FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

TECHNICAL MEMORANDUM NO. 48 OF 1967.

THE F.R.I. RECORDING FLAME METHANOMETER MODEL A.

BY

A.A. MEINTJES

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PRINCIPLE OF OPERATION.

The sensing element of the methanometer is a small hydrogen flame which burns in air at the tip of a metal jet. The electrical resistance of the pure hydrogen flame is extremely high ($\sim 10^{-15}\ \Omega$) and is decreased when an organic substance (in this case methane) burns in it. The decrease in resistance is due to ion formation.

The resistance of the flame is measured by making the metal jet an electrode and placing a second insulated electrode in a suitable position above the flame. Complete ion collection by the upper electrode requires that the positive and negative electrical charge carriers formed in the flame be separated as soon as they are formed so that recombination cannot occur. Recombination of oppositely charged ions is prevented by subjecting the flame to an adequate electrical field (30 V) applied across the electrodes.

A transistorised amplifier which is connected across the electrodes amplifies the ionisation current for registration by a moving coil graphic recorder. The ionisation current is directly proportional to the percentage of methane in the combustion air drawn into the flame.

The full scale sensitivity of the methanometer is 1%.

CONSTRUCTION.

Figure 1 is a block diagram of the sub-units of the methanometer.

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The fuel supply for the methanometer consists of a light-alloy high-pressure gas cylinder which contains pure hydrogen. A primary pressure regulator reduces the outlet pressure of the gas cylinder to 50-80 lb/sq. inch from where it is fed via a short length of flexible tubing to the detector unit. When filled to 1200 lb/sq. inch the gas cylinder contains 15 cubic feet of hydrogen which is sufficient for 10 days continuous operation of the methanometer at a gas flow-rate of 30 ml. per minute.

The detector unit is constructed in the form of a mine safety lamp. The lower tank assembly which normally contains the fuel and wick is replaced by a larger hollow case which houses the secondary precision gas flow regulator. The fuel gas flow is held constant to within $\pm$ 5 per cent. The upper lamp assembly (safety glass and gauzes) is retained. The hydrogen flame burns at the jet in the position normally occupied by the wick of the safety lamp. The heat generated by the hydrogen flame causes a draught through the lamp which expels the combustion products and draws in fresh air. A thin metal chimney placed around the flame enhances the draught past the flame. The insulated electrode above the flame is connected to a co-axial plug on the base of the lamp. Details of the electrodes are given in Figure 2.

The upper lamp assembly and chimney must be removed before the hydrogen issuing from the jet can be ignited. No provision is made to ignite the flame when the detector unit is fully assembled. The detector unit is rendered tamperproof by suitable locking devices.

The hydrogen supply is coupled to the detector unit by means of a Swagelok "quick-connect". When the quick-connect is separated sufficient hydrogen is trapped in the interconnecting tubing and pressure regulator in the base of the detector unit for the hydrogen flame to remain burning for approximately 5 minutes. This enables a fresh hydrogen supply to be connected to the detector without the flame going out. Figure 3 is an exploded view of the detector unit.

The amplifier-recorder unit is shown in Figure 4. The recorder is manufactured by the Record Electrical Co.,

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Ltd. and has an eight-day hand-wound mechanism which drives a paper chart under a pen. The pen is connected to a 1 mA. F.S.D. moving coil meter with an internal resistance of ca. 1000 ohms. The recorder is contained in a portable, dustproof, glass fronted metal case. The amplifier, batteries and associated components are mounted on the rear of the recorder. A metal cover encloses the amplifier assembly.

The electrical circuit of the methanometer is shown in Figure 5. The ionisation current flowing through the hydrogen flame gives rise to a voltage drop across R_3. This voltage is amplified by the amplifier A and registered on the recorder M. The exact circuit of the "Nexus" amplifier is not known. R_1, R_2 and R_3 form a potential divider which limits the voltage which can be applied to the input of the amplifier to a safe value. R_4 and R_5 are negative feed-back resistors which establish the gain of the amplifier. R_6 is used to adjust the electrical zero of the amplifier.

The 30 volt battery B_1 is two 15 volt Eveready HB 54 batteries connected in series by a composite resistor formed from a 12 k. ohm wire-wound and a 10 M. ohm carbon resistor (in series). This resistor (R_1 + R_2) limits the short circuit current of B_1 to 3μA. Battery B_2 is twelve 1.35 volt Mallory mercury cells (type RM 12) connected in series and provided with a centre tap. Resistors R_7 and R_8 limit the short circuit current of B_2 to 80 mA. Batteries B_1 and B_2 are encapsulated in "Araldite" with their respective current-limiting resistors. Resistors R_9 and R_{10} are placed in the recorder by its manufacturer and are apparently for the purpose of adjusting the full scale sensitivity and total resistance of the recorder. Batteries B_1 and B_2 have a life of three and one month respectively.

Figure 6 is a photograph of the complete methanometer. Detailed operating instructions for the F.R.I. recording methanometer are given in an addendum to this technical memorandum.

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5th January, 1968.
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A.A. MEINTJES
Research Officer

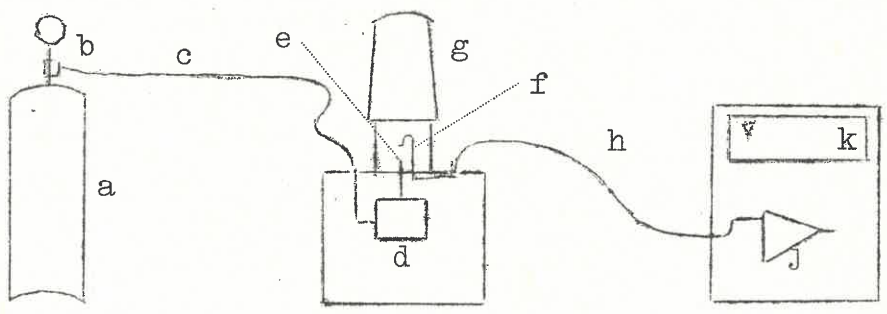

FIGURE 1. The methanometer sub-units

I Fuel Supply.

a. Hydrogen cylinder
b. Primary pressure regulator
c. Pressure hoze
d. Secondary precision gas flow regulator

II Detector.

e. Metal flame jet
f. Insulated electrode
g. Flame-proof housing

III Amplifier and Recorder.

h. Interconnecting co-axial cable
j. Transistorised amplifier
k. Clockwork chart recorder

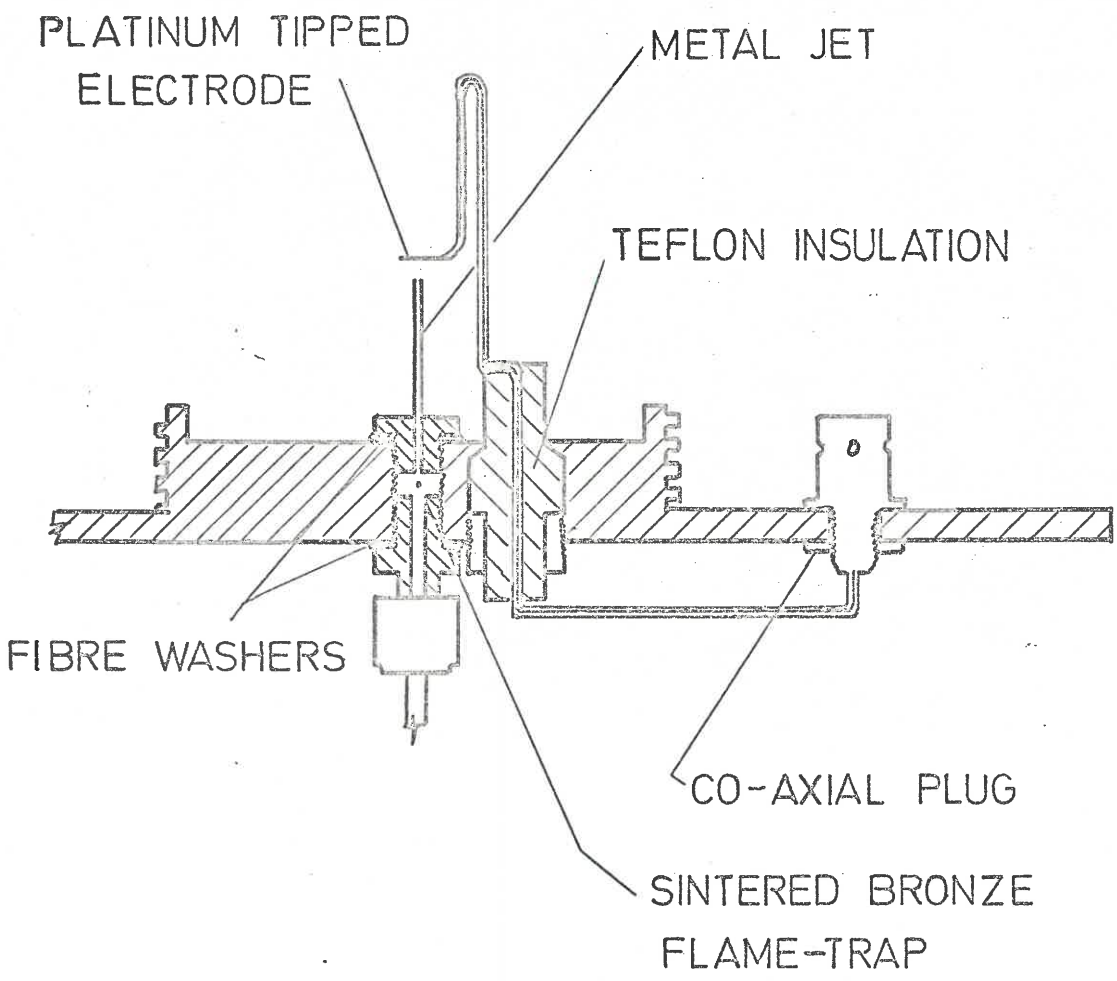

FIG. 2: DETAILS OF THE JET AND INSULATED ELECTRODE

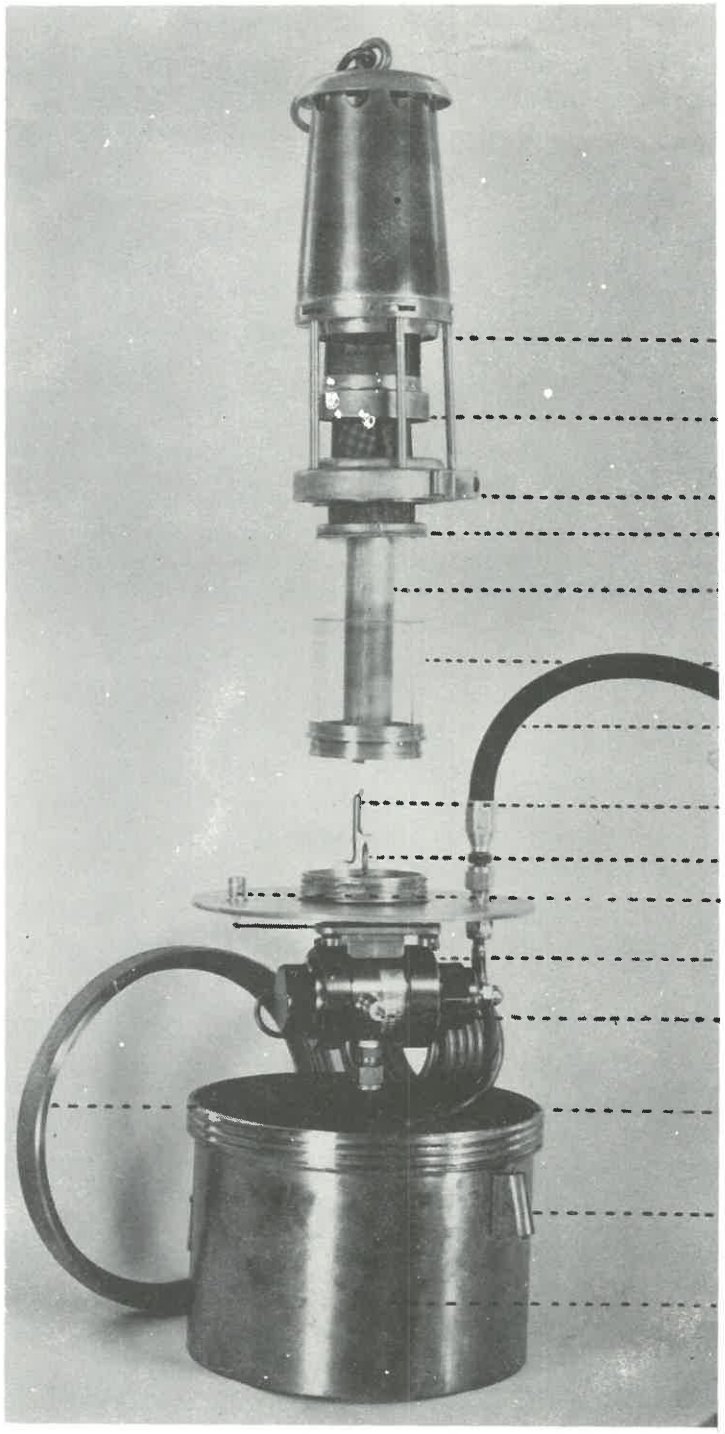

Figure 3. An exploded view of the detector unit.

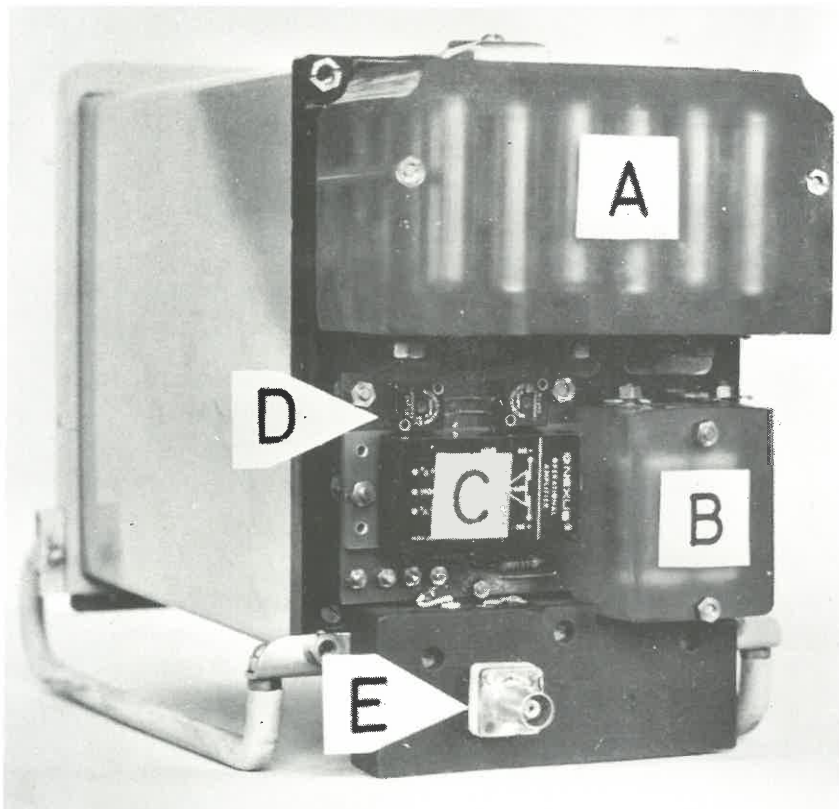

Figure 4. Rear view of the amplifier-recorder unit.

A. 16 Volt battery
B. 30 Volt battery
C. "Nexus" amplifier
D. Amplifier zero adjustment
E. Co-axial plug

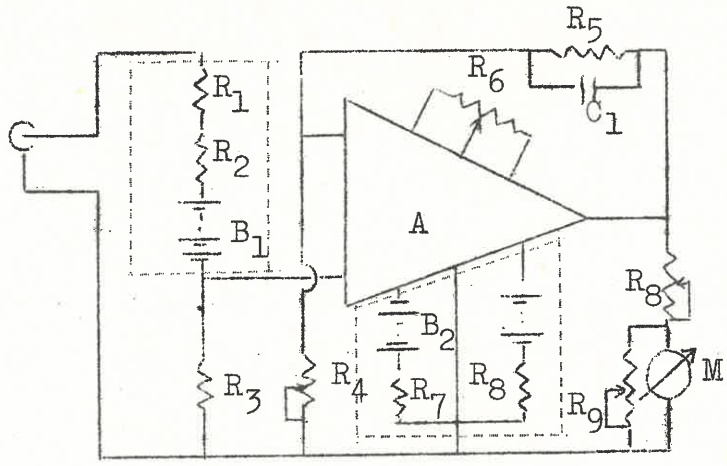

FIGURE 5. The electrical circuit of the methanometer

COMPONENTS.

R_1, 10 MΩ ½ W. carbon 10% - see text.
R_2, 12 KΩ 5 W. wire-wound - see text.
R_3, 1 MΩ ½ W. carbon 5%.
R_4, 100Ω trimpot, wire-wound. Beckman Model 71C.
R_5, 10 KΩ ½ W. carbon 5%.
R_6, 500Ω trimpot, wire-wound. Beckman Model 71C.
R_7, R_8 100Ω 5 W. wire-wound.
R_9, 1000Ω wire-wound - see text.
R_{10}, 500Ω wier-wound - see text.
C_1, 1 μF 35 V tantalum - non-polarised.
B_1, 30 volt carbon-zinc battery (two Eveready HB 54 batteries in series).
B_2, 16 volt mercury battery (twelve Mallory type RM 12 cells in series).
A, "Nexus" operational amplifier, type LFT-1 made by: Nexus Research Laboratory Inc. Mass. U.S.A.
M, "Record" 1 mA F.S.D. moving coil graphic recorder made by: The Record Electrical Company, Broadheath England.

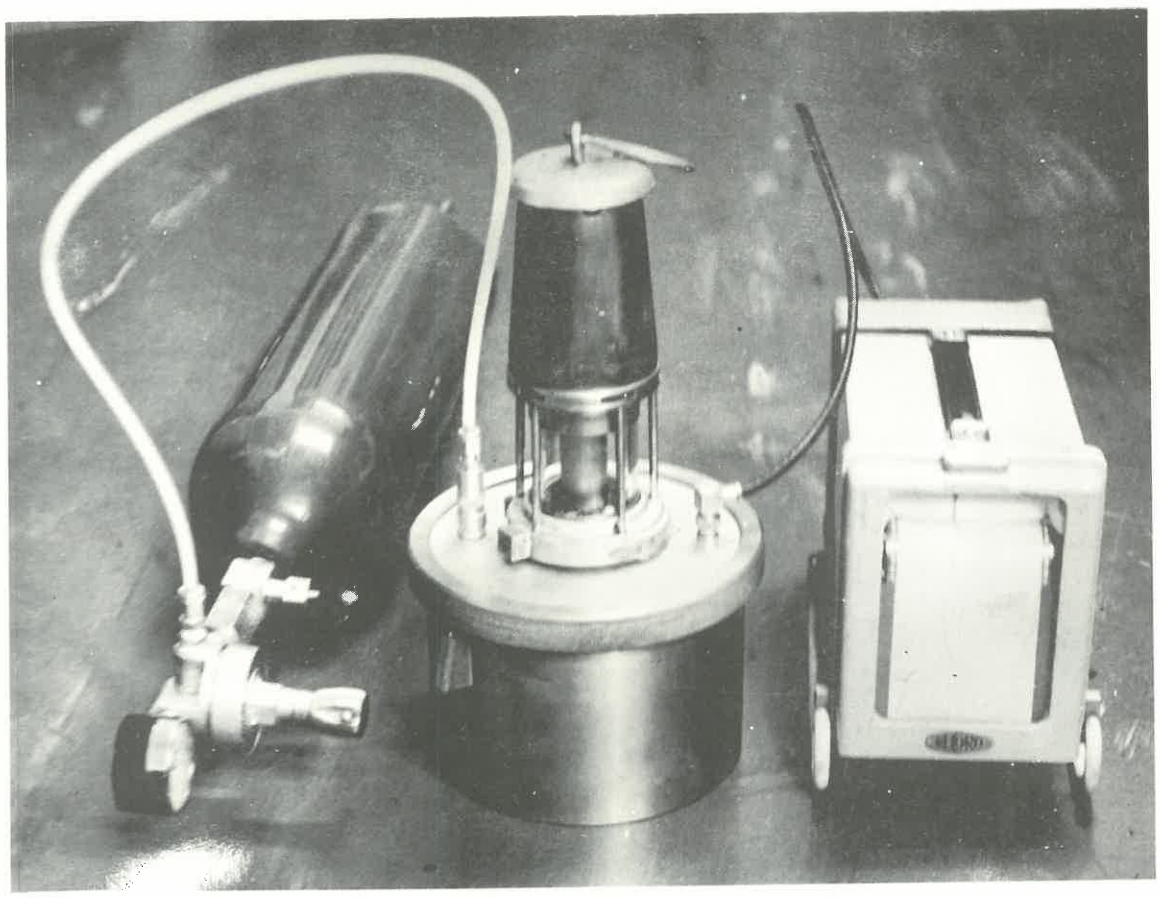

Figure 6. A view of the complete methanometer.

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ADDENDUM TO TECHNICAL MEMORANDUM NO. 48 OF 1967.

SCHEDULE OF OPERATING INSTRUCTIONS FOR THE FRI RECORDING METHANOMETER MODEL A.

This recording methanometer must be operated and serviced only by trained laboratory personnel.

These operating instructions are to be used in conjunction with F.R.I. Technical Memorandum No. 48 of 1967 in which the methanometer is fully described.

DISMANTLING

The Detector Unit.

Note: The detector unit must be dismantled only in a room authorised for this purpose. The room must be well ventilated and free from inflammable gases.

1. Close the needle valve on the hydrogen cylinder and disconnect the cylinder from the detector at the Swagelok quick-connect. Disconnect the co-axial cable which leads to the amplifier-recorder unit.
2. Loosen the set-screw which locks the upper lamp assembly in position and remove the two gauzes, safety glass and metal chimney to expose the metal flame jet and insulated electrode.
3. Remove the lower case which encloses the gas flow regulator after loosening the lock screw and removing the large retaining ring.

The detector is now sufficiently dismantled for routine maintenance and inspection. The three fibre seals should be inspected and renewed if damaged in any way. Any dust deposits should be removed from the inner and outer gauzes.

The Amplifier-recorder Unit.

1. A separate detailed instruction manual is supplied by the manufacturer of the chart-recorder to which reference must be made when the recorder is serviced.

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2. Loosen the four recessed screws of the back of the recorder and remove the metal cover to gain access to the amplifier and batteries. Each battery fits over two long studs and is held in position by two nuts. Note that the centre contact of the 16 volt battery is offset to ensure that it can be replaced correctly.

3. The electrical zero of the amplifier is set by adjusting the small trimming potentiometer on the printed circuit board. No means is provided for switching off the amplifier. The batteries must be removed if the methanometer is not in use.

ASSEMBLY.

The Detector Unit.

1. Connect the hydrogen supply to the detector unit. Open the needle valve on the hydrogen cylinder one quarter of a turn. Increase the gas pressure from the cylinder to between 50 and 80 lb/sq. inch. Test all connections for leaks with a soapy water solution. The slightest leak must be corrected.

2. Connect a soap bubble flowmeter to the jet and adjust the needle valve on the precision flow regulator to obtain a hydrogen flow of 30 ml. per minute. This adjustment must be made after all the air has been flushed from the system ($\frac{1}{2}$ hour).

3. Ignite the hydrogen issuing from the jet and assemble the detector unit. Ensure that the three fibre seals, both gauzes, the safety glass and the metal chimney are in position. The set screw which locks the upper assembly in position fits into a recess and must not bind directly on the thread.

4. Replace the lower case and lock its retaining ring in position.

The Recorder Amplifier Unit.

1. If the batteries have been removed they should be replaced and held in position by the retaining nuts.

2. Replace the metal cover on the rear of the recorder and connect the co-axial cable to the detector unit.

The complete methanometer must be placed in the protective cage which is padlocked when installed underground.

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Note: The expanded metal cage must be orientated so that the hydrogen cylinder always remains downwind of the detector unit. The hydrogen cylinder must also remain downwind of the detector when it is replaced by a full one at weekly intervals.

ROUTINE MAINTENANCE.

Weekly:

1. Replace hydrogen cylinder.
2. Wind recorder chart drive.

Monthly:

1. Replace 16 volt battery.
2. Check zero of the amplifier.
3. Check hydrogen flow rate.
4. Remove dust deposits from detector.
5. Replace recorder chart.
6. Replenish recorder ink.

Three Monthly:

Replace 30 volt battery.