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Design and Implementation of Addressable Fire Detection and Alarm System in Ready-made Garments Sector of Bangladesh

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ABSTRACT

Fire accidents in the ready-made garments sector of Bangladesh have become an alarming issue in the recent era, hampering the safety of the garments workers. The source of the fire originates from electrical short circuits, storage of flammable materials, transformer explosion, etc. The dilatoriness in the fire detection system results in catastrophic mishaps. The conventional fire alarm detection process of our country cannot locate the exact fire origin on time causing fire hazards. The addressable fire alarm system resolves the problem by assigning a unique address to each detector to locate the exact position of the fire for further protection system. In this paper, an addressable fire alarm system is designed in 'AutoCAD' by following the NFPA (The National Fire Protection Association) rules for a garments factory of Bangladesh constituting of multi-detectors (heat/smoke), heat detectors, smoke detectors, sounder strobes, and manual call points, etc. The designed addressable fire alarm system sends the signal of the particularly addressed detector to the control panel for pinpointing the origin of the fire. This concept has not been implemented in ample garments factories of Bangladesh; thus, holding a major contribution indeed to ensure fire safety.

Keywords: Addressable, NFPA, FACP, BNBC, Detector, Sounder Strobe.

1. Introduction

Ready-made garments hold the first position in the export sector of Bangladesh, generating more than 78% of the countries' total foreign income. In the fiscal year of 2010-2011, Bangladesh earned USD $17.91 billion by exporting apparel which made this country the second-largest apparel exporter in the world [21]. According to the statistics of 2009, the fatality number is the highest in the garments sector among the other industrial sectors [19]. In 2017, the statistics of the last 69 incidents in the garments industry of the previous 22 years show that 94.2% of incidents were occurred by fire, and building collapse were held responsible for only 3% of incidents and another 3% by other different incidents [10]. On 24 November 2012, the catastrophic fire accident of the Tazreen Fashion factory in the Ashulia district on the outskirts of Dhaka, Bangladesh took out the lives of at least 117 people and caused injury to 200 people [16]. This rampant fire of the Chowdhury Knitwear and Garment factory at Shibpur, near Dhaka, on the night of November 25, 2000 killed at least 48 workers and injured 150 workers [1]. These accidents hinder the profitability and sustainability of our RMG sectors, causing a great loss to our country's economy. Improper maintenance of the factory and unsuitable design of the garments lead to these fire accidents. The garments should follow the BNBC (Bangladesh National Building Code) rules to reduce the building collapse and NFPA rules for ensuring the fire safety system. In the USA, the first Factory Act accompanying with a factory inspection initiative were undertaken in Massachusetts as a governmental action after the occurrence of catastrophic fire at the Granite Mills [15]. The consequence of boiler explosion in 1905 at R. B. Groover shoe factory in Brockton near Boston at Massachusetts, USA [20] where the massive explosion ripped the boiler components through the floor and turned the four-storied building into a graveyard [2] as well as emphasized the ratification process of the Factory Act. In Hong Kong, the fire safety codes were very crude and the occupational buildings were not differentiated from the commercial buildings. But after 1987, sprinkler systems were developed in most of the commercial high-rise buildings [3]. Asian countries, such as South Korea and Japan use conventional FACPs (fire alarm control panel) and detectors as they are economical [12]. As a proof of this, 54,534 FACPs were approved by the Korea Institute of Fire Industry and Technology in 2011 out of a total of 56,081 approved FACPs, corresponding to 97.4% [14]. In the conventional fire alarm detection process, fire is detected by the sensors with the help of the circuit board, but the sensors are not

addressed in a wired system. But in the addressable fire alarm system, the detectors are arranged in a coded form with the control panel each having a unique address to call the address for fire alarm and send the signal of the occurrence of fire to the control unit which resolves the problem of the conventional fire alarm detection process [4]. The addressable fire alarm systems provide information of each sensor to the control panel allowing a pre-alarm warning while the conventional systems only provide information about the specific circuits. Addressable fire alarm systems are omnipresent in the developed countries in a great amount. The traceable heat detectors are officially approved in South Korea [13]. But the developing country like Bangladesh does not abide by the NFPA rules in designing the fire safety system in garments. The conventional fire alarm system is existent in some of the well-established garments in Bangladesh. But the addressable fire alarm system is quite a new approach to many garments of Bangladesh which is very favorable in detecting smoke without any effort and automatically, providing protection systems to the affected area. In this paper, an addressable fire detection and alarm system will be introduced in a garments factory of Bangladesh by following the NFPA rules which is a great contribution indeed.

2. Methodology

Addressable Fire Detection and Alarm System process assigns addresses to each detector, audible devices, and the addresses are stored in the control memory unit. The controller monitors each detector. If multiple alarms are detected, a general alarm is sounded via all devices. If only one alarm is notified, an assigned sequence number is placed on the audible, visible devices. Thus, the controller provides preventive action and safest egress to the particular alarmed area. The accurate position of the generation of fire is detected and sufficient water supply and preventive action are provided.

Addressable detectors are connected via two-wire connections, both forming a loop for the integration of the circuit. They are addressed through a dip switch. Output devices are handled on the zone circuit and address messages are sent as command instruction to the output device [4]. The analog output-smoke, gas are transmitted to the detectors and transitions of this output signal current informs the control panel about the room temperature to take necessary actions.

The conventional fire alarm system is disadvantageous as it only detects the zone of the detectors, but not the individual locations of the specific detectors. Moreover, in the conventional fire alarm system, all the detectors of the specific zone become inactive at the state of the fire detection [12]. But, the addressable detectors detect the signals with a regular interval, named the count pulse and contrast the counted number with their own addressable ID number to send information to the exact device. The addressable systems allow text labels for easy identification of the detectors. For example, if detector 2 is labeled as ‘Bedroom 2’ if it is in bedroom 2. The addressable systems can also change the alarm thresholds for different operating conditions along with clock and real-time log records. Some addressable systems incorporate programming options to control the outputs of specific events [4].

In this paper, this addressable system with some traceable smoke and heat detectors and multi-detectors is introduced in a garments factory of Bangladesh. The garments sectors constitute of cutting section, sewing section, washing and drying section, finishing section, warehouse area, office area, and utility section.

The addressable detector systems mounted in almost each sector of the garments factory are discussed in the next phrases.

2.1. Cutting Section

Fabrics are cut according to a pattern in the cutting section and it is the heart of the whole apparel manufacturing process. Fabrics are received from the storage area and cut in a pattern and sent into the sewing station to complete the rest of the process [18]. Apparels are easily incendiary and such occurrence of fire is very frequent in nature. The reasons behind the fire incidents are electric short circuits, faulty electrical wirings, smoking materials, boiler explosion, etc. The origin of fire in the garments factory is in the forms of electrical short circuit (100%), storage of flammable materials (37.14%), boiler explosion (44.29%), canteen kitchen (24.17%), transformer explosion (28.57%), overheating (8.57%), and others (21.43%) [10]. Fire accidents can also originate from fire extinguishers with zero operating pressure, blockage of exit doors by furniture, etc. [23]. Moreover, almost 77.14% of garments workers are informed about the fire by factory alarm, 20% workers are informed from management and 2.86% are notified by the employee for leaving the workplace [11].

As an introduction of the addressable system, multi-detectors, sounder strobe, and manual call points are installed in the cutting section for extinguishing the fire.

2.1.1. DI-9101E Intelligent Combination Heat and Photoelectric Smoke Detector

The heat and smoke detector used in the cutting section is ‘DI-9101E Intelligent Combination Heat and Photoelectric Smoke Detector’. Along with the smoke sensor, and semi-conductor heat sensor, DI-9101E Intelligent Combination Heat Photoelectric Smoke Detector’ (multi-detector) ensures photoelectric detection and rise of temperature at fire detection. Combination of the smoke detector with the heat detector overcomes the

disadvantages of the detectors being insensitive to black smoke and can also detect fire at the rise of the temperature of alcohol flame, thus extending its range [6]. The distinct characteristics, specifications, programming process and installation process are delineated in the following sections.

Specification:
Model: DI-9101E
Temperature: (-10°C to 50°C)
Standby Current: ≤ 0.8 mA
Alarm Current: ≤ 1.8 mA

Installation Process of the Multi-detector:

In many cases, the PVC conduit is installed inside the concrete of the ceiling. But for easy maintenance, the PVC conduit is installed on the surface of the ceiling. A PVC conduit holding fire rated cable (1.5 mm^2) exits from a fire alarm control panel which is used to join all other detectors through it. The PVC female connector is used to connect the PVC conduit to the junction box. The junction box holds the multi-detector. There is another PVC conduit exiting from the junction box through a female connector. The outlet PVC conduit interconnects another detector. The PVC conduit leaving from the last multi-detector is connected to the control panel. This installation procedure ensures easy installation and maintenance and forms an integrated system.

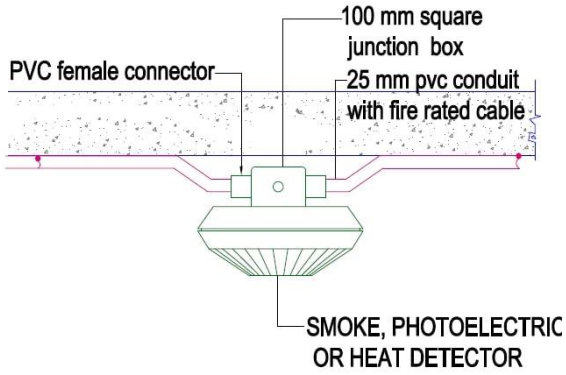

Fig. 1 Heat/ smoke detector Surface Mounted details with Embedded PVC Conduit.

Calculation Regarding Installation Process:

The multi detectors cover 30 ft. around it with a radius of 15 ft. As this coverage is not considered as square shape, so there is a safety factor assuming it as a circle. Detector spacing reduction is based on ceiling height. The reduction factor and the safety factors are multiplied with the coverage measurement. The reduction factor is taken as 0.84 by considering the ceiling height of 12 ft. using Table 1 [17]. The safety factor is considered as 0.70.

$$\text{Detector spacing} = \text{Detector coverage} \times \text{Reduction factor} \times \text{Safety factor}$$

$$= 30 \times 0.84 \times 0.7 = 17.64$$

Thus, the spacing between the detectors is 17.64 ft.

Table 1 Detector Spacing Reduction Based on Ceiling Height.

Ceiling Height Greater than (>)		**Up to and Including**		**Multiply Listed Spacing by**
ft.	**M**	**ft.**	**m**	
0	0	10	3.0	1.00
10	3.0	12	3.7	0.91
12	3.7	14	4.3	0.84
14	4.3	16	4.9	0.77
16	4.9	18	5.5	0.71
18	5.5	20	6.1	0.64
20	6.1	22	6.7	0.58
22	6.7	24	7.3	0.52
24	7.3	26	7.9	0.46
26	7.9	28	8.5	0.40
28	8.5	30	9.1	0.34

Two beams and their corresponding columns can create a pocket. The detectors are set in the middle of these pockets. Sometimes, more than one detector is installed in one pocket.

2.1.2. C-9403 Conventional Sounder Strobe

C-9403 is a sounder strobe alerting people on the occurrence of fire by providing alarm. It provides audible along with visible alarm signals when applied to an external 24V DC power [9].

Specification:
Operating Voltage Power: 24V DC (20V~28V)
Flash Frequency: 1.4 × (1±20%) Hz
Operating Current Start Current: ≤ 35 mA
Sound Level: Tone 1: not lower than 95 DB (at 1 m distance)
Tone 2: not lower than 95 dB (at 1 m distance)

Installation Process of the Sounder Strobe:

The sounder strobe is attached at 2.5 m from the finished floor level which is shown in Fig. 2. The base can be mounted on the back box when the conduit is embedded. The conduit is embedded when the shallow base is used. The deep base should be adopted at the time of surface mounting. The sounder is connected by a cable (2.5 mm^2) from the control panel. One sounder is connected with another sounder parallel. An end of line resistance is connected to the last sounder to complete the circuit.

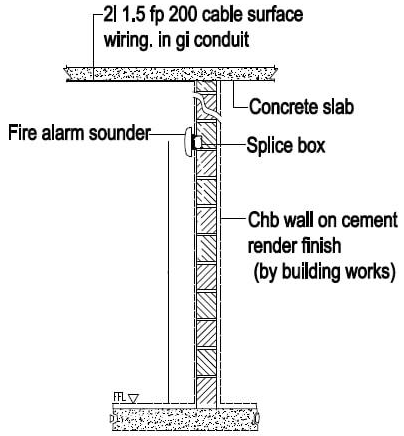

Fig. 2 Installation Details of Fire Alarm Sounder.

2.1.3. DI-M9204 Digital Manual Call Point

Manual call points are attached to the walls of the garments for safety. The victims press the frangible element on the manual call point to notify the control panel about the fire incident. After receiving the signal of the manual call point, the control panel addresses the exact location of the device and generates siren [5].

Specification:
Operating Voltage Loop: 24V (16V~28V)
Alarm Current: ≤ 1.8 mA
Standby Current: ≤ 0.6 mA

Installation Process of the Manual Call Point:

The manual call point is installed at 1.2 m from the finished floor illustrated in Fig. 4. The back box is installed into the wall with screws according to Fig. 3. The base is installed onto the back box. The juts of the MCP is hooked to the base. The cable (1.5 mm^2) passing from the detectors or control panel is connected with the manual call points. Another cable is connected from the exit of the manual call point and is connected to the next device or can get back to the control panel.

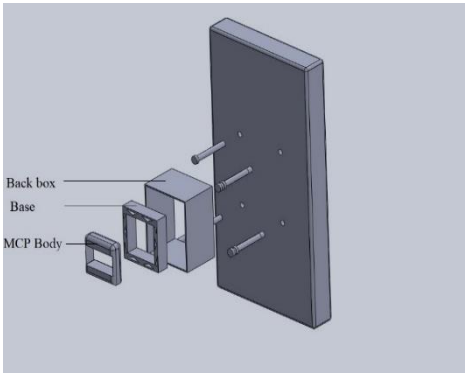

Fig. 3 Installation Details of Manual Call Point.

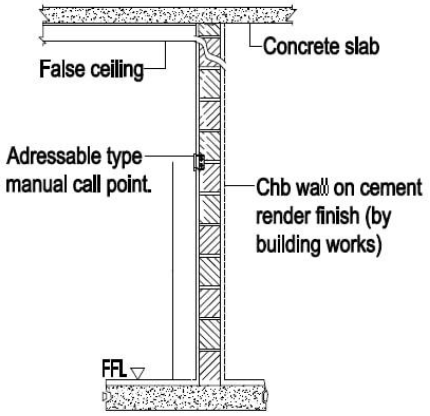

Fig. 4 Installation Process of Manual Call Point on the wall.

2.2. Sewing, Drying and Washing Section

After cutting the fabrics, they are sent to the sewing station, drying, and washing section for the following processes. In these sections, electrical short-circuit, heavy machine work can cause fire. The same models of addressable multi-detectors, sounder strobes and manual call points of the cutting section are installed in these sections. The installation process is also similar to the cutting section.

2.3. Finishing Section, Office Area, and Warehouse/ Store Area

The fabrics processed from the cutting, sewing, washing, and drying section are sent to the finishing section. The finishing section constitutes of checking, final inspection, pressing, packing, etc. After the finishing process, the inventories are stored in the warehouse or storage area. These places do not consist of heavy machinery, and thus the sharp rise of fire is very rare. A small fire incident with little smoke can occur here at most. The office area of the administrative workers is also not susceptible to excess fire-related accidents. These consequences create the necessity of the smoke detectors at these locations instead of multi-detectors or heat detectors.

2.3.1. DI-9102E Intelligent Photoelectric Smoke Detector

'DI-9102E Intelligent Photoelectric Smoke Detector' is a new generation breakthrough product which turns on the fire LED for indicating the fire signal and transmits it to the control panel. The maintenance of this detector is easy with a high endurance of dust contamination and environmental light [7]. The smoke detector can adapt to the changing temperature, humidity, and dust accumulation by figuring out these drift variances to reduce sensitivity resulting in a constant amount of smoke for fire detection according to the drift

compensation algorithm. These consequences result in a constant amount of smoke generation irrespective of any environmental condition.

Specification:
Operating Voltage Loop: 24V (16V~28V)
Alarm Current: ≤ 1.8 mA (without remote indicator)
≤ 3.8 mA
(with remote indicator)
Standby Current: ≤ 0.8 mA

Installation Process of the Smoke Detector:

The base is fixed with the electric box by two taping screws. A portion of the bottom of the detector is aligned to a portion of the base by rotating the detector. The mounting is illustrated in the following figure. The installation procedure of this smoke detector on the surface and the attachment to the control panel is similar to the installation of heat detectors.

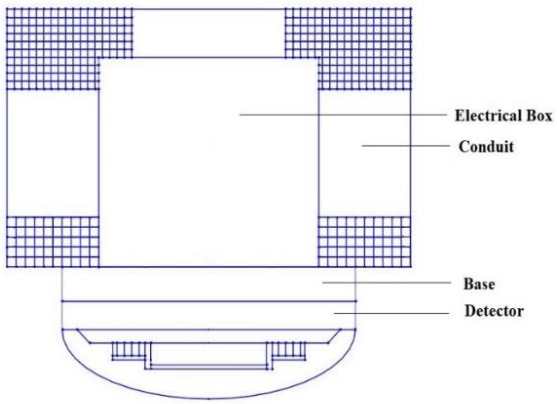

Fig. 5 Installation Details of Smoke Detector.

The same models of the sounder strobes and manual call points of the cutting section are installed in this section with a similar installation procedure. In addition, as utility section is highly prone to fire, 'DI-9103 Digital Dual Heat detector' [8] is used in this section to detect the sharp rise of fire. The installation process of the heat detector is not delineated in the paper.

3. Results

A typical garments factory constitutes many sections stated above. A 9 storied garments factory of 15,000 square feet area can have 87 multi-detectors, 18 heat detectors, 128 smoke detectors connected to the control panel. The Fire alarm control panel will be connected to the 220-240 V AC source. There should have a backup system in case of AC (alternating current) power failure. There is a pair of battery of 12V as per requirement of the fire alarm control panel that can be used as a backup source. The sizing of the battery for the fire alarm control panel along with these devices is shown in Table 2.

Table 2 Fire Alarm System Secondary Battery Set

Description	Standby Current per Unit (Amp)	Quantity	Total Standby Current per Item	Alarm Current per Unit	Quantity	Total Alarm Current per Unit
Fire Alarm Control Panel	1.0000	1	1.0000	0.2000	1	0.2000
Smoke Detector	0.0008	128	0.1024	0.0038	128	0.4864
Heat Detector	0.0006	18	0.0108	0.0035	18	0.0630
Multi Detector	0.0008	87	0.0696	0.0038	87	0.3306
Manual Call Point	0.0006	38	0.0228	0.0018	38	0.0684
Fire Alarm Bell	0	58	0.0000	0.035	11	0.3850
Output Module	0.001	46	0.0460	0.003	46	0.1380
Total system standby current (Amp)			1.2516	Total system alarm current		1.6714

Calculation Worksheet.

Required standby capacity, alarm capacity, total capacity and adjusting battery capacity are calculated from Table 2.

Required standby capacity (Amp-hrs.) = Required standby capacity (Amp-hrs.)
= 24 × 1.2516 Amp-hrs.
= 30.0384 Amp-hrs.

Required alarm capacity (Amp-hrs.) = Required alarm time (hrs.) × Total system alarm current (Amp)
= 0.12 × 1.6714 Amp
= 0.200568 Amp

Total capacity (Amp-hrs.) = Required alarm capacity (Amp-hrs.) + Required standby capacity (Amp-hrs.)
= 30.0384 + 0.200568 Amp-hrs.
= 30.238968 Amp-hrs.

Adjusting battery capacity (Amp-hrs.) = Total capacity (Amp-hrs.) × Derating factor
= 30.238968 × 1.2 Amp-hrs.
= 36.2867616 Amp-hrs.

4. Discussion and Conclusion

Addressable fire alarm system is introduced in different sections of garments- cutting, sewing, drying, finishing, warehouse, utility, and office area, etc., to accurately locate the fire source. The installation process of the addressable detectors by following NFPA rules, specification, and features of the detectors are delineated in this paper. All the detectors, sounder strobes, and manual call points are well integrated with each other and released in the control panel. The control panel is powered by a DC battery backup source in case of AC power failure. The calculation of this battery sizing is also provided in this paper. Finally, the AutoCAD designs of the addressable system in the typical garments sectors are attached in the Appendix section of the paper for better illustration. The paper only ensures the detection system, but the protection system is necessary to a great extent after the detection system. The future work of this research incorporates designing a fire protection system, such as- sprinkler system for the reduction of fire hazards. The rate of fire accidents will alleviate by cohesive addressable fire detection with a protection system.

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