ECMA
EUROPEAN COMPUTER MANUFACTURERS ASSOCIATION

INFORMATION TECHNOLOGY EQUIPMENT RECOMMENDED MEASURING METHOD FOR OZONE EMISSION

ECMA TR/56

June 1991

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Brief History

In 1988, ECMA published Standard ECMA-129, Safety of Information Technology Equipment. This standard contained a section, section IV, describing future requirements for safety and safety assessment.

One of the clauses of this section, defined a method for the measurement of ozone emission.

This method was subsequently submitted to IEC TC74 as a technical contribution. A number of comments were received in this occasions, and these were used to improve the method.

Subsequently, ECMA TC12, Safety, agreed that it was time that the measuring method be given a more formal presentation. In view of the fact that no limits for ozone emission are defined, it was agreed that this document be presented as an ECMA Technical Report rather than a Standard. The document was therefore submitted to the ECMA GA for approval.

Adopted as ECMA TR/58 by the ECMA General Assembly on 13th June 1991

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1 Scope

This ECMA Technical Report defines a method for the measurement of ozone emission from Information Technology Equipment.

2 General

Standard ECMA-129 and of IEC Publication 950 state, in 1.7.2, that the concentration of ozone shall be "limited to a safe value".

It is expected that these standards will be modified to indicate that, for equipment that may produce ozone, the installation instructions shall state the minimum space to be allocated for each equipment in a room without mechanical ventilation. It is expected that this value will be based on a maximum room concentration of ozone of 0,2 $mg.m^{-3}$ (0,1 ppm).

For cases where the minimum space is not available, the manufacturer shall provide instructions for additional precautionary measures. These may include additional ventilation, ozone filters or control of the rate of utilization of the equipment (and thus of the rate of production of ozone.). For these reasons, the manufacturer shall have available the results of measurement of the equipment ozone emission rate.

In a modern office with a range of complex machinery being used there, the employer must rely increasingly on the manufacturers of the equipment for help in discharging his responsibilities. Chemical emission data are necessary if the employer is to maintain a healthy environment. The manufacturer must provide both the identity of any hazardous chemical being emitted from the equipment and the quantity, rate or effect of that emission.

However the actual concentration of a chemical in the air around a piece of equipment during a day of operation will depend on several factors:

- the equipment utilisation rate;
- the environment in which the equipment is operated (e.g. room size, ventilation);
- the emission rate of the chemical from the equipment.

It is impossible to reproduce the operating modes and conditions of every customer to provide test data. Equally a "standard operating mode" in a "standard test environment" is unlikely to approximate more than a small percentage of actual placements. Even if the latter were adopted it would not enable the effect of multiple installations to be estimated. For multiple installations of equipment from different suppliers there is a need for data which can be used to predict interactions. A prerequisite is a uniform method of data generation and interpretation.

3 References

ECMA-129	Safety of Information Technology Equipment (1988)
IEC 950 : 1991	Safety of Information Technology Equipment including Electrical Business Equipment

4 Definitions

For the purpose of this Technical Report the following definitions apply.

4.1 Equipment utilisation rate

The time during which ozone is produced by the equipment, expressed as a percentage of an 8-hour working day.

4.2 Emission characteristics

The effective ozone emission rate divided by the allocated room volume. Measured in mg.min^{-1}.m^{-3}.

4.3 Effective ozone emission rate

The generation rate of ozone during continuous operation. Measured in mg.min^{-1}.

5 Description of the measuring method

This method is intended to determinate the effective ozone emission rate. The effective ozone emission rate is the generation rate (in mg.min^{-1}) of ozone during continuous operation. This parameter is only dependent on the machine and independent of placement factors (e.g. room size, ventilation).

The determination of the effective ozone emission rate is done by monitoring the build-up of the ozone concentration in a well characterized test-chamber taking into account the ozone decay in the room, the ozone decay in the air re-circulating through the machine and the ventilation of the room during operation.

The effective ozone emission rate can subsequently be used, in mathematical modelling techniques, to predict room concentrations produced by specific operating modes in single or multiple installations of defined environmental characteristics.

6 Principle of the measuring method

When an ozone source (e.g. copier, printer) is placed in a ventilated room, the generated ozone is removed by the ventilation air, by decay in the room (on surfaces, etc) and by decay in the equipment itself. The mass balance is represented schematically in figure 1.

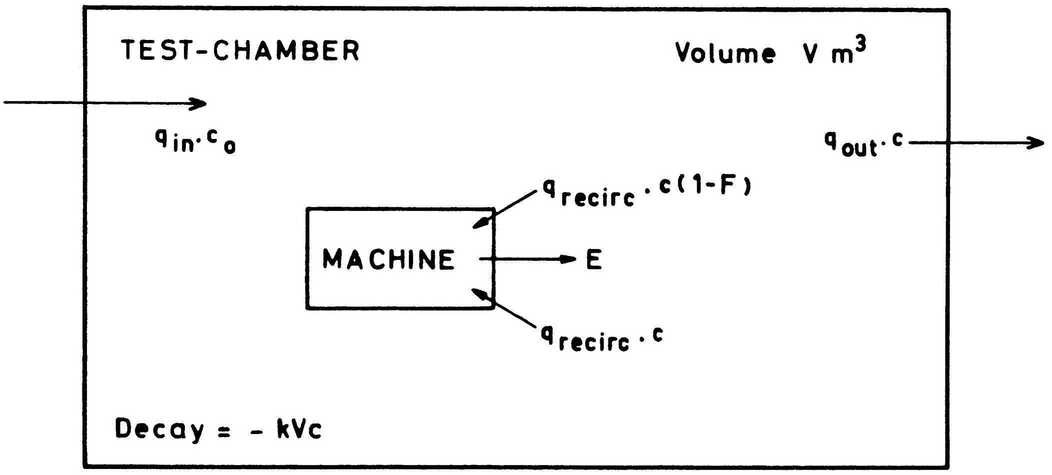

Figure 1 - Schematic representation of the mass balance

where:

V = the room-volume (m^3)
c = the ozone concentration (mg.m^{-3})
t = the time (min)
E = the effective ozone emission rate (mg.min^{-1})
k = the ozone decay constant (min^{-1})
q_{recirc} = the amount of air drawn through the machine (m^3.min^{-1})
q_{room} = the ventilation of the test room (m^3.min-1)
F = the filtering efficiency of the EUT
c_o = the ozone concentration in the incoming air (mg.m^{-3})

The decay in the air which is re-circulated through the machine is taken into account by considering that it is a filtering loop where a small amount of air, q_{recirc}, is removed from the room, after which filtering takes place (with efficiency F) and the air is returned to the room.

The EUT is adjusted to ensure that it operates at its maximum ozone generation rate.

Assuming that the ozone concentration in the incoming air is negligible the concentration at a certain time t (c_t) can be described as:

$$C_t = \frac{E}{q_{room} + kV + q_{recirc} \times F} \times \left[1 - e^{-t \times \left[\frac{q_{room} + kV + q_{recirc} \times F}{V}\right]}\right] \qquad (1)$$

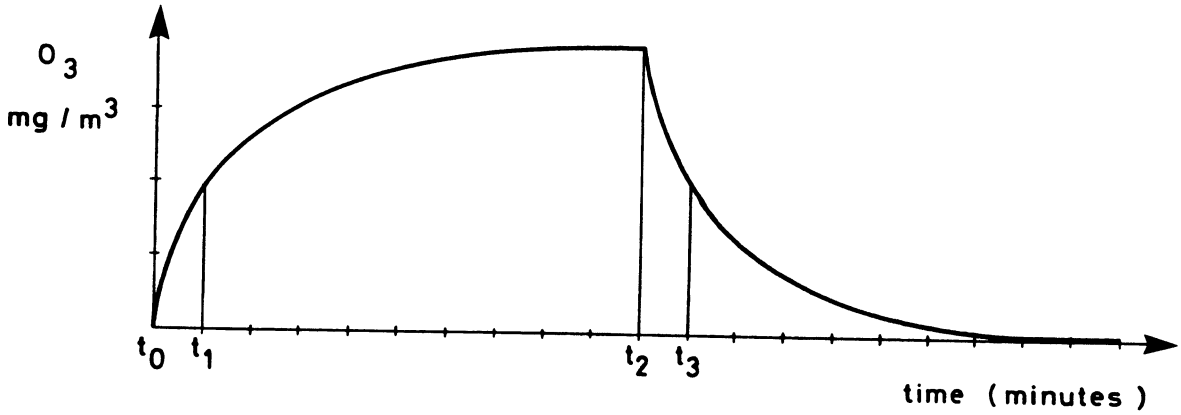

Figure 2 - The build-up and decay of ozone in a room

When the ozone producing mode is switched off the ozone decays according to

$$C_t = C_0 \times e^{-(k + V') \times t} \qquad (2)$$

where V' is the number of air changes per minute.

The determination of the effective ozone emission rate is done in several steps. First an ozone atmosphere is created using an ozone generator. Then after switching off the generator the ozone decay is monitored to determine the ozone half life time. The ozone half life time is then determined by doing a regression analysis on the decay data (using formula 2).

Following this the equipment under test is switched on and the ozone build up caused by the machine is monitored. The effective ozone emission rate and the expected equilibrium concentration are then determined by doing a regression analysis on the concentration data ($t_0 \rightarrow t_2$ in figure 2, using formula 1).

After switching off the equipment the ozone decay is again monitored and the concentration data are used to determine the ozone half life time after the test.

The ozone build up cannot be determined accurately when the effective ozone emission rate is low. In this case extra ozone is introduced in the test chamber during operation ($t_2 \rightarrow t_3$ in figure 3) using an auxiliary ozone generator. After switching off the generator the ozone decay is monitored ($t_3 \rightarrow t_5$ in figure 3) and the effective ozone emission rate and the expected equilibrium concentration are determined by doing a regression analysis on the decay data. After this, the equipment under test is switched off and the ozone decay is again monitored and the concentration data used to determine the ozone half life time after the test.

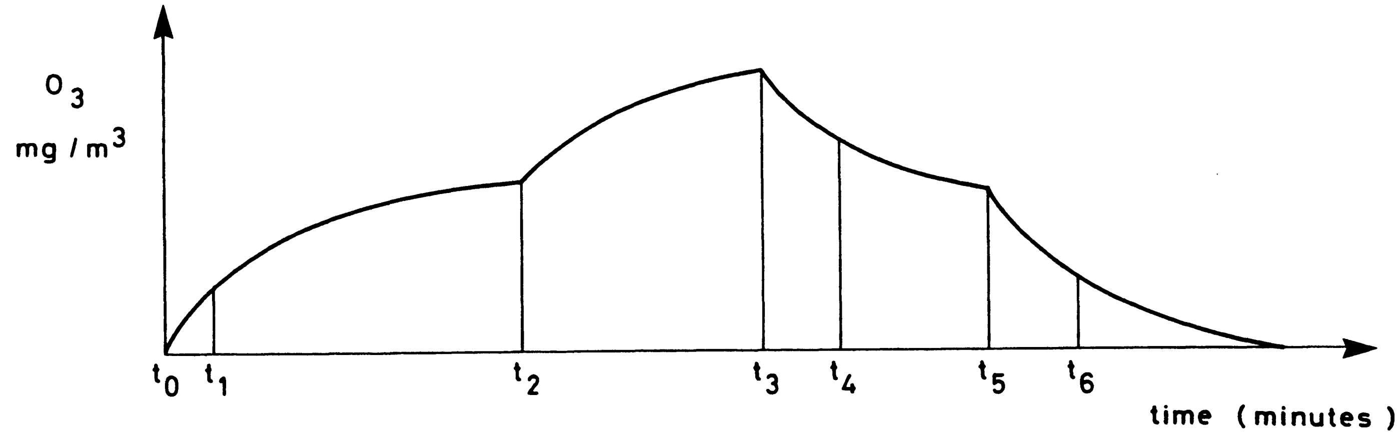

Figure 3 - Build-up and decay curve using an additional ozone source

The measuring method is presented in respect of ozone as it is an inherent emission from many types of equipment and has been the species of greatest concern to users and protection/enforcement agencies. Other vapours and gases can be subjected to similar analysis, however in these cases there is no spontaneous decay with time.

7 Measurement Procedure

Warning
When high ozone levels are expected, personal protective equipment should be used to ensure the safety of the testing personnel.

7.1 The Equipment Under Test (EUT) is placed in a chamber of known volume and atmospheric pressure, having controlled and recorded temperature, humidity and ventilation. The air in the test-chamber is homogenized thoroughly (e.g. using ventilators). A room with inert walls, ceiling and floor is preferred, since the ozone concentration in such a room will be higher than in an ordinary room and thus the accuracy of the ozone measurements is improved. At least 1 meter clearance is allowed around the EUT. All measuring and recording equipment is located externally to the test chamber, air samples being taken from the test chamber to the measuring equipment via PTFE tubing. The sample tube is located 0,3 m from the front of the test subject and 1,2 m above the floor.

7.2 The EUT is located in the centre of the previously cleaned test chamber. An auxiliary ozone generator is used to create an ozone concentration of at least 0,4 $mg.m^{-3}$ for a minimum of 12 h before commencing the test. All surfaces contain active sites which react with ozone over a period of time. "Soaking" the EUT and test chamber (including any contained equipment) in a high ozone concentration immediately prior to the tests temporarily neutralizes these sites and ensures that stable ozone decay conditions exists for the period of the test.

7.3 The decay rate of ozone in the test chamber (ozone half time or time taken for the ozone concentration to reach half the initial concentration) is determined with the EUT in position but not energized, by using an auxiliary ozone generator to create an ozone concentration of approximatively 0,2 mg.m^{-3}. The ozone source is switched off and the ozone concentration is monitored continuously as it decays over a period of at least 25 min. Use a continuous-recording calibrated ozone analyzer (accuracy and detection limit both approximatively 0,002 mg.m^{-3} (0,001 ppm), measuring principle e.g. UV-absorption or chemiluminescence).

The half time is determined by carrying out a regression analysis on the ozone measurement data, using the computer program (MS-DOS BASIC) given in annex A.

After the computer program is running the identity of the EUT and the test chamber data are entered. Ozone concentration values at 1 minute intervals up to approximately 20 data points are entered; the program will give the initial ozone half time. The program is left running to accept and process data obtained from steps 7.5, 7.6 and 7.7.

An unsatisfactory regression analysis (correlation coefficient smaller than 0,98) indicates instabilities during the test and rerunning the test should be considered.

Ozone half times obtained with the EUT operating will generally be lower than the initial and final half times. This difference is an indication of the effect that the EUT may have on ozone decay in the customer environment. If the program is used to calculate effective emission rate from the stabilized concentration the shorter half time should be used for that calculation.

Differences between the ozone decay rates before and after the test are also indicative of instabilities. When the decay rates vary more than 20% the test should be repeated.

7.4 The ozone concentration is determined just before the EUT is switched on (t_0 = 0). Background concentration must be below 0,005 mg.m^{-3} and variations in background concentration shall not exceed 0,01 mg.m^{-3} for the duration of the test.

7.5 With the EUT switched to continuous operation (at maximum speed) the ozone concentration is measured continuously for at least 25 min or until equilibrium is reached (stabilized concentration). The effective emission rate is determined by doing a regression analysis on the ozone concentration data using the following procedure:

After the computer program is running the EUT identity and the test chamber data are entered. Ignoring the first five minutes of data collection, ozone concentration values at 1 minute intervals up to approximately 20 data points are entered; the program will give the effective emission rate, ozone half time and predicted stabilized concentration.

NOTE
When the emission rate is low it may not be possible to measure the build up concentrations accurately. In these cases the additional procedure in 7.6 can be used, otherwise 7.7 is carried out.

7.6 With the EUT continuing to operate (see 7.5) the auxiliary ozone generator is switched on (at time t_2, see figure 3) to create an ozone atmosphere of about 1,5 to 2 times the predicted ozone concentration. The auxiliary ozone generator is then switched off (t_3), the ozone concentration is monitored as it decays to stabilization (3 concentration measurements at 5 min intervals within 0,01 mg.m^{-3}). Commencing at t_3 enter concentrations at 1 min intervals into the program until about 20 data points have been entered. The program will give the effective emission rate, ozone half time and predicted stabilized concentration.

7.7 After the measurements the EUT is switched off. The ozone concentration is monitored until it has decreased by at least 60 %. The half life time of ozone is determined by using the regression analysis procedure as described in 7.3 and compared with the half life time determined in 7.3 to ensure that no significant changes have occurred during the test.

NOTE

Where the stabilized concentration is reached very rapidly (within 15 min) measurement variations cause the concentrations recorded at the end of the period to depart from the mathematical model, in consequence the regression analysis carried out by the program produces meaningless results. In these cases the stabilized concentration can be utilized together with the half time, obtained with the EUT operating, to calculate the emission rate. The program will prompt for this data and carry out the calculation.

7.8 Report the effective ozone emission rate in mg.min^{-1}.

8 Determination of Minimum Space Allocation

The nomograph given in figure 4 shall be used, in conjunction with the measured effective emission rate, to determine the minimum space to be allocated in a room without mechanical ventilation,

A straight line shall be used to join the equipment utilisation rate to the target room concentration limit of 0,2 mg.m^{-3} and extended to give the limiting emission characteristic. The measured effective emission rate divided by the limiting emission characteristic is the minimum space to be allocated.

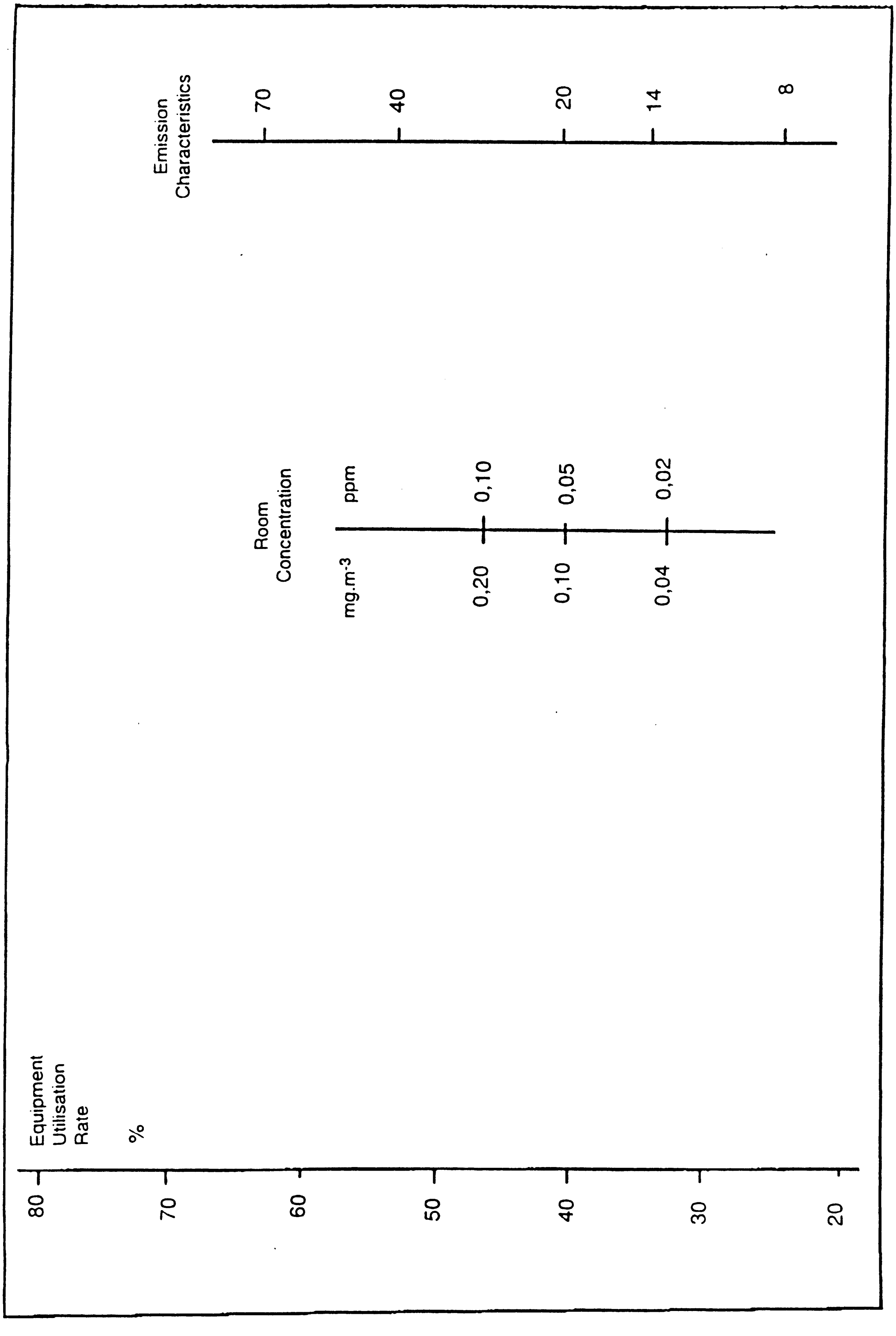

Figure 4 - Determination of minimum room space

Annex A

Computer program for the evaluation of the concentration data

The following program, designed for estimating effective ozone emission rates for office copiers, is provided as an example.

This program has been written in CP/M Basic language. It may need to be revised for use with other operating systems.

A run-only copy of this program can be obtained by sending a DOS-formatted floppy disk to

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114 Rue du Rône
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Switzerland

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10 PRINT
20 PRINT"THIS PROGRAMME WILL ACCEPT RAW DATA FROM BUILD-UP/DECAY"
30 PRINT"CURVES (AT ONE MINUTE INTERVALS)AND ESTIMATE THE CHAMBER"
40 PRINT"HALF-LIFE (WITH MACHINE OPERATING) AND EFFECTIVE EMISSION RATE FROM"
50 PRINT"EACH SET OF DATA. FROM THE INITIAL BUILD-UP DATA IT WILL ALSO"
60 PRINT"PREDICT THE STABILISED CONCENTRATION. ALLOWANCE IS MADE FOR TEST"
70 PRINT"CHAMBER CHARACTERISTICS TO BE EVALUATED PRE AND POST TEST.",PRINT
80 PRINT TAB (10)"INPUT DATA"
90 PRINT
100 DIM SX(100),SY(100),SZ(100),SW(100)
110 DIM D (500),C(100)
120 INPUT"MACHINE TYPE",M$
130 INPUT"AIR CHANGES PER HOUR",A
140 AC=A/60,REM CHANGE TO AIR CHANGES PER MINUTE
150 INPUT"ROOM VOLUME(CUBIC METRES)",V
160 INPUT"TEMPERATURE(DEGREES C)",K
170 KK=K + 273,REM CHANGE TO DEGREES KELVIN
180 INPUT"ATMOSPHERIC PRESSURE(mm.Hg)",P
190 PRINT
200 INPUT"IS THIS DATA CORRECT (Y OR N)",B$
230 PRINT
240 IF B$ ="N"THEN GOTO 120
250 IF B$ ="Y"THEN GOTO 260
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260 PRINT TAB(10)"ANALYSIS OF "M$" OZONE CHAMBER DATA"
270 PRINT
280 PRINT TAB(5)"ROOM VOLUME"TAB(35)V" CUBIC METRES"
290 PRINT TAB(5)"TEMPERATURE"TAB(35)K" DEGREES C"
300 PRINT TAB(5)"ATMOSPHERIC PRESSURE"TAB(35)P" mm.Hg"
310 PRINT TAB(5)"ROOM VENTILATION"TAB(35)A" AIR CHANGES PER HOUR"
320 INPUT"ARE CONCENTRATIONS IN ppm?(Y or N)",Z$
330 IF Z$ ="N" LET WW = 1 ELSE LET WW = P*V*770/KK
340 INPUT"DO YOU HAVE DATA FOR THE INITIAL CHAMBER DECAY (Y OR N)?";F$
350 IF F$ ="N"THEN GOTO 420
360 IF F$ ="Y"THEN GOTO 370
370 PRINT
380 PRINT
390 PRINT TAB(5)"INITIAL CHAMBER DECAY CONCENTRATION DATA"
400 GOSUB 1040
410 PRINT
420 INPUT"DO YOU HAVE DATA FOR THE BUILD-UP CURVE (Y OR N)";E$
430 IF E$ ="N"THEN GOTO 490
440 IF E$ ="Y"THEN GOTO 450
450 PRINT
460 PRINT
470 PRINT TAB(5)"BUILD-UP CURVE CONCENTRATION DATA"
480 GOSUB 1040
490 PRINT
500 PRINT"DO YOU HAVE DATA FOR A DECAY FROM A 'BOOSTED' CONCENTRATION WITH"
510 INPUT"THE MACHINE PRINTING? (Y OR N)";C$
520 IF C$ ="Y"THEN GOTO 540
530 IF C$ ="N"THEN GOTO 680
540 PRINT
550 PRINT
560 PRINT TAB(5)"DECAY CURVE CONCENTRATION DATA (MACHINE PRINTING)"
570 PRINT
580 GOSUB 1040
590 PRINT
600 INPUT"DO YOU HAVE DATA AT STABILISATION",M$
```

```
610 IF M$ ="N"THEN GOTO 680
620 IF M$ ="Y"THEN GOTO 630
630 PRINT
640 PRINT
650 PRINT TAB(5)"STABILISED CONCENTRATION DATA (MACHINE PRINTING)"
660 PRINT
670 GOSUB 1040
680 INPUT"DO YOU HAVE DECAY DATA FOR THE MACHINE IN STANDBY. (Y OR N) ?";D$
690 IF D$ ="N"THEN GOTO 1030
700 IF D$ ="Y"THEN GOTO 710
710 PRINT
720 PRINT
730 PRINT TAB(5)"DECAY CURVE CONCENTRATION DATA (MACHINE IN STANDBY)"
740 PRINT
750 GOSUB 1040
760 PRINT
770 INPUT"DO YOU HAVE FINAL CHAMBER DECAY DATA (Y OR N) ?";G$
780 IF G$ ="N"THEN GOTO 1030
790 IF G$ ="Y"THEN GOTO 800
800 PRINT
810 PRINT TAB(5)"FINAL CHAMBER DECAY CONCENTRATION DATA"
820 GOSUB 1040
830 INPUT"CALCULATE GENERATION RATE FROM ALTERNATE DATA (Y OR N)",G$
840 IF G$ ="N"THEN GOTO 1030
850 IF G$ ="Y"THEN GOTO 860
860 PRINT
870 INPUT"STABILISED CONCENTRATION",CS
880 INPUT"HALF LIFE",HL
890 PRINT
900 INPUT"ARE THESE CORRECT",H$
910 IF H$ ="Y"THEN GOTO 920
920 LET G =CS*WW*(AC + (LOG 2/HL))
930 IF Z$ ="N" LET Y$ ="mg/m3" ELSE LET Y$ ="ppm"
940 PRINT
950 PRINT TAB(5)"STABILISED CONCENTRATION DATA"
```

```
960 PRINT
970 PRINT "MEASURED STABILISED CONCENTRATION" CS Y$
980 PRINT "ROOM HALF-LIFE AT STABILISATION "HL" mins."
990 PRINT
1000 PRINT
1010 PRINT "GENERATION RATE FROM THIS DATA IS "G" micrograms/min."
1020 PRINT
1030 END
1040 PRINT
1050 REM SUBPROG STARTS HERE
1060 LET SX =0
1070 LET SY =0
1080 LET SZ =0
1090 LET SW =0
1100 LET SV =0
1110 LET C(I) =0
1120 LET D(I) =0
1130 INPUT"NUMBER OF DATA POINTS AT MINUTE INTERVALS(INCLUDING FIRST & LAST)",N
1140 PRINT
1150 FOR I = 1 TO N
1160 PRINT"AT TIME" (I-1) MINUTES";
1170 INPUT"RECORDED CONCENTRATION",C(I)
1180 NEXT I
1190 PRINT
1200 INPUT"IS THIS CORRECT (Y OR N)",A$
1210 PRINT
1220 IF A$ ="N"THEN GOTO 1130
1230 IF A$ ="Y"THEN GOTO 1240
1240 PRINT
1250 PRINT
1260 PRINT TAB(12)"TIME"TAB(22)"CONCN"
1270 PRINT TAB(12)"MINS"TAB(23)Y$
1280 PRINT
1290 FOR I =1 TO N
1300 PRINT TAB(13)(I-1);TAB(22)C(I)
```

```
1310 NEXT I
1320 PRINT
1330 PRINT
1340 FOR J =1 TO(N-1)
1350 LET X =C(J)
1360 LET Z =X*X
1370 LET Y =C(J + 1)
1380 LET W =X*Y
1390 LET YY =Y*Y
1400 LET SX =SX + X
1410 LET SY =SY + Y
1420 LET SZ =SZ + Z
1430 LET SW =SW + W
1440 LET SV =SV + YY
1450 NEXT J
1460 LET M =(((SX*SY)/(N-1))-SW)/(((SX*SX)/(N-1))-SZ)
1470 LET MM =LOG(M)
1480 LET MN =(-1)*LOG(2)/(MM +AC)
1490 PRINT
1500 PRINT"THE ESTIMATE OF THE HALF-LIFE FROM THIS DATA IS "MN"MINUTES"
1510 LET AY =SY/(N-1)
1520 LET AX =SX/(N-1)
1530 LET B =AY-(M*AX)
1540 LET G =(B*(-1)*MM*WW)/(1-M)
1550 PRINT
1560 PRINT"THE ESTIMATE OF THE GENERATION RATE FROM THIS DATA IS "G"
MICROGRAMS PER MINUTE"
1570 PRINT
1580 LET RX =(SZ/(N-1))-(AX*AX)
1590 LET RX =SQR(RX)
1600 LET RY =(SV/(N-1))-(AY*AY)
1610 LET RY =SQR(RY)
1620 LET RR =M*RX/RY
1630 PRINT "THE CORRELATION COEFFICIENT FOR THESE ESTIMATES IS" RR
1640 PRINT
```

```
1650 LET T =MN
1660 LET D =C(1)
1670 LET E =EXP(-(AC +(LOG(2)/T)))
1680 LET Q =1-E
1690 LET MN =AC +(LOG(2)/T)
1700 PRINT
1710 PRINT
1720 PRINT "THE ESTIMATED STABILISED CONCENTRATION FROM THIS DATA IS "L,Y$
1730 PRINT
1740 PRINT
1750 LET L =G/(WW*MM)
1760 PRINT "THE BEST FIT' FOR THE ABOVE DATA IS:"
1770 PRINT
1780 PRINT TAB(17)"MIN";TAB(30)"CONCN"
1790 FOR I = 1 TO 15
1800 LET D(I) =(D*E) + (L*Q)
1810 PRINT TAB(17)I;TAB(27)D(I)
1820 LET D = D(I)
1830 NEXT I
1840 PRINT
1850 PRINT
1860 RETURN
```