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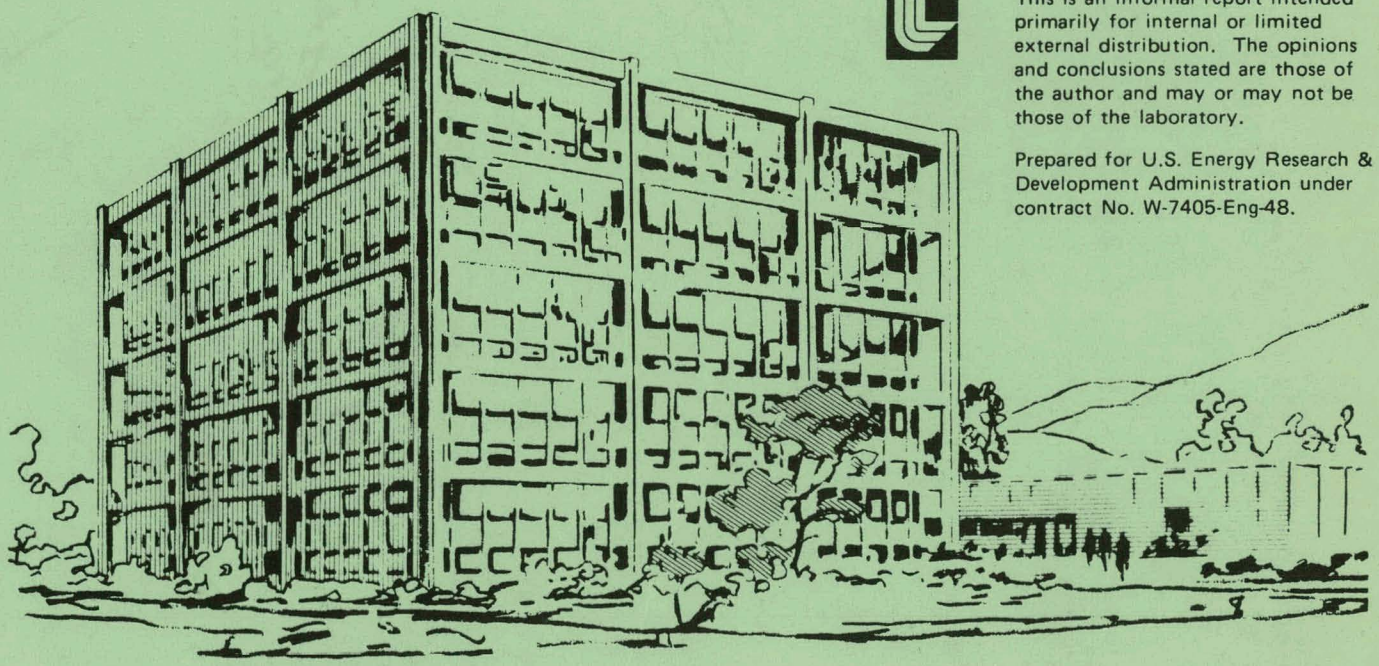
INSTRUCTION MANUAL FOR A MICROWAVE AMMONIA MONITOR

MASTER

LAWRENCE W. HRUBESH

JUNE 13, 1977



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DISCLAIMER

INSTRUCTION MANUAL FOR A MICROWAVE AMMONIA MONITOR

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CONTENTS

I. General Information

A. Introduction

The microwave ammonia monitor is a self contained (the vacuum pump is external) microwave rotational spectrometer that selectively detects and monitors ammonia vapor in air. A solid-state oscillator is used as the microwave source and a microwave cavity made from waveguide provides a chamber for the sample analysis. The air sample is continuously flowed through the waveguide cavity so that changes in the trace concentration of ammonia in air can be determined.

The principle of operation of the microwave ammonia monitor is based on the absorption of microwave radiation by a vibration-rotation quantum transition of the ammonia molecule. Ammonia absorbs microwave radiation in a very narrow frequency range with its peak at 23,870.18 MHz. The microwave source is electronically controlled to oscillate only at this frequency and to provide a very stable output power. Thus, even a very small amount of microwave power that is absorbed by the ammonia gas is detectable and no other gas in the air sample is known to absorb any microwave radiation within the frequency output band of the oscillator.

The stability of the excitation frequency is assured for long periods of operation time because the microwave oscillator is "frequency locked" to the ammonia absorption in a reference cell within the instrument.

The power input to the absorption cell has been adjusted so that traces of ammonia gas in mixture with air at a cell pressure of approximately 0.05 Torr will absorb the maximum possible microwave power. With this condition, the response of the instrument to trace quantities of ammonia is linear over the dynamic range of minimum detectable to about 100 ppm.

Low level signal detection is accomplished by modulation of the absorption microwave detection by a very low noise point contact crystal rectifier, and synchronous detection at the modulating frequency. Electric field modulation (Stark effect modulation) applied through the gas sample "chops" the absorption signal, thereby causing an amplitude modulation on the microwave carrier frequency. The crystal demodulates the carrier, leaving just the "chopped" signal. This signal is compared with a reference signal of the same frequency and phase. After amplification, the resultant dc signal is proportional to the amount of absorption by the gas in the cell. This output signal can be easily calibrated to represent the concentration of gas in the mixture because the total pressure in the cavity absorption cell is kept constant throughout the measurement.

A dimethyl-silicone membrane molecular separator is used to interface the microwave cavity to the atmosphere. Ammonia vapor passes through this material approximately 15 times faster than air; thus an effective enrichment of ammonia by that factor exists in the absorption cell (at the time of measurement) which increases the sensitivity for ammonia detection.

The inlet vacuum line as well as the absorption cell is kept at about 80°C at all times to reduce effects of adsorption of ammonia on the walls. At lower temperatures these effects are known to cause very long instrumental response times for changes in ammonia concentrations.

The instrument has been designed to be rugged and reliable, simple to operate, and easy to calibrate. The instrument operates automatically from turn-on and can be calibrated with an external gas source after only 30 minutes of warm-up time. A large meter is provided with a three position range switch that allows direct readout in parts-per-million from 0 to 100 in three scales. A 0-10 volt output is also available at the rear panel for recording data on an external recorder.

B. Specifications

Molecule detected - gaseous $^{14}NH_3$

Interferences - none known

Minimum detectable quantity - Approximately 0.1 ppm in air with S/N = 1 (tangential)

Detection Range - 0.0 to 100.0 ppm

Linearity - less than 10% deviation from linearity for all concentrations when calibrated for full scale use on any scale.

Stability -

Zero Drift - less than 0.5% of full scale per 24 hour warmup and at 23°C ± 1°C.

Frequency Stability - better than 1 part in 10^6 per day.

Peak response stability - less than 1% deviation from peak maximum in 30 days.

Temperature Range - 4°C to 38°C ambient.

Response time - 90% response to step change in 3 minutes.

Modes of Operation - 1) continuous "sniffing" mode: used when sampling a large sample volume or gas stream.

2) batch sampling mode: used when a minimum of sample is available.

Output - 1) a front panel meter readout in parts-per-million of ammonia in three ranges; 0-1, 0-10, 0-100 ppm.

2) 0 to 10 volt analog signal at BNC recorder output on rear panel.

Dimensions - Rack mountable 19" x 21" x 9" (vacuum pump external)

Total Weight (excluding vacuum pump) - 70 pounds.

Power Requirements - 115V, 10 amps, 60Hz (approximately 200W continuous)

II. Installation

A. Preparation for Use

1) The instrument can either be installed on a bench or in a 19' rack.

2) It is recommended that the vacuum pump be connected to the instrument and started before power is applied to the instrument. Two corrugated tubes are supplied for connecting the pump to the instrument.

a) Connect the smaller diameter tube to the instrument at the connector on the rear panel labeled "reference vacuum".

b) Connect the larger diameter tube to the instrument at the connector on the rear panel labeled "analytical vacuum".

c) Be sure that the two hand operated valves on the pump are closed (fully clockwise) before starting the pump.

d) Plug the vacuum pump power cord into a suitable AC outlet.

e) The instrument requires an AC power source of 115V, 10A, 60Hz. A three wire AC power cord is supplied with the instrument. Plug the cord into a suitable power outlet.

f) To prepare the instrument for operation first make sure the "inlet valve" at the front panel is closed (fully clockwise).

g) After the vacuum pump has started, slowly open both valves on the pump to a full open position (fully counter - clockwise).

III. Operation

A. Description of Controls

The following is a list of controls on the instrument, their locations, and their functions.

Control	Location	Function
Panel Meter	Front Panel	Displays the quantity of detected ammonia in parts-per-million.
"Concentration Range" Switch	Front Panel	Provides a scale adjustment for the meter readout in 3 range settings, 0.1, 0-10, and 0-100.
"Power"	Front Panel	Provides main power to the instrument. The external vacuum pump should always be connected to the monitor and pumping before this button is pushed on. Push off to disrupt main power to the instrument.
"Ready" lites	Front Panel	When both "lock" and "vacuum" lites are lit, the instrument is operational and ready to measure ammonia. Do not take data if either of these lites is extinguished.
"Zero" knob	Front Panel	Used to zero the panel meter.
"Calibrate" knob	Front Panel	Used to set the panel meter to the proper ppm value during the calibration procedure.
"Time Constant" Toggle Switch	Rear Panel	Provides either a 3 second or 100 second time constant (signal average) for the detection system.

Control	Location	Function
"Recorder" connector	Rear Panel	Connector for external recorder. Supplies 0-10V proportional to the signal amplitude.
"Test" connector	Rear Panel	Connector for test meter to be used for testing the functional operation of the instrument. Not needed for normal operation.
"Fuse"	Rear Panel	Provides overload protection for the instrument.
"Analytical Vacuum" connector	Rear Panel	Connects to an external vacuum pump to provide reduced pressure in the analytical cell.
"Reference Vacuum" connector	Rear Panel	Connects to an external vacuum pump to provide reduced pressure in the reference cell.
"Reference Gas" connector	Front Panel	Provides access to a chamber which holds a permeation device to supply a reference gas. Close both valves on the vacuum pump before removing this connector.
"Inlet" Valve	Front Panel	When open, allows sample gas to pass through the analytical cell. When closed, the analytical cell is pumped out.
"Sample Inlet" connectors	Front Panel	Provides an inlet to the instrument for the sample. A gas flow can be accommodated by attaching a pump to either connector.

B. Turn-on Procedure

1) After completing the procedure under section II-A above, the instrument is ready to be turned on for operation.

2) Press the "Power" push button on the front panel. The push button should light, indicating that the instrument has been energized.

3) Within one minute after power on, the two lites on the front panel labeled "lock" and "vacuum" should light. When both lites are lit, a ready condition exists and the instrument is operational.

C. Calibration

The instrument may be calibrated at any number of concentrations over its range. However, it has been found useful and expedient to calibrate at a single concentration about in the center of the concentration range of interest. The accuracy of measurements of concentrations above and below the calibration points can be predetermined from a more thorough calibration procedure done less often.

The following calibration procedure is recommended:

1) Zero the instrument. The instrument must be flushed with an ammonia free carrier gas and pumped at least one hour before a calibration is initialized. A true zero can be determined by closing the "inlet Valve" on the front panel. Set the meter to read zero by adjusting the "zero" knob on the front panel then open the "Inlet Valve". Any signal which appears after the "Inlet Valve" is reopened is from residual ammonia in the system. This signal should either be totally removed by flushing and pumping or it should be nulled out by resetting the zero with the "Zero" knob on the front panel.

2) Determine which mode of instrument operation is to be used as indicated under Section III-D. Also determine which time constant is desired and set the toggle on the rear panel accordingly.

Note: A small offset voltage may occur when the "time constant" toggle is switched from 3 sec. to 100 sec. This offset may make it necessary to re-zero the meter for operation at 100 sec. time constant.

3) Connect a source of known ammonia concentration to one of the fittings on the "sample inlet" at the front of the instrument.

4) Allow the instrument 15 minutes for full response. Then adjust the "Calibrate" knob on the front panel so that the meter reads the desired concentration of ammonia in parts per million. The instrument is now calibrated for measurements near that value.

5) Further calibration points can be used to determine the instrument's linearity. Supply known concentrations of ammonia to the instrument and allow 15 minutes for full response. The new meter reading establishes the instruments response to the new calibration concentration.

6) After calibration, depending upon the mode of operation, replace the calibration source with the unknown sample. The instrument will monitor the ammonia concentration in the sample.

D. Modes of Operation

This instrument has been principally designed to operate as a continuous "sniffing" monitor of ammonia in air. However, the instrument is capable of operating in either of two different modes. The following discusses how to prepare the instrument for operation in each of these modes.

1) Continuous "Sniffing" Mode -

In this mode, the sample is presented to the absorption cell with minimum delay, therefore, resulting in the fastest response. A typical response time for this mode is 90% of peak response within 3 minutes after initiation of "sniff". (with a 3 second time constant for the electronics)

To prepare the instrument for operation in this mode, the following procedure is recommended:

a) Turn on the instrument exactly as described in B of this section. Wait for both ready indicators to light.

b) If a calibration is desired, proceed as indicated under C of this section.

c) Attach a 1/4" O. D. teflon tube to the "Sample Inlet" port on the front panel using appropriate fittings.

d) Set the "Zero" adjust to zero the meter while sniffing a zero-gas reference sample or while sniffing a background sample. Note: to determine the true zero close the inlet valve toggle and allow a 5 minute pump down.

e) The instrument is now ready to monitor in the "fast response" mode.

2) Batch Sampling Mode -

If a minimum sample is available, (less than 1 liter) this mode can be used. In this mode the absorption cell is isolated from the vacuum pumps so that the sample can expand into it and not be pumped away. Caution must be used here to insure that there is no residual NH_3 in the cell before the sample is let in. The following procedure is recommended for this mode:

a) Turn on the instrument as described in B of this section.

b) If a calibration is desired, proceed as indicated under C of this section. Allow the system to pump for at least 1 hour after NH_3 has been in the instrument.

c) Close the hand valve at the vacuum pump that connects the line to the "analytical vacuum" on the rear panel.

d) Make a test for residual NH_3 in the cell by opening the "inlet valve" on the front panel. The pressure inside the cavity will rise due to the gas supplied by the membrane separator at the inlet. Monitor the "vacuum" lite on the front panel while the pressure is rising. When the lite extinguishes close the "sample inlet" valve. Then momentarily reopen the valve at the pump until the lite comes on again. The signal output should be near zero and not rise if the cell is free of NH_3.

e) Reopen both the "inlet" and pump valves and allow the cell to be pumped for at least 5 minutes.

f) Close the pump valve and attach the sample container to the "sample inlet" port. Repeat as in (d) above. The instrument will give a static measurement of the NH_3 content within the cell.

E. Turn-Off Procedure

The following turn-off procedure is recommended so that the instrument may be restarted, when desired, in a minimum of time.

1) Close the "inlet valve" on the front panel (fully clockwise).

2) Press the "power" off push button.

3) Close both hand valves on the vacuum pump (turn fully clockwise).

IV. Principles of Operation

A. Introduction

The instrument described in this manual is based on the principle of observing the absorption of microwave radiation which is in resonance with one of the quantized molecular rotations of gaseous ammonia molecules. Molecular rotations have low energies (much lower than vibrational energies) and at low pressures, they can cause very sharp absorptions of microwave radiation. The absorptions are so sharp, in fact, that a million single resonances from many different kinds of molecules can all be resolved from a spectrum taken over a 20 Gigahertz frequency range. The microwave frequencies, on the other hand, are produced from electronic oscillations, are already quite mono-energetic, and they can be continuously tuned. These properties are responsible for the very high qualitative specificity for detecting molecules in a mixture with others by this technique of microwave rotational spectrometry.

The properties described above are utilized to the fullest in this instrument. For example, the pressure of the sample gas is maintained low enough to assure that the ammonia absorption line width is less than 400 KHz in the detection cell. The microwave energy needed to excite the molecular resonance of ammonia is supplied by a solid-state bulk semiconductor commonly known as a Gunn-effect oscillator. Its oscillations are stabliized to a specific ammonia absorption line in a reference cell. Output frequency is thus made to exactly match that of the peak of the ammonia resonance in the analytical cell.

For very small quantities of ammonia gas in a mixture, the actual amount of microwave power absorbed is very small. A significant signal to noise enhancement over dc absorption signals is gained by applying an on-off electric field through the sample. This modulates the absorption signal, resulting in an AC signal which is amplified then synchronously detected. A DC signal proportional to the ammonia absorption is then delivered to a meter and is made available for external recording.

Automatic control is always desirable in a monitoring instrument. In this instrument, a series of interlocks are provided to assure the user that the system is functioning properly. These interlocks provide for automatic operation while the instrument is in continuous use.

The basic sensitivity of the technique used here is limited to approximately 1 ppm levels by the very small absorption signals. To extend the detectability range, a rubber membrane molecular separator device is used to enrich the ammonia sample that enters the microwave cell by more than 1 order of magnitude, thus extending the minimum detectability for ammonia to near 0.1 ppm.

A brief description of the functional circuits of the instrument is given in the following sections. References are made to the block diagram of the instrument (sheet 1 of the schematic diagrams) which can be used to follow the given descriptions.

B. Frequency Stabilization Technique

To insure that the source oscillator is at exact coincidence with the ammonia absorption line at 23,870.1 MHz and for reliable long term stabilization, the source oscillator is "frequency locked" to the ammonia absorption line itself. A sufficient amount of ammonia gas to provide a sharp absorption line at 23.8 GHz is supplied to the reference cell by vapor which permeates a small teflon tube (commercially available from Metronics, Inc., Palo Alto, Calif.). The permeated vapor is continuously pumped through the reference cell. Microwaves from the Gunn-effect oscillator pass through the reference cell to a crystal detector. Two types of modulation are applied to the microwaves in order to provide a discriminant type of feedback signal to stabilize the oscillator. First, a small amount of modulation applied to the varactor voltage causes frequency modulation of the microwave carrier. Next, a high voltage is applied through the gas in the reference cell which amplitude (Stark) modulates the microwave carrier only when the microwave frequency is near an ammonia absorption line. After the microwaves are detected by the crystal rectifier, the signal is first amplified in a low noise preamplifier, then it is synchronously detected at the Stark modulation frequency. The output of the first synchronous detector is then synchronously detected again at the frequency that is applied to the varactor. The output of the second synchronous detector is the first derivative of the ammonia absorption line and is used as a discriminant signal to feedback to the varactor diode in the oscillator. A search-lock circuit is provided to insure frequency lockup at initial turn on or if the frequency stabilization is interrupted for any reason.

When the "frequency lock" has been accomplished the Gunn oscillator has an output frequency 23,870 MHz which corresponds to the peak of the ammonia absorption line. This frequency has a short term stability of better than 1 part in 10^6 per second, and a long term stability limited only by the lifetime of the reference gas.

C. Signal Detection, Amplification and Presentation

Electric field (Stark effect) modulation and synchronous detection are used in this instrument for optimum signal to noise characteristics for the detected absorption.

A 2 KHz square-wave, zero based, 400 V peak-to-peak voltage is applied to an electrode at the center of the analytical cell waveguide. An electric field produced by this voltage is thus applied through the sample gas. When the field is on, the ammonia absorption is moved to other frequencies. When the field is off, the ammonia absorption coincides with the microwave oscillator frequency and can absorb power from the input. The effect of this on-off field is to amplitude modulate the microwaves in the analytical cell at a 2 KHz rate if ammonia molecules are present there. This amplitude modulation then appears on the microwaves that enter the detector crystal and subsequently also on rectified output. This 2 KHz signal is amplified in a low noise preamplifier then synchronously detected with a reference 2 KHz signal from the Stark voltage generator. The output of the synchronous detector is a DC signal which is proportional to the amplitude of the ammonia absorption. It is further amplified and an RC time constant is applied to it before it goes to a meter readout or to an output connector to drive a recorder.

D. Instrument Vacuum and Sampling System

A block diagram of the vacuum and sampling system is included in Section VII.

A single pump with a capacity of 3.5 ℓ/min. provides the vacuum for the instrument. Two vacuum lines attach to the instrument. The 1/4" diameter line goes to the reference cell. A needle valve is provided internally to adjust the pressure in the reference cell at approximately 20 milli Torr. A connector on the front of the instrument marked "reference gas" can be removed to allow replacement of the reference gas tube. The 1/2" diameter line goes to the analytical cell in the instrument. Note that the molecular sieve trap at the vacuum pump prevents the ammonia in the reference line from back diffusing into the analytical line. Two thermo-couple gauges are included in the analytical cell line. One monitors the pressure for the interlock system (explained in IV-E) and the other is used to measure the pressure within the analytical cell during operation. An input valve is included (accessable at the front panel), to isolate the analytical cell from the input membrane sample. The membrane separator provides the interface between the atmosphere and the low pressure ($\sim$ /50 milli Torr) in the analytical cell.

E. System Interlock Controls

The instrument is functional when two conditions are true. One, the Gunn-effect oscillator must be stabilized to the reference gas absorption line. Two, the pressure in the cell must be within the operating range. This also insures that the modulating Stark voltage is maintained on.

From turn-on, the instrument automatically controls itself to make the above conditions true. As each of the conditions becomes true, a lite on the front panel indicates a true. Should either of these conditions change during the operation, the "ready" lites will extinguish and data should not be taken during that time.

NOTE: Under normal operation it is possible that transients can be generated which cause the Gunn-effect oscillator to momentarily unlock. The "lock" lite will momentarily extinguish while a search oscillator causes the Gunn-oscillator to find a lock again. This procedure takes less than 1 second time so that no significant loss of data occurs. A "glitch" will appear, however, during this unlocked time if output is observed on a recorder.

V. Maintenance

A. Routine, Periodic Instrument Maintenance

The ammonia monitor should operate maintenance free on a continuous basis for one month periods. A routine maintenance procedure should be carried out once each month of instrument operation. This procedure should include the following:

1. Change the reference gas permeation tube.

2. Change the dimethyl silicone membrane.

After each six months of operation the following should be done:

3. Change the oil on the mechanical vacuum pump.

4. Bake out the molecular sieve trap.

The instrument need not be turned off, for this maintenance. The "down" time can be as short as a few hours, depending upon the length of time taken to bake out the molecular sieve trap.

Detailed procedures for each of the four maintenance operations listed above is given in the following sections.

B. Vacuum System Maintenance

Once every six months of continuous operation the oil should be changed in the mechanical pump. The following procedure is recommended:

1. Close the "inlet valve" at the front panel.

2. Turn both hand valves on the vacuum pump to the "off" position (fully clockwise).

3. Pull the wall plug to stop the pump.

4. After the vacuum pump has cooled off sufficiently drain and change the oil in the pump. Use Welch mechanical pump oil or equivalent for the mechanical pump.

5. After the oil has been changed restart the pump.

It is recommended as a part of the vacuum system maintenance procedure, that the molecular sieve trap be baked out. The following procedure can be used:

1. After changing the pump oil and restarting the pump, but before opening the hand valves on the vacuum pump, the sieve trap can be baked.

- CAUTION -

While the molecular sieve trap is being baked out, the two hand valves on the vacuum pump must be fully closed (fully clockwise), or the gases given off from the trap will pass back into the instrument.

2. Make sure the two hand valves on the vacuum pump are in the "closed" position and the pump is on. Plug the auxiliary AC cord (on the sieve trap heating element) into a suitable outlet. Let the trap bake for a minimum of 1 hour.

3. After a suitable bakeout period (1 hour min.) remove the AC plug from the outlet and allow 15 minutes for the trap to cool.

4. Re-open both hand valves on the pump. When the "ready" lites re-lite, the instrument is operational.

C. Changing the Silicone Membranes

Under normal operation and in normal environments, the silicone membrane within the separator device should have an unlimited lifetime. However, in certain environments (e.g., high ozone content or particulate matter) the permeation characteristics of the membrane material can change significantly. Also, some silicone rubber material has been observed to rupture while in use, probably because of the expansion of pin holes under stressed conditions.

Indications of failure used in the separator are as follows:

1. An unexplained loss in sensitivity

2. The microwave cell pressure rises above 0.07 Torr (the ready light will extinguish in this case).

A large sheet of silicone-rubber membrane is included with the instrument. If replacement of the membrane material is required, the following procedure is recommended:

a) The membrane can be changed without turning off the instrument. Turn the "inlet valve" on the front panel to the closed position (fully clockwise).

b) Remove the four screws on the front of the separator at the front panel.

c) Using a reasonable force,break the seal at the point where the old membrane material can be seen.

d) Peel the old membrane off the end piece and discard it. Clean the grease off the end pieces with acetone or an appropriate solvent. Re-grease the end pieces with any vacuum type grease (silicone vacuum pump also works). Lay a new piece of silicone rubber over the end piece and press it down so that the grease holds it in place. With a razor blade or sharp knife, cut along the edge of the end piece, leaving about 1/4" excess rubber over the edge, all around. Also cut holes in the membrane where the screws penetrate it.

e Replace the cover piece over the membrane material, align the screw holes, and repace the four screws - tighten appropriately.

f Re-open the "inlet valve" at the front panel. After 1 minute the "vacuum" ready lite on the front panel should light; if it does not, tighten the four screws on the separator. Failure of the "vacuum" ready to light suggests a leak and the above procedure should be repeated.

Note: A new calibration is recommended with each change of silicone membrane.

D. Changing the Reference Permeation Tubes

The "lock" ready light on the front panel indicates the status of the reference cell. If it is either blinking or extinguished a change of permeation tube is likely required. The permeation tubes can be purchased from Metronics Assoc., Palo Alto, Calif. A single two centimeter length of a standard ammonia permeation tube should be ordered. Shelf life of these tubes is approximately 2 months at room temperature and 4-6 months under refrigeration.

When the permeation tube is changed the following procedure is recommended:

a) Close the hand valve on the vacuum pump that leads to the reference cell (1/4" line).

b) Unscrew the fitting at the front panel marked "permeation tube".

c) Remove and check the old permeation tube. Liquid ammonia can be observed in a full or partially full tube when held up to a light and viewed. If the old tube is not empty, it should not need replacement, and other electronic troubles are likely if the "lock" light is extinguished.

d) Replace the old permeation tube and tighten the connector.

e) Re-open the valve at the vacuum pump. Note - the pressure in the reference cell can be monitored at this time with the electronic test box.

f) The "vacuum" and "lock" ready lites should both re-light to indicate that the instrument is operational.

E. Use of Electronic Test Box

The electronic test box which accompanies the instrument is required for the instrument to function as a monitor. It is, however, a handy indicator for testing the different functional circuits within the instrument. Additionally, it includes a thermocouple vacuum gauge which can be used as an indicator of the pressure in both the reference and analytical cells in the instrument.

For purposes of trouble-shooting possible circuit malfunctions, the following list of meter readings is given-these are typical readings during normal operation: Note that the meter is center zeroed and that the following convention is used; a reading to the right of zero is (+) and a reading to the left of zero is (-).

#1 Pressure: Approximately 100 microns
#2 Pressure: Approximately 30 microns
Absorption Signal: Approximately (-36)
Dispersion Signal: Approximately (+10)

VI. Parts List

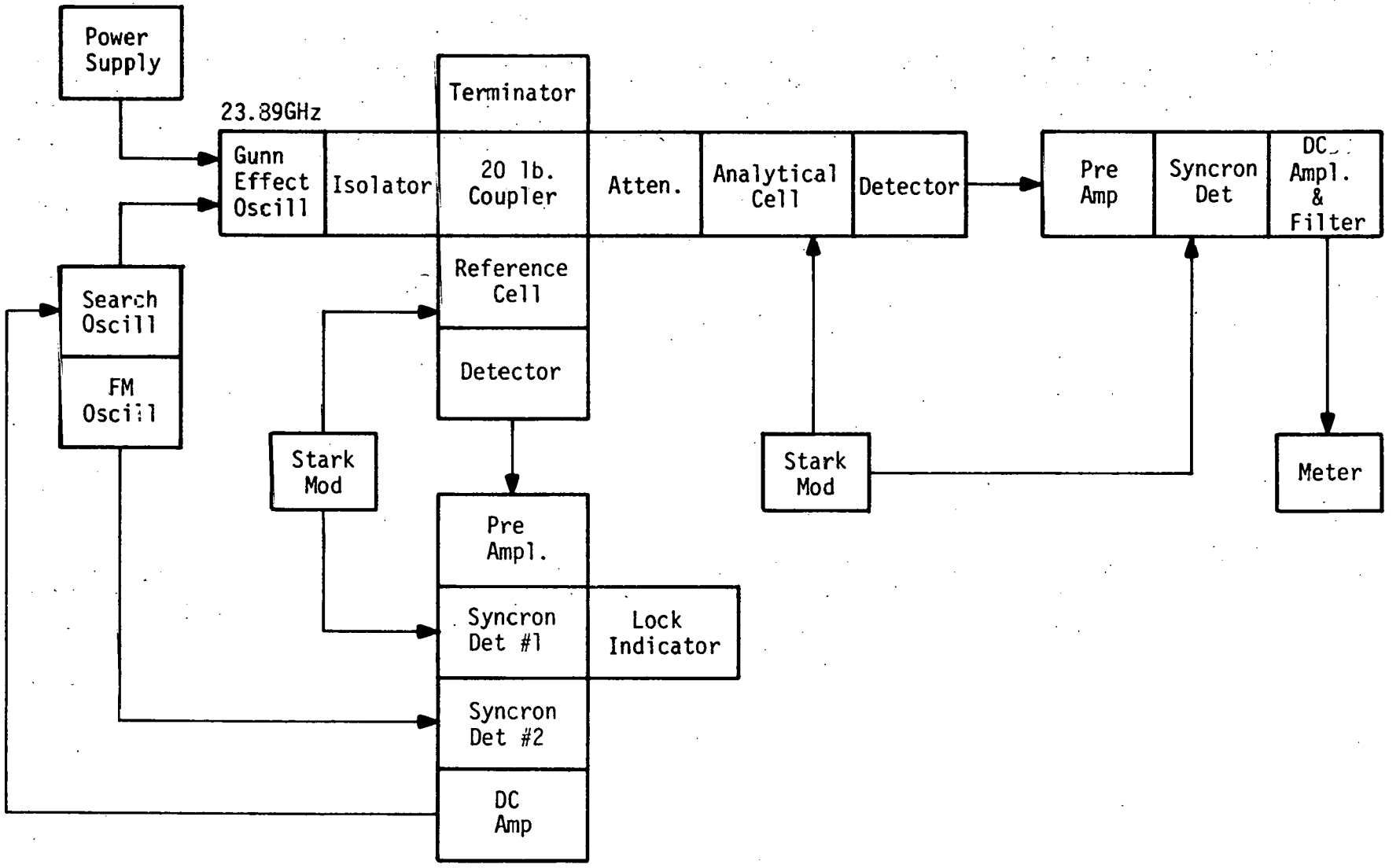
The following is a list of replaceable parts used in the instrument including the manufacturer and approximate replacement cost.

Item #	Name	Model Number	Approx. Repl. Cost
1	Gunn Effect Oscillator		$750
2	Silicone Membrane	General Electric	$20
3	Permeation Tube	Metronics	$15
4	Detector Diodes (2)	Hewlett Packard K422A	$80

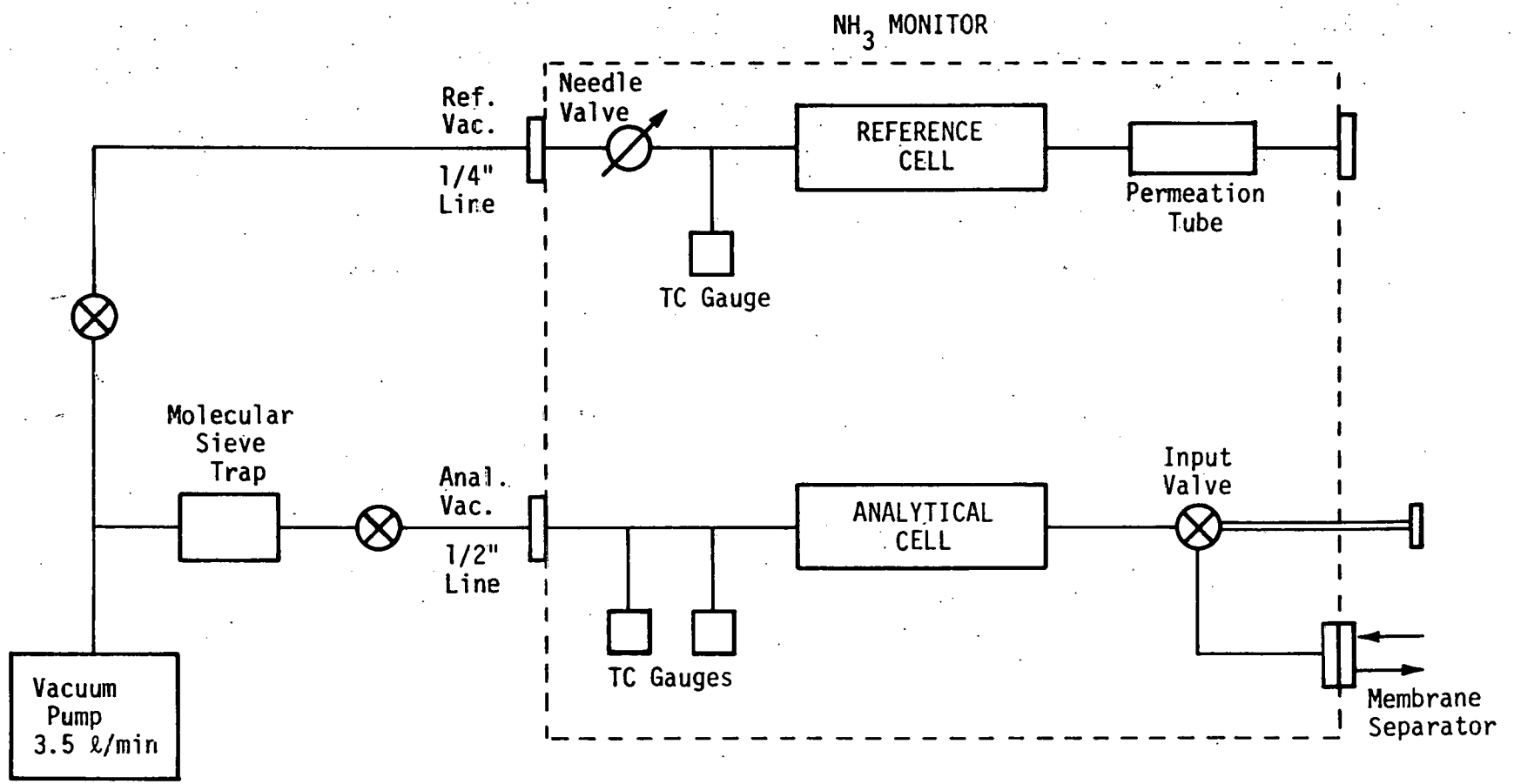
VII. Pictures, Schematics, and Engineering Drawings

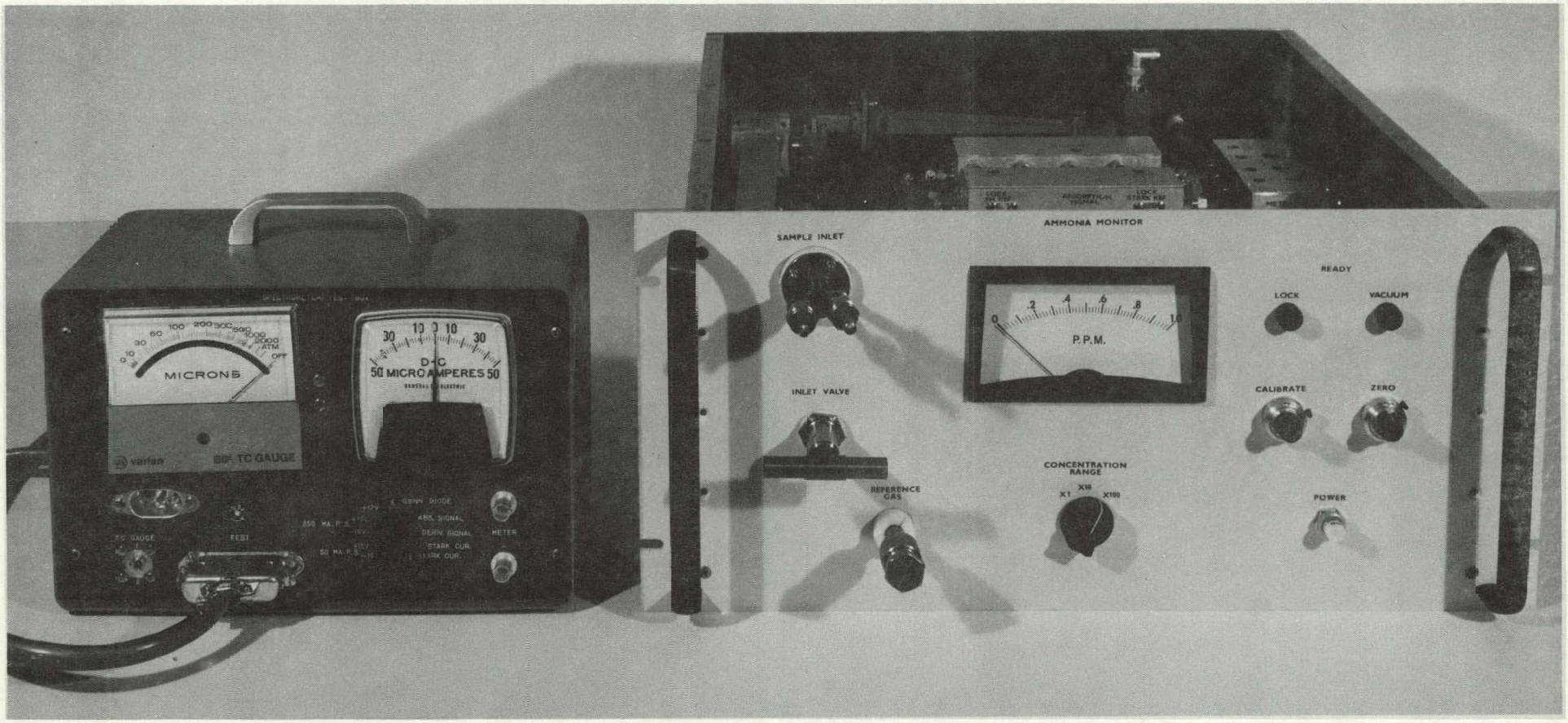
The following pages include photographs of the instrument, electronic schematics and wiring diagrams.

BLOCK DIAGRAM OF NH_3 MONITOR ELECTRONICS



BLOCK DIAGRAM OF VACUUM AND SAMPLING SYSTEM




AMMONIA MONITOR
SAMPLE INLET
INLET VALVE
REFERENCE GAS
P.P.M.
READY
LOCK
VACUUM
CALIBRATE
ZERO
CONCENTRATION RANGE
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X10
X100
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varian
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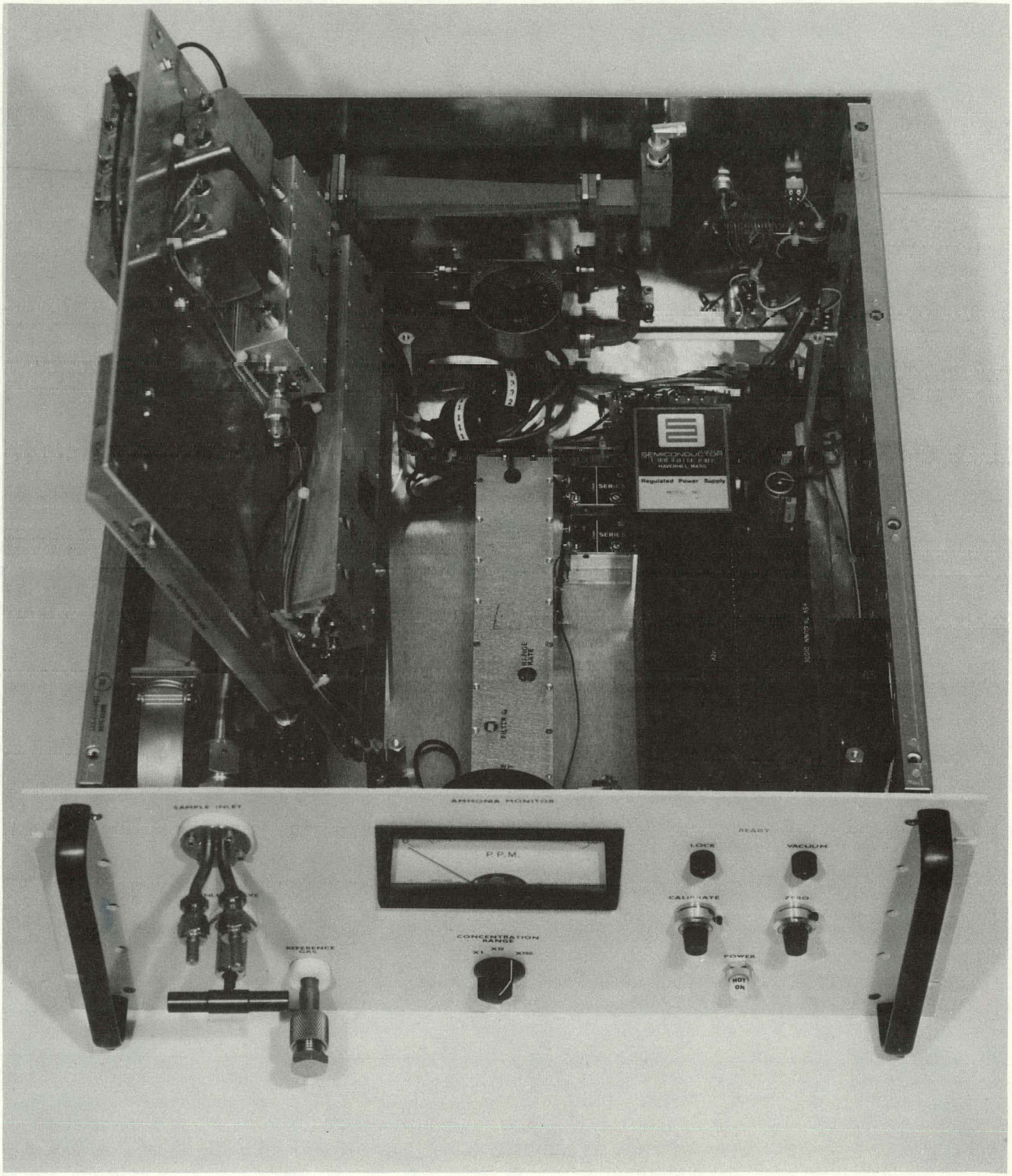
Regulated Power Supply
AMMONIA MONITOR
SAMPLE INLET
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CONCENTRATION RANGE
X1
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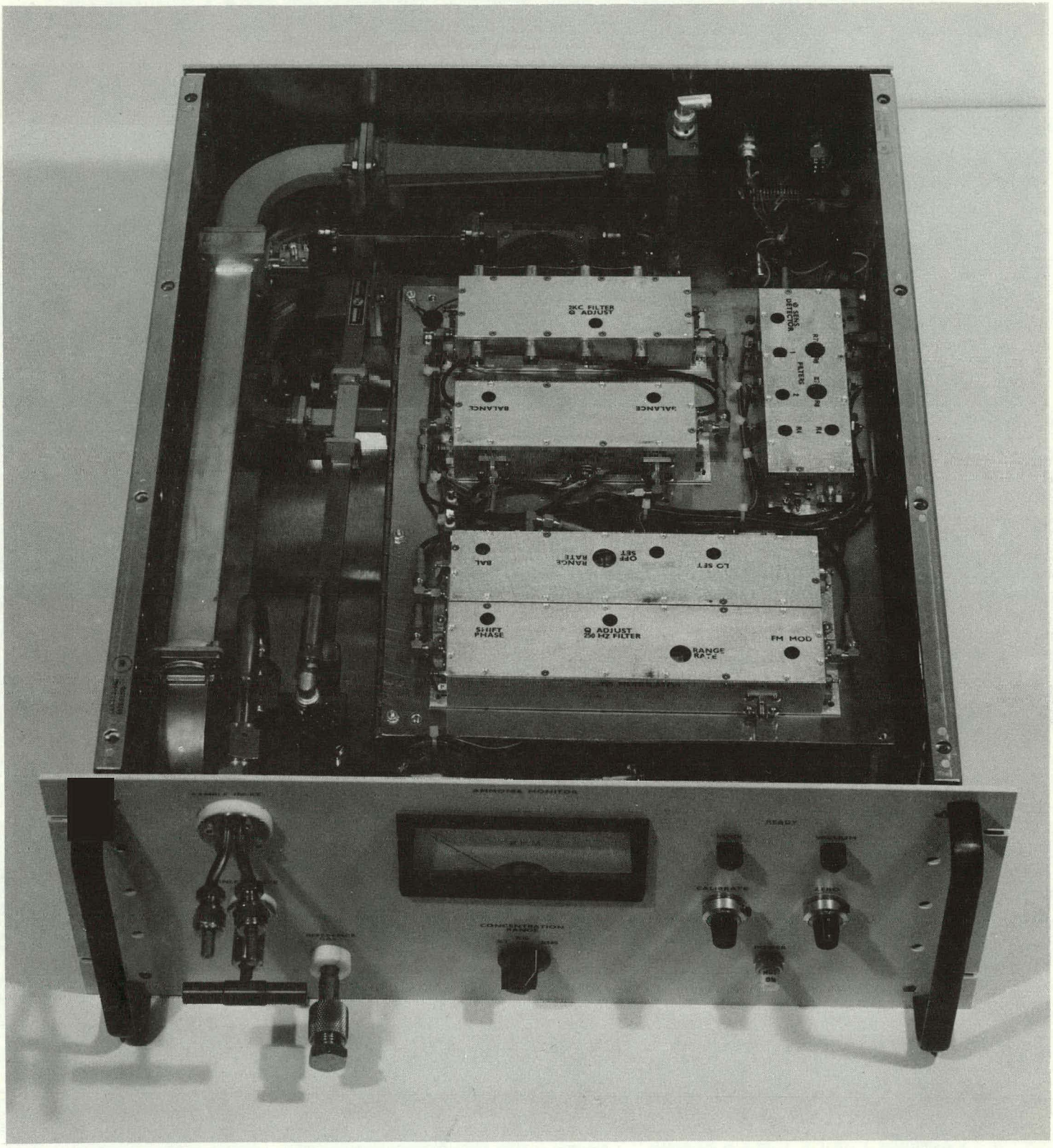
2KC FILTER
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BALANCE
BALANCE
RANGE RATE
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SHIFT PHASE
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READY
CALIBRATE
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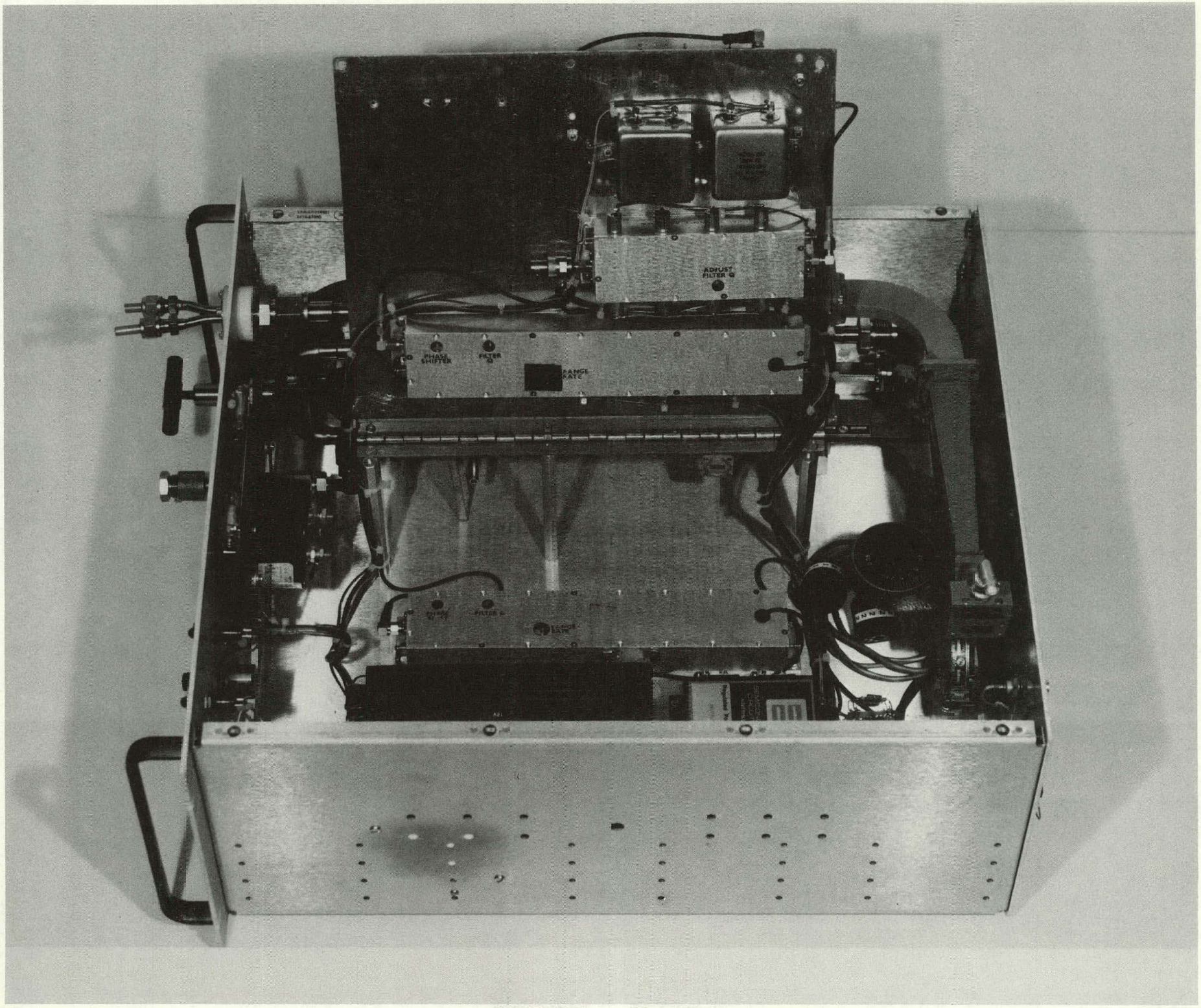
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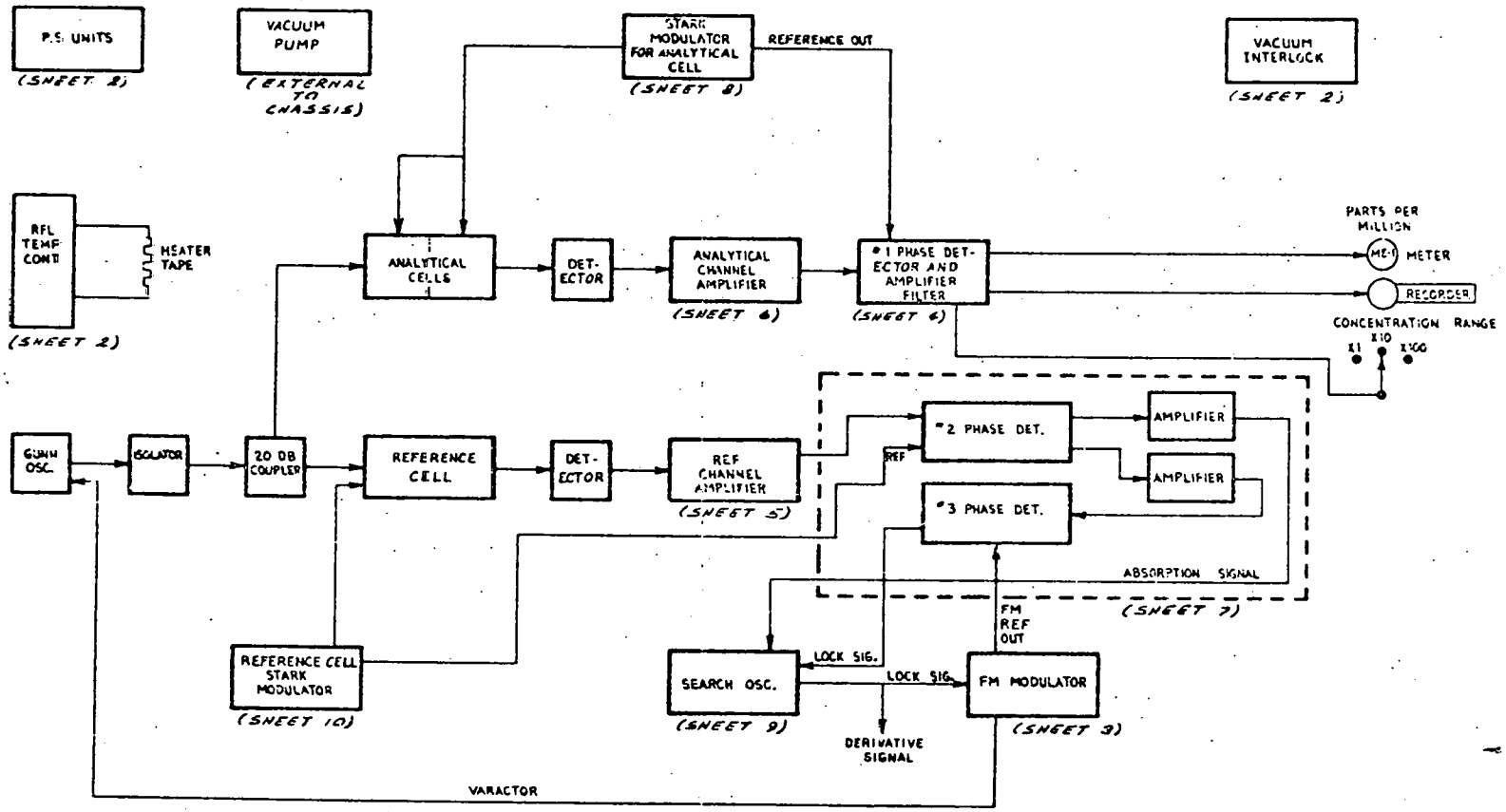
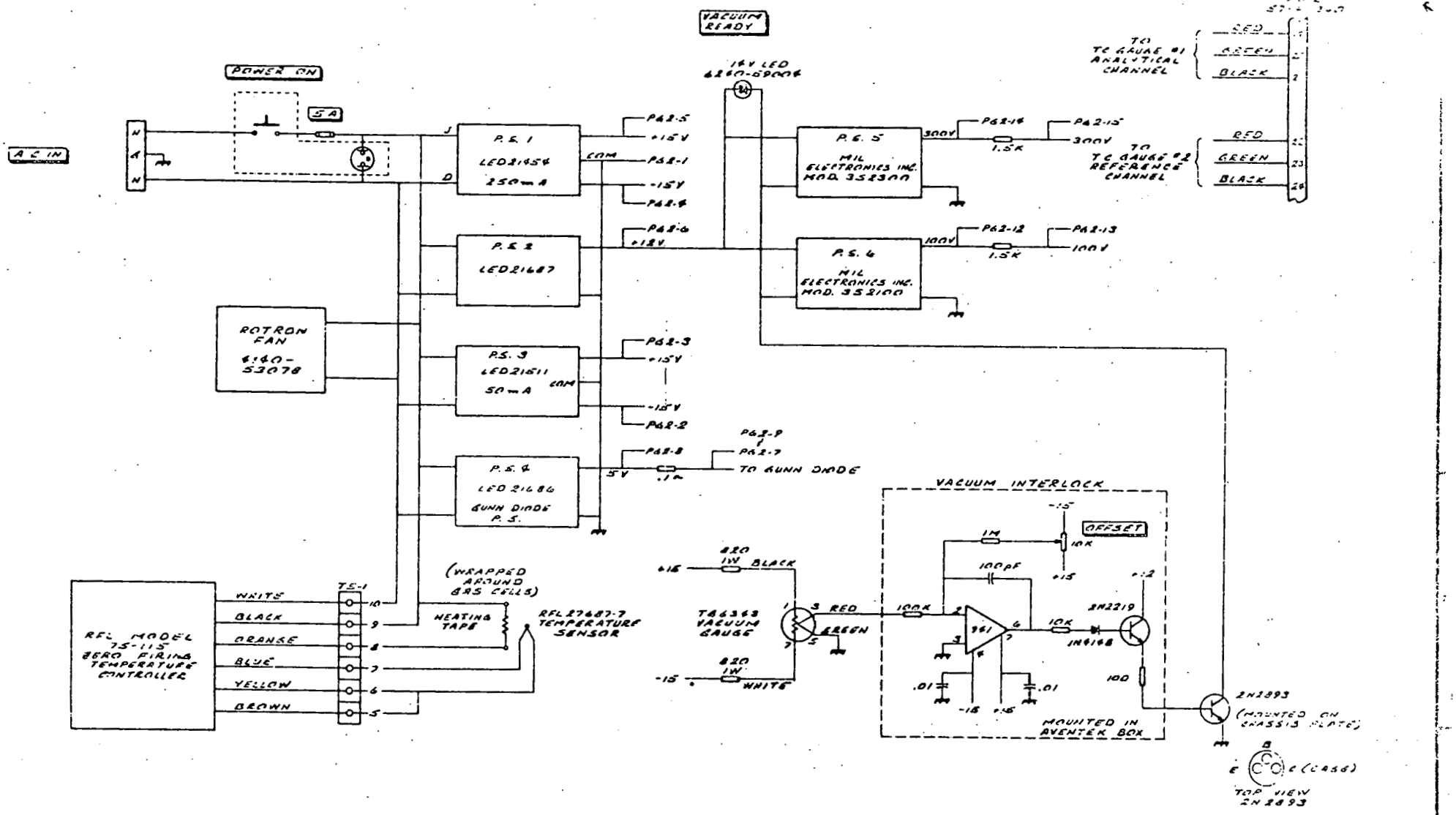
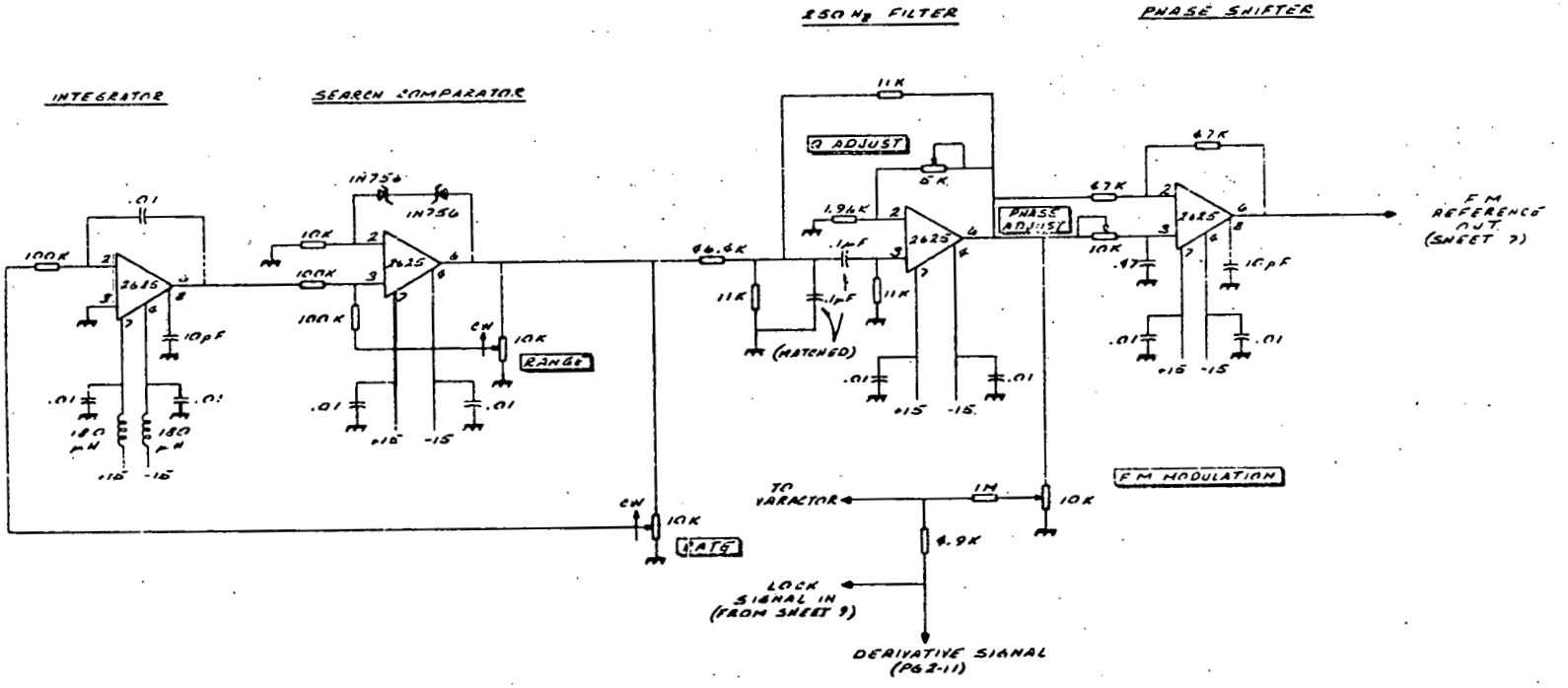
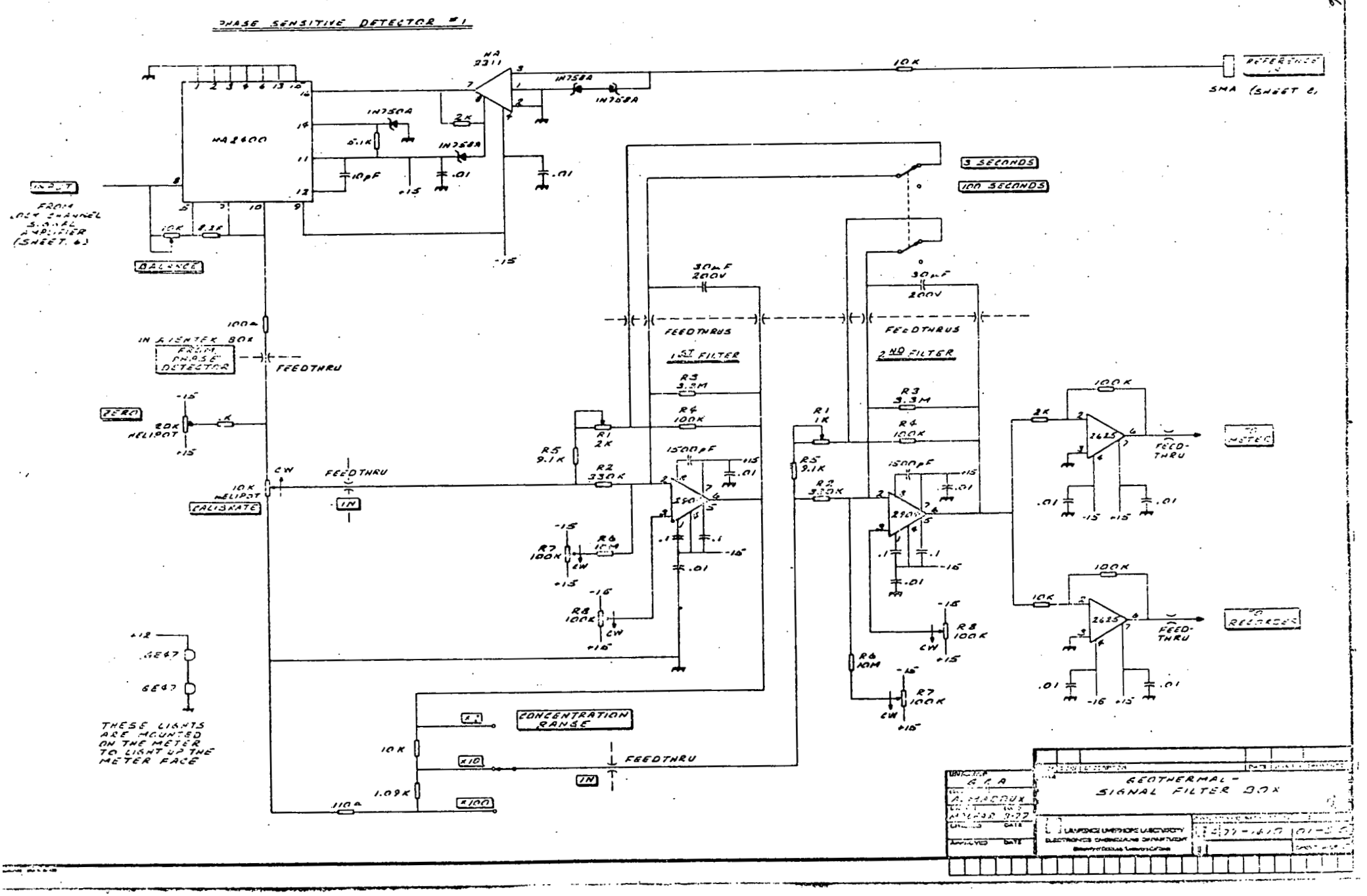


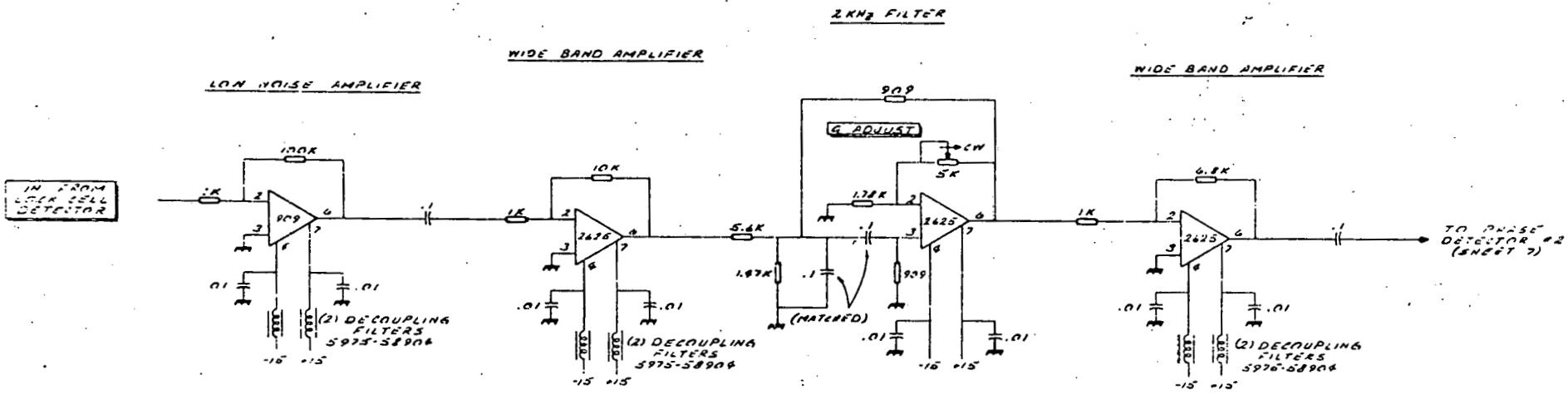
GEOTHERMAL
AMMONIA SPECTROMETER


POWER ON
5A
AC IN
N
A
N
J
D
P.S. 1
LED21454
250mA
COM
P62-5
+15V
P62-1
-15V
P62-4
P62-6
+18V
P.S. 2
LED21687
ROTRON FAN
6140-53078
P.S. 3
LED21611
50mA
COM
P62-3
+15V
-18V
P62-2
P.S. 4
LED 21686
GUNN DIODE P.S.
P62-8
5V
.1A
P62-9
P62-7
TO GUNN DIODE
VACUUM READY
14V LED
6260-69006
P.S. 5
MIL ELECTRONICS INC.
MOD. 352300
300V
P62-14
P62-15
1.5K
300V
P.S. 6
MIL ELECTRONICS INC.
MOD. 352100
100V
P62-12
P62-13
1.5K
100V
P.S. 7
TO TC GAUGE #1 ANALYTICAL CHANNEL
RED
GREEN
BLACK
TO TC GAUGE #2 REFERENCE CHANNEL
RED
GREEN
BLACK
21
22
23
24
VACUUM INTERLOCK
OFFSET
-15
IN
10K
100pF
+15
+12
100K
10K
2N2219
1N4148
961
.01
.01
100
-15
+15
2N2893
(MOUNTED ON CHASSIS PLATE)
MOUNTED IN AVENTEK BOX
820 1W BLACK
+15
820 1W WHITE
-15
T46343 VACUUM GAUGE
RED
GREEN
RFL MODEL 75-115 ZERO FIRING TEMPERATURE CONTROLLER
TS-1
WHITE
BLACK
ORANGE
BLUE
YELLOW
BROWN
10
9
8
7
6
5
(WRAPPED AROUND GAS CELLS)
HEATING TAPE
RFL27687-7 TEMPERATURE SENSOR
B
E
C (CASE)
TOP VIEW 2N2893
GEOTHERMAL
POWER SUPPLIES, VACUUM INTERLOCK AND RFL TEMPERATURE CONTROLLER
LAWRENCE LIVERMORE LABORATORY



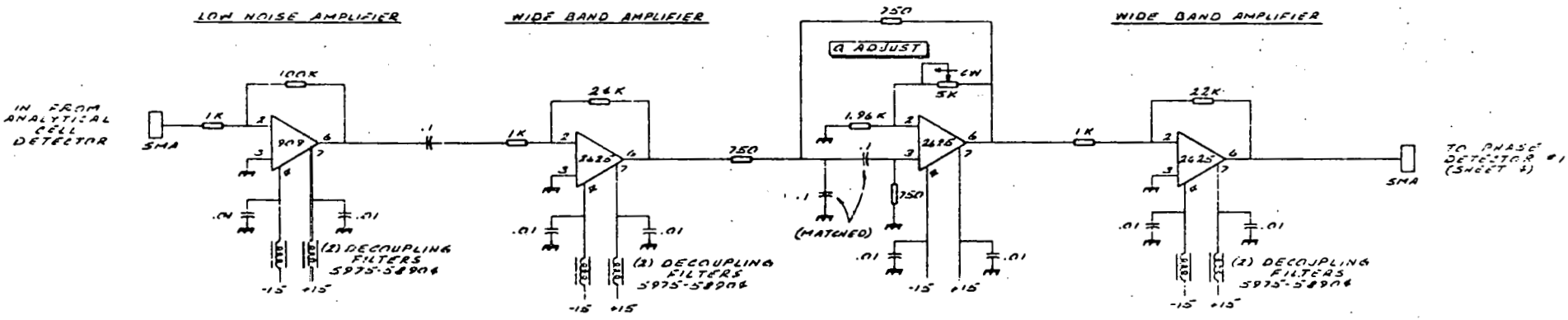
GEOTHERMAL
FM MODULATOR


PHASE SENSITIVE DETECTOR #1
HA 2600
HA 2311
IN758A
10K
REFERENCE IN
SMA (SHEET 6)
INPUT
FROM LOCK CHANNEL SIGNAL AMPLIFIER (SHEET 6)
BALANCE
3 SECONDS
100 SECONDS
30mF 200V
FEEDTHRUS
1ST FILTER
2ND FILTER
R1 2K
R2 330K
R3 3.3M
R4 100K
R5 9.1K
1500pF
ZERO
20K HELIPOT
CW
FEEDTHRU
IN
10K HELIPOT
CALIBRATE
R6 10M
R7 100K
R8 100K
CONCENTRATION RANGE
x1
x10
x100
10K
1.09K
110Ω
100Ω
IN AIRTEK BOX
FROM PHASE DETECTOR
2625
TO METER
TO RECORDER
+12
6E67
THESE LIGHTS ARE MOUNTED ON THE METER TO LIGHT UP THE METER FACE
GEOTHERMAL - SIGNAL FILTER BOX
A. MADDUX
LAWRENCE LIVERMORE LABORATORY

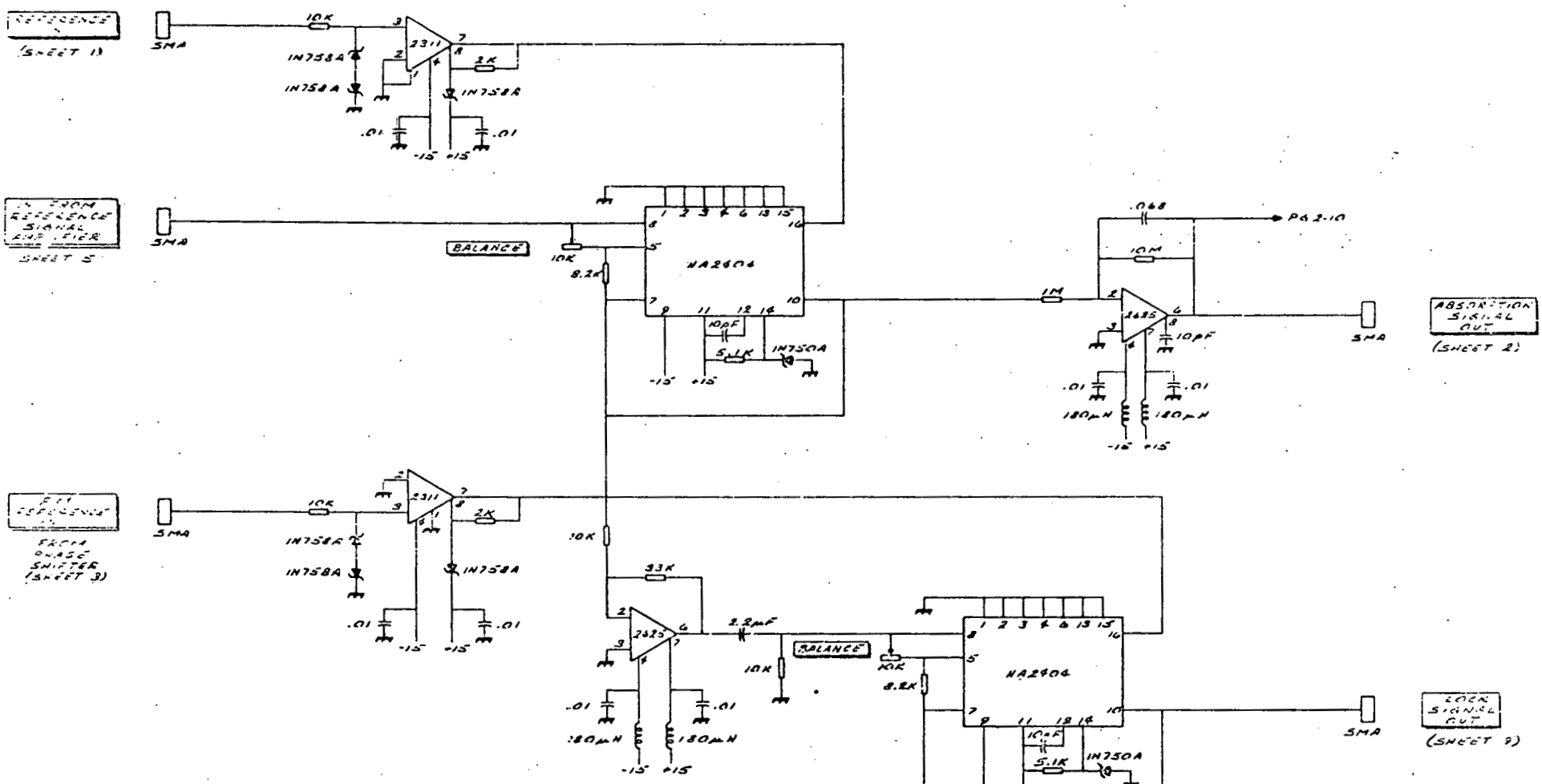


DRAWN	A.C.B	GEOTHERMAL - SIGNAL AMPLIFIER - LOCK CHANNEL
ENGR	A. MADDUX	
MFG'R	3-72	
CHECKED		
APPROVED		LAWRENCE LIVERMORE LABORATORY, ELECTRONICS ENGINEERING DEPARTMENT, University of California, Livermore, California
		LE 77-1010

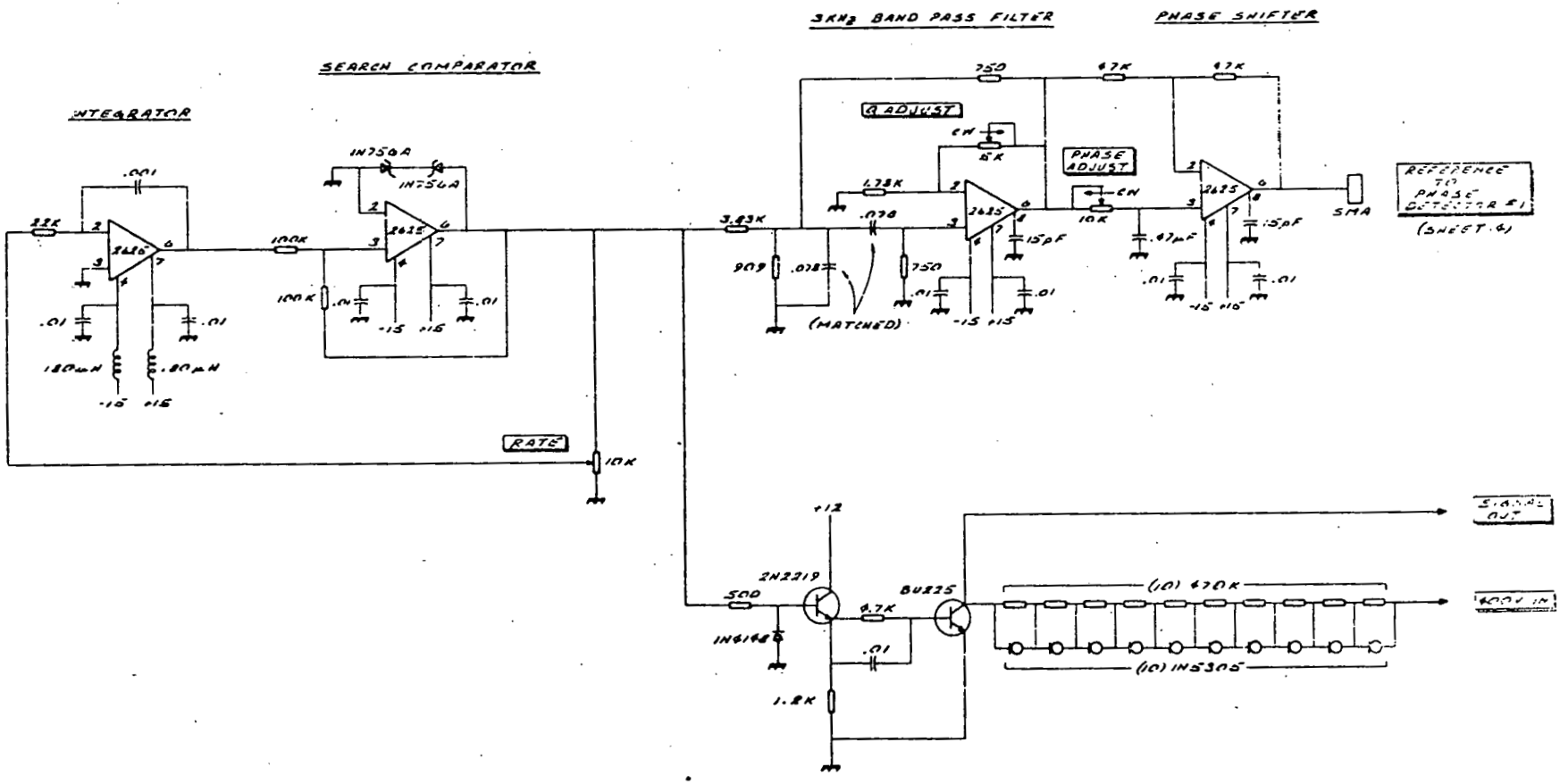
3 KHz FILTER



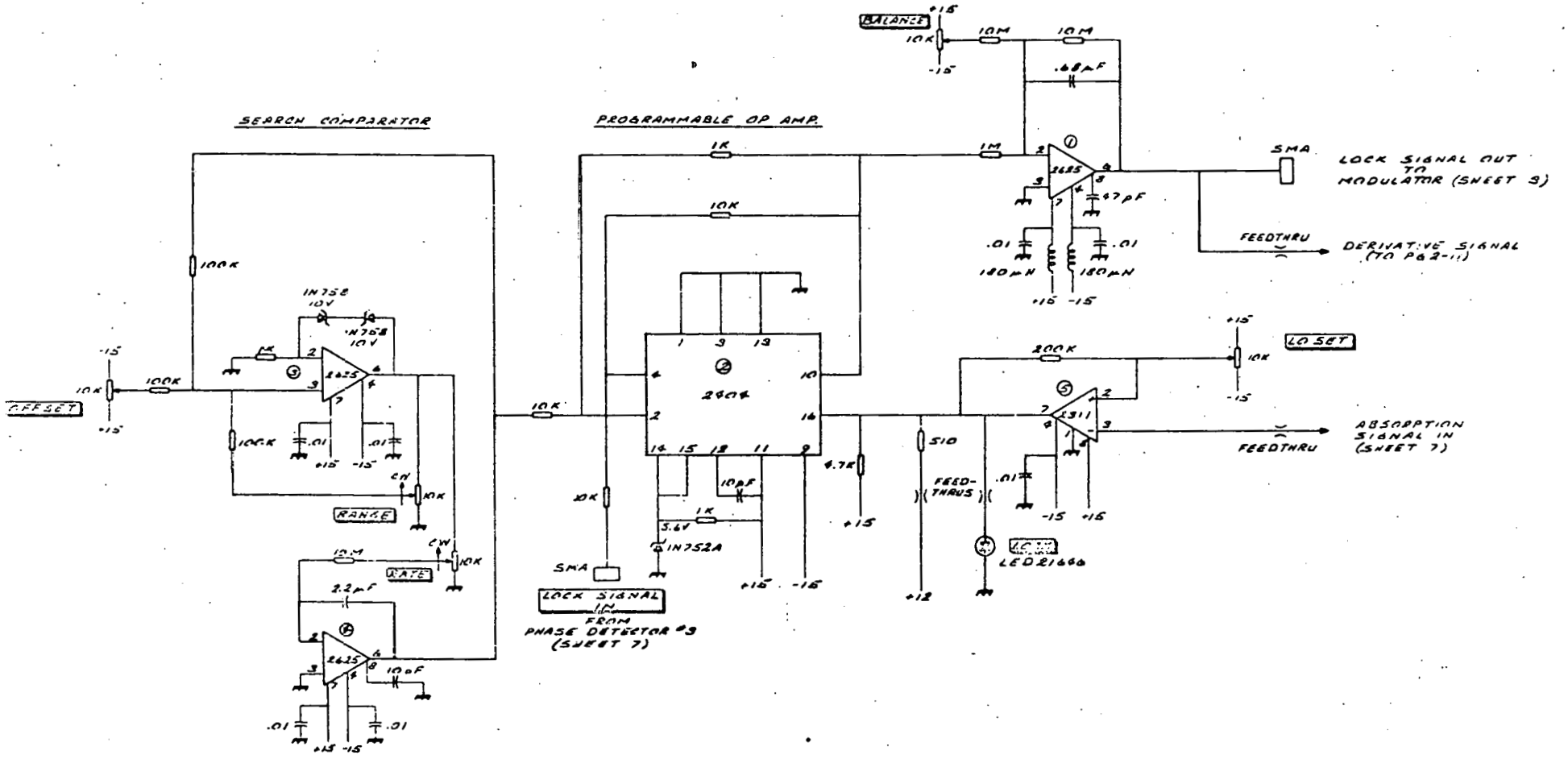
	GEOTHERMAL - ANALYTICAL CHANNEL AMPLIFIER
	LAWRENCE LIVERMORE LABORATORY



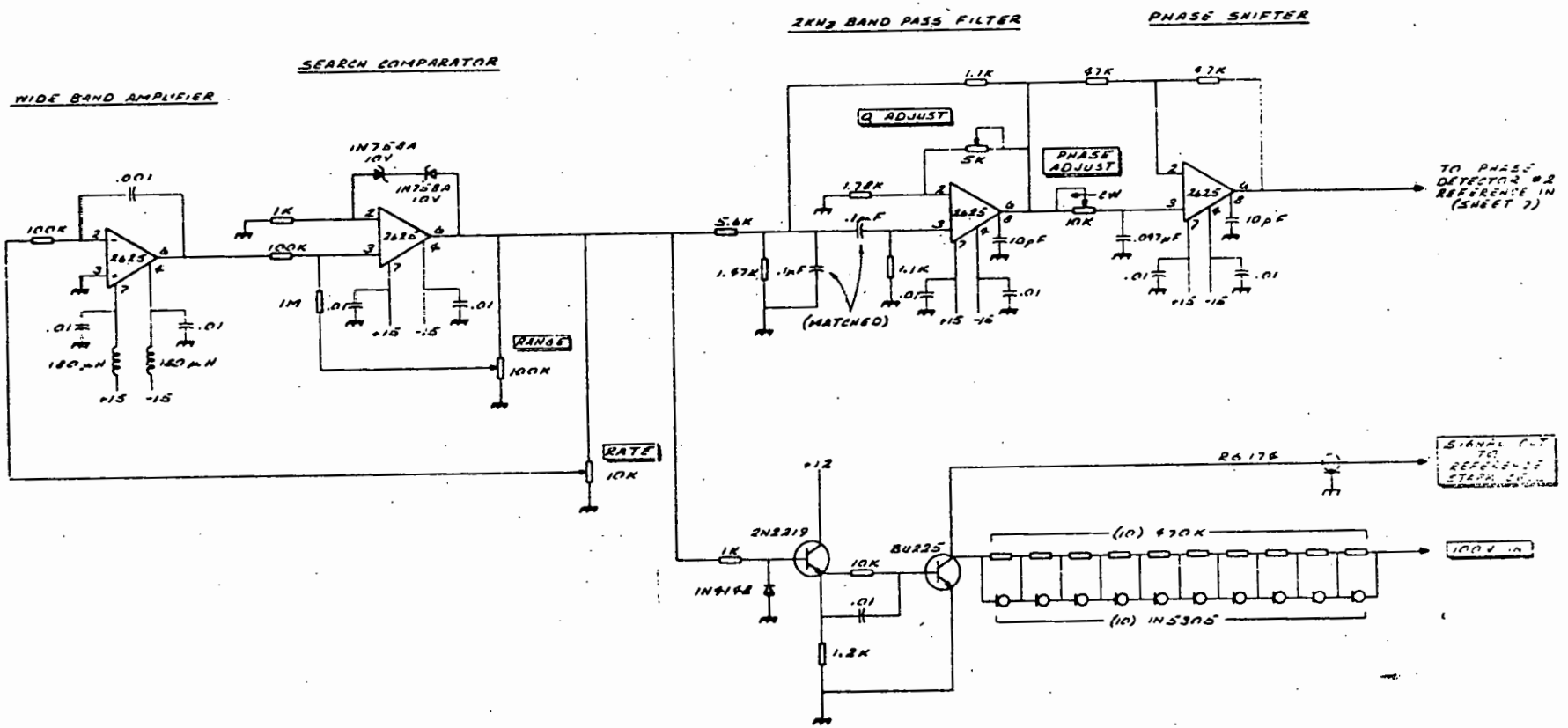
GEOTHERMAL -
LOCK-IN CHANNEL PHASE DETECT.



DES.	GEOTHERMAL - STARK MODULATOR ANALYTICAL CELL
APPROVED	LAWRENCE LIVERMORE LABORATORY, ELECTRONICS ENGINEERING DEPARTMENT



C.C.P.	AEOTHERMAL — SEARCH OSCILLATOR
A. HADDUK	
M.C. ENG. 9-77	



DRAWN	R.F.W.	GEOTHERMAL - STARK MODULATOR - REFERENCE CELL
TRACED	A. MODUK	
CHECKED	M. CLAR 9-77	
APPROVED		LAWRENCE LIVERMORE LABORATORY, ELECTRONICS ENGINEERING DEPARTMENT
		LEA 77-1610

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