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BHABHA ATOMIC RESEARCH CENTRE

बंबई, भारत

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AEROSOLS

AIR CLEANING

FILTERS

COST

ABSTRACT

Radioactive laboratories designed to handle toxic substances such as plutonium are required to have "once through" ventilation scheme. This is an expensive proposition particularly when conditioned air is required. A recent approach is to have recirculatory system with exhausted air passing through absolute (HEPA) filters. This scheme not only drastically reduces capital costs but also substantially cuts down maintenance and running costs. Experiments employing aerosol clearance techniques were conducted to specifically establish that this new scheme meets all the health physics safety stipulations laid down for such installations. It is shown that the "once through" system is three times more expensive compared to the recirculation system adopted in Purnima Laboratories. Further a saving of 70% is also achieved in running and operating costs. Therefore the new approach deserves serious consideration in future planning of similar projects. This, particularly in view of the fact that the considerable savings achievable both in terms of money and energy are without in any way compromising on safety.

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1. Introduction

Active Laboratories built to handle toxic radioactive substances, apart from being suitably equipped for the purpose, need specially designed ventilation systems. There were two basic prerequisites which characterise such systems. One of them is to have high efficiency particulate filters to trap the particulate activity in the exhausted air stream and prevent its release into the atmosphere after being discharged through the stack. The other is to ensure a minimum of ten air changes in the working areas so that any accidentally released airbone activity is promptly and quickly reduced. The standard accepted norm so far in such laboratories is to employ the "once through" ventilation scheme. This is an expensive proposition when conditioned air is required and desired, which invariably is the case. One of the new approaches is to recirculate the laboratory air through absolute filters to produce the desired ventilation rate in the laboratory.

In the design of such a ventilation system, the portions of the laboratory likely to cause activity releases on a continuous basis such as glove boxes and fume hoods should be exhausted by means of a once through system, whereas the working areas not facing the continuous releases can be put on a recirculating system through absolute filters. Laboratories may contain only glove boxes, glove boxes and fume hoods, or only fume hoods. Economies achievable by the recirculating system will be greatest for the laboratories containing only glove boxes and least for laboratories containing only fume hoods. In this report the ventilation system of Purnima Laboratories, where such a system has been installed for the first time has been taken up as a case study. The ventilation scheme is described and results obtained of an experimental evaluation by aerosols clearance technique is presented. The comparative costs and savings achievable are pointed out and conclusions based on this study are finally given. The new approach deserves attention by projects where such ventilation systems are contemplated because of considerable savings possible without compromising on safety.

2. Description of the ventilation system

Salient features of the system are given in Figs. 1 to 3. The system consists of two parts: (i) The ventilation of the working areas with a circulation arrangement through high efficiency absolute filters. This system is designed to provide two (adjustable) air changes by fresh air and more than ten air changes by the recirculated air. (ii) The exhaust of the glove boxes and fuel storage area is once through, and is taken to stack through high efficiency filters.

The procedure in the event of an emergency when activity release is likely to occur in the working areas is to switch off the recirculation system and switch on the standby exhaust fan to augment the other exhaust fan of the glove box after opening the "once through" exhaust grills.

In the normal course nearly 6200 CMH of the ventilation air is recirculated and about 2000 CMH is allowed once through. The system ensures better than 10 air changes per hour in the working areas and sufficient negative pressures in glove boxes and fuel storage area, meeting the requirements of health physics. Further details of the system is given in Appendix A.

3. Evaluation of the system by aerosol clearance method

A large nebuliser designed and fabricated in Health Physics Division of BARC was used for generating the aerosols of fluoroscein. This nebuliser has the following characteristics: (i) mass output = 14 mg/min, when 2% ammoniacal solution of fluoroscein is used, (ii) operating Pressure = 30 psi, (iii) aerosol flow rate = 30 litres per minute (iv) mass median diameter of aerosol particles = 0.8 μm (v) the geometric standard deviation = 2.0. Such a nebuliser produces aerosol that can remain stable that is continue to be suspended in the atmosphere without settling on the floor for long periods of time.

The supply and exhaust fans of the laboratory were switched off and the aerosol generator operated at the middle of the room at a height of 2 metres above the floor level for a period of about half an hour. Aerosol was allowed to spread uniformly in the room. A one minute air sample was taken using a high volume air sampler on a suitable filter paper after stopping the aerosol generator. This sample provided the initial concentration of aerosols in the room. The supply and exhaust were started and further samples were taken at different times for fixed intervals to determine the concentration of aerosol as a function of time. It can be shown[2] that the concentration at any time t, after start up of ventilation is given by the following equations:

$$C = a e^{-vt} \qquad \text{---(1)}$$

where a is constant, C is the concentration of aerosol at any time 't', v is the ventilation rate in number per hour, t is the time in hrs after the start up of the ventilation.

Above equation holds good provided there is no further supply of aerosols after the start up of the ventilation. Recirculation of air through absolute filters ensured that this condition was valid. A set of five experiments were carried out by determining the concentration at various times at a fixed location (middle of the room, 2 metres above floor). The concentration of aerosols in room air was plotted against time on a semilog graph paper. Computer fitted least square lines were drawn through the data points as shown in Figure 4. Table I gives the results obtained.

Table - I

Results

Expt. No.	a	v	r
1	0.93	12.4	0.9659
2	1.15	12.0	0.9365
3	1.10	13.5	0.9647
4*	0.72	14.3	0.9690
5*	0.74	14.4	0.9503

* Not Plotted to avoid overcrowding of data points
r corresponds to the correlation coefficient.

Following conclusions are drawn from the results:

(i) Concentration decreases exponentially with time as predicted by equation with a good correlation coefficient. (ii) The mean number of air changes determined by this procedure was 13.32 ± 1.09, (iii) The filtration system performed satisfactory to remove the aerosol from the room. The experiments yield higher ventilation rate since it was conducted in the middle of the room where it is expected to be more effective whereas the design value specified is the average rate for the entire Laboratory.

4. <u>Economics of recirculation system</u>

Economics of the recirculation system can be evaluated in comparison with the once through system. Table - 2 gives the comparative costs for the two systems for Purnima laboratories. The figures quoted are based on the cost data as in 1980. Percent saving has been calculated by taking the ratio of the cost difference to the cost of the once through system. It is thus seen that the recirculation system is indeed more economical. There is a saving of 72% in installation costs and 70% in operating costs.

It is also important to note that the absolute filters used in the recirculation system are not likely to become highly radioactive and they can be disposed off more economically. There is also a saving on safety related efforts and expenditure. Since fewer number of highly contaminated filters have to be handled in this case.

TABLE - 2

Comparitive Costs of Recirculation and Once through systems (PURNIMA LABS)

S.No.	Description	Recirculation A/c. System.	Once through A/c. System.
1.	Tonnage 650 M^3 Volume considered for design)	15 TR	60 TR
2.	Air - changes provided	12 Recirculation 3 Once through	15 Once through
3.	Cost of Installation (using chilled water system) but without the cost of exhaust Air system & without standby capacity.	* 2,70,000	* 9,60,000
4.	Cost of Exhaust system (with 100% standby capacity)	25,000	1,00,000
** 5.	Operating Cost per annum (Energy)	32,000	1,05,000
** 6.	Make up water charges per annum	540	1,800
** 7.	Maintenance cost,(excluding Water and Energy charges as at item 5 & 6 above)	15,000	50,000
8.	Total capital cost (No.3 + No.4)	2,95,000	10,60,000
9.	Total running cost per annum (No.5 + No.6 + No.7)	47,540	1,56,800

* Inclusive of costs of absolute filters incorporated in the system.

Savings in capital costs = 72%

Savings in running costs = 70%

** One shift, 270 days operation per annum.

There is no significant cost difference in the filtration system between once through and recirculating system since the total number of absolute filters needed are the same in both cases.

5. Conclusions:

From Table-2, it can be seen that there is a significant saving both in capital cost and in the running cost. This saving has been achieved without sacrificing any safety features of the laboratory.

It is important to note that the economics indicated in this report are applicable to the system analysed. Economics of the new approach for any other laboratory should be worked out separately taking into account the safety aspects of the respective laboratory.

A significant saving in the running cost is attributable to the saving of energy. In the present day energy crisis which is likely to become more acute in the future, it is worth examining the feasibility of such systems for future radioactive installations.

Acknowledgements:

Authors are grateful to Shri S.D. Soman, Head, Health Physics Division for his advice to prepare this report in the present format.

Reference:

1. M. Srinivasan, K. Chandramoleshwar et.al "Preliminary Safety Analysis for PURNIMA II", BARC/I-488 (1978)

J. Shapiro, "Tests for the evaluation of airborne hazards from radioactive surface contamination", Health Physics Journal Vol 19, PP 501 to 510, 1970.

Appendix A

Description of Ventilation System

Purnima Ventilation system is designed to cater to two 9M x 6M x 6M High active laboratories that also house glove boxes to enable handling of radioactive materials. There are two separate systems, one "once through" exclusively for the glove boxes and the other, a recirculatory type for working areas in the vault with arrangement that the exhausted air is routed through HEPA filters which constitutes the departure from normal recirculatory systems. Two filter banks (one standby) has been provided in the return air passage line. Six filters are incorporated in each filter bank (absolute filter size 609 x 300 mm thick ; capacity 1700 CMH). Necessary manual dampers are included in the system for isolating the standby chamber. These dampers are multi-louvered type and not of leak tight construction. After filteration of the return air, the same passes through common air plenum, cooling coil, booster fan etc.

The conditioned air is supplied to the active labs through insulated sheet metal ducting, strip heaters are provided for humidity control. The cooling capacity of the coil is 20 TR. The blower capacity is 10,000 CMH.

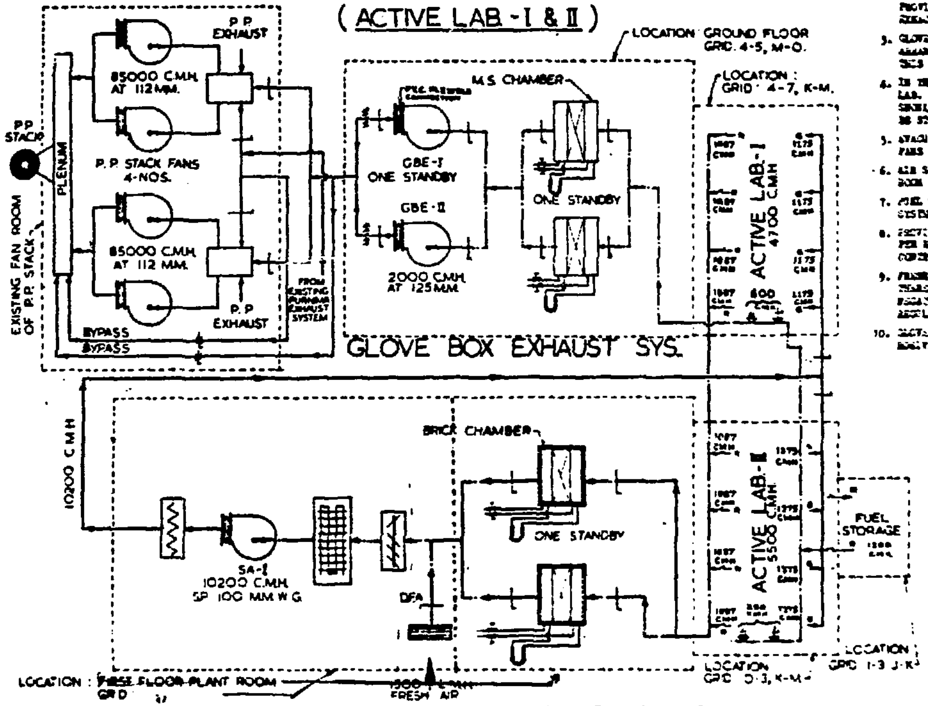
Provision is made to give 1 to 3 changes per hour of fresh air for this system. Recirculation air changes are in the range 10-12 per hour. The design conditions specified to be maintained inside the Lab. is 24.1°C ± 1°C in temperature and 55 ± 5% in relative humidity.

A separate common exhaust system has been provided for the glove boxes, fuel storage room and emergency exhaust by providing separate blowers and air filteration arrangement. There are two blowers and two air filteration units out of which only one set is normally working. The system is electrically interlocked with supply fan of the active labs in such a way that in case of failure of exhaust fan, the supply fan should be automatically stopped to avoid pressurisation of the laboratory. The exhaust fan capacity is 1700 CMH against 175 mm W.G. static pressure.

The system is working on 24 hour basis and arrangement is provided for emergency generator power to be automatically switched on in case of electricity failure. In case of any accidental activity release first the air supply system has to be stopped. Then the standby exhaust fan should be manually switched on to augment the other exhaust fan which is already operating. The air from working areas of active labs would then be exhausted at the rate of 1200 CMH and is expected to provide once through ventilation of four air changes per hour. Figure 1, 2 and 3 present the schematic of the ventilation system alongwith its salient features.

OVER-ALL VENTILATION SCHEMATIC FOR PURNIMA REACTOR EXTENSION SUPPLY & EXHAUST SYS.

(ACTIVE LAB - I & II)



ACTIVE LAB-I & II RECIRCULATORY AIR-CONDITIONING SYSTEM

NOTE

1. GLOVE BOX EXHAUST FANS GBE-I & II ARE ELECTRICALLY INTERLOCKED WITH SUPPLY FAN SA-I OF ACTIVE LAB. IN CASE OF FAILURE OF GLOVE BOX EXHAUST FAN THE SUPPLY FAN AUTOMATICALLY STOPS TO AVOID PRESSURISATION OF THE LAB.
2. VISUAL INDICATION FOR GLOVE BOX EXHAUST FANS GBE-I & II ARE PROVIDED IN THE HEALTH PHYSICIST ROOM INDICATING WHETHER THE EXHAUST SYSTEMS ARE WORKING OR NOT.
3. GLOVE BOX EXHAUST SYSTEM SHALL BE WORKING ON 24 HOURS BASIS. ARRANGEMENT IS ALSO PROVIDED FOR EMERGENCY POWER CONNECTION FOR THIS LAB. FROM EXISTING EMERGENCY POWER SUPPLY SYSTEM OF P.P.
4. IN THE EVENT OF SUDDEN RELEASE OF RADIO ACTIVITY IN THE ACTIVE LAB. I & II, THE SUPPLY SYSTEM SA-I LOCATED ON FIRST FLOOR SHOULD BE STOPPED AND STAND BY FAN OF GLOVE BOX SYSTEM SHOULD BE STARTED. BOTH THE OPERATIONS SHALL BE MANUALLY CARRIED OUT.
5. EVACUATING TIME OF LAB. I & II BY RUNNING BOTH THE GLOVE BOX FANS GBE-I & II SHALL BE 16 MINUTES.
6. AIR SUPPLY TO FUEL STORAGE ROOM IS INDUCED TYPE, THEREFORE THE ROOM SHALL NEVER BE UNDER POSITIVE PRESSURE AT ANY TIME.
7. FUEL STORAGE ROOM EXHAUST IS CONNECTED TO GLOVE BOX EXHAUST SYSTEM WHICH IS TO WORK ON ROUND THE CLOCK BASIS.
8. PROVISION OF [illegible] PRESSURE IS MADE TO GIVE [illegible] AIR CHANGES PER HOUR FOR ACTIVE LAB. I & II. FRESH AIR INTAKE CAN BE CONTROLLED BY MEANS OF DAMPER DFA.
9. FRESH AIR INTAKE 1,500 CMH AND GLOVE BOX EXHAUST IS [illegible]. THEREFORE, LAB. SHALL BE MAINTAINED UNDER [illegible] NEGATIVE PRESSURE. NEGATIVE PRESSURE CAN BE VARIED BY [illegible] REGULATING INTAKE AIR BY DAMPER DFA.
10. GLOVE BOX EXHAUST DUCT IS M.S. [illegible] DUCT PAINTED WITH [illegible] PAINT.

LEGEND :

- MANUAL MULTILOUVERED DAMPER
- GRAVITY DAMPER
- ABSOLUTE FILTER
- FRESH AIR FILTER
- FACE & BYPASS DAMPER
- COOLING COIL
- HEATER BOX
- CENTRIFUGAL
- MANOMETER
- SUPPLY AIR GRILL
- RETURN AIR GRILL
- DIRECTION OF AIR FLOW
- VALVE FOR AIR SAMPLING PURPOSE
- GLOVE BOX TAPPINGS
- SLIDING ORIFICE CONNECTION

FIG. 1

ACTIVE LAB. I & II RECIRCULATORY AIR-CONDITIONING SYSTEM

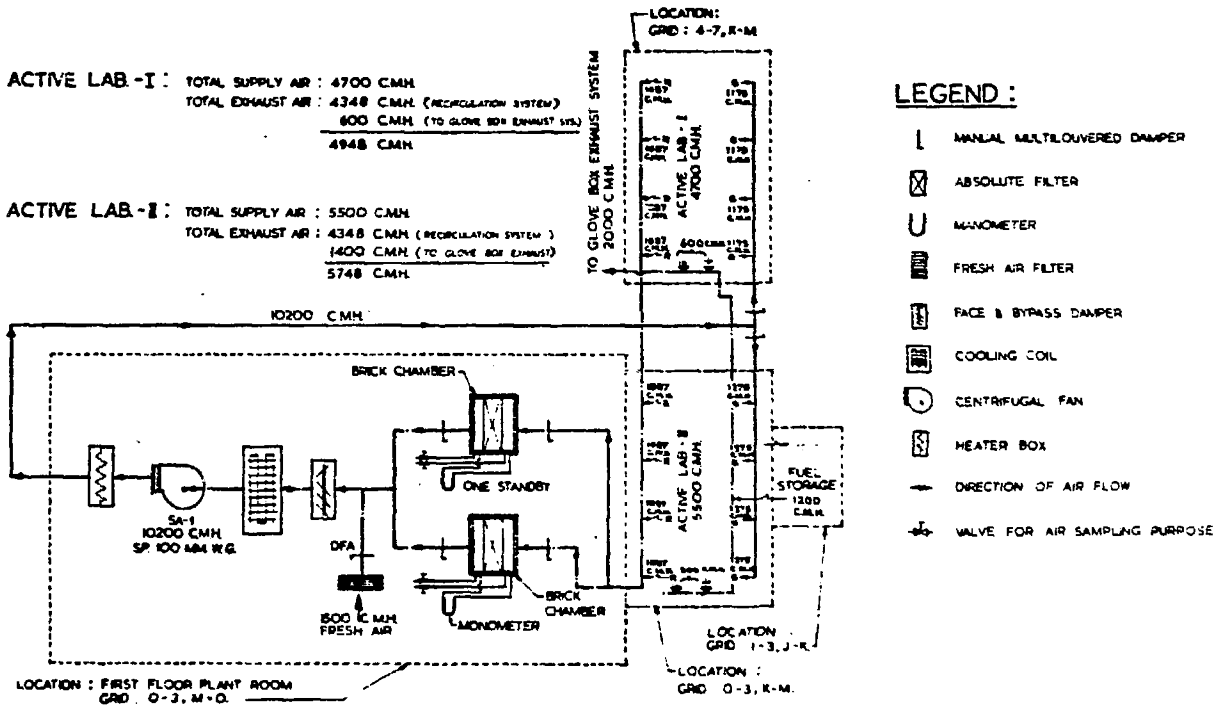


Fig. 2

GLOVE BOX EXHAUST SYSTEM

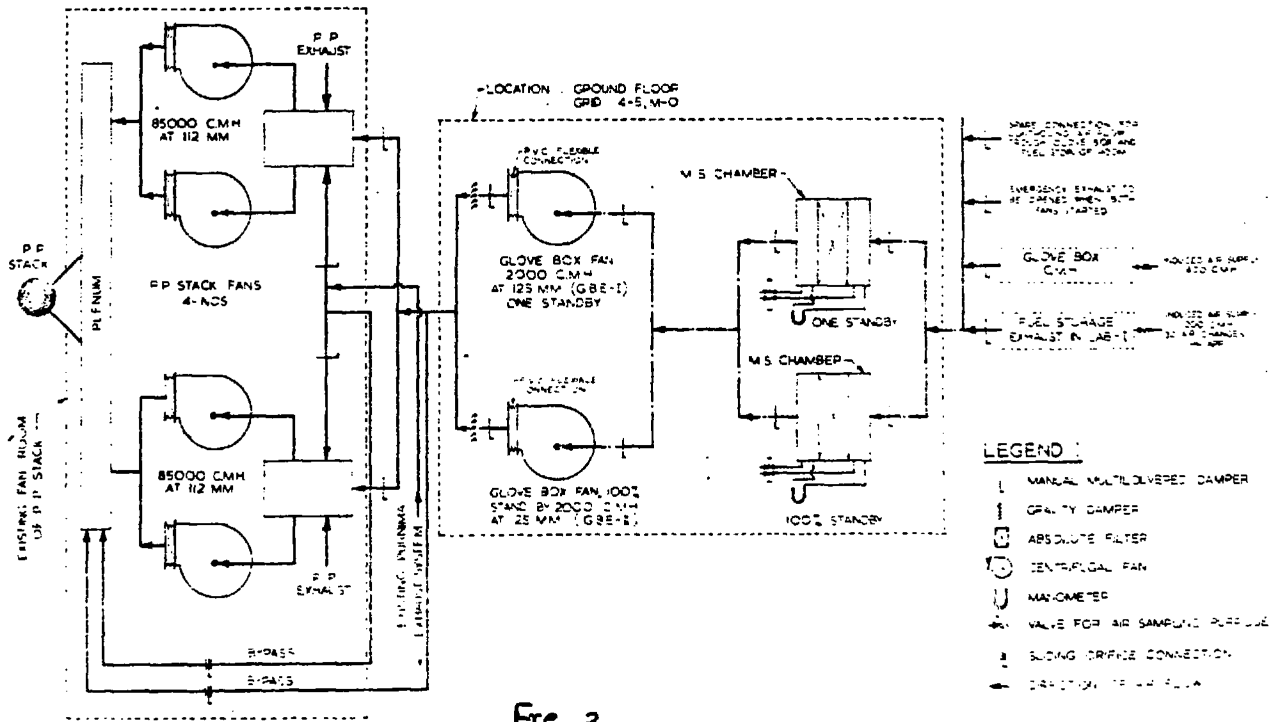


Fig. 3

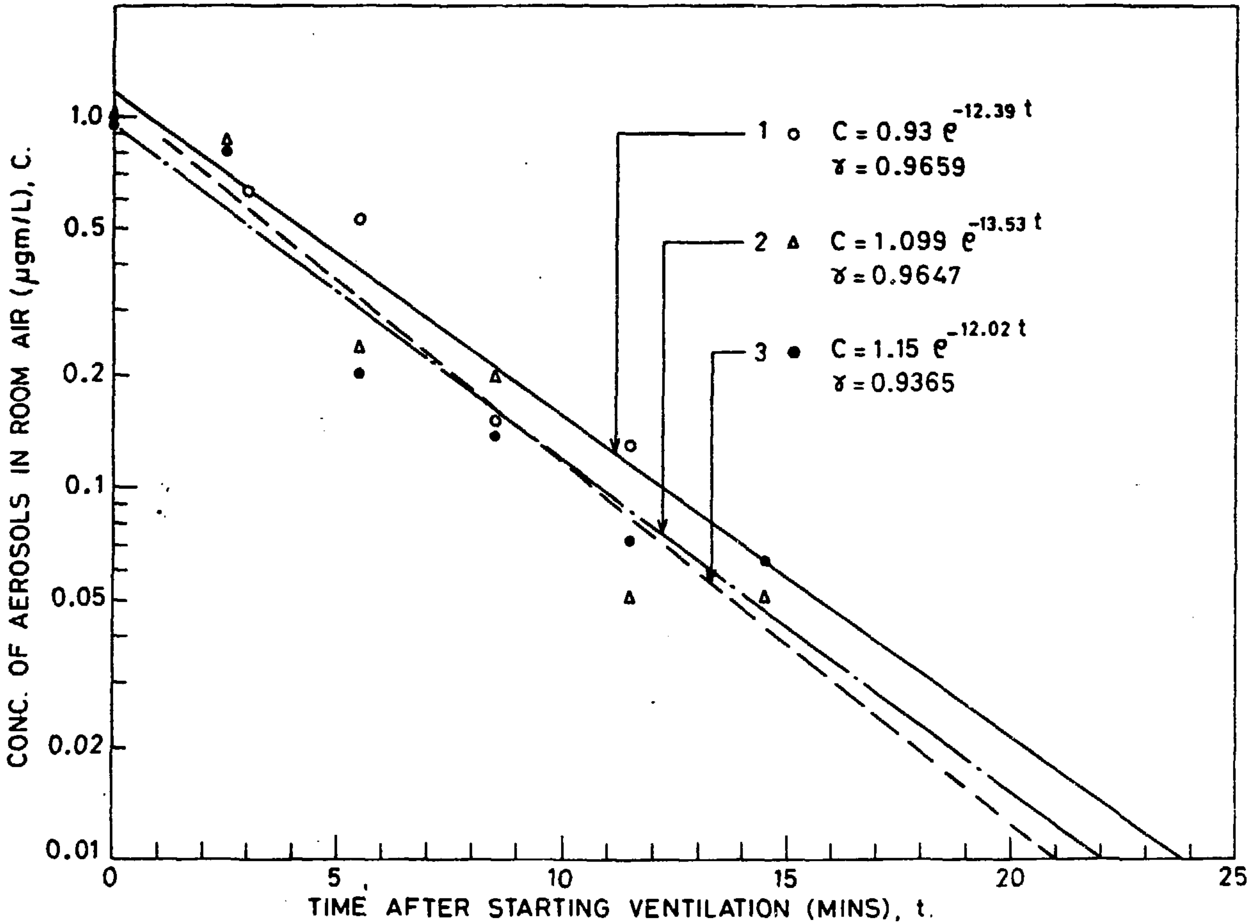


FIG. 4. CONCENTRATION OF AEROSOLS IN ROOM AIR AT DIFFERENT TIMES AFTER THE START UP OF VENTILATION