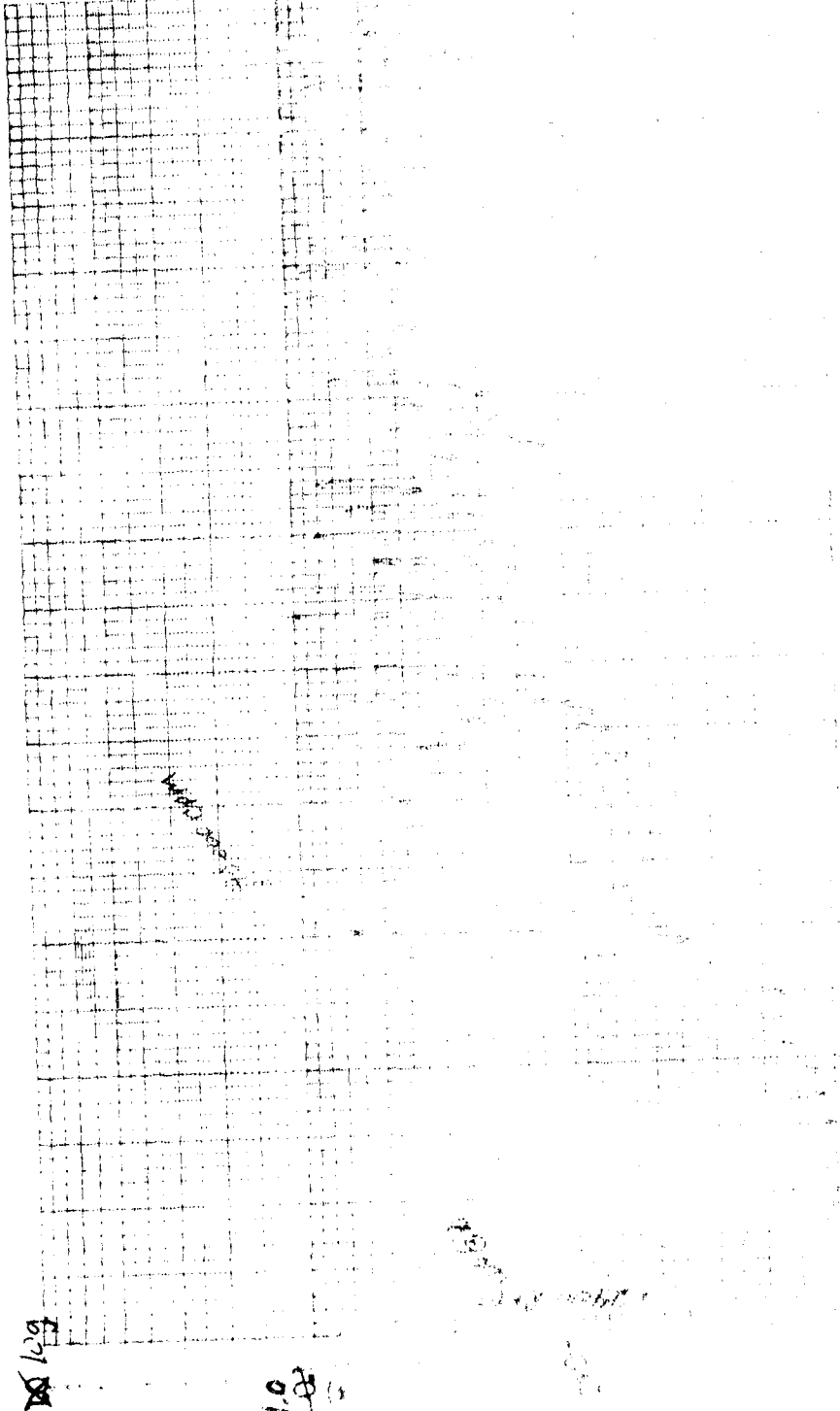


VIBRATION SPECIALTY CORPORATION

200 Geiger Road P.O. Box 100, 215, 400, 410

figure 77

SANDERS + THOMAS  
20419 3/19/79 ANT 64 117 5601 7H -16 05607 05608  
LOADED 240000



U.S. SPECIAL COMMISSION

20  
0  
2  
11  
2  
0  
11  
0  
11

NAEC-92-146

APPENDIX C

VIBRATION RESPONSE AND PERFORMANCE  
OF MONITORS AT VIBRATION SIGNATURE  
LEVELS OF THE AHT-64 TEST STAND



**VIBRATION SPECIALTY CORPORATION**

100 GEIGER ROAD PHILADELPHIA, PA 19115 • (215) 698-0996 • (202) 472-1888

August 27, 1980

Mr. Edwin Roberts  
Sanders & Thomas  
P.O. Box 50  
Lakehurst, New Jersey 08733

Dear Mr. Roberts:

Enclosed is the report of the test conducted on the two oil monitoring systems as furnished by you. We would at any time appreciate the opportunity to serve you again. If you have any questions, please call.

Very truly yours,

*Eugene J. Schramm*  
EUGENE J. SCHRAMM  
Manager of Engineering  
and Technical Services

EJS/mf

Enclosure

The test was conducted in two phases; the first being the Environment One concept and the second being HIAC Pacific Scientific concept.

A. TEST SET UP

The initial test setup is as shown in Picture No. 1. It contained an oil reservoir of approximately three gallons and a motor pump combination capable of delivering up to 10.3 gallons per minute at approximately 20 psi and 3.3 gallons at 100 psi. The piping system was set up with a bypass so that all or any portion of the fluid could be returned directly to the reservoir. Through this method we were able to flow from 1 1/2 gallons per minute up to the maximum of 11 gallons per minute by adjusting the control valve in this line. Two pressure gauges were inserted in the line to monitor the pressure and see if there was a substantial pressure drop through the sensing device. The vibration was imparted to the test article by an electromagnetic shaker system mounted under a resonant beam that was tuned to 360 HZ. The control accelerometer was used to verify the vibration level and controlled to read 2.2 g's  $\pm$  5 percent.

During the initial attempts to calibrate and check out the Environment One concept, problems were encountered with air trapped in the system so that adequate flow and pressure could not be obtained. The reservoir and plumbing were altered slightly by increasing the volume of the reservoir and installing a stand pipe to bleed off any entrapped air. At the same time, the flex hoses were changed from a convoluted type to a smooth interior wall. This enabled us to obtain any flow or pressure combination we desired.

## B. TEST PROCEDURE

The following sequence was established for both systems. Due to problems with the HIAC concept, it was necessary to deviate from this procedure. The procedure used on the Environment One unit was as follows:

- 1) with the unit installed and hooked up for fluid flow,
- 2) the sensor was positioned on the resonant beam and the controller on the nearby table. Oil was pumped through the system and the meters monitored for response. Approximately 10 minutes were spent at this configuration.
- 3) Still in the same position, the shaker was activated to impart vibration only to the sensor. The meter was monitored for any changes. Approximately five minutes were spent in this mode.
- 4) The controller was now positioned on the resonant beam and fastened to the beam.
- 5) The shaker was again activated and the meter monitored for any change. At all times, the force input was controlled to 2.2 g's. Approximately 10 minutes were spent in this mode.

The procedure for the HIAC was to be the same, but throughout any attempt which included vibrating the sensor, we were unable to obtain any indication that the unit was working. The light on the front of the panel labeled check sensor showed no malfunction as did the alarm. As a last resort, a large quantity of AFD was added to the fluid and pumped through the system for some time. Again, no reading of any kind could be seen. As a precaution, the cable was checked to make sure that it was intact.

C. RESULTS

The results can best be illustrated by Pictures 3 and 4. Throughout any attempt to cause a deviation, the fluid flow test, the vibration test, the loosening and jingling of the sensor, rotating the sensor through 90° and 180°, the readings remained rock steady. The flow meter performed as designed. We reduced the flow to 1.6 gallons and it read 8 percent of full scale. We increased the flow to full flow and it read 52 percent of full scale, or 10.4 gallons. We repeated each condition several times, with it repeating the reading constantly.

Although no attempt was made to rotate the controller, you could pick it up by the handle and move it in any direction; up/down, back forth, with no effect.

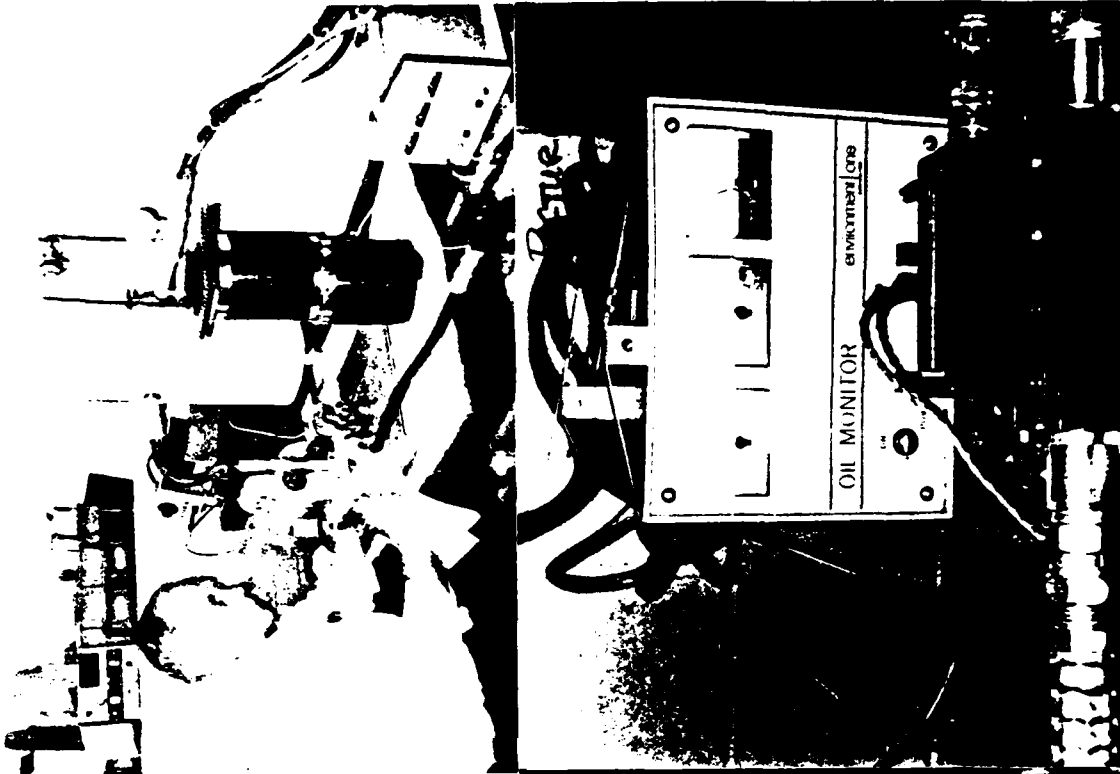
The HIAC tests were discontinued at the direction of Mr. Roberts, since no data could be obtained.

D. CONCLUSIONS

The Environment One unit performed as its specifications delineated and was not effected in any way by the 360 HZ at 2.2g.

The HIAC unit was judged to be unsatisfactory since it would not function at all.

Picture 2



Picture 1





END

DATE  
FILMED

7-81

DTIC