FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

TECHNICAL MEMORANDUM NO. 25 OF 1966.

A RECORDING METHANOMETER (PROTOTYPE).

BY:

A. A. MEINTJES.

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The recording methanometer was developed for the purpose of monitoring the methane content of the air in collieries. In order to determine the effect of mining operations and other factors such as changes in atmospheric pressure on the discharge of methane from colliery workings it is desirable to measure the methane concentration for extended periods.

Instruments available for this purpose are designed for use under circumstances where the methane concentration may exceed safe limits and are generally calibrated to record methane to within 0.1 per cent in the concentration range between 0 and 5 per cent. The methane concentration in the upcast ventilation shafts of South African collieries seldom exceeds 0.1 per cent and the sensitivity of available recording methanometers is therefore too low.

The sensing element of the methanometer developed at the Fuel Research Institute consists of a small hydrogen flame which burns in air at the tip of a small metal jet. The electrical conductivity of the hydrogen flame is extremely low and is increased when an organic substance (in this case methane) burns in it. The increase in conductivity is due to ion formation.

The conductivity .../

The conductivity of the flame is measured by making the 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 charge carriers formed in the flame be separated as soon as they are formed, so that recombination of these species cannot occur. Recombination of oppositely charged ions is prevented by subjecting the flame to an adequate electrical field applied across the electrodes. The applied field must not be so great as to produce ion multiplication by impact of electrons accelerated through excessive voltage gradients.

Satisfactory jet-electrode geometry can be achieved by studying the current-voltage curves for a particular configuration. Figure 1 shows the variation in ionization current with ionization voltage.

The initial rise in ionization current at low voltages shows first the overcoming of attraction between ions of opposite charge to remove those of one charge and then the improved ion capture as sufficient voltage is applied to the electrodes. The proximity of the metal jet to the zone of ion formation and the high field gradient resulting from the small jet diameter lead to efficient removal of ions of one charge at the jet. A lower voltage is required to reach the plateau of the current-voltage curve when electrons are drawn to the jet. "Blow-by" occurs when the gas flow sweeps ions out of the region of strong electrical field before they have been drawn to the appropriate electrode. The minimum

voltage .../

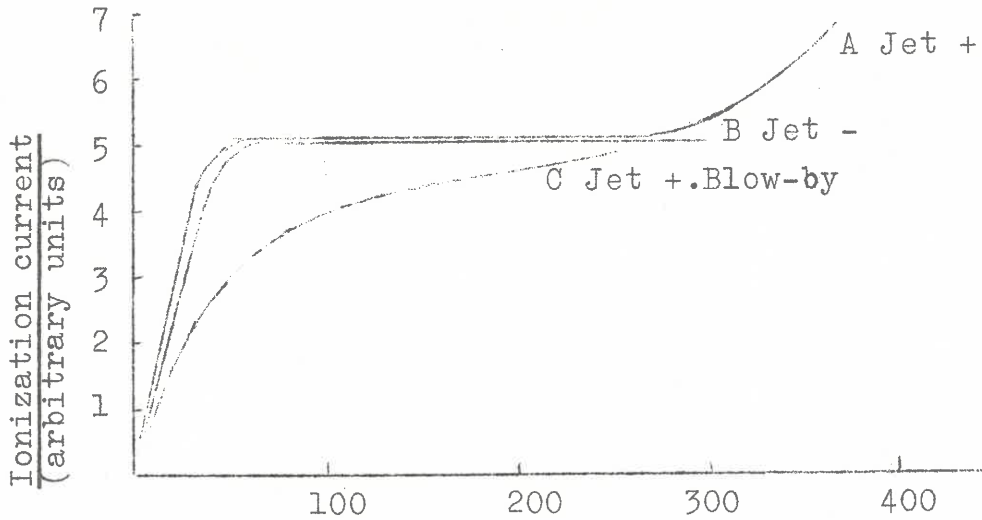

FIGURE 1. Relationship between ionization voltage and ionization current for various electrode configurations. A; good. B; good. C; incomplete ion collection ("blow-by").

voltage at which saturation can be reached depends on the form of the electrodes, the electrode gap, the flame temperature and hydrogen flow rate. The value of the ionization voltage does not have to be regulated as long as it remains within the limits of the plateau. The ionization current is not increased by the presence of oxygen, nitrogen, water vapour, carbon monoxide, carbon dioxide and oxides of nitrogen.

A simple transistorized amplifier connected to the electrodes serves to convert the ionization current into voltage values which can be registered by a chart recorder. The ionization current originates from a source of very high impedance and the recorder has a much lower input impedance. The amplifier in its intermediary position serves as an impedance converter.

Figure 2 is a block diagram of the methanometer.

Figure 2 .../

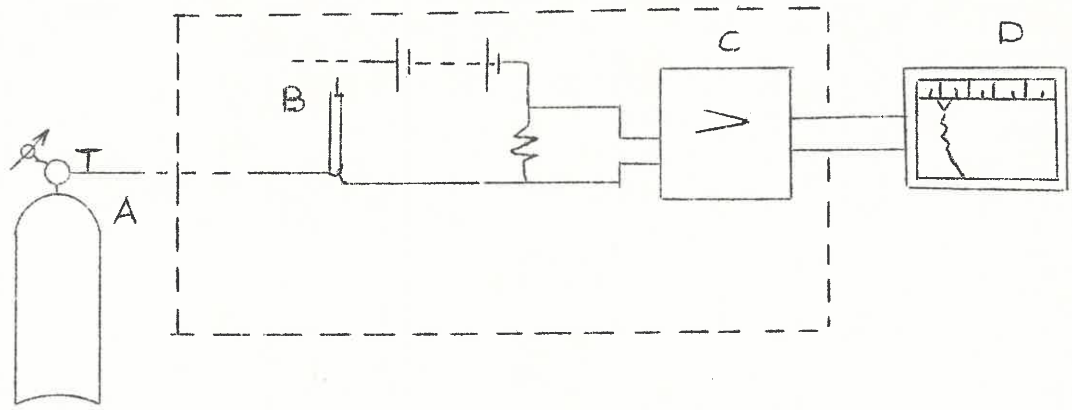

FIGURE 2. Block Diagram of the Methanometer.

A. Hydrogen supply via pressure regulator and needle valve.
B. Hydrogen jet.
C. Amplifier.
D. Recorder.

The components within the dotted lines are housed in a mine safety lamp.

The prototype was constructed in the form of a mine safety lamp as shown in Figure 3. The lower tank assembly which contains the fuel and wick was replaced by a hollow base which houses the batteries and amplifier for the methanometer. The upper lamp assembly which contains the safety gauze and glass is retained. The hydrogen flame burns at the tip of the jet in the position normally occupied by the wick of the safety lamp. The metal jet was constructed from a hyperdermic needle (~0.020 inch I.D.) cut square and silver-soldered into a finned holder. The cooling fins dissipate the heat generated at the jet and cause a draught through the lamp which draws in fresh air and expels the combustion products (mainly water). The insulated

electrode .../

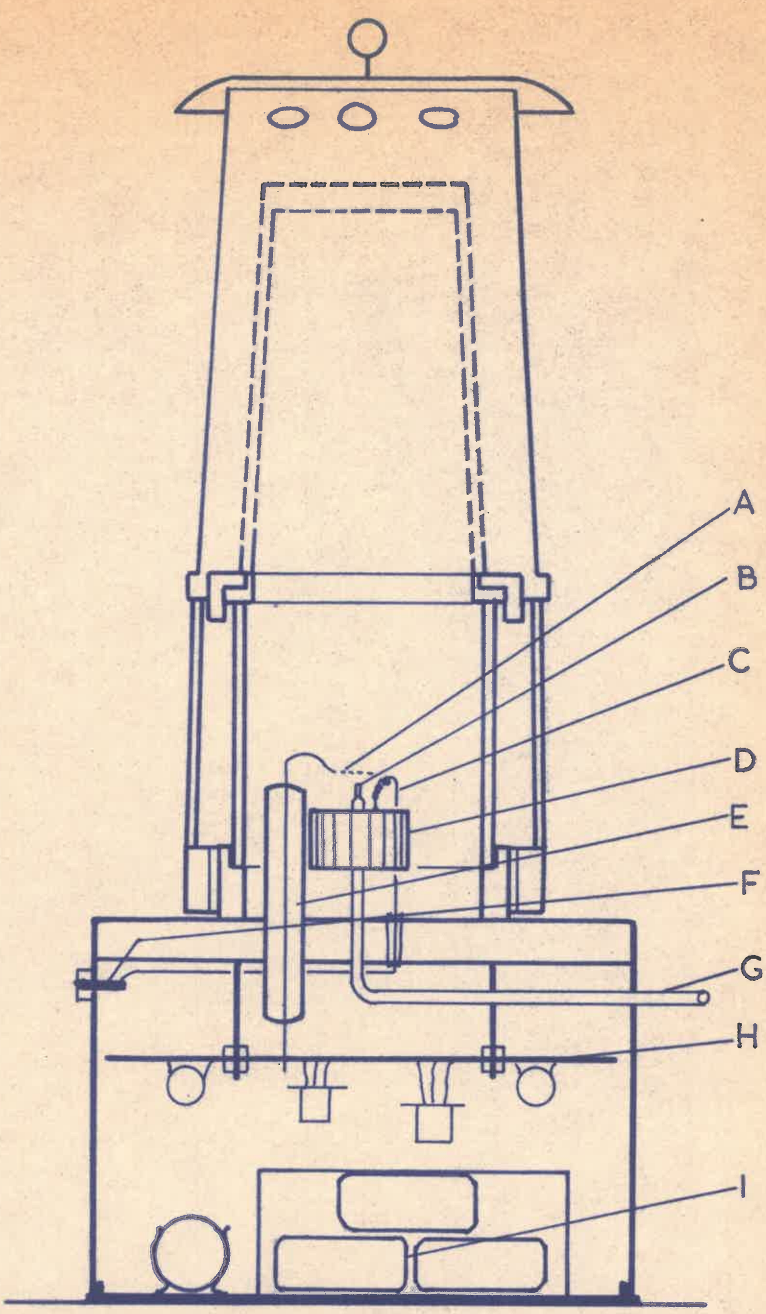

FIG. 3 : CROSS SECTION OF METHANOMETER

A : ELECTRODE
B : HYDROGEN JET
C : IGNITION SPIRAL (PT.)
D : COOLING FINS
E : TEFLON INSULATION
F : CONNECTIONS TO RECORDER
G : HIDROGEN SUPPLY
H : AMPLIFIER MOUNTED ON P.C. BOARD
I : BATTERIES

electrode placed above the flame is connected to the amplifier in the lamp base. The metal jet which is grounded to the base forms the second electrode. The flame is ignited by heating a platinum spiral at the level of the flame but to one side so that it is definitely outside the direct flame space. The hydrogen flame is stable with the specified jet orifice size and a hydrogen flow of 20 ml. per minute. The hydrogen flow is kept constant to within 5 per cent by a precision pressure regulator and needle valve.

The theoretical amplifier circuit is shown in Figure 4a. The circuit is basically a Wheatstone bridge with two of its resistance arms replaced by Field-Effect transistors. With no potential applied to points A and B the bridge can be balanced with R_5. An external potential applied to points A and B will unbalance the bridge and a potential difference will appear across points C and D. The circuit has a voltage gain of less than unity but effectively isolates the input (A-B) and output (C-D). The second transistor in the circuit is inserted to cancel the effect of temperature variations on the circuit. Figure 4b shows the practical circuit as used in the methanometer. The resister combination R_6, R_7, R_8 was chosen to eliminate the thermal drift of the amplifier as far as possible.

Coupled to a 10 mV chart recorder the methanometer is capable of detecting 0.01 per cent methane. The sensitivity of the instrument can be increased by a factor of a least ten, provided that the

thermal .../

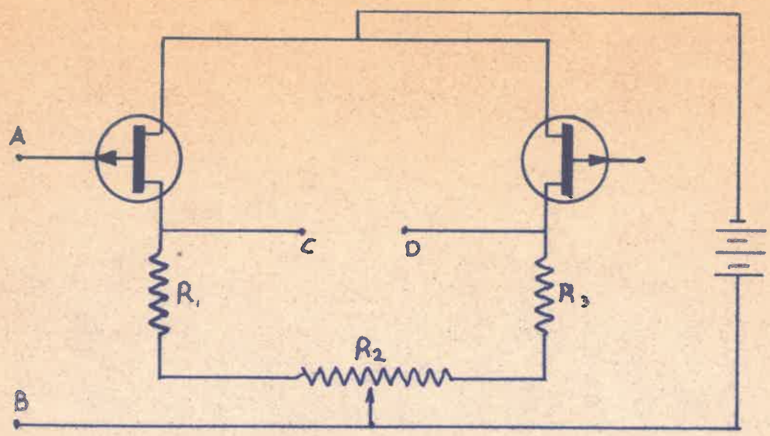

FIG. 4a : THEORETICAL CIRCUIT FOR THE IONIZATION CURRENT AMPLIFIER

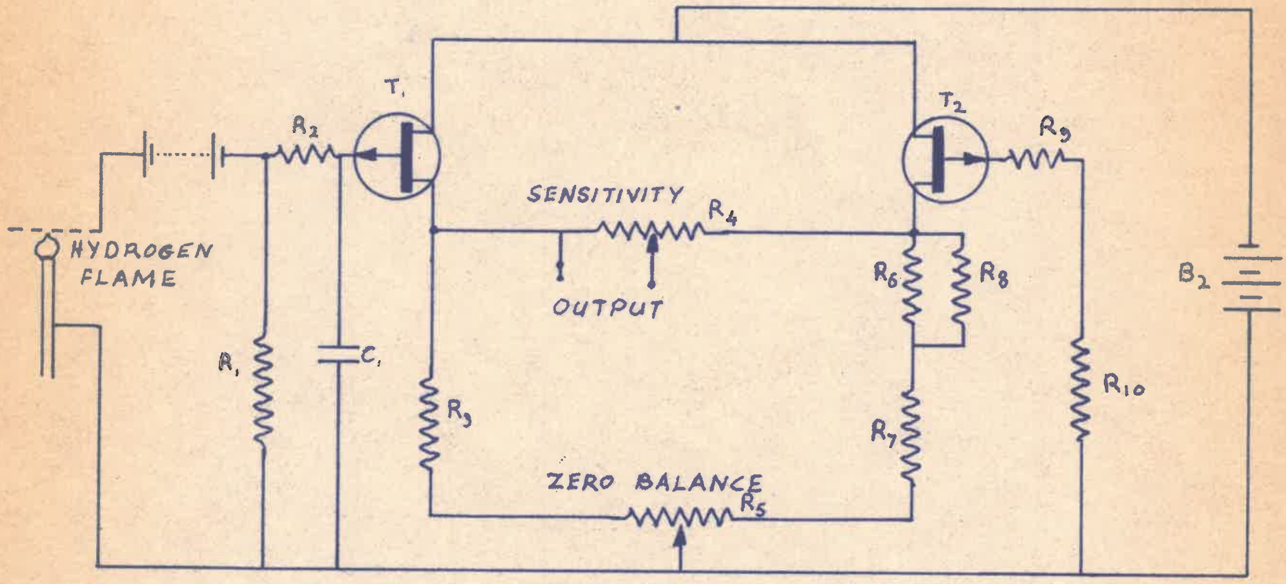

FIG. 4b : PRACTICAL CIRCUIT FOR THE IONIZATION CURRENT AMPLIFIER

- B_1 – 3×22.5 Volt (Eveready HB 51)
- B_2 – 3×1.35 Volt (Mallory RM-12R)
- R_1, R_{10} – 500 MΩ (Welwyn)
- R_2, R_9 – 22 MΩ, ½ W Carbon 10%
- R_3 – 4.7 KΩ, ½ W Carbon 5%
- R_4 – 100 KΩ Skeleton Potentiometer
- R_5 – 1 KΩ " "
- R_6 – 3.3 KΩ, ½ W Carbon 5%
- R_7 – 1 KΩ, ½ W Carbon 5%
- R_8 – 3 KΩ NTC Resistor (Siemens)
- T_1, T_2 – 2N2386 (Texas)
- C_1 – 0.001 μF

thermal drift of the amplifier can be eliminated. The methanometer is not flame-proof in its present form and its mechanical construction must be suitably modified.

(SIGNED) A. A. MEINTJES.

RESEARCH OFFICER.

PRETORIA.
18/7/66.