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A COMPUTER PROGRAMME FOR EVALUATING THE DUST BURDEN OF DUST-LADEN GASES FLOWING IN LARGE DUCTS.

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SYNOPSIS

A computer programme (code-named "Dusty") and its operating instructions are presented for the evaluation of the dust burden, the total gas flow rate, and the total dust emission rate of dust-laden gases flowing in large rectangular ducts.

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1. The dust burden of dust-laden gases flowing in large ducts is generally determined by sampling. To obtain a representative dust sample, the sampling must be carried out at a sufficiently large number of points (a 24 point traverse generally suffices) and must be isokinetic. The latter can best be achieved by monitoring the local gas velocity, using a pitot tube, and adjusting the aspiration rate accordingly. The sampled dust is collected in a cyclone-filter combination and the pressure drop across the cyclone is an indication of the aspiration rate.

Since the conditions in the duct can vary, the data are recorded at the beginning, middle and end of the sampling period for each sampling point. The average local gas velocity and the average gas velocity in the probe nozzle are calculated for the respective sampling points, and these are subsequently used to evaluate the dust burden, the overall gas flow rate, and the overall dust emission rate. The relevant equations are reproduced in the appendix.

Although the calculations are relatively straight forward, the number of repetitions involved is sufficient to warrant the use of a computer and this report, therefore, describes such a programme and the method of its execution.

/2. ......

2. One of the features of the programme, listed in the appendix, is the data-check routine preceding the execution of the programme proper. The data are checked both for the correct number of data items and the correct format. Error detection results in a diagnostic print-out at the computer terminal, and the execution of the programme is terminated to prevent unwarranted expenditure.

The programme is so designed that the results of the computations are filed automatically and can only be removed intentionally. Thus, accidental severing of the terminal-computer link cannot result in the loss of results.

The duct is generally fitted with a number of access ports, each of which allows for the positioning of the probe at a predetermined, but constant, number of sampling points. The location of the sampling points on the cross-section of the duct is indicated by means of alpha-numeric identification, generated by the computer. The numeral identifies the sampling port and the letter identifies the corresponding sampling position. In general, if M sampling ports and N positions per port are specified, the alpha-numeric identification is generated in the following sequence:

1A, 1B, ... 1N, 2A, 2B, ... MA, MB, ... MN

and this sequence must be observed when entering the data. The programme makes provision for a maximum of 12 sampling ports and a maximum of 6 positions per port.

/3. ......

3. The data tape is prepared as follows. Each data line commences with a line number, starting at 100 and subsequently incremented by 10. The items in a data line are separated by spaces and not by commas.

The first three data items serve as headings, must be enclosed by quotation marks, and may not exceed 70 characters each. Each of these three items should preferably be assigned a single data line.

The first data item identifies the power station, e.g. "ABC Power Station".

The second data item identifies the duct, e.g. "L.H. inlet to unit 2".

The third data item identifies the boiler and records the date on which the test was performed, e.g. "Boiler No. 8   8/10/1971".

The next eight data items, in that order, are:

Barometric pressure, in mm Hg;
Apparatus number;
Duct height, in meters;
Duct width, in meters;
Total mass of dust sampled, in grams;
Number of sampling ports;
Number of sampling positions per port;
Sampling period per position, in minutes.

The recorded data for each sampling position are then entered in the following repetitive sequence:

/Thermocouple ......

Thermocouple meter reading, in ^{o}C.
Ambient temperature, in ^{o}C.
Static pressure*, in mm Hg.
Gas velocity head, in mm H_2O.
Cyclone pressure drop, in mm H_2O.

The foregoing is repeated if more than one duct was tested.

4. When the data tape is completed, proceed as follows:

1. Sign on.
2. Load the data tape.
3. Type: NAM DAT
4. Type: TAP
5. Run the data tape.
6. Type: SAV
7. Load the master tape code-named "Dusty"
8. Type: NAM DUSTY
9. Type: TAP
10. Run the master tape.
11. Type: SAV
12. Type: RUN

/13. ......

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* To be entered as a negative quantity if the pressure in the duct exceeds atmospheric pressure.

13. If the computer replies*by typing "now at 1030" then proceed as follows:
14. Type: LOA RES
15. Type: LIS NN
16. Type: REM
17. Type: LOA DAT
18. Type: REM
19. Type: LOA DUSTY
20. Type: REM
21. Sign off.

/Appendix ......

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* At this point the computer may indicate the occurrence of errors on the data tape.Sign off and prepare a new tape on which only the erroneous data lines are corrected, and proceed as follows:

(i) Sign on.
(ii) Type: LOA DAT
(iii) Type: TAP
(iv) Run the correction tape.
(v) Type: SAV
(vi) Type: LOA DUSTY
(vii) Proceed with step 12, etc.

APPENDIX

Nomenclature

Symbol	Description	Units
AD	Duct Area.	m^2
AP	Probe nozzle area.	m^2
B	Barometric pressure.	mm Hg
C	Thermocouple calibration correction.	K
DB	Dust burden, corrected to N.T.P.*	mg/m^3
g	Gravitational acceleration.	m/s^2
K	Factor correcting to isokinetic sampling. (For isokinetic sampling, K = 1)	
M	Factor correcting volumes to N.T.P.*	
N	Number of test points.	
PC	Cyclone pressure drop.	mm H_2O
PS	Static pressure.	mm Hg
PV	Local velocity head of flue gas.	mm H_2O
Q1	Flue gas volume emitted, corrected to N.T.P.*	m^3/h
Q2	Flue gas volume sampled, corrected to N.T.P.*	m^3/h
T	Sampling period per sampling point.	min.
TA	Ambient temperature.	^oC
TM	Thermocouple meter reading.	^oC
U1	Local flue gas velocity, corrected to N.T.P.*	m/s
U2	Velocity in nozzle, corrected to N.T.P.*	m/s
V1	Average** local flue gas velocity, corrected to N.T.P.*	m/s
V2	Average** velocity in nozzle, corrected to N.T.P.*	m/s
WE	Weight of dust emitted.	kg/h
w	Total weight of dust sampled.	g
α	Factor converting cyclone pressure drop to the corresponding velocity head.	
γ	Flue gas density.	kg/m^3

/Notes ......

Notes

*In converting volumes to N.T.P., no correction was made for condensation.

**The average velocity was calculated from the three individual velocities at a sampling point.

Formulae

$$M = \frac{273\ (B-PS)}{760\ (TM+TA+C)}$$

$$\gamma = 1{,}328\ M$$

$$U1 = M\sqrt{\frac{2g\ PV}{\gamma}}$$

$$U2 = M\sqrt{\frac{2g\alpha\ PC}{\gamma}}$$

$$V1 = 1/3 \sum_{1}^{3} U1$$

$$V2 = 1/3 \sum_{1}^{3} U2$$

$$Q1 = \frac{3600AD\ \Sigma\ V1}{N}$$

$$Q2 = \frac{3600AP\ \Sigma\ V2}{N}$$

$$WE = \frac{6w.AD}{100\ N.K.AP.T}$$

$$K = \frac{AD.Q2}{AP.Q1}$$

$$DB = \frac{WE}{Q1} \times 10^6$$

/Apparatus ......

Apparatus constants

Apparatus No.	x	AP	C
1	1,9272	$0,4585 \times 10^{-4}$	271,6
2	1,5375	$0,4620 \times 10^{-4}$	271,0
3	1,2625	$0,4620 \times 10^{-4}$	272,0
4	1,7375	$0,4585 \times 10^{-4}$	271,1

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PRETORIA.
20/8/1973.
TCE/KW.

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10' THIS PROGRAM COMPUTES THE DUST BURDEN OF DUST LADEN
20' GASES,THE RATE OF FLUE GAS EMISSION,THE RATE OF DUST
30' EMISSION,AND A CORRECTION FACTOR INDICATING THE
40' DEVIATION FROM ISOKINETIC SAMPLING.

100:      ###  ####    ###.#   ###    ###.#   ###.#    ######.##    ######.##
110:      PT     TM       TA     PS       PV       PC          V1            V2
120:                                                       ######.##    ######.##
130:      ################################################################
140DIM A$(72),B$(72),C$(72),A(20,20)$(15)
150FORI=1TO6
160FORJ=1TO12
170READA(I,J)$
180NEXTJ
190NEXTI
200DATA "1A","2A","3A","4A","5A","6A","7A","8A","9A","10A","11A","12A"
205DATA "1B","2B","3B","4B","5B","6B","7B","8B","9B","10B","11B","12B"
210DATA "1C","2C","3C","4C","5C","6C","7C","8C","9C","10C","11C","12C"
215DATA "1D","2D","3D","4D","5D","6D","7D","8D","9D","10D","11D","12D"
220DATA "1E","2E","3E","4E","5E","6E","7E","8E","9E","10E","11E","12E"
225DATA "1F","2F","3F","4F","5F","6F","7F","8F","9F","10F","11F","12F"
230FORK=1TO4
240FORL=1TO3
250READX(K,L)
260NEXTL
270NEXTK
280FILES DAT,RES
290SCRATCH#2
300IFEND#1THEN380
310INPUT#1,A$,B$,C$,A9,B9,C9,D9,E9,F9,G9,H9
320H=5*F9*G9*3
330ONERRORGOTO370
340INPUT#1,A
350N1=N1+1
360GOTO330
370IFN1<>HTHEN980
371N1=0
372GOTO300
380RESTORE#1
390IFL2<>0THEN1030
400IFEND#1THEN1030
410INPUT#1,A$,B$,C$,B,A,D,W,W1,X8,X9,T
420PRINT#2USING130,A$
430PRINT#2USING130,B$
440PRINT#2USING130,C$
450PRINT#2,"      APPARATUS NO.";A
460PRINT#2,"      ATM.PRESSURE=";B
470PRINT#2,"      DUCT AREA,AD=";D*W
480PRINT#2
490PRINT#2USING110
500FORP=1TOX8
510FORQ=1TOX9
520INPUT#1,T1,T2,P1,P2,P3
530M=.3592*(B+P1)/(T1+T2+X(A,3))
540G=.753/M
550Y1=M*SQR(19.62*P2*G)
560Y2=M*SQR(19.62*P3*X(A,1)*G)
570V1=V1+Y1
580V2=V2+Y2
590C=C+1
600IFC=3THEN630
610PRINT#2USING100,A(Q,P)$,T1,T2,P1,P2,P3
620 GOTO520
```

```
630V1=V1/C
640V2=V2/C
650C=0
660PRINT#2USING100,A(Q,P)$,T1,T2,P1,P2,P3,V1,V2
670S1=S1+V1
680S2=S2+V2
690V1=V2=0
700NEXTQ
710NEXTP
720PRINT#2USING120,S1,S2
730PRINT#2
740PRINT#2
750Q1=3600*D*W*S1/(X8*X9)
760Q2=3600*X(A,2)*S2/(X8*X9)
770PRINT#2,"      FLUE GAS VOL. EMITTED(N.T.P.),Q1=";Q1
780PRINT#2,"      FLUE GAS VOL. SAMPLED(N.T.P.),Q2=";Q2
790H1=Q1/Q2
800PRINT#2,"      RATIO:Q1/Q2=";H1
810H2=D*W/X(A,2)
820PRINT#2,"      RATIO:AD/AP=";H2
830PRINT#2,"      CORR. FACTOR K=";H2/H1
840PRINT#2,"      TOTAL WT. OF DUST SAMPLED=";W1
850W2=W1*H1*60/(1000*X8*X9*T)
860PRINT#2,"      WT. OF DUST EMITTED,WE=";W2
870W3=W2*1E6/Q1
880PRINT#2,"      DUST BURDEN(N.T.P.),DB=";W3
890S1=S2=0
900PRINT#2
910PRINT#2
920PRINT#2
930PRINT#2
940PRINT#2
950GOTO400
960DATA1.9272,.4585E-4,271.6,1.5375,.462E-4,271
970DATA1.2625,.462E-4,272,1.7375,.4585E-4,271.1
980PRINT"NO. OF DATA ITEMS=";N1+8;"AND SHOULD=";H+8
990PRINT"ERROR IN DATA OF APPARATUS NO.";B9
1000N1=0
1010L2=L2+1
1020GOTO300
1030END
```