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EVALUATION OF THE PERFORMANCE OF FIRE DETECTION SYSTEM IN AN INSTITUTIONAL BUILDING

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ABSTRACT

Analysis of statistical records on the number of faults and unwanted alarms due to detectors reported in an institutional building of Open University of Hong Kong (OUHK) for 4 years will be reported. Site inspections and detailed analysis on the automatic fire detection systems were performed. The location of detectors and environmental conditions were measured. The main causes of the faults and unwanted alarms in detectors were studied and compared with the BS standard, NFPA Code and manufacturer's guides. Suggestions were made for improving the system performance. In order to find out the relation of the selection and location of detectors to the number of faults and unwanted alarms, a proposed experiment will be performed in the next semester.

1. INTRODUCTION

The basic functions of a fire detection system include notifying building occupants of emergency conditions for evacuation purposes; detecting specific stages of a fire, e.g., smoldering or flaming of fire development; actuating fire suppression systems; supervising fire suppression system; alerting organized assistance, such as the Hong Kong Fire Services Department, to undertake fire fighting operations; and supervising processes for abnormalities that might cause fire.

Because of the frequent occurrence of unwanted alarms, occupants are not so alert when there is alarm for real fires. On the other hand, the problem of malfunction detectors will expose certain areas to lack of protection from the fire detection system. All these will increase the potential danger of the premise.

The purpose of this research is to investigate the parameters affecting the malfunction of detectors and the occurrence of unwanted alarms, and to determine any parameters that can help to predict and avoid both defects. Finally, an improved maintenance scheme should be formulated in order to solve these problems.

2. LITERATURE REVIEW

The Open University of Hong Kong (OUHK) Ho Man Tin campus is chosen for study in this research project because the building is used for different purposes including lecture theatres, laboratories, student common rooms, stores, hostels, offices and E & M plant rooms. The relation of unwanted fire alarms and malfunction detectors for different functional rooms can be studied. Secondly, there are many students and staff inside the campus, a reliable automatic fire detection system is of significant importance. However, according to the maintenance records, faults and unwanted fire alarms are frequent. Therefore, a detailed investigation has to be carried out and a better maintenance scheme should be formulated in order to solve these problems.

The OUHK campus is a 16-storey building including a 2-storey basement. The usage of the building is as follows: L-2 basement is F.S. pump room; L-1 basement is stores, lecture theatres and E & M plant rooms; L0 is entrance and student common rooms; L1 & L2 are learning resources centre; L3 is laboratories; L4 is tutorial rooms; L5 is offices and seminar rooms; L7 is offices and hostels; L8-L11 are offices; L12 is multi-purpose rooms and plant rooms; and L13 is E & M plant rooms.

Analogue fire detection system is used for this campus. It is an automatic fire detection and alarm system in which a signal representing the value of the sensed phenomenon is processed with a view to enable more than two output states to be given. It represents the normal condition, fire condition and at least one other abnormal condition. The processing may take the form of application of fixed thresholds to the value of the sensed phenomenon [1] .

In consideration with the new structures of the code BS5839-1 2002, the sections on design, installation, commissioning, and maintenance are virtually standalone. It should also be noted that the recommendations on limitation of false alarms have been elevated to the status of an entire section of the code, rather than simply a single clause as in the last version [2]. It is clear that the limitation of false alarm would become important in the future.

In order to tackle successfully the problems of false alarms and faults due to detectors in an existing premise, site inspections are carried out many times. It is found that architectural features would affect the detectors at some points. A proposed experiment with simulation to the actual site condition will be performed to find out the relation of this parameter in the coming semester. Meanwhile, a periodic testing and maintenance for the detection system should not be ignored. This is because fire detection systems and devices will not function properly unless they are maintained and tested regularly.

Proper maintenance is as important as regular testing for a fire alarm signaling system. Automatic fire detectors maintenance depends on the type of detector used, local environmental conditions, and manufacturer's recommendations. The manufacturer's recommendations should be implemented in the maintenance program to maintain system reliability. Each detector should be visually inspected to ensure that it remains in good physical condition and that there is no change such as building modifications, occupancy hazards, and environmental effects that would affect detector performance. Detectors require periodic cleaning to remove dust or dirt that has been accumulated. The frequency of cleaning depends upon the type of detector and the local ambient conditions. High air velocity environment may create increased dust contamination, demanding more frequent maintenance. For each detector, the cleaning, checking, operating, and sensitivity adjustment should be performed according to the manufacturer's instructions.

3. AIMS AND OBJECTIVES

The purpose of this research is to investigate the parameters affecting the malfunction of detectors and the occurrence of unwanted fire alarms. The number of unwanted fire alarms and the number of malfunction of detectors were analysed by means of studying the distribution of the number of malfunction and unwanted alarms against the parameters and siting of detectors and to discuss the predictability and avoidance of both. Finally, an improved maintenance scheme should be worked out. From the result of the experiment, the site measurement and maintenance record, a design guide will be established for selecting the suitable detector sensitivity and location so as to achieve optimum fire detection.

4. METHODS

There are three main types of detectors used in this building. One is Honeywell's intelligent fixed temperature heat detector model TC808A. Others are Honeywell's ionization smoke detectors with models TC807A and TC807B. These are tamper-resistant solid-state devices which sense temperature levels and particles of combustion respectively. Each sensor has a unique point address from 01 to 99 on an intelligent loop interface circuit and provides continuous, analog signals to FS90 Plus panel. The sensor can be tested using a FS90 Plus panel and can be tested locally using an externally applied magnet to the sensor base.

Smoke detectors, even when working properly, have sensing limitations. Detectors that have photoelectronic sensing chambers tend to detect smoldering fires better than flaming fires, which have little visible smoke. Model TC807A and TC807B, which have ionizing-type sensing chambers, tend to detect fast flaming fires better than smoldering fires.

In this campus, the electronic fixed temperature heat detectors are installed in A/C plant rooms, pump rooms and generator room on several floors. Ionization smoke detectors are installed in electrical switch rooms, meter rooms, wiring closet, L0 warehouse, store, L7 low block hostels and L8 high block office area. The zonings of the detection system, break glass, alarm bell and sprinkler flow switch are connected individually at each floor. The Honeywell Excel FS90 panel is located at G/F F.S. control room with air conditioning. It is used to monitor and indicate the status of sprinkler system, fire hydrant/ hose reel system and fire alarm system. It consists of break glass unit signals, flow switch signals, preaction panel repeat signals and all pumps status signals. The system is connected to Fire Services Control Centre of Chubb. When the F.S. panel receives the signal, it will transmit the alarm signal to the Fire Services Control Centre of Chubb. It is possible to accept the audible signal which shall siren when a second fire alarm occurs. Alarm points can be checked through the keyboard of fire control panel.

FS90 Plus panel continuously scans sensors to determine their condition. When alarm threshold is reached, this panel identifies the device type and location, and commands indicating circuits and individual relays to respond to the alarm. FS90 Plus panel recognizes normal conditions, alarm conditions, below-normal sensor values that reveal a trouble condition, and above-normal values that indicate either a prealarm condition or the need for maintenance. An operator at the FS90 Plus can read sensor address and condition. The operator can also adjust alarm and prealarm thresholds and other parameters.

In this campus, all architectural features of the detector points that can be accessible are marked. The data are divided into four orientations, which are east, south, west and north. Fault and unwanted fire alarm records are read from the Honeywell Excel FS90 panel. In addition, considering the maintenance records of fire detection system, the frequency of faults and unwanted fire alarms is quite high at some detectors such as point 3055 on L13 pump room, point 2055 on L1 main entrance, point 1003 on L2 AHU room L0217, point 1085 on L0 staircase no. 1, point 2024 on L-1 warehouse, point 4061 on L7 male toilet and point 2008 on L-1 lobby (Table 1). For these critical points, the digital loggers HOBO are used to measure the temperature and relative humidity.

5. RESULTS

The causes of unwanted alarms in OUHK are mainly divided into five types as listed below:

- System fault: False alarm due to defect or malfunction of a system component such as defective smoke detector or panel fault.
- Human error: False alarm caused by careless mistake by people inside the premise, such as the workers disconnect the detectors without isolation of that loop of detectors during the maintenance period and some occupants.
- Work progresses: Work progresses from the contractors may also actuate unwanted alarms. For example, during the renovation work in this campus, the workers welding metals without deactivation of smoke detectors may also cause unwanted alarms or the installed detectors had insufficient protection to prevent the ingress of dust. The ingress of dust may create a potential risk of unwanted fire alarm and the use of dust cover of detector or removal of sensors can avoid the nuisance alarms.
- Environment factor: False alarm due to the environmental conditions such as dusty or steamy environment or environment similar to situation of fire.
- Unknown: The cause of alarm that cannot be identified.

In order to study the cases in detail, the monthly and daily distribution of the reported faults and unwanted fire alarms are shown in Tables 2a, 2b and 3a, 3b respectively.

Table 1

Location	Measurement Period	Average Temp. (℃)	Average Humidity (%)	Maximum Temp. (℃)	Maximum Humidity (%)
Pt 2055 L1 Main Entrance	12/11/02~13/11/02	24.7	73.3	27.9	82
Pt 3055 L13 Pump Room	12/11/02~13/11/02	26	72.7	26.3	76
Pt 1085 L0 Staircase 1	14/11/02~15/11/02	26.1	80.3	28.3	88.2
Pt 1003 L2 AHU Room	14/11/02~19/11/02	22.2	73.8	29.5	99.1
Pt 2024 L-1 Ware House	15/11/02~19/11/02	21.7	67.7	27.1	81.8
Pt 4061 L7 LB Male Toilet	19/11/02~21/11/02	22	73.4	25.17	81.3
Pt 2008 L-1 Lobby	19/11/02~21/11/02	22.3	64	26.7	69

Table 2a: Monthly distribution of detector faults

Month	Detector Faults			
	1999	2000	2001	2002
January	4	1	5	4
February	2	1	2	3
March	2	2	3	6
April	3	1	8	1
May	5	14	7	6
June	10	13	9	8
July	5	6	7	3
August	7	11	6	6
September	1	3	2	3
October	4	8	4	*
November	7	0	2	*
December	6	1	1	*

* the number of unwanted fire alarm is excluded

Table 2b: Monthly distribution of unwanted fire alarms

Month	Unwanted Fire Alarms due to Detectors			
	1999	2000	2001	2002
January	0	0	2	0
February	0	0	0	1
March	0	0	0	0
April	0	0	1	0
May	0	0	0	3
June	0	1	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
October	0	0	0	*
November	0	0	0	*
December	0	0	0	*

* the number of unwanted fire alarm is excluded

Table 3a: Daily distribution of the detector faults

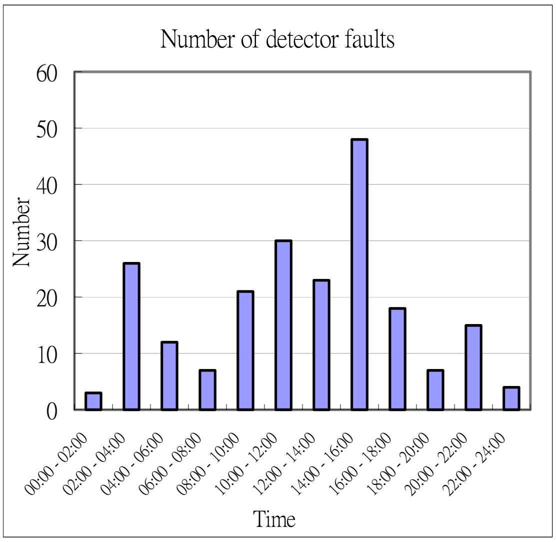
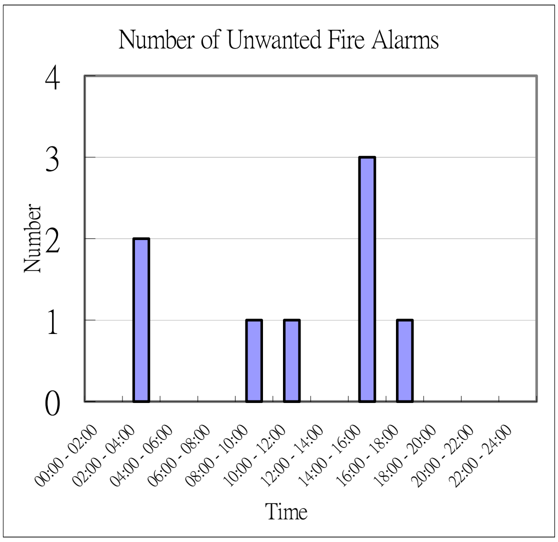


Table 3b: Monthly distribution of unwanted fire alarms



6. COMPARISON WITH RELEVANT STANDARDS

Codes and standards fall into three broad categories: codes, installation standards, and performance standards.

Codes specify circumstances under which a given type of protection is required. For example, NFPA 101, Life Safety Code, requires specific types of systems and devices for specific occupancies.

Installation standards detail how the protection specified by the code is to be achieved. In addition to details on installation and use, these standards include requirements for maintenance and periodic testing of the installed equipment.

Performance standards specify which functions and capabilities are required of the hardware and conditions under which the equipment must operate. Standards developed by testing laboratories, such as Underwriters Laboratories Inc. (UL) are examples of performance standards.

Codes and standards with requirements applicable to fire alarm signaling system are listed in Table 4.

Table 4: Code and standard requirements for fire alarm and detection systems

CODE and Standard	Requirements
NFPA 70	Wiring requirements for fire alarm signaling systems.
NFPA 72 Chapter 7	Notification Appliances for Fire Alarm Systems-
NFPA 72 Chapter 10	Inspection, Testing and Maintenance
NFPA 101	System or protective functions required in various occupancies.
BS EN 54-1: 1996	Fire Detection and fire alarm systems-Part 1: Introduction
BS EN 54-2: 1998	Fire Detection and fire alarm systems-Part 2: Control and indicating equipment
BS EN 54-3: 2001	Fire Detection and fire alarm systems-Part 3: Fire alarm devices-sounders
BS EN 54-5: 2001	Fire Detection and fire alarm systems-Part 5: Heat Detectors -- Point Detectors
BS EN 54-7: 2001	Fire Detection and fire alarm systems-Part 7: Smoke Detectors -- Point Detectors using scattered light, transmitted light or ionization.
BS EN 54-12	Fire Detection and fire alarm systems-Part 12: Smoke Detectors -- Optical Beam Detectors
BS 5839-1:2002	Fire detection and alarm systems for buildings. Code of practice for system design, installation, commissioning and maintenance
BS 5839-3:1988	Fire detection and alarm systems for buildings. Specification for automatic release mechanisms for certain fire protection equipment
BS 5839-5:1988	Fire detection and alarm systems for buildings. Specification for optical beam smoke detectors
HKFSD COP FSI	Code of Practice for Minimum Fire Service Installation and Equipment, Inspection, Testing and Maintenance of Installation and Equipment

7. EXPERIMENTS

The effectiveness of an automatic fire detection system will be affected by obstructions between heat or smoke detectors and the products of combustion. It is important that heat and smoke detectors are not mounted too close to obstructions to the flow of hot gases and smoke towards the detector. At the junction of a wall and a ceiling, there is a "dead space", within which heat or smoke detection would not be adequately effective. Similarly, as the hot gases and smoke flow horizontally across a ceiling, there is a stagnant boundary layer at the surface of the ceiling; this precludes the sensitive element of a heat or smoke detector from being mounted flush with a ceiling [1]. Moreover, air conditioning and ventilation systems with high air change rates may adversely affect the response of detectors. Therefore, in siting heat, smoke and combustion gas detectors, consideration needs to be given to the possible pattern of air movement in the premises.

From the site inspection, it is found that there were many combinations of architectural features that can affect the operation of detectors. In addition, the effect of detectors due to the location of luminaire and diffuser should also be considered. Therefore, a proposed experiment will be carried out to verify the relation of siting of detector to different combination of architectural features.

In this experiment, different distance from the detector to beam and wall will be simulated in the laboratory. The varying of the threshold readings can be observed and analysed from FS90 Plus panel at different cases with various room temperature, relative humidity and wind speed. On the other hand, the affect of luminaire and diffuser can also be measured by using the same method. Finally, the combinations of the above can also be counted and optimum fire detection will be achieved by selecting the suitable detector sensitivity and location.

The distance (in metre) performed in the laboratory setup is shown in Table 5.

Table 5

Trial	a	b	c	d	e	f
1	1.5	3	1.5	0.5	-	-
2	1.5	1	1.5	0.5	-	-
3	1.5	1	1.5	3	-	-
4	1.5	2	1.5	2	-	-
5	1.5	2	1.5	2	0.5	-
6	1.5	2	1.5	2	2	-
7	1.5	2	1.5	2	-	0.5
8	1.5	2	1.5	2	-	1.25
9	1.5	2	1.5	2	0.5	0.5
10	1.5	2	1.5	2	2	1.25
11	1.5	2	1.5	2	0.5	1.25
12	1.5	2	1.5	2	2	0.5

The Honeywell Excel FS90 Panel will be set up at the laboratory of Department of Building Services Engineering to show the varying of threshold reading instantaneously. This panel is the same as the one in OUHK. The result from this experiment would be useful to solve the problem occurred in OUHK. According to the site measurement and experimental data, a design guide will be established for selecting the suitable detector sensitivity and location so as to achieve optimum fire detection.

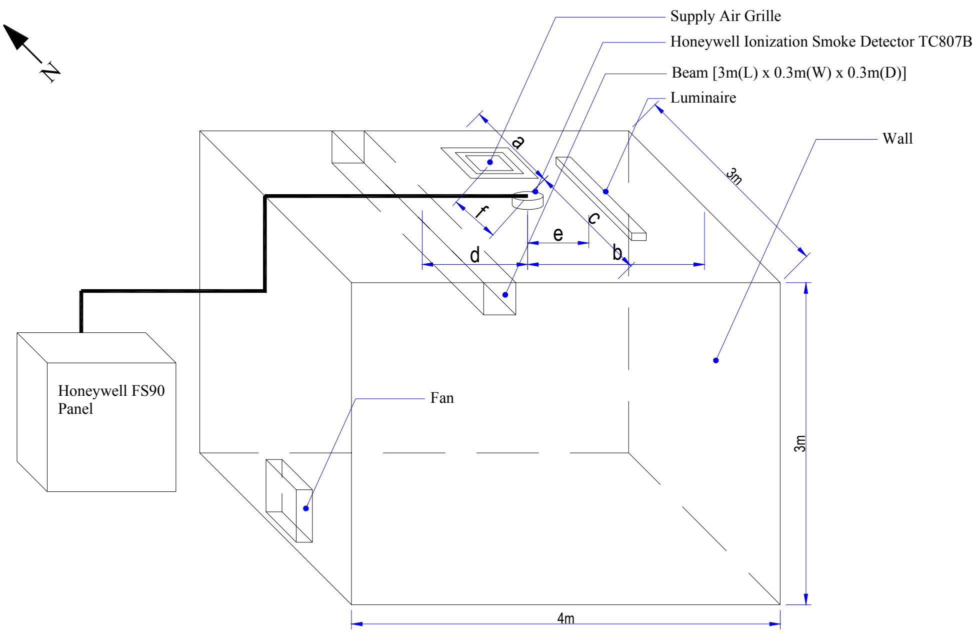


Fig. 1: Laboratory setup for threshold response of detector at different architectural features

8. CONCLUSIONS AND FUTURE WORK

For a large fire detection system in an institutional building, faults and unwanted alarms cannot be entirely eliminated no matter how perfect the system is designed, installed, operated and maintained. This is due to the complexity of the system components, frustrated environmental factor and unpredictable human factors. All these will affect the performance of the system seriously. However, it is believed that the number of faults and unwanted fire alarms can be reduced if recommendations outlined below are strictly followed.

- A thorough evaluation of the building should be performed to ensure that the smoke detectors are placed away from areas that would normally be humid, dusty, smoky, or insect-laden. Detectors should also not be located in areas with temperature extremes, excessive RF noise, or other electrical noise on the power line or in the area. Any of these could be the source of false alarms.
- Dust covers are an effective way to limit the entry of dust into the smoke detector sensing chambers. However, they may not completely prevent airborne dust particles from entering the sensor. Therefore, it is recommended to remove the detectors before beginning construction or other dust-producing activity.
- Regular cleaning of all smoke detectors should be performed as recommended by the manufacturer and NFPA 72 Standard.
- The detector sensitivity should be regularly checked and recorded. Detectors that have drifted away from their normal setting should be replaced.
- Smoke detectors should be installed away from smokers, if possible, prohibit smoking in the area.
- Multi-sensor detectors avoid the sensitivity extremes of both ionization and optical detectors, they should be confidently retro-fitted where ionization detectors are no longer tolerated or permitted [3].

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2. C. Todd, "Fire detection codes and standards-current status and the future", Fire Safety Engineering, pp. 8-12, July (2001).
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Q & A

Q1: How will you correlate the time of occurrence of false alarm and the cause of unwanted alarm?

Tse: The locations of detector are different throughout the building. The causes of unwanted alarm at different times are not recorded.

Q2: What is the reason for the high rate of unwanted alarm during the time 14:00 – 16:00?

Tse: It is mainly due to human factor for maintenance of equipment.

Q3: Have you excluded those unwanted alarms caused by human activities such as smoking?

Tse: The study of unwanted alarm in this project is intended to include various architectural configurations and environmental factors, but not human activities.

Q4: Have you included lightning effect as a cause of unwanted alarm? I am a fireman. It seems that lightning contributes to a significant number of unwanted false alarms from fireman's experience.

Tse: Currently, it is not included.

Q5: In your experiment, you have altered the distances between the detector and various architectural features including beam, air grille and luminaire. Have you considered the effect induced by air movement such as measurement of air speed?

Tse: Currently, it is not included but I will consider it in the future.

APPENDIX

The number of fires and number of unwanted fire alarms in institutional buildings from 1997 to 2001 are indicated in Table I and II respectively.

Table I: No. of fires in institutional buildings from 1997 to 2001

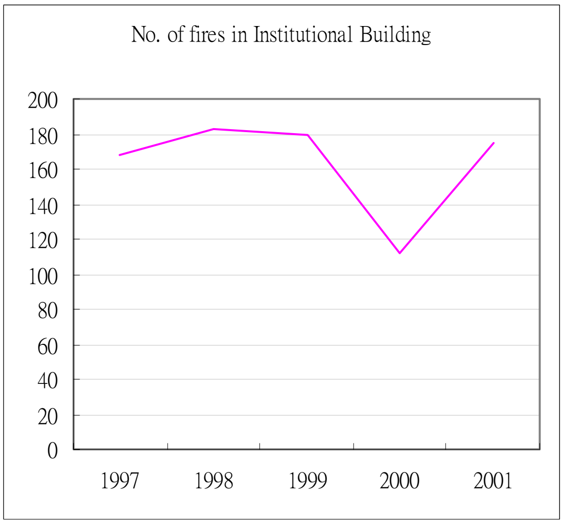
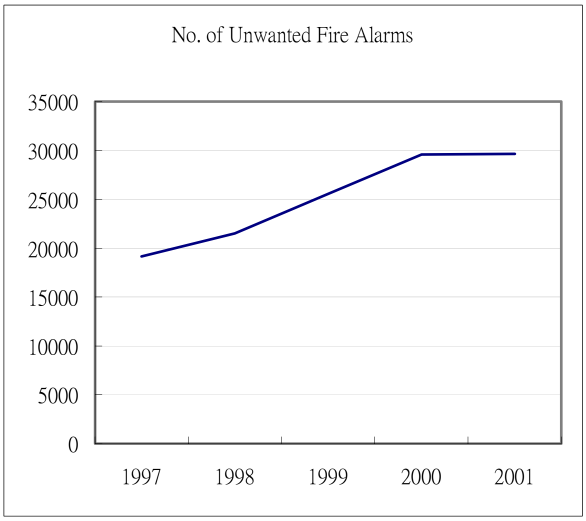
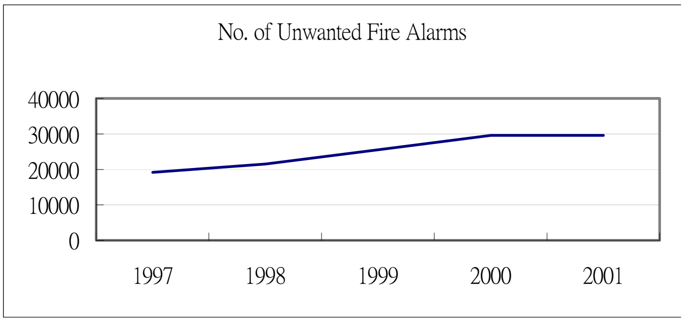
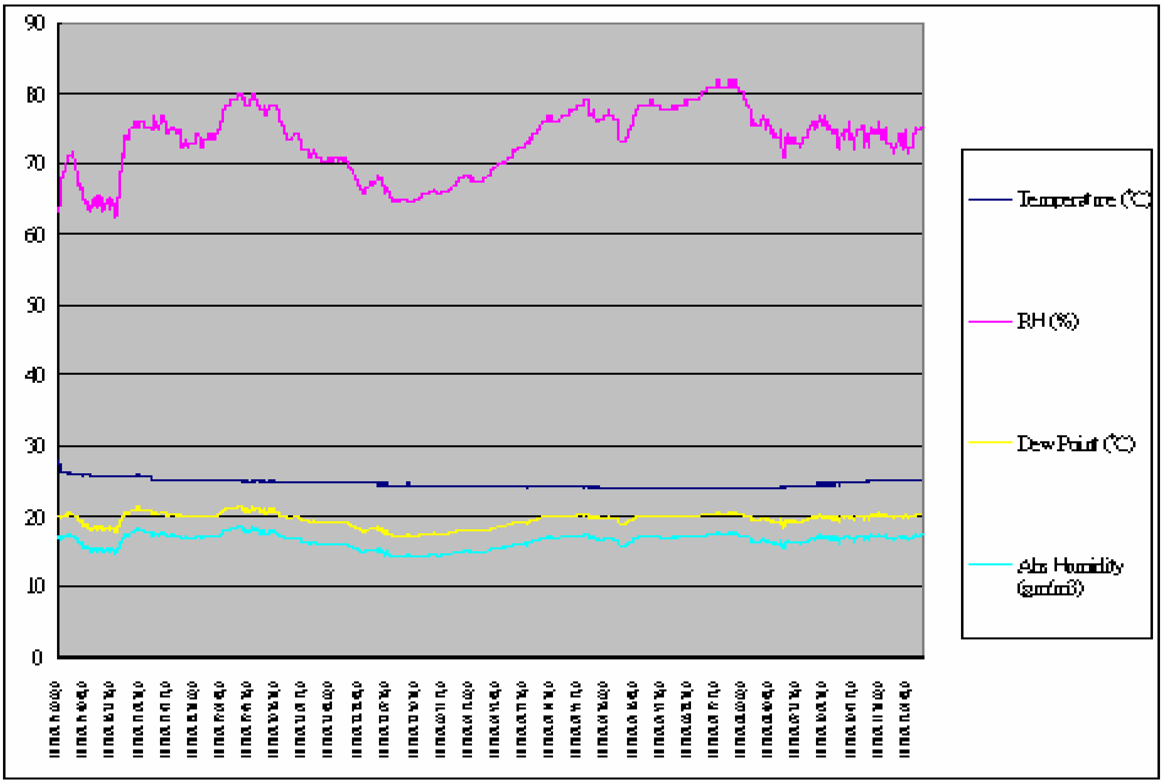


Table II: No. of unwanted fire alarms in institutional buildings from 1997 to 2001

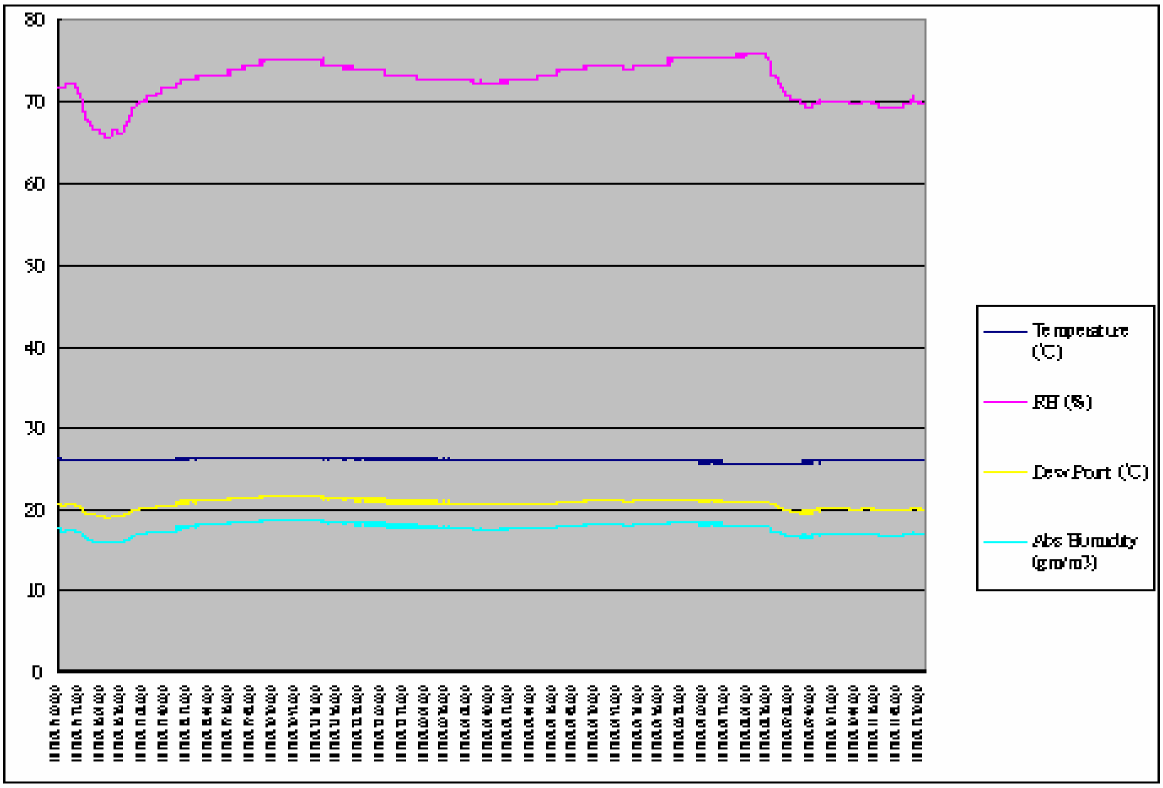




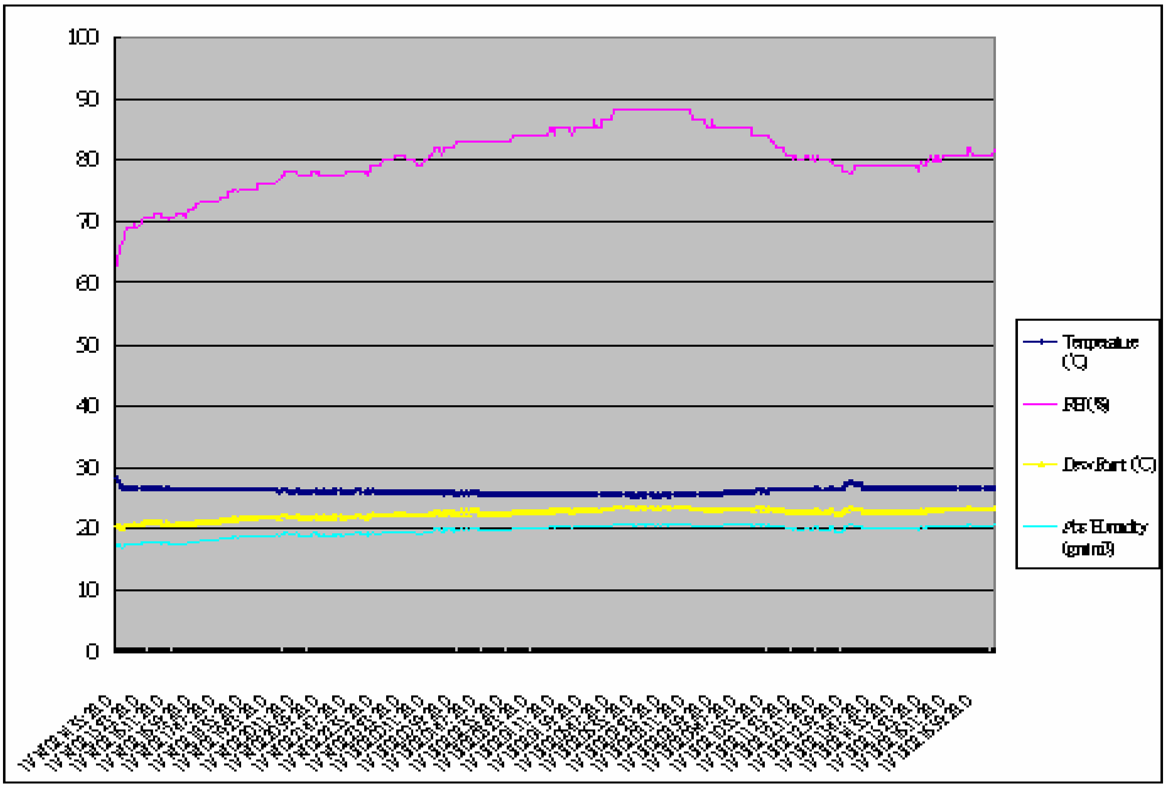
* Data is taken from the Fire Services Review from FSD 1997-2001



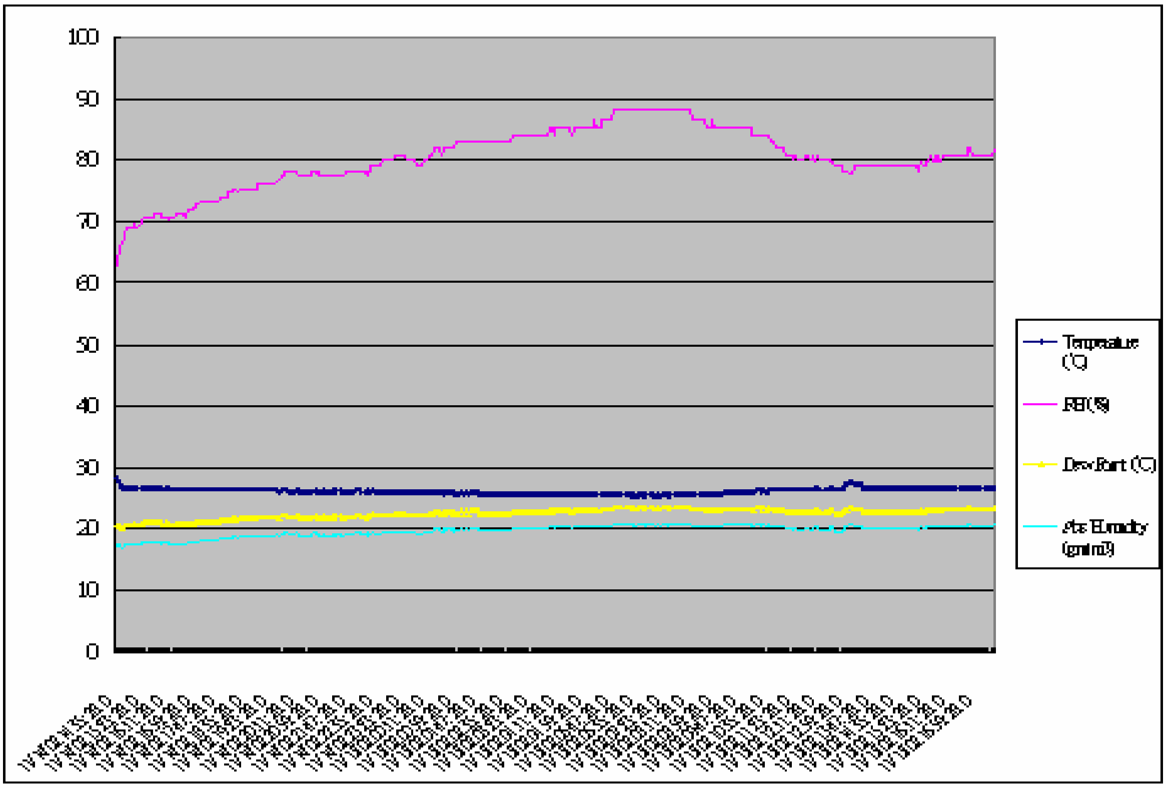
Distribution of environment condition at Point 2055 L-1 main entrance



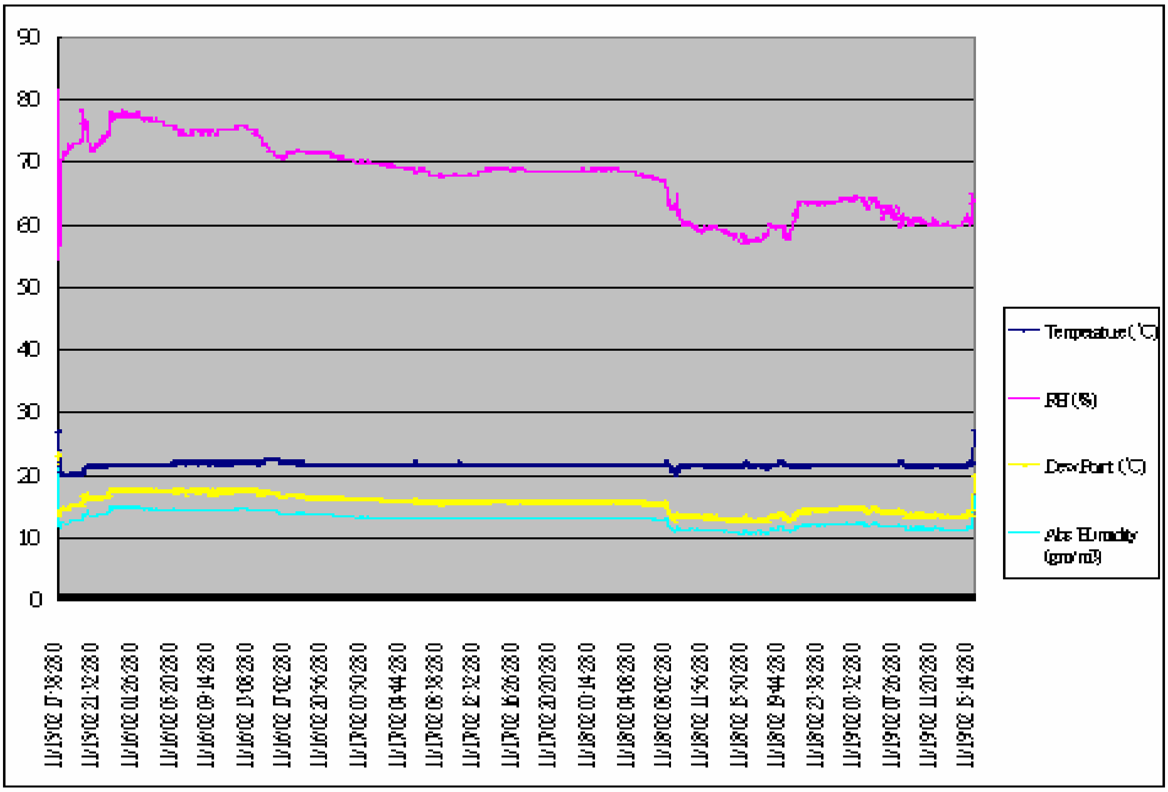
Distribution of environment condition at Point 3055 L13 pump room



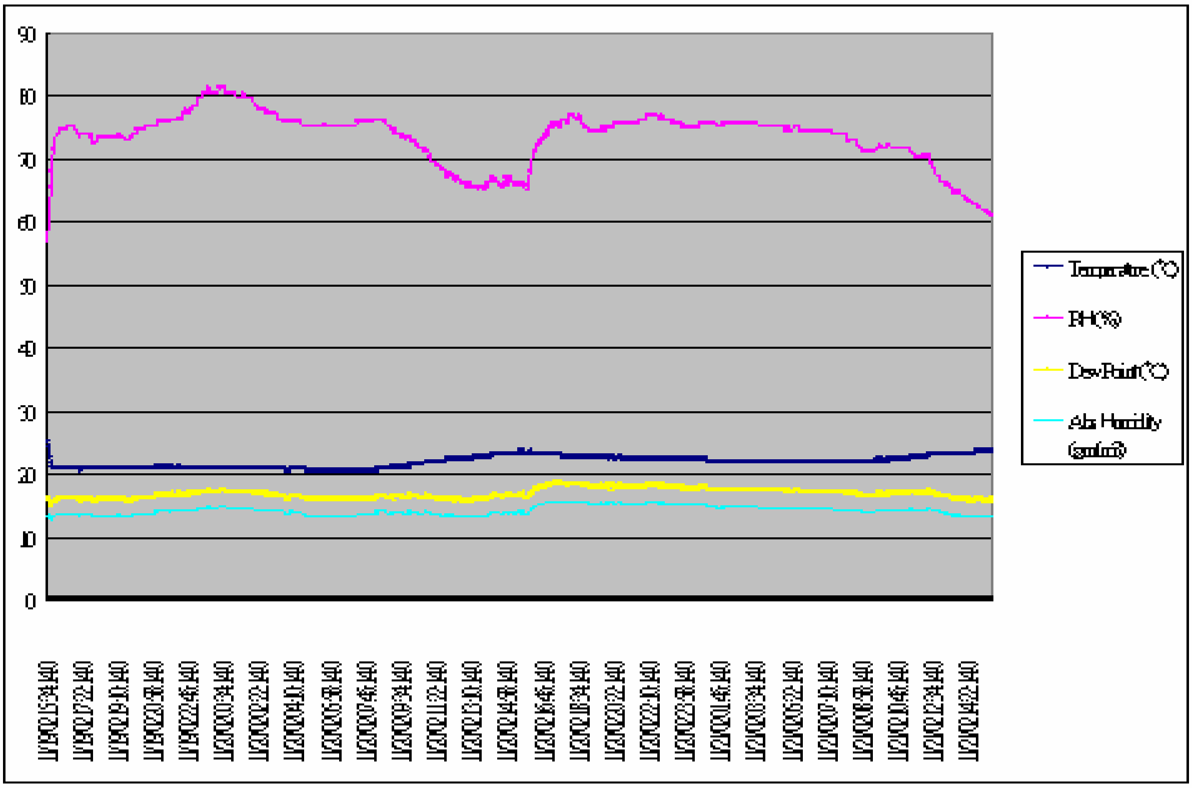
Distribution of environment condition at Point 1085 L0 staircase 1



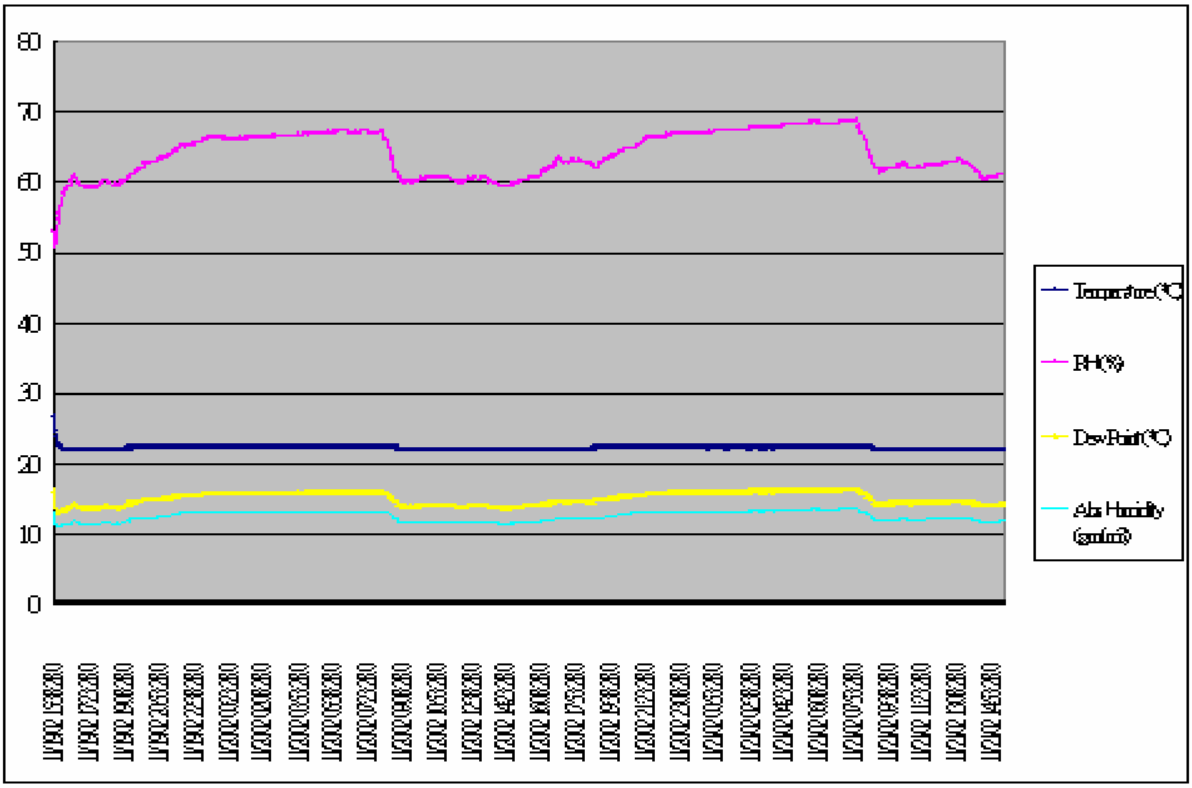
Distribution of environment condition at Point 1003 L2 AHU room L0217



Distribution of environment condition at Point 2024 L-1 ware house



Distribution of environment condition at Point 4061 L7 L.B. male toilet



Distribution of environment condition at Point 2008 L-1 lobby