A SURVEY STUDY OF ISOLATION ROOMS FOR TUBERCULOSIS IN TAIWAN

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ABSTRACT

Isolation rooms for Tuberculosis in fifteen hospitals have been surveyed and measured in two phases. In phase 1 the isolation rooms in seven hospitals were checked after the hospitals renovation construction had been finished. However in phase 2 all the design drawings of the air-conditioning and ventilation/exhaust system of isolation rooms in eight other hospitals were checked and revised by ERL's engineer before starting construction. The survey items include ventilation rate、static pressure、temperature and humidity. All the measuring data were checked in order to understand whether or not the performance of the air-conditioning and ventilation/exhaust system of isolation rooms for Tuberculosis meet the recommendations of ASHRAE.

The survey results of all hospitals are illustrated in this paper in more detail. And we draw a very important conclusion that the design drawings of the air-conditioning and ventilation/exhaust system of isolation rooms should be checked and revised by qualified engineers before starting renovation construction.

1. INTRODUCTION

During recent years the tuberculosis case rate has been around 0.6% in Taiwan and its death rate per 100,000 population was 7.52 in 1995[1]. Tuberculosis has long been recognized as a disturbing to public health. Transmission of tuberculosis from patients who have infectious TB to other patients and health workers has been reported in hospitals in Taiwan. The increasing level of concern has aroused attention among government officers in the Health Department and healthcare workers. How to control the nosocomial infection of tuberculosis has become the mission to hospitals. Health Department in Taiwan has proposed a five-year program to sponsor 50 hospitals to set up TB isolation rooms in order to accommodate tuberculosis patients. Because many engineers working in the hospital have no experience setting up isolation rooms ERL's engineers have been invited to be consultants and to test the performance of the air-conditioning and ventilation/exhaust system in TB isolation rooms.

2. TUBERCULOSIS NOSOCOMIAL INFECTION CONTROL PROGRAM

The TB infectious control program of the department of health in Taiwan include two levels of control plans. The first level is the use of administrative measures intended to reduce the risk of exposing uninfected persons to persons who have infectious TB. The second level is the use of engineering controls. This paper focuses on discussing the effective engineering controls to prevent the spread and reduce the concentration of TB droplet nuclei in isolation rooms.

The use of engineering controls is illustrated as follows:

(a) Negative pressure control is a process during which the amount of exhausted air from a room exceeds the amount of total supply air.
(b) Ventilation is a diluted process during which the concentration of TB droplet nuclei in a room can be reduced by supplying fresh air or exhausting the mixed room air.
(c) Air cleaning devices can be used. For example, the high efficiency particulate arrestance filters (HEPA) and ultraviolet germicidal irradiation (UVGI) have been used to remove the TB droplet nuclei.

3. PROJECT FOR EVALUATION OF AIR CONDITIONING AND VENTILATION / EXHAUST SYSTEM OF TB ISOLATION ROOMS

The purpose of this project is to evaluate the performance of the air conditioning and ventilation/exhaust system of isolation rooms and develop as well as install the appropriate engineering controls to reduce the transmission of mycobacterium tuberculosis in hospitals. It is very difficult to retrofit the air conditioning and ventilation/exhaust system for renovating the existing hospital facilities into TB isolation rooms which need special ventilation characteristics for the purposes of isolation. In order to use the existing facilities and minimize the cost of renovation engineers should consider many items, for example, (a) whether or not to use the existing fan coil; (b) anteroom location; (c) negative pressure control; (d) ventilation rate; (e) air flow pattern; (f) exhaust flow treatment; (g) building sealing; (h) temperature and humidity control; (i) monitoring instruments; (j) repair and maintenance.

3.1 RECOMMENDATION FOR PRESSURE RELATIONSHIP AND VENTILATION RATE

The TB isolation rooms should be designed having a minimum of 6 air changes per hour (ACH) based on the recommendation of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) [2]. In order to prevent the escape of TB droplet nuclei the infectious isolation rooms should be operated and maintained under negative pressure for achieving unidirectional airflow [3].

3.2 EXPERIMENTAL TECHNIQUES AND METHODS

The performance of the air conditioning and ventilation/exhaust system of TB isolation rooms in fifteen hospitals have been surveyed and measured in two phases. Phase 1 the isolation rooms in seven hospitals were checked after the hospitals renovation construction had been finished. However in phase 2 all the design drawings of the air conditioning and ventilation/exhaust system of TB isolation rooms in eight other hospitals were checked and revised by ERL's engineers before starting construction. The survey items include ventilation rate、static pressure、temperature and humidity. All the measuring data and survey results were checked in order to understand whether or not the performance of the air conditioning and ventilation/exhaust system of TB isolation rooms meet the recommendation of ASHRAE.

Negative Pressure Control

The purpose of negative pressure is to control the direction of airflow between the TB isolation rooms and adjacent areas, thereby preventing contaminated air escaping from these rooms into other areas. The negative pressure achieved will depend on the difference between the exhaust and supply flows in the room. The differential pressure gauge is used to measure the pressure difference between the isolation room and adjacent area. We suggest that negative pressure should be maintained at 7 Pa or higher to keep the unidirectional flow.

Ventilation Rate and Measurement

The ventilation of the isolation rooms maintains air quality by dilution and removal of airborne contaminants. The ventilation rate is expressed in air change rate (ACH). The number of ACH is expressed as the ratio of the volume of air entering the room per hour to the room volume and is equal to the exhaust airflow (Q) divided by the room volume (V) multiplied by 60, i.e. $ACH = Q \div V \times 60$.

Tracer gas decay is a direct measurement of the air change rate. An inert gas which is easily detected at very low concentration is released and uniformly mixed within the isolation room. Assuming the gas does not react with the surrounding materials, the gas concentration will decrease as dilution air flow into room. The rate of decrease is proportional to the ventilation rate.

The air change rate is calculated using the following equation:

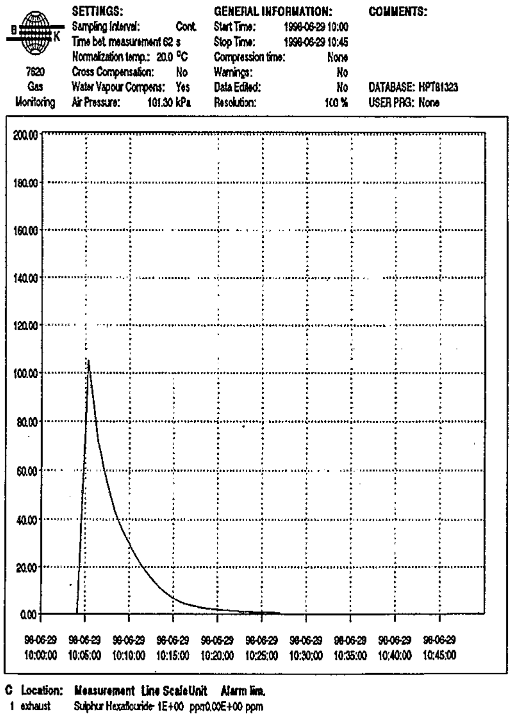
$$C(t) = C(0)^{-It}$$

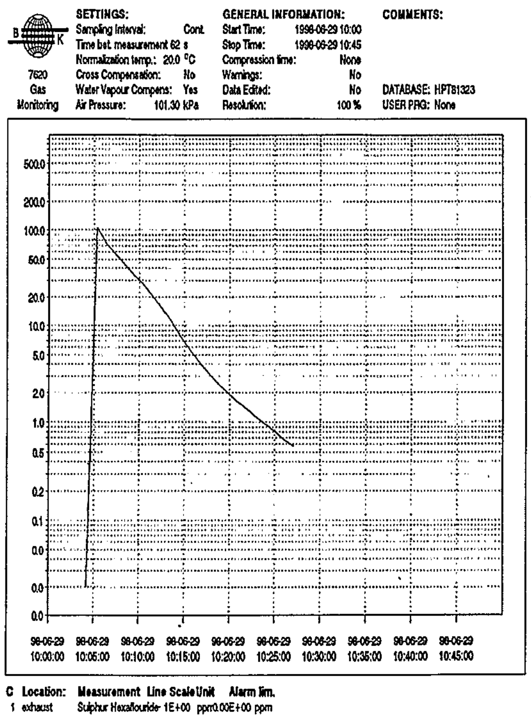
Where:
$C(t)$ = tracer gas concentration at time t
$C(0)$ = tracer gas concentration at time $t = 0$
I = air change rate
t = total measurement time

This equation can be rearranged to yield the following expression:

$$I = [\ \ln C(0) - \ln C(t)\ ] \div t$$

The sulfur hexafluoride (SF_6) was used as a tracer gas. A multi-gas monitor based on the photoacoustic infra-red detection method is used to measure the concentration of sulfur hexafluoride every minute[4]. The concentration of tracer gas shown on the left figure is found to decay exponentially with time. By plotting the natural logarithm of gas concentrations against time a straight line shown on the right figure is obtained and the gradient of the line is the value of air change rate.





4. RESULTS & DISCUSSION

From the point of view of preventing contaminated air escaping from an infectious isolation room into other areas in hospital the three most important criteria to the TB isolation rooms are negative pressure, ventilation rate and anteroom. During the period of phase 1 we surveyed the performance of the air conditioning and ventilation/exhaust system of TB isolation rooms after all seven hospitals renovation construction had been finished. Table 1 lists the survey results of seven hospitals in phase 1.

Table 1. The survey results of seven hospitals in phase 1

Hospital	Pressure (Pa)	ACH (h^{-1})	Anteroom
A	-6.5 ~ -13	19	Yes
B	-6 ~ -11	8	Yes
C	-2	5	No
D	+0.5	3	Yes
E	-4	18	No
F	0	10	Yes
G	0	2	Yes

However in phase 2 all the design drawings of the air conditioning and ventilation/exhaust system of isolation rooms in eight hospitals were checked and revised by ERL's engineer before starting renovation construction. Table 2 lists the survey results of eight hospitals.

Table 2. The survey results of eight hospitals in phase 2

Hospitals	Pressure (Pa)	ACH (h^{-1})	Anteroom
H	-5 ~ -6	9	Yes
I	-8	12 ~ 20	Yes
J	-18 ~ 30	5 ~ 7	Yes
K	-16	8 ~ 12	Yes
L	-15 ~ -17	14 ~ 16	Yes
M	-3 ~ -4	8 ~ 13	Yes
N	-4	10	Yes
O	-25	30	Yes

The surveyed results of all hospitals are illustrated as follows：

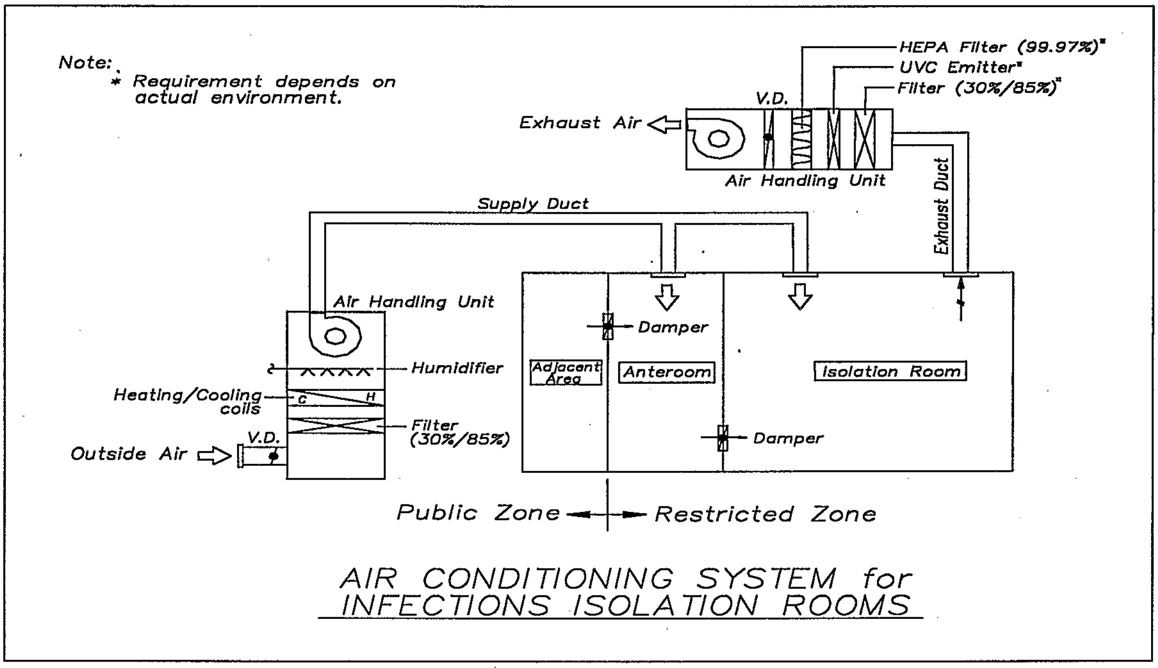
1. The performances of the air conditioning and ventilation/exhaust system of isolation rooms in ten hospitals meet the recommendation of ASHRAE. The data of negative pressure of the isolation rooms distributed from 3 Pa to 25 Pa. The data of air change rate of the surveyed isolation rooms are distributed from 5 to 30. All test data were diversified because the different design should accommodate the existing ventilation and air-conditioning strategies.
2. The air change rate of isolation rooms of three hospitals can not meet the recommendation of ASHRAE.
3. The negative pressure of isolation rooms can not be set up in three hospitals.
4. The anteroom for isolation room has not been built in two hospitals.
5. The isolation rooms in five hospitals have been designed to use recirculated air.
6. The air conditioning and ventilation/exhaust system of TB isolation rooms in five hospitals should be renovated again.

5. CONCLUSIONS AND RECOMMENDATIONS

Considering the issue of facilities repair and maintenance the ERL's engineers proposed the TB isolation rooms should meet the following requirements:

- Air lock
- Dedicated air conditioning and ventilation /exhaust system
- No special filtration
- No air recirculated
- Negative air pressure relative to the corridor and the surrounding areas
- At least supply rate of 6 air changes per hour
- Pressure gauge and alarm system
- Visible labeling
- Grouping isolation rooms together in one area of the building

The ERL's engineers recommended a design drawing of the air conditioning and ventilation/exhaust system for infectious isolation rooms shown as the following figure.



And we draw a very important conclusion that the design drawings of the air conditioning and ventilation/exhaust system of isolation rooms should be checked and revised by qualified engineers before starting renovation construction.

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7. REFERENCES

1. Health and Vital Statistics in Republic of China, 1996
2. ASHRAE (1995) Health Care Facilities, in 1995 ASHRAE Handbook: Heating, Ventilating and Air-Conditioning Applications, American Society of Heating, Refrigerating and Air-Conditioning Engineers. Atlanta, Georgia, p. 7.5
3. CDC (1994) Guidelines for Preventing the Transmission of Mycobacterium tuberculosis in Health-Care Facilities, 1994. MMWR 43(RR-13), U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Atlanta, Georgia
4. Instruction Manual, Vol.1, Multi-gas Monitor Type 1302, Bruel & Kjær