

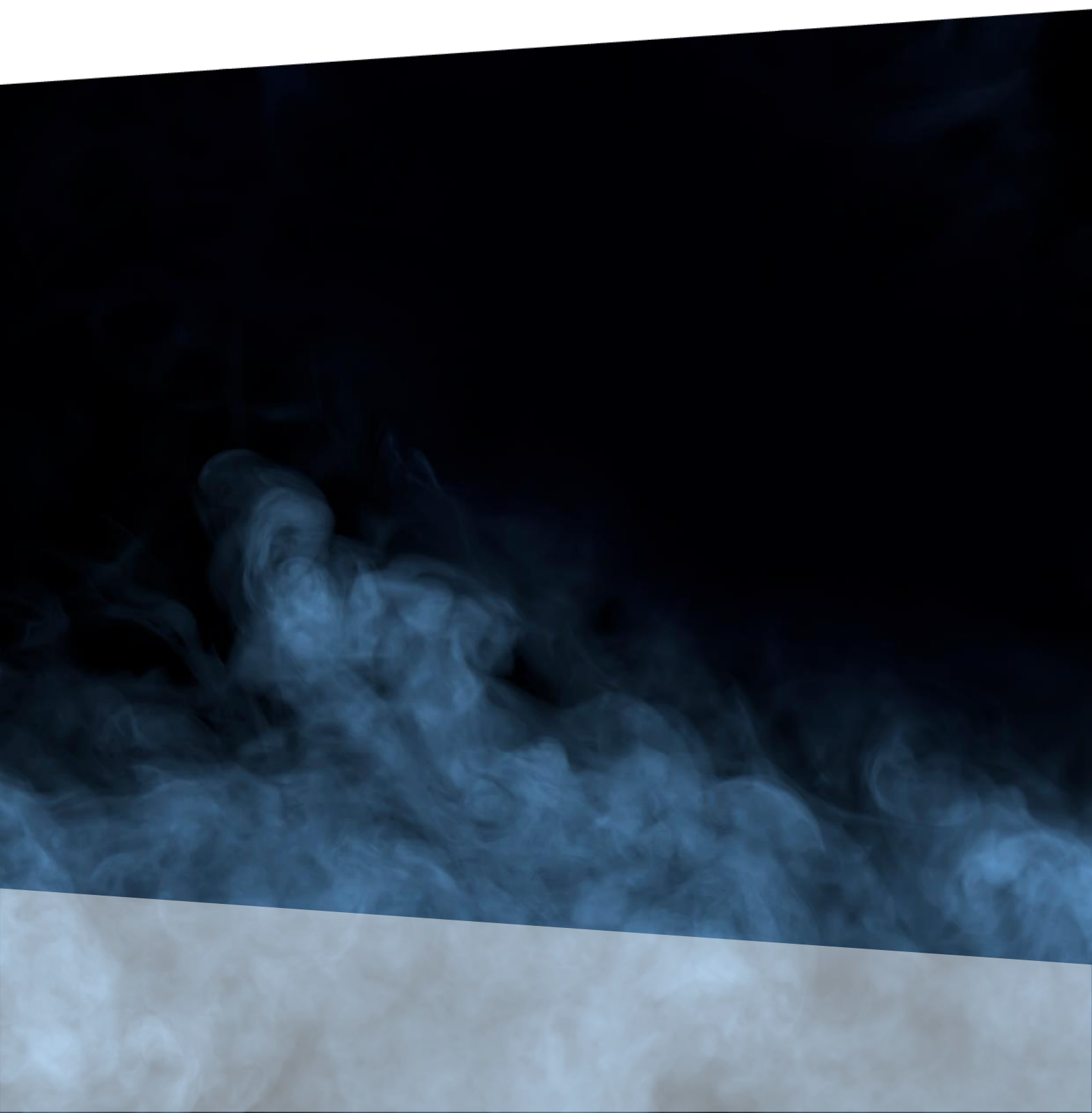
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# Instruction Manual for Smoke Measuring Equipment EC-912



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## List of symbols

I	[A]	current
U	[V]	voltage
R	[ $\Omega$ ]	resistance
$\tau$	[s]	time constant
p	[Pa]	pressure
t	[ $^{\circ}$ C]	temperature
h	[%]	relative humidity

## List of subscripts and abbreviations

MIC		Measuring Ionization Chamber
MIREX		Measuring InfraRed EXtinction
FCU		Flow Control Unit
AMCU		Analog MIC Control Unit
IMCU		Intelligent MIC Control Unit
CC		Control Cabinet
VP		Vacuum Pump
CAL		Calibration
GND		Ground
CH (C)		Chamber
CHO		Chamber, equilibrium
in	(i)	input
out	(o)	output
C.W.		Clockwise
C.C.W.		Counter clockwise

# 1 General information

## WARNING

THE MEASURING IONIZATION CHAMBER EC-912-10  
CONTAINS A WEAK RADIOACTIVE SOURCE. DO NOT  
ATTEMPT TO DISMOUNT THE MIC WITHOUT FOLLOWING  
THE SAFETY PRECAUTIONS GIVEN IN SECTION 5.1.1 .

## 1.1 Introduction

Smoke density can be measured using several different techniques. However, for reference measurements of smoke density in connection with testing of ionization smoke detectors for automatic fire detection systems, it is advantageous to use a measuring instrument based on the ionization chamber principle. This is because of the complex nature of smoke, which means that measuring errors are likely to occur if the reference measuring instrument reacts to other properties of the smoke than the detector under test.

Different reference ionization chambers have been developed in the past. See ref. [1][3][4]. However, since the measuring characteristics of the ionization chamber depend on several parameters, including the design of the ionization chamber, it is important to reach international acceptance of one particular ionization chamber design in order that measuring results may be comparable in general.

The measuring ionization chamber (MIC) which is the smoke sensor in smoke measuring equipment EC-912 has reached this status. The chamber, which is originally designed by Cerberus AG, Switzerland [2][3], has been included in the European standards for smoke alarms EN14604 [5] and smoke detectors EN54-7 [6] issued by CEN<sup>1</sup> and the UL<sup>2</sup> standards UL 217 and UL 268 [8][9]. Furthermore, the chamber is also specified in "ISO<sup>3</sup> 7240-7 Fire detection and alarm systems" for point smoke detectors.

The MIC instrument can be used alone or in combination with different types of optical smoke measuring equipment.

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<sup>1</sup> CEN: European Committee for Standardization

<sup>2</sup> UL: Underwriters Laboratories Inc.

<sup>3</sup> ISO: International Organization for Standardization

## 1.2 General description

The smoke measuring equipment EC-912 comprises a measuring ionization chamber, a control cabinet and a vacuum pump as shown in Fig. A.1.1 in Annex 1.

The 19" control cabinet (CC) comprises either an Analog MIC Control Unit (AMCU) or an Intelligent MIC Control Unit (IMCU) for the measuring ionization chamber, a flow control unit and a power supply.

The measuring ionization chamber (MIC) is placed in the location where the smoke density is to be measured. The MIC is provided with a wind shield which makes the measurements of the device independent of air movement in the location where it is mounted. This wind shield, however, makes it difficult for the smoky air to merge into the measuring volume, so air is sucked through the MIC by a vacuum pump (VP).

The air passes the flow control unit (FCU) on its way from the MIC to the VP. In the FCU the air can be set to a flow rate with needle valve. An exchangeable filter is inserted before the flow meter in order to reduce smoke deposits in this instrument.

The current in the MIC, which is proportional to the smoke density, can be measured with either an Analog MIC control unit (AMCU) or an Intelligent MIC Control Unit (IMCU). The current in the MIC is transformed into a proportional voltage in a built-in amplifier in the MIC. This voltage is fed to the MCU and transformed to an expression for smoke density which can be presented on the display of the AMCU. Furthermore, a recorder output is provided. The AMCU is provided with an electrical calibration facility for check and setting of zero point and full scale deflection of the measuring system.

The IMCU gives you full control of the MIC via a standard Ethernet connection and can directly replace the Analog MIC Control Unit placed in the 19" control rack without any modifications to the existing hardware or cabling.

## 1.3 Applications

As mentioned in the introduction, the MIC smoke measuring equipment EC-912 is intended for reference measurements of smoke density in type approval tests of smoke detectors. The following two applications are typical in this area:

### a) **Smoke tunnel (box) measurements.**

The smoke measuring equipment is used to measure the actual smoke density in the smoke tunnel where the detector under test is subjected to a slowly increasing smoke density. The sensitivity of the detector is expressed in terms of the value of smoke density measured at the moment of response. The detector sensitivity under specific reference conditions and the change in sensitivity due to variations in the operating parameters environment etc., are measured in this way.

### b) **Measurements during fire sensitivity tests.**

The smoke measuring equipment is used to measure the smoke density under the ceiling in the fire test laboratory, where the detectors under test are subjected to different test fire categories. The smoke readings are used for determining if the test fires are correctly reproduced.

The smoke measuring equipment can also be used in other applications, where measurements of smoke density are needed.

## 1.4 Specifications

### 1.4.1 System specifications

**Measuring accuracy:** The overall measuring accuracy of the whole system is limited by the measuring accuracy of the MIC, which is better than  $\pm 4\%$  of full scale reading ( $X = 1$ ) for  $0 \leq X < 0.9$ .

**Mains supply:** 115 to 230 Vrms, 50 to 60 Hz without switch-over. Power consumption max. 120 W independent of the applied voltage. Mains supply for vacuum pump, see Section 1.4.5.

**Cabinet:** 19 inch desktop/subrack cabinet with power supply for MIC.

The control cabinet and the vacuum pump are intended for operation in normal laboratory environment. However, the measuring ionization chamber may be applied in the temperature range 0-100°C.

### 1.4.2 Measuring Ionization Chamber (MIC) type EC-912-10

**General:** The MIC is designed to fulfil the specification in EN54-7 and EN14604. See Ref. [5][6].

#### Radioactive source:

Isotope: Am 241

Activity: 129.5 kBq (3.5  $\mu$ Ci)  $\pm 5\%$

Average  $\gamma$ -energy: 4.5 MeV  $\pm 5\%$

Mechanical construction: Americium oxide embedded in gold between two layers of gold. Covered with a hard gold alloy. The source is in the form of a circular disc  $\varnothing = 27$  mm, which is mounted in a holder in such a way that no open cut edges are accessible.

#### Ionization chamber:

Chamber quiescent current:  $I_{\text{CHO}} = 100$  pA

Chamber impedance:  $R_{\text{CHO}} = 1.9 \cdot 10^{11} \Omega \pm 5\%$

The characteristics are measured in aerosol free air at:

Air pressure:  $p = 1.013 \cdot 10^5$  Pa (760 mm Hg)

Air temperature:  $t = 25^\circ\text{C}$

Rel. humidity:  $h = 48\%$

Measuring time delay  $\tau$  # 10 sec. where  $\tau$  is defined as the time from the moment when the MIC is subjected to a smoke step function to the moment when the output has reached 63% of its final value. The figure for  $\tau$  is based on a flow rate of 30 l/min.

$$\text{Relative smoke sensitivity: } \frac{X}{X_{R\text{MIC}}} = 1.00 \pm 3\%,$$

where  $X_{R\text{MIC}}$  is the smoke density measured with FORCE Technologies world reference standard chamber MIC, type EC 23095-1 Serial no. 830101.

Refer to Section 5.2 and the certificate of calibration for further details.

Output: Multipole connector for the cable to the CC.

### 1.4.3 Analog MIC Control Unit (AMCU) type EC-912-20

Readout: 3.1 digit LCD display. Chamber voltage or smoke density X can be selected.

Recorder output X: 0.0 to 10.0 VDC corresponding to a smoke density X of 0.00 to 1.00.

Recorder output  $U_c$ : Approx. 14 to 25 VDC corresponding to the chamber voltage.

### 1.4.4 Intelligent MIC Control Unit (IMCU) type EC-912-25

Readout on front panel: 1 pc. LED "Power" The color of the LED is green under normal operation, red during power up and flashing red in case an error is detected.

1 pc. LED "Calibrating" The color of the LED is green under normal operation, red during calibration and flashing red in case an error is detected.

1 pc. LED "Link" The color of the LED is yellow when connected and flashing yellow when there is activity on the Ethernet.

1 pc. Ethernet interface via RJ45 connector

1 pc. USB web interface / service port

Recorder output X: 0.0 to 10.0 VDC corresponding to a smoke density X of 0.00 to 1.00.

Recorder output  $U_c$ : Approx. 14 to 25 VDC corresponding to the chamber voltage.

For further information about the IMCU please refer to the separate IMCU-manual.

### 1.4.5 Flow Control Unit (FCU), type EC-912-40

Flow rate: Adjustable between 0-50 l/min

Filter: Replaceable filter element: type EC999-01.



## 1.4.6 Vacuum Pump (VP), Thomas VTE 3, type EC-999-08

### Technical data:

Mains voltage:	230 V $\pm$ 10%, 50-60 Hz 115 V $\pm$ 10%, 60 Hz 100 V $\pm$ 10%, 50-60 Hz
Motor rating:	Approx. 0.15 kW
Capacity:	3.5 m <sup>3</sup> /h $\approx$ 58 l/min, 50 Hz 4.2 m <sup>3</sup> /h $\approx$ 70 l/min, 60 Hz
Degree of protection:	IP54
Weight:	6.5 kg
l x w x h	209 x 152 x 165 <sup>4</sup> mm

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<sup>4</sup> To top of pipe branches

# 2 Installation

## 2.1 Preparation for use

### 2.1.1 Unpacking

Unpack the smoke measuring equipment and remove tape strips etc. used for fixing during transportation.

**Check that the following items are enclosed in the shipment:**

- 1 Measuring Ionization Chamber, type EC-912-10
- 1 Allen wrench, 1.5 mm metric
- 1 P.V.C. hose (in the ordered length)
- 1 Multicable (in the ordered length)
- 1 Control Cabinet with Analog MIC Control Unit, type EC-912-20 or Intelligent MIC Control Unit, type EC-912-25) and Flow Control Unit, type EC-912-40.
- 1 Mains cord with plug.
- 1 Vacuum pump
- 1 Instruction manual in USB-stick
- 1 Certificate of calibration of the MIC chamber

Inspect the items for possible damage due to transportation and report to the forwarding agency as soon as possible if damages are found.

Check for correct voltage rating of the vacuum pump (VP).

### 2.1.2 Mains cord

Plugs corresponding to the type of electrical outlet in concern have to be mounted on the mains cord to the control cabinet and vacuum pump in accordance with the following information:

Control cabinet: 3-wire mains cord:

Brown	-	live
Blue	-	neutral
Green/yellow	-	ground (chassis)

Vacuum pump: 3-wire mains cord:  
See connection information on the lid of the terminal housing

Consult an electrician for proper mains installation.

**Note:** The MIC must be earthed through the mains connection (green/yellow wire).

### 2.1.3 Performance check using an Analog MIC Control Unit (AMCU)

Check the performance of the smoke measuring equipment as follows:

- a) Interconnect the MIC and the Control Cabinet (CC) with the multicable, the MIC connectors have yellow insulation rings. Align the code marks and push the plug gently into the connector when fitting the cable.
- b) Connect a voltmeter (range 0-10 VDC) to recorder output X on the rear of the CC.
- c) Connect the CC to the mains and switch on power. The AMCU display shall light up, the MODE indicator shall indicate Uc mode and the CAL ON indicator shall light up.
- d) Press the AMCU MODE button to indicate mode X. The AMCU display may read a value deviating from 1.00.
- e) Adjust the offset trimmer on the AMCU until the display reads 1.00. The corresponding recorder output voltage shall be 10.0 VDC.
- f) Press the AMCU CAL button. The CAL ON indicator shall extinguish. The display may read a value deviating from 0.00.
- g) Adjust the Uc trimmer on the AMCU until the display reads 0.00. The corresponding recorder output voltage shall be 0.0 V.
- h) Press the AMCU MODE button to indicate mode Uc. The display shall read a value between 14.0 and 25.0 (19.0 is typical). The voltage on recorder output Uc at the rear of the MCU shall be the same as the value on the display.
- i) Connect the Vacuum Pump (VP) and air outlet on the rear of the Flow Control Unit (FCU) with a piece of hose.
- j) Turn the flow meter needle valve in the FCU fully C.W.
- k) Connect the VP to the mains and switch on power. The ball in the flow meter on the FCU shall stay in its lowest position.
- l) Turn the flow meter needle valve C.C.W. until the middle point of the ball indicates approx. 30 1/min. Block the air inlet on the rear panel of the FCU with a finger and control that the ball drops to its lowest position. Fasten the finger screws on the filter unit and checks for leaks if this does not happen.

**Attention:** Do not remove your finger from the air inlet before the VP has been switched off and stopped. Otherwise, the ball may be damaged by collision with the flow meter needle valve.

### 2.1.4 Performance check using an Intelligent MIC Control Unit (IMCU)

Check the performance of the smoke measuring equipment as follows:

- a) Interconnect the MIC and the Control Cabinet (CC) with the multicable, the MIC connectors have yellow insulation rings. Align the code marks and push the plug gently into the connector when fitting the cable.

- b) Interconnect a PC and the IMCU with a RJ45 LAN cable or USB cable.
- c) From a Web browser enter the MIC Webpage by selecting the address 172.16.99.100.

OBS You might need to force your PC to scan the IP range from IP 172.16.99.50 (in network preferences TCP/IPV4).

The following web-page appears:

The screenshot displays the DELTA MIC Controller Web Interface. It features a blue header with the title 'DELTA MIC Controller Web Interface' and the DELTA logo. The main content is divided into three panels:

- Measurement:** Shows 'X' at 0.00, 'U<sub>C</sub>' at 17.5 V, 'Last Calibrated' as 'Calibrating (6)...', 'Auto calibrate' with a 'Start' button, 'Relay' set to 'Off' with a 'Toggle' button, and 'Set U<sub>C</sub> manually' with an 'Update' button.
- Measurement buffer:** Shows 'Oldest result' as '2021-01-21 11:33:43' and 'Results available' as '471'.
- MIC Controller Info:** Shows 'System time' as '2021-01-21 11:34:30', 'Program version' as '1.30', 'Serial #' as '001dd9', and 'Ethernet IP address' as '172.16.99.100'.

At the bottom left, there is a link for 'System setup'.

- d) The calibration is initiated by pressing the Start button. The LED “Calibrate” on the IMCU turns ON.

The Calibrate button should only be pressed, when the Measuring Ionization Chamber, MIC, is known to contain clean aerosol free air.

When the calibration is done and the MIC system is ready for normal operation, the Last Calibrated time stamp is updated.

- i) Connect the vacuum pump (VP) and air outlet on the rear of the Flow Control Unit (FCU) with a piece of hose.
- j) Turn the flow meter needle valve in the FCU fully C.W.
- k) Connect the VP to the mains and switch on power. The ball in the flow meter on the FCU shall stay in its lowest position.
- l) Turn the flow meter needle valve C.C.W. until the middle point of the ball indicates approx. 30 1/min. Block the air inlet on the rear panel of the FCU with a finger and control that the ball drops to its lowest position. Fasten the finger screws on the filter unit and checks for leaks if this does not happen.

**Attention:** Do not remove your finger from the air inlet before the VP has been switched off and stopped. Otherwise, the ball may be damaged by collision with the flow meter needle valve.

## 2.2 Installation of Measuring Ionization Chamber (MIC)

The MIC is intended for mounting on a plane surface (e.g. wall, ceiling, etc.) in the location in concern, as shown in Fig 2.2. A circular opening in the mounting surface 10-12 cm in diameter is adequate. Keep a distance of min. 12 cm to objects behind the mounting surface in order to prevent the cable and hosing from being bent sharply.

The MIC should not be mounted too close to devices which may be sensitive to air movements since the air flow through the MIC causes slight disturbances in the surrounding air. The nominal flow rate of 30 l/min. corresponds to a mean air velocity of approx. 4 cm/sec. near to the air entrance openings in the chamber housing. Since the air velocity decreases rapidly with the distance from the entrance openings, a spacing of 10 cm or more between the MIC and other devices is usually sufficient.

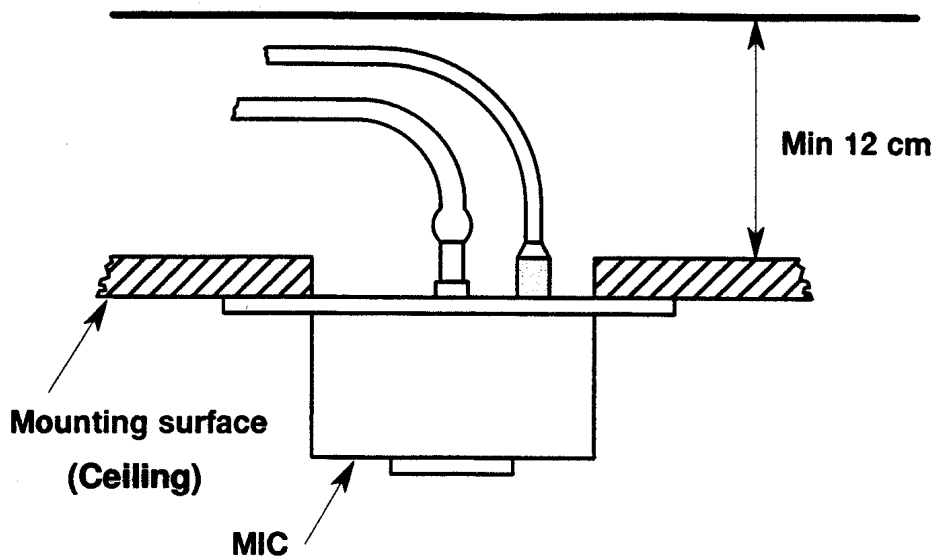


Fig. 2.2 Mounting of MIC

# MIC chamber mounting holes

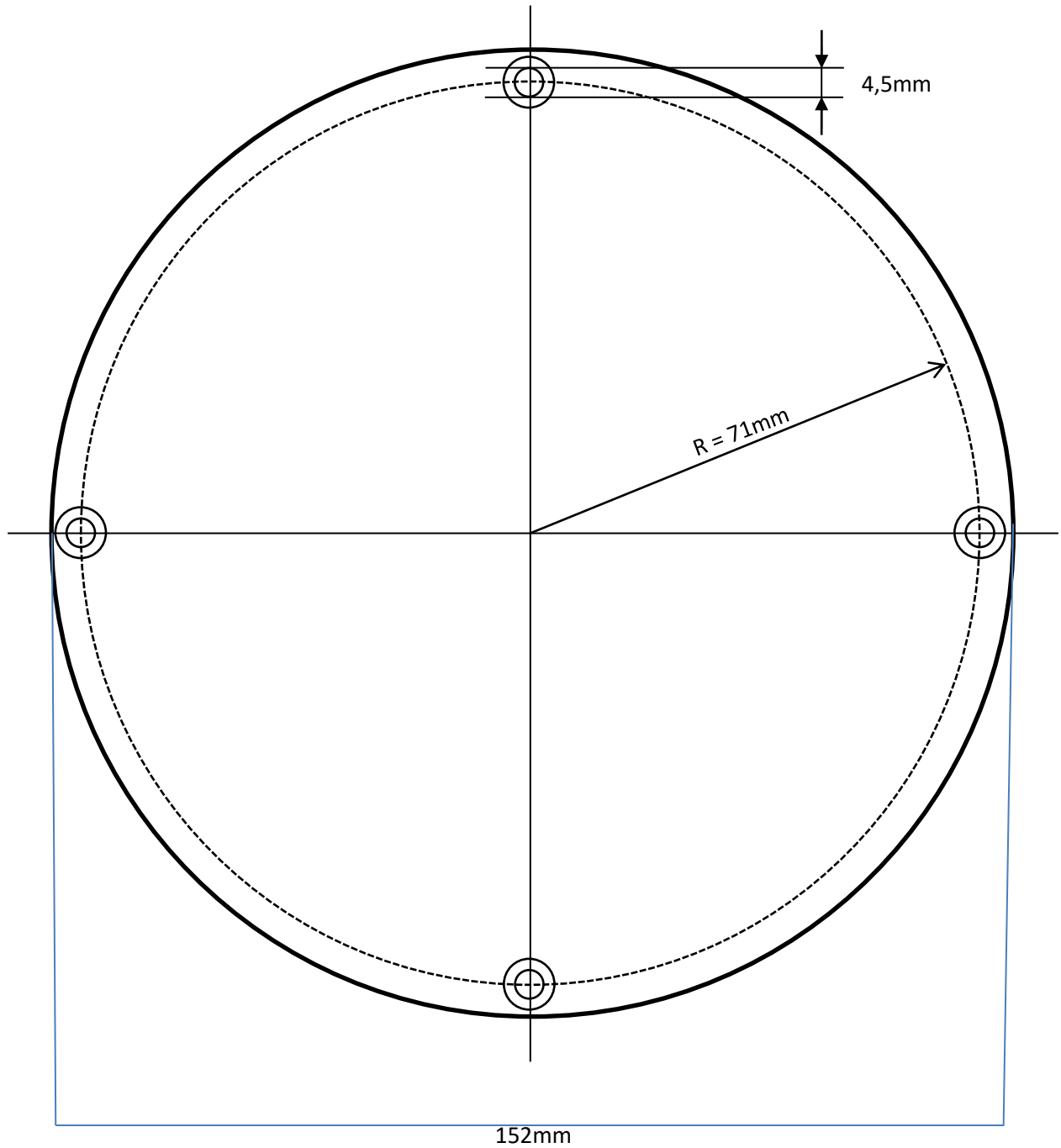


Fig. 2.3 MIC chamber mounting holes

## 2.3 Installation of Vacuum Pump (VP)

The smoke measuring equipment EC-912 is delivered with a vane-type vacuum pump Thomas type VTE 3. The VTE 3 pump is quiet in operation (noise level 58 dBA with exhaust hose). The pump is provided with a factory-set bypass valve, which prevents damage in case the inlet is blocked. An outlet is provided, from where the smoky air can be led to the outside via a hose. So, the VTE 3 pump can be placed in a suitable place in the laboratory.

Refer to the installation instructions from Thomas in: Pump spec. 2012 BA187-EN.

## 2.4 Installation of Control Cabinet (CC)

The CC is housed in a 19 inch cabinet which can be used as a desktop cabinet or as a subrack for mounting in a 19 inch rack system. The CC is delivered as a desktop cabinet with a bottom plate with four feet. If the CC is to be installed in a 19 inch rack system the whole bottom plate has to be removed, by unscrewing the four screws in the bottom plate.

# 3 Operation

## 3.1 Operating controls, connectors and indicators

The function of the controls, connectors and indicators located on the different units of smoke measuring equipment EC-912 is defined as follows:

### 3.1.1 Measuring Ionization Chamber (MIC)

**Multipole connector:** The male connector of the multicable fits into this connector. Align the code marks and push the plug gently into the connector. Do not use force. When disconnecting the cable, be sure to pull on the fluted part of the connector and never on the cable.

**Air outlet:** Pipe branch for hose to air inlet on rear of FCU.

### 3.1.2 Control Cabinet (CC)

Rear plate (see Fig. A.1.4 in Annex 1)

**Mains switch:** The mains switch is part of the EMI filter and is placed on the left side of the rear part of the cabinet.

**Connector MIC:** The female plug of the multicable fits into this connector. Align the code marks and push the plug gently into the connector. Do not use force. The plug on the cable is secured with a locking system which avoids unwanted disconnecting. When disconnecting the cable, be sure to pull on the fluted part of the connector and never on the cable.

**Sockets  $U_c$ :** The actual chamber voltage  $U_c$  is present on these sockets.

Black: Ground      Red: Output voltage  
 $14.0 \text{ VDC} \leq U_c \leq 25.0 \text{ VDC}$   
Load impedance  $\geq 100 \text{ k}$

**Sockets X:** A voltage which is proportional to the measured X signal is present on these sockets.

Black: Ground      Red: Output voltage  
0.0 VDC for X = 0.00  
10.0 VDC for X = 1.00  
Load impedance  $\geq 100 \text{ k}\Omega$

### 3.1.3 Analog MIC Control Unit (AMCU)

Front panel (see Fig. A.1.3 in Annex 1)

**MODE button:** With this button unit chamber voltage  $U_c$  and smoke or density X can be selected.

**CAL button:** When the button is pressed indicator ON light up and the MIC is now ready for offset calibration by means of the offset trimmer.



Offset trimmer: Screwdriver trimmer for offset calibration.

U<sub>c</sub> trimmer: Screwdriver trimmer for adjustment of the chamber CAL voltage.

### 3.1.4 Intelligent MIC Control Unit (IMCU)

Front panel (see Fig. A.1.5 in Annex 1). See also the separate IMCU user manual.

### 3.1.5 Flow Control Unit (FCU)

Front panel (see Fig. A.1.3 in Annex 1)

Flow meter valve: Needle valve for adjustment of air flow rate in the range 0-50 l/min. The flow rate is indicated on the flow meter and read at the middle of the ball.

Rear panel (see Fig. A.1.4 in Annex 1)

Air inlet: Pipe branch for hose to air outlet on MIC.

Air outlet: Pipe branch for hose to air inlet on VP.

Finger screws: Screws for disassembling the filter unit.

### 3.1.6 Vacuum Pump (VP)

Air inlet: Pipe branch for hose to air outlet on rear of FCU.

Air outlet: Pipe branch for hose to appropriate place.

Bypass valve: Valve for adjustment of minimum pressure. The bypass valve is fitted to ensure that the pressure does not drop below 150 mbar, when the inlet is blocked. Before delivery of a new vacuum pump from FORCE Technology, the bypass valve is adjusted to a minimum pressure of approx. 500 mbar. This setting is locked with lacquer and should not be changed.

## 3.2 Smoke density measurements

### 3.2.1 Measuring set-up

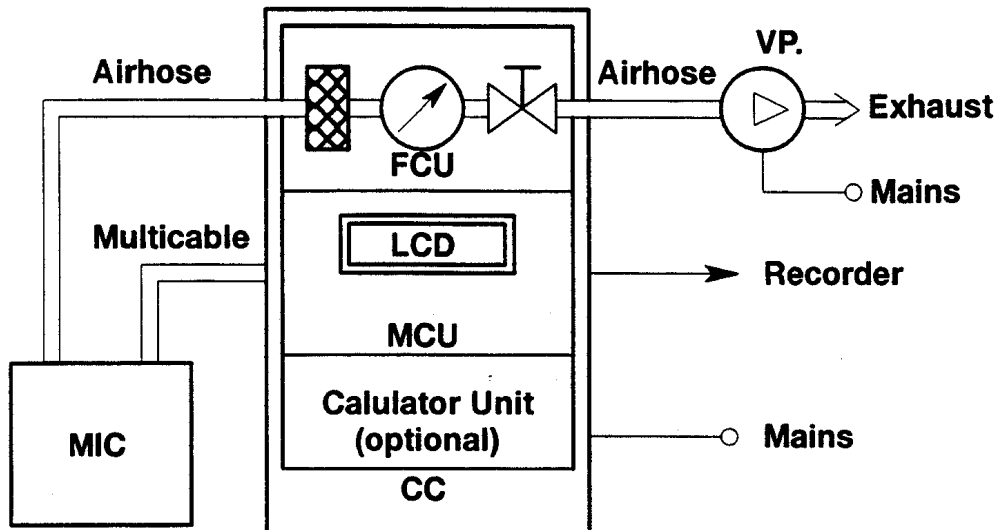


Fig. 3.2.1 Measuring set-up principle

#### Connections:

- Air hose between air outlet on MIC and air inlet on FCU.
- Air hose between air outlet on FCU and air inlet on VP.
- Multicable between MIC and the MIC connector on the rear of the CC.
- Cable to recorder from outputs at the rear of the CC (if used).
- Mains cord for VP and CC.

### 3.2.2 Measuring procedure with AMCU

- Turn the flow meter needle valve in the FCU fully C.W.
- Switch on the mains to the VP and turn the needle valve on the FCU slowly C.C.W. until the flow meter reads 30 l/min. Rate of flow is read at the middle point of the ball.
- Switch on the mains on the control cabinet and allow the instrument to stabilise for at least 15 min.
- Press the MODE button on the AMCU to indicate mode X.

- e) Press the CAL button on the AMCU (CAL ON indicator lights up) and adjust the offset trimmer until the display reads 1.00 or the recorder output X is 10.0 VDC.
- f) Press the CAL button again (CAL ON indicator extinguish) and adjust the U<sub>c</sub> trimmer on the AMCU until the display reads 0.00 or the recorder output X is 0.0 VDC.
- g) Subject the MIC to the smoke exposure the density of which shall be measured.
- h) Subject the MIC to aerosol-free air and repeat point e) and f) before the next smoke density measurement. Also check the rate of air flow, point b).

For measuring procedure when using an Intelligent MIC Control Unit please refer to the separate IMCU user manual.

## 4 Theory of operation

### 4.1 General working principle for ionization chambers for smoke density measurements

The use of ionization chambers as smoke sensors is well known and the associated theory outlined in the literature.

The working principle for the ionization chamber for smoke density measurements is shown in Fig. 4.1.

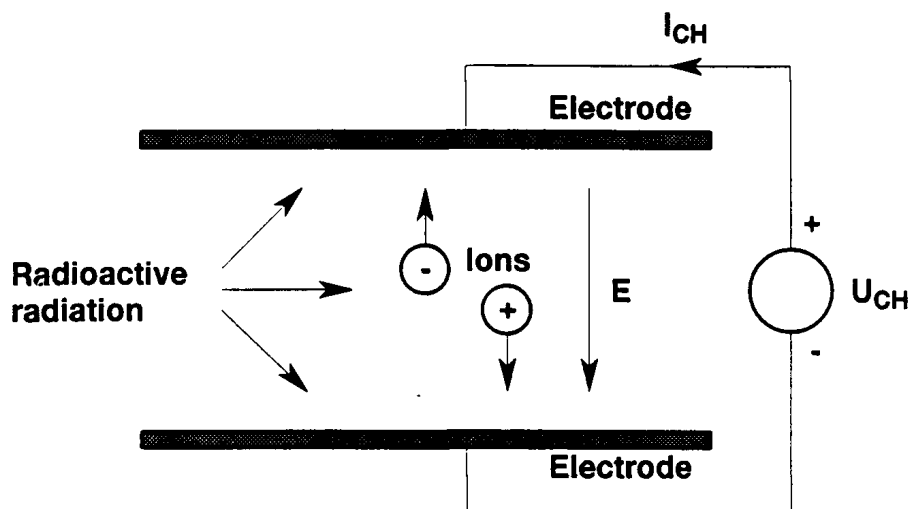


Fig. 4.1 Working principle for ionization chamber

The chamber consists of a pair of electrodes between which a volume of atmospheric air is present. The electrodes are connected to a voltage source  $U_{CH}$  so an electrical field  $E$  is applied to the air. Radioactive radiation from a small radioactive source bombards the air and ion pairs are created between the electrodes. The positive and negative air molecules forming the ion pairs are deflected towards the negative and positive electrode, respectively. Some of the ions recombine before they reach the electrode surfaces and become neutral air molecules. Other ions exchange electrons with the electrode surfaces. This electron exchange results in a small electrical current  $I_{CH}$  in the external circuit.

When the air between the electrodes is clean, the ions formed move to the electrode with a certain mean velocity and each ion which does not recombine in the volume contributes to the current. However, if smoke particles penetrate the volume between the electrodes, the ions and the smoke particles will be attached to each other with a certain probability. Since the smoke particles are much heavier than the ions, the mobility of ions attached to smoke particles is greatly reduced and the probability for recombination increased. So, their contribution to the external current becomes negligible. Thus the external current is a function of the smoke particle density in the measuring volume.

The smoke density can be defined in terms of X as follows:

$$X = \frac{I_{\text{CHO}} - I_{\text{CH}}}{I_{\text{CHO}}} \quad (0 \leq X \leq 1) \quad (4.1.1)$$

$I_{\text{CHO}}$  [A] is the chamber quiescent current (clean air)

$I_{\text{CH}}$  [A] is the chamber current when smoke is present

It appears from eq. 4.1.1 that  $X = 0$  in clean air and  $X = 1$  when the smoke density is infinite.

Smoke density can also be expressed in Y-values which are related to the X-values as follows [1]:

$$Y = X \cdot \frac{2 - X}{1 - X} \quad (4.1.2)$$

The Y-value can also be transferred to a value related to a chamber voltage of 20 V. This  $Y_{20}$ -value is related to the Y-value as follows:

$$Y_{20} = \frac{Y}{U_c} \cdot 20 \quad (4.1.3)$$

The advantage of expressing the smoke density in terms of Y and  $Y_{20}$ -values is that these values are proportional to the number of smoke particles per unit volume.

Besides smoke density, the X, Y, and  $Y_{20}$ -values depend on the design of the ionization chamber and a number of environmental parameters.

So, the readings obtained from different ionization chamber configurations cannot be compared unless the correction factor for the chambers is known, e.g. from calibration.

## 4.2 Measuring Ionization Chamber (MIC)

### 4.2.1 Ionization chamber design

The MIC has a parallel plate electrode configuration in which the radioactive source (Am 241) is part of one of the electrodes. This configuration provides a measuring volume in which the ionization is uniform and approx. parallel to a constant electrical field.

The air is sucked through the chamber in order to reduce wind dependence, but the air in the measuring volume between the electrodes is stationary since the sucked air flows in a duct which is separated from the measuring volume by means of a wire mesh. Smoke is transferred from the air flow to the measuring volume by diffusion.

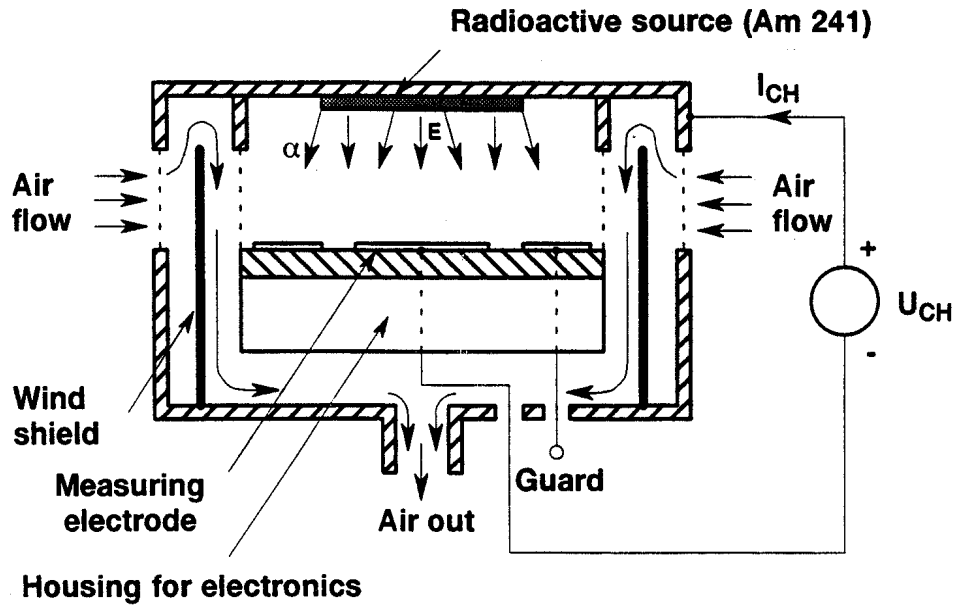


Fig. 4.2.1 Principle of ionization chamber design in the MIC

The radioactive source is mounted in a holder which may be unscrewed for cleaning purposes, refer to Section 5.1.1.

The chamber is operated in the proportionality range with a clean air quiescent current of  $10^{-10}$ A (100 pA) corresponding to a chamber voltage of approx. 19 V.

### 4.3 Electronics for impedance transformation

An impedance transforming circuit is built into the MIC. The principle of the impedance transforming circuit is shown in Fig. 4.2.2. The circuit converts the ionization current at a high impedance level to a proportional voltage at a low impedance level. So, the length of the connecting cable between the MIC and the CC becomes uncritical.

The relay, which is shown in Fig. 4.2.2, is used for calibration of the impedance transforming circuit and the MCU. This facility will be described in Section 4.4.

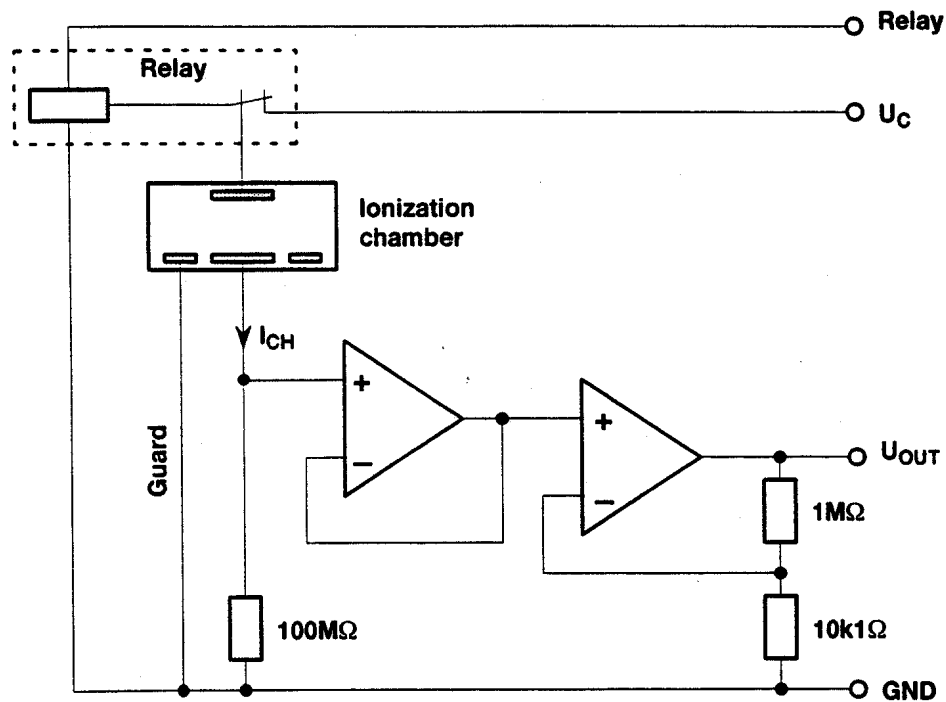


Fig. 4.2.2 Principle of MIC impedance transforming circuit

## 4.4 Analog MIC Control Unit (AMCU)

The low impedance voltage from the MIC is first amplified 100 times by a differential amplifier. Then the voltage is inverted and the offset voltage set by the offset trimmer on the front of the MCU is added. This resulting voltage is transferred to the display and the recorder output X when the AMCU is in X mode.

During calibration the relay in the MIC disconnect the chamber voltage and the chamber current becomes zero. The voltage to the MCU also becomes zero and the offset trimmer is then used to adjust the X value to 1.00.

The voltage from the  $U_C$  trimmer is amplified and used for adjustment of the chamber voltage in the MIC. The chamber current is proportional to the applied chamber voltage and the chamber voltage is used to adjust the chamber current to 100 pA in aerosol free air. A chamber current of 100 pA equals hence an X value of 0.00.

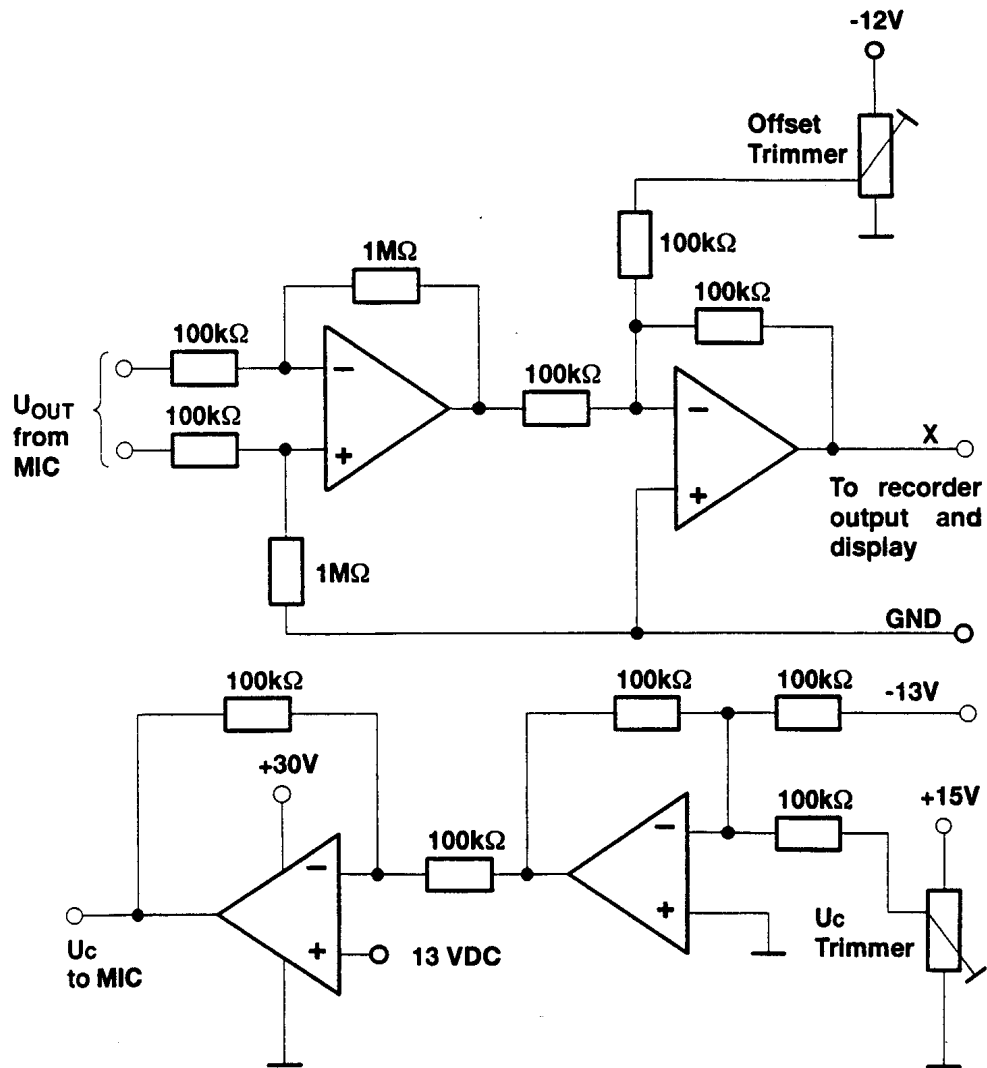


Fig. 4.2.3 Principle of AMCU analogue circuit

## 4.5 Intelligent MIC Control Unit (IMCU)

Please refer to separate IMCU user manual



# 5 Maintenance and service

## 5.1 Periodic maintenance

### 5.1.1 Measuring Ionization Chamber (MIC)

The MIC should be cleaned at regular intervals since smoke deposits in the ionization chamber especially on the radioactive source and the electrode assembly can affect the measuring characteristics. Smoke deposits on the radioactive source will increase the clean air chamber resistance while smoke on the electrode assembly may cause leakage currents.

#### **Cleaning of the radioactive source:**

The holder for the radioactive source may be unscrewed for cleaning, without dis-mounting other parts of the MIC, by loosening the locking screw (refer to Fig. A.1.2 in Annex 1) and unscrewing the source holder. Make sure that the serial number of the source corresponds to the ionization chamber (see note in Section 5.2).

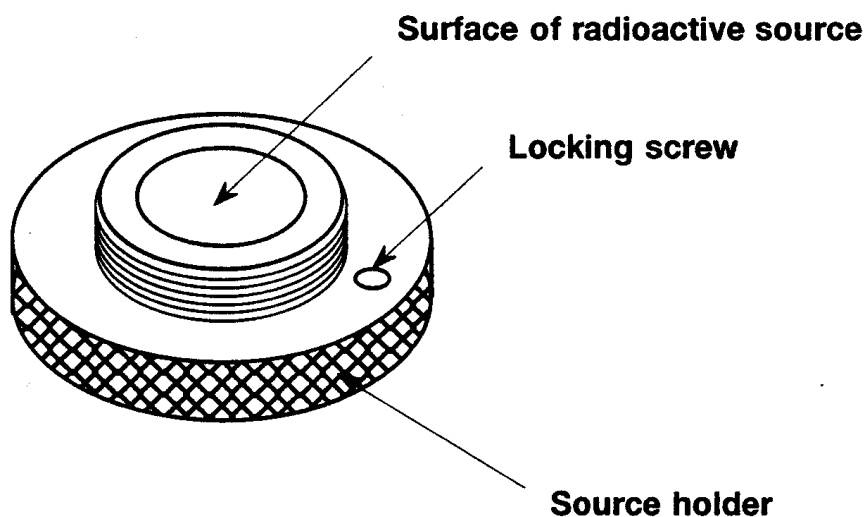


Fig. 5.1.1 Holder with radioactive source

#### **The following procedure and precautions should be followed for radiation pro-tECTION reasons:**

- a) Never touch the surface of the radioactive source (see Fig. 5.1.1) with your fingers, use disposable gloves during the work.
- b) Avoid scratching the surface with hard metal tools or the like.
- c) Keep a distance of at least 10 cm from the unscrewed source holder to your eyes.
- d) Do not take the source holder apart.
- e) Clean the surface of the source with paper tissues wetted with alcohol. Do not touch the tissues with your fingers, use plastic tweezers.

- f) Dispose the tissues in a metal container marked "radioactive disposal". Leave the container to the competent national authority for destruction when filled up.
- g) Never leave the source holder on the table after cleaning. Screw it into the MIC and fasten the locking screw.
- h) Wash your hands after having cleaned the radioactive source.

#### **Cleaning of ionization chamber:**

Attention should be given to the fact that the insulating materials (polycarbonate<sup>5</sup>) in the MIC, especially the electrode support plate can be attacked by a number of liquids. So, it is highly recommended to follow the procedure below. Modern cleaning techniques, such as ultrasonic, should not be used. Furthermore, the amount of cleaning liquid should be kept to a minimum to avoid ingress to the electronic housing.

For your information a list of liquids to which polycarbonate is claimed to be resistant, respectively not resistant is given below. The list should not be regarded complete.

#### **Polycarbonate is resistant to:**

Alcohol (Ethanol)  
Benzine  
n-Butyl or sec-Butyl Alcohol (1- or 2-Butanol)  
Cyclohexane  
Acetic Acid, 10%

#### **Polycarbonate is NOT resistant to:**

Bases  
Organic Solvents  
Acetone  
Chloroform (Trichloromethane)  
Carbon Tetrachloride (Tetrachloromethane)  
Toluene  
Xylene

- a) Dismount the MIC housing by loosening the three screws around the holder for the radioactive source and gently pulling the housing from the mounting plate.
- b) Clean the inside of the housing with paper tissues with a little alcohol. The radio-active source shall be unscrewed and cleaned separately as described above.
- c) Clean the measuring electrode, the guard ring and the insulating electrode support plate with paper tissues with a little alcohol, avoid excessive liquid.
- d) Allow the parts of the MIC to dry before assembling.

#### **Assembling:**

Be careful not to leave any fingerprints or other impurities on the internal parts of the MIC during assembling.

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<sup>5</sup> Brand names: LEXAN, MAKROLON

- a) Assemble the MIC by pressing down the housing and aligning the three distance pieces with the three holes in the housing and fasten the screws. Make sure that the alignment marks on the housing and mounting plate match.
- b) Screw the holder with radioactive source in the top of the housing and fasten the locking screw (Allen screw 1.5 mm, metric).

### 5.1.2 Analog and Intelligent MIC Control Unit (AMCU and IMCU)

No maintenance of the AMCU and the IMCU is required.

### 5.1.3 Flow Control Unit (FCU)

The maintenance of the FCU concerns cleaning of the flow meter and needle valve and exchange of filter element.

#### Cleaning of flow meter:

Before cleaning the flow meter is has to be dismantled from the FCU and disassembled in the following way:

- a) Remove the FCU from the CC by loosen the four screws in the front plate, remove the two air hoses from the pipe branch on the rear plate and on the filter and pull out the FCU by pressing on the filter unit.
- b) Remove the four screws in the rear plate, loosen the hose connections on the flow meter and remove the rear plate with the filter and the two hoses.
- c) Loosen the four screws holding the flow meter mounting plate and pull back the mounting plate with the flow meter approx. 5 cm. The screws are accessible through holes in the two side profiles of the FCU and can slice in the two slices in the side profiles.
- e) Remove the two screws holding the flow meter to its mounting plate and pull out the flow meter.
- d) Turn the flow meter needle valve fully C.C.W. and pull out the needle. Remove the upper hose connector and unscrew the rest of the needle valve with a 16 mm ratchet socket.
- e) Remove the screw on the top of the flow meter and take out the ball by inverting the flow meter and allowing the ball to fall into your hand.

The flow tube, needle valve and ball can now be cleaned with a little pure soap and wa-ter and a bottle brush. Avoid the use of benzene, acetone, carbon tetrachloride, alkaline detergents, caustic soda, liquid soaps which may contain chlorinated solvents, etc. and avoid prolonged immersion. Remove the soap water by rinsing with clean water and allow the flow meter to dry before assembling.

To assemble the flow meter and the FCU just follow the above instructions in the op-posite order. A little stop cock grease or petroleum jelly on the O-rings will help main-tain a good seal as well as facilitate assembly.

### Exchange of filter element:

The filter unit is incorporated in the FCU to reduce the smoke deposits in the flow me-ter. The filter element can be exchanged by dismounting the removable part of the filter unit on the rear of the FCU (refer to Fig. A.1.4 in Annex 1). The filter unit is intended for filter element EC 999-01 manufactured by FORCE Tehnology. This part is pressed into the fixed filter unit and the filter unit assembled. (Refer to Fig. 5.1.2).

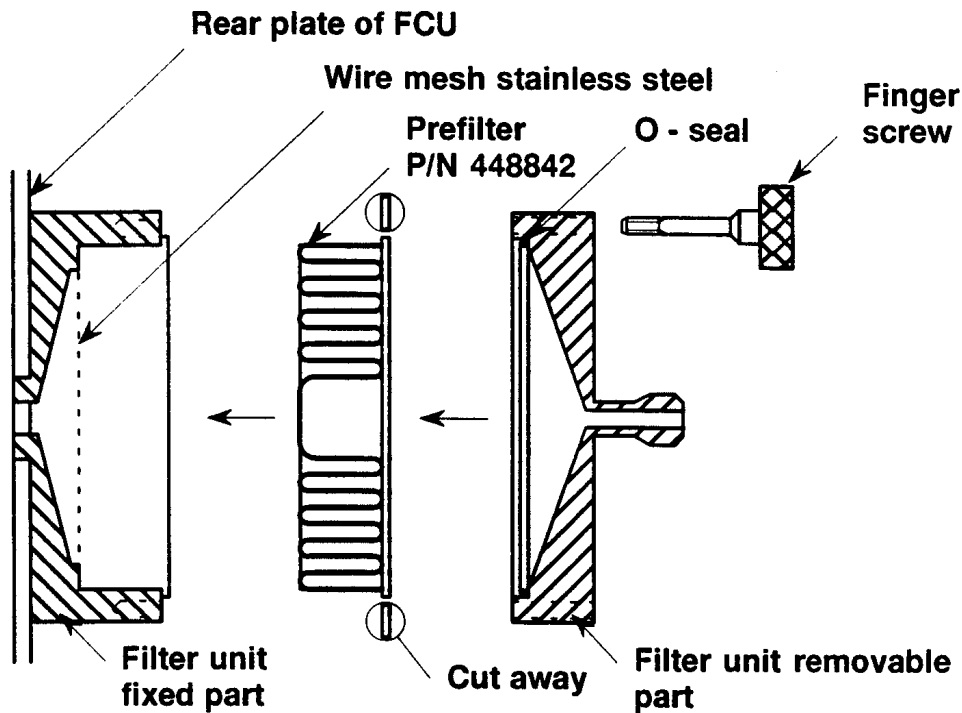


Fig. 5.1.2 Exchange of filter element

The filter element may be blocked by smoke more or less rapidly depending on the type of smoke measured. In some applications it may be more practical to replace the MSA filter with a 10-12 mm thick polyurethane filter cut circular with a diameter of 68 mm.

The consequence of this is of course that cleaning of the flow meter is needed more of-ten. A filter combination which prevents smoke deposits in the flow meter and gives acceptable operating times without filter exchange should be aimed at.

When assembling the filter unit make sure that the O-seal remains in position in the removable part.

Check the filter unit for tightness by the method outlined in Section 2.1.3 k) and l), after assembling filter unit.

### 5.1.4 Vacuum Pump (VP)

The Thomas type VTE 3 pump contains an inlet filter and rotor blades which should be checked regularly. The rotor blades may be replaced by new blades when necessary.

## 5.2 Periodical calibration of the MIC

To ensure that the MIC measures correctly we highly recommend calibrating your MIC system, in regular intervals no longer than 2 years, against FORCE Technology's world reference MIC for smoke measurements.

The test procedure, the setup and the results of the smoke calibration are documented in 2 Certificate of Calibration – one measured before cleaning, and one measured after .

The MIC contains a radioactive source and the manufacturer specifies that the RWL (Recommended Working Life) of the source is 10 years calculated from the date of first use. However the life time may be extended, when routine inspections are performed on a regular basis.

Before we deliver any MIC, the radioactive source is examined and checked for any leakage by executing a WIPE-test according to ISO 9978:1992, clause 5.3.1.

The WIPE test of the radioactive source ensures that the MIC is safe to use for a period of up to 2 more years.

**Note:** Before the smoke calibration, the electrode distance and the active area of the radioactive source of the individual measuring ionization chambers have been adjusted. So the serial number of the radioactive source must correspond to that of the MIC.

## 5.3 Possible errors and hints

### 5.3.1 Flow system

If it is not possible to adjust the flow rate on the flow meter to 30 l/min then there is either a leak or a block in the VP, the FCU or the hose connections. First check the performance of the VP and the FCU as described in Section 2.1.3 point i) to l) by using a short new piece of hose. If the performance of the VP and FCU is OK there is either a leak or a block in the hose connections. Inspect the hose connections for a possible leaks or blocks and replace the damaged hose connection. If the performance of the VP and MCU is not OK then there is probably a block in the filter for the MCU, in the flow meter or in the filter for the VP. Refer to Section 5.1.3 for cleaning of flow meter and exchange of filter element in the FCU.

### 5.3.2 Electronics

The mains fuse is located in the mains plug assembly which is placed on the left side of the rear part of the CC. First remove the mains plug and then remove the fuse holder with a screwdriver.

Recorder output X should follow the reading on the display with a factor of 10. If this is not the case then either the load impedance on the recorder output is too low (load impedance >100 k $\Omega$ ) or the AMCU / IMCU electrical circuit is malfunctioning. Refer to Section 5.4 if the latter is the matter.

If the chamber voltage  $U_c$  necessary for calibrating the MIC is greater than 25 V, the radioactive source is probably covered with smoke deposits and needs cleaning. Refer to Section 5.1.1 for cleaning of the radioactive source.

### 5.3.3 Electrical leakage

The leakage current in the MIC can be checked by dismounting the holder for the radioactive source as described in Section 5.1.1 and following the below procedure:

- a) Press the MCU MODE button to indicate mode U<sub>c</sub> and adjust the U<sub>c</sub> trimmer on the MCU until the display reads 25.0.
- b) Press the MCU MODE button to indicated mode X.
- c) Press the MCU CAL button. The CAL ON indicator shall light up.
- d) Adjust the Offset trimmer on the MCU until the display reads 1.00.
- e) Press the MCU CAL button. The CAL ON indicator shall extinguish
- f) Notice the display reading XLEAK.

The leakage current in the MIC is:  $I_{LEAK} = 100 \cdot (1.00 - XLEAK) [\mu A]$

The leakage current in the MIC should be less than 1 pA. If the leakage current in the MIC is greater than 1 pA the electrode assembly is probably covered with smoke de-posits and needs cleaning. Refer to Section 5.1.1 for cleaning of ionization chamber.

## 5.4 Spare parts

The following spare parts can be ordered separately:

Type:	Designation
EC-999-01	Air filters for flow control unit (20 pcs)
EC-999-08	Vacuum pump VTE 3 complete with adjusted reduction valve
EC-999-09	PVC hose, 15m standard
EC-999-10	MIC cable, 10m standard (other lengths upon request)
EC-999-12	Maintenance kit for vacuum pump (1 filter, 2 sealings, 4 blades)
EC-999-13	Set of O-rings for Flow Control Unit
EC-999-40	Flow Control Unit complete with air filter
EC-912-20	Analog MIC Control Unit (AMCU)
EC-912-25	Intelligent MIC Control Unit (IMCU)

## 5.5 FORCE Technology contact information

If you need any assistance for calibration, spare parts or repair of your MIC, please contact:

FORCE Technology

Venlighedsvej 4

DK-2970 Hørsholm

Denmark

Tel. +45 72 19 40 00

e-mail: [MICSales@forcetechnology.com](mailto:MICSales@forcetechnology.com)

WWW: <http://MIC.madebydelta.com>

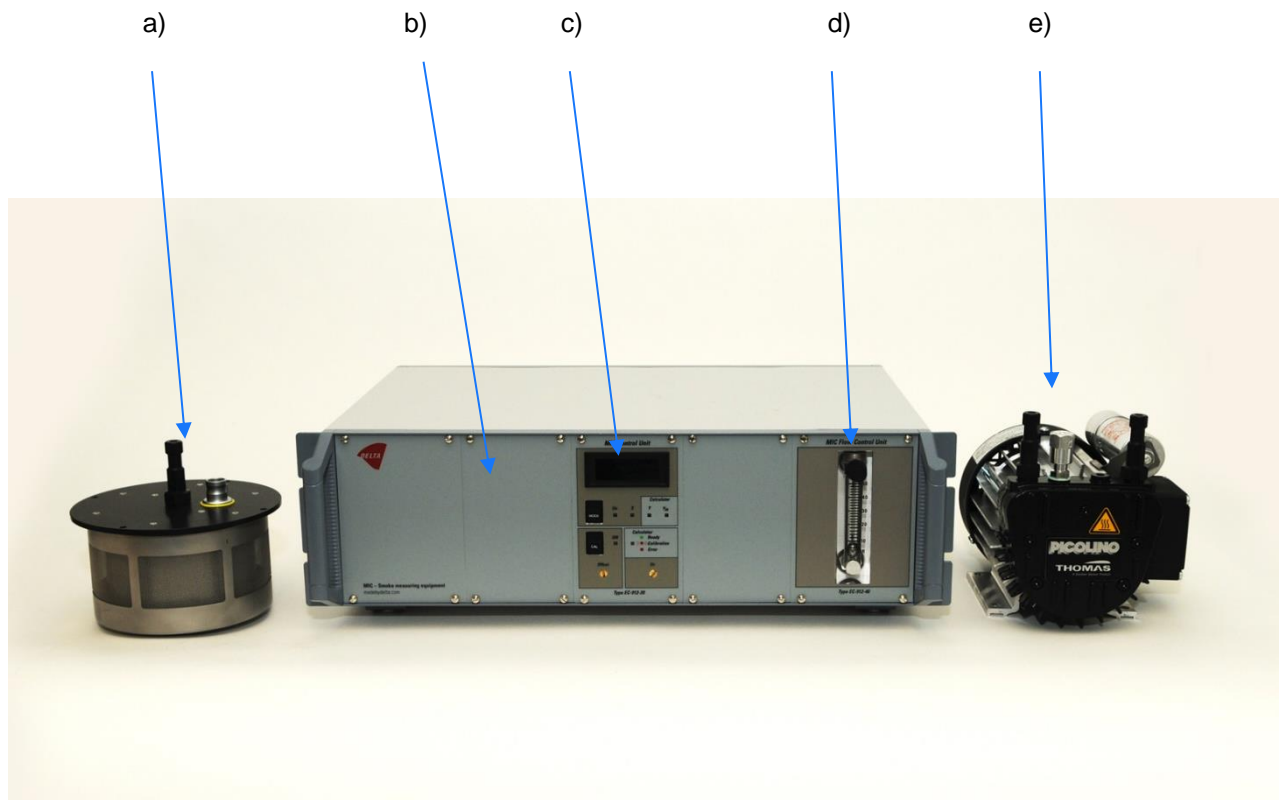
## 6 References

- [1] **H.H. Gilson & J.P. Hosemann:**  
Messkammer nach dem Kleinionen-an-lage-rungs-princip zum quantitativen Nachweis von Aero-solpartikeln. Forschungsberichte des Landes Nordrhein-Westfalen Nr. 2336 Westdeutscher Verlag Opladen 1973.
- [2] **A. Scheidweiler, Cerberus AG:**  
The ionization chamber as smoke-dependent resistance.
- [3] **A. Scheidweiler, Cerberus AG:**  
Description of the Measuring Ionization Chamber (MIC).
- [4] **P.E. Burry:**  
Standard Ionization Chambers. Tagungsbericht zum 7. internationalen Vortragsseminar über Probleme der automatischen Brandentdeckung, Aachen 5. und 6. März 1975. Page 243-255.
- [5] **CEN, European Committee for Standardization:**  
EN14604: Smoke alarm devices.
- [6] **CEN, European Committee for Standardization:**  
EN54-7: Point type smoke detectors. Detectors using scattered light, transmitted light or ionization.
- [7] **M. Avlund:**  
ECR-71: Reference Measurements of Smoke Density, ElektronikCentralen, May 1977.
- [8] **Underwriters Laboratories Inc.**  
UL 217, single and multiple station smoke alarms.
- [9] **Underwriters Laboratories Inc.**  
UL 268, smoke detectors for fire protective signalling systems.



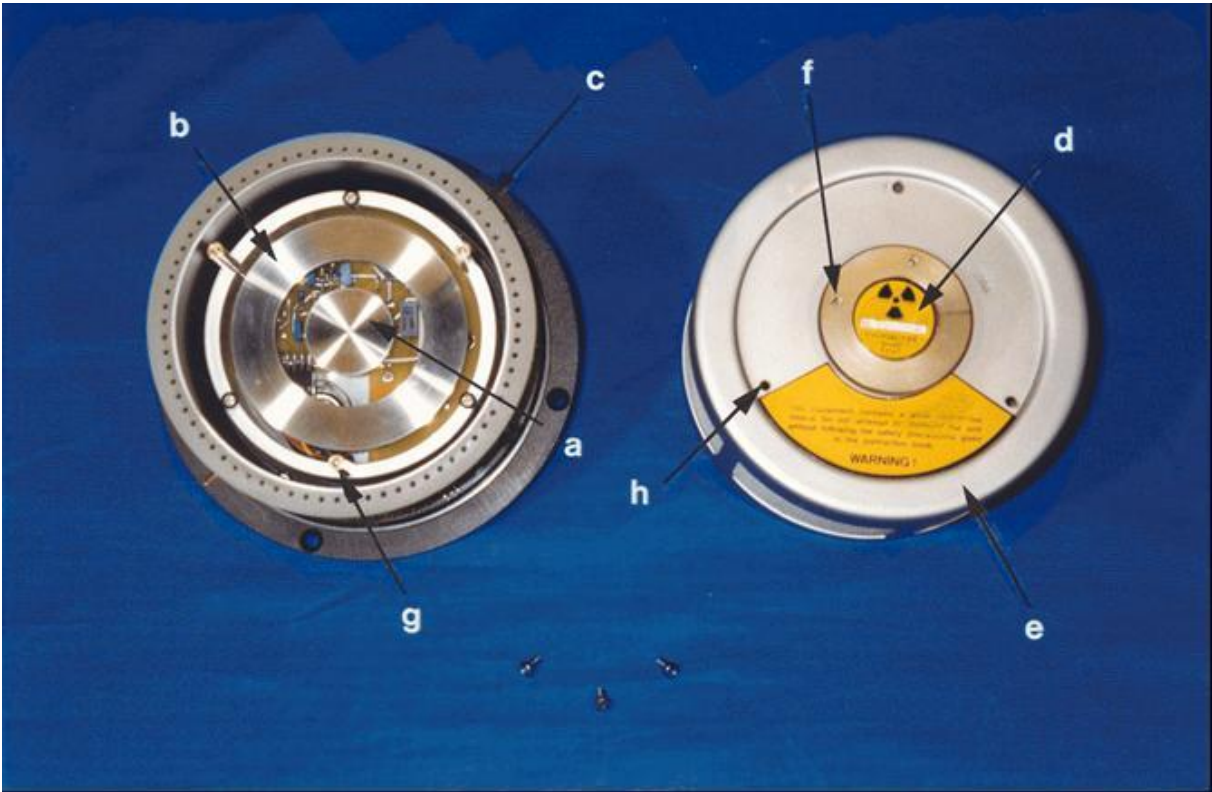
# Annex 1 Figures

Figure A.1.1. Smoke measuring equipment EC-912



- a) Measuring Ionization Chamber (MIC), type EC-912-10
- b) Control Cabinet (CC), type EC-999-04
- c) Analog MIC Control Unit (AMCU), type EC-912-20 or  
Intelligent MIC Control Unit (IMCU), type EC-912-25
- d) Flow Control Unit (FCU) EC-912-40
- e) Vacuum Pump, (VP) Thomas VTE 3, type EC-999-08

Figure A.1.2. Measuring Ionization Chamber (MIC) EC-912-10 with chamber housing re-moved



- a) Measuring electrode
- b) Guard ring
- c) Wind shield
- d) Radioactive source holder
- e) Chamber housing
- f) Locking screw for radioactive source holder
- g) Distance pieces for chamber housing
- h) Holes for screws to distance pieces

Figure A.1.3. Analog MIC Control Unit (AMCU) type EC-912-20

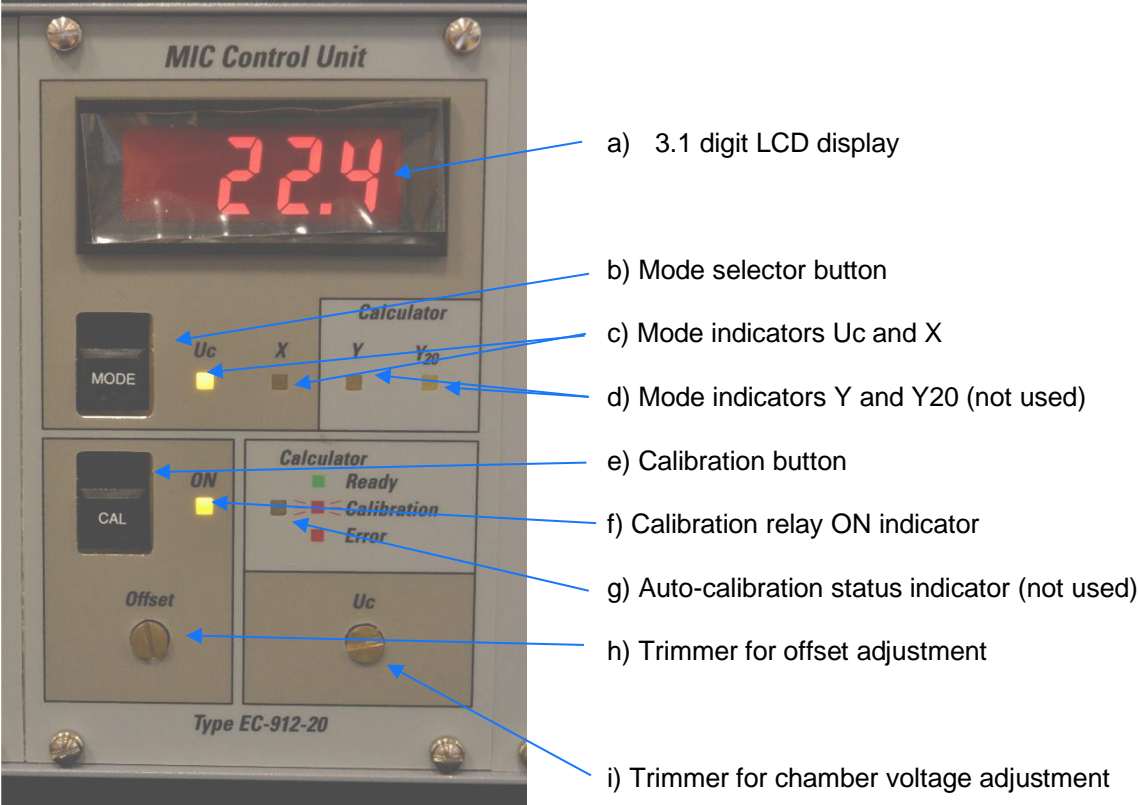
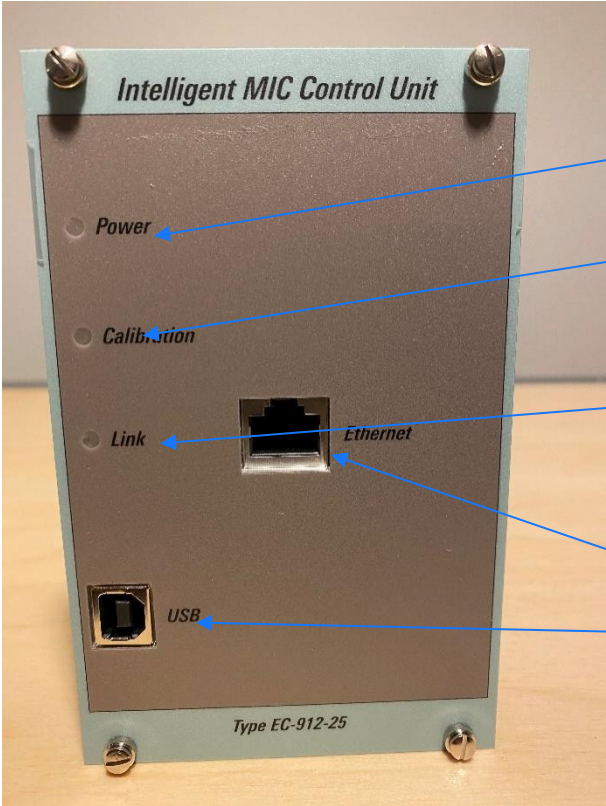


Figure A.1.4. Intelligent MIC Control Unit (IMCU) type EC-912-25



- a) LED "Power" The color of the LED is green under normal operation, red during power up and flashing red in case an error is detected.
- b) LED "Calibrating" The color of the LED is green under normal operation, red during calibration and flashing red in case an error is detected.
- c) LED "Link" The color of the LED is yellow when connected and flashing yellow when there is activity on the Ethernet.
- d) Ethernet interface via RJ45 connector
- e) USB web interface / service port

Figure A.1.5. Flow control unit type EC-912-40

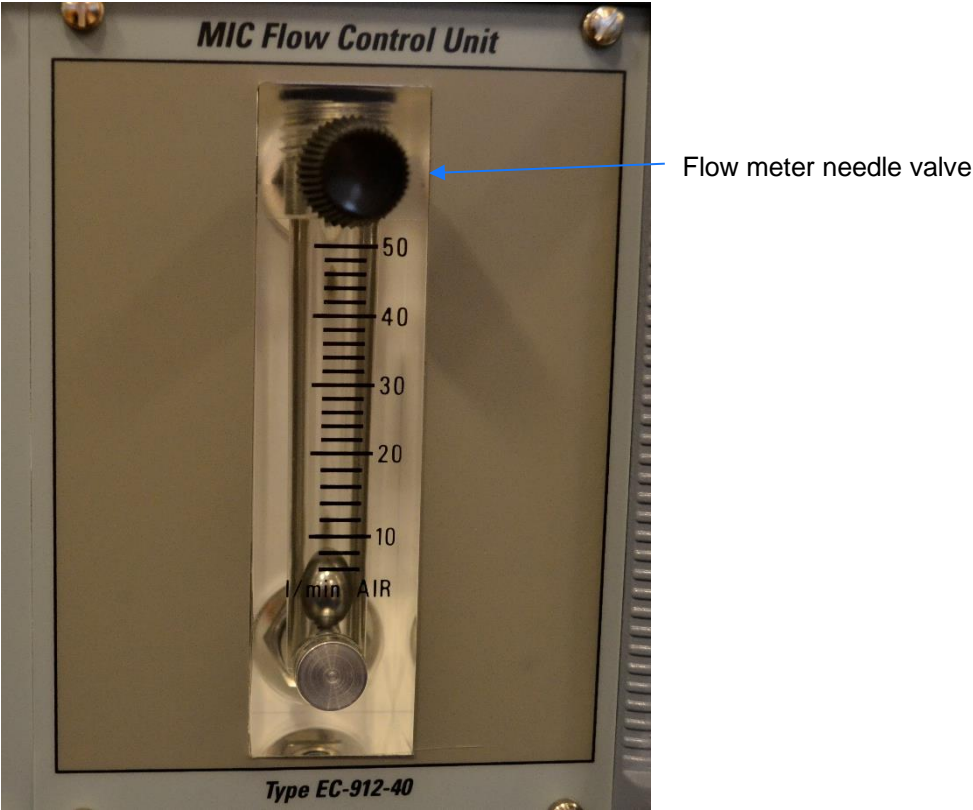
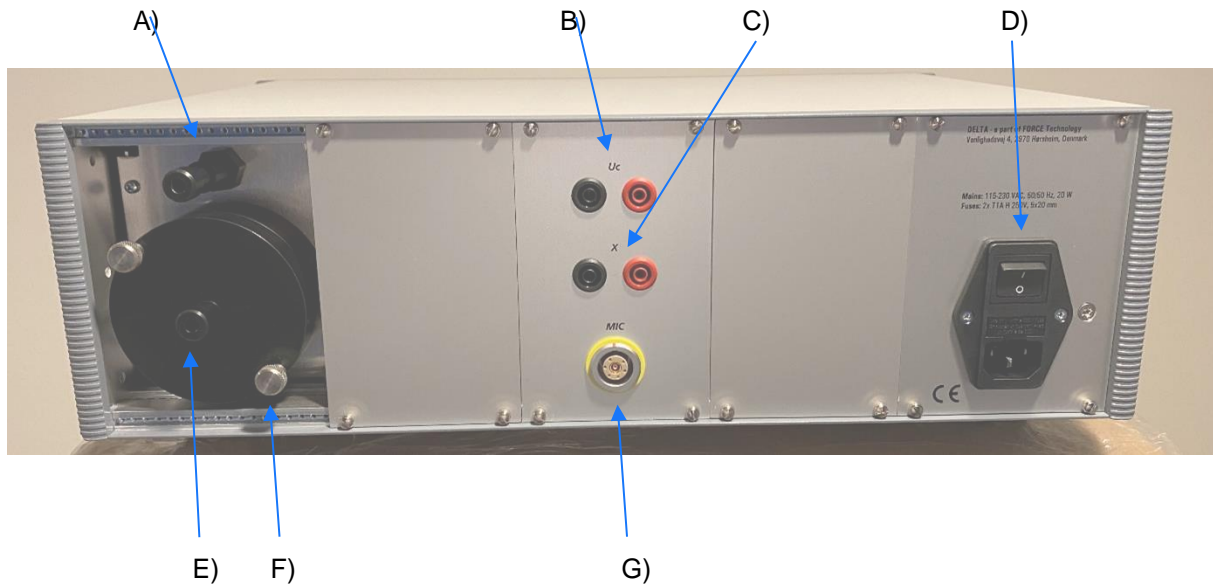


Figure. A.1.6. Rear of control cabinet EC-910-10



- A) Air outlet pipe branch for hose to vacuum pump
- B) Analogue recorder output for chamber voltage  $U_c$
- C) Analogue recorder output for smoke density  $X$
- D) EMI filter with mains switch, mains socket and fuse holder
- E) Air inlet pipe branch for hose from MIC
- F) Finger screws for disassembling of filter unit
- G) Connector for multicable to MIC