

Strategic Research on Safety Evacuation of Clean Workshop

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Keywords: Clean workshop, Safe evacuation, Clean level, Air shower unit, Evacuation countermeasure.

Abstract. Due to high airproof of clean workshop and special requirement for environment during the technical process of production, it is more difficult for people to safely evacuate from clean workshop and also for the fire fighting and rescue job. So it is necessary to establish one suitable, simple, efficient and reliable safe evacuation system for clean workshop so that to ensure that employee may safely evacuate and reduce property loss. This essay aims is from area of clean workshop building and technology essential safety to analyze the fire hazard of the clean workshop and problems existing during safe evacuation, and take corresponding measures regarding safety evacuation when set up the evacuation system of clean workshop.

Introduction

Clean workshop refers to the workshop temperature, cleanliness, indoor pressure, air speed and distribution, noise vibration, lighting, static shall be controlled within one specific required scope, and the harmful air, fine particles, bacteria and other pollutant shall be eliminated. No matter how the outside air condition changes, the indoor temperature, humidity and pressure is able to be maintained. Its main function is to make the product to be produced and manufactured in a good environment and space, so that the product meet relevant technical requirements and reduce the disqualification rate. It is mainly applied in industry with special requirement for production environment such as pharmaceuticals, biological products, some precision machining, and precision microelectronics.

In recent years, with the deepening of reform and opening up, China has become a major production base of international large-scale enterprises, and there exists more and more clean workshop higher and higher requirements for the workshop. Since most enterprises with the clean workshop manufacture high-tech products with special requirements for their production technology, including airtight performance for the clean workshop. Therefore, once the confined space of the workshop is in the event of a fire, the heat is difficult to dissipate and produce large amounts of smog which may cause greater difficulties to the evacuation. So during the clean workshop fire fighting and rescue, evacuation is the most important issue which is directly related to the life safety of each employee in the workshop. It is quite important and necessary for the employees who work in the clean workshop of industries like electronics and pharmaceuticals to control safe evacuation.

The fire risk of clean workshop

Due to the specialty of clean workshop, the fire risk is also different from that of other ordinary

buildings, which lead to the safe evacuation of personnel in the event of a fire to be more difficult than that in ordinary buildings, mainly in the following aspects:

(1) Since the cleanliness of product may not be the same or quite different in each production process, it is necessary to set up cleaning room in different size inside the clean workshop to ensure the cleanliness of each process. Each cleaning room is one relatively confined space, some of which even have no windows without ventilating windows. And between these relatively independent cleaning rooms, there is mostly no obvious fire separation or the fire separation facility loses its function as separation because of production technology needs. Once the cleaning room catches fire, it will generate a lot of heat which may not be dissipated and smog which may not be eliminated in time, thus the fire is likely to spread around in any direction because there is no fire separation or fire separation loses its function. Violent and rapid burning is very easy to occur powerful thermal current and form large areas of burning, which cause difficulty for the evacuation and fire fighting by the fire brigade.

(2) Most of clean workshops are long span architecture with decoration plate made by non-flammable materials. Due to the requirements of the production technology, most of clean workshops are large-span steel structure body. When the temperature exceeds 300℃, its strength will be weakened. When the temperature reaches 500℃, the strength of it is only half of which is in room temperature. When the temperature is over 600 degrees, the strength is almost zero^[1]. The mechanical property of the steel structure gets poor under the high fire temperature and it gets inevitably distorted under the vertical pressure and horizontal tensile leading the plant collapse easily^[1]. Besides, when large span factory catches fire, there will be a lot of spreading fire, forming a large area of fire which increases difficulty of the rescue and relief work.

(3) The production equipments in the clean workshop are intensive. The corridor, channel tube are arranged in twists and turns. This not only makes personnel evacuate difficult, but also greatly increases the evacuation time. The longer the evacuation takes, the more casualties it will cause.

(4) Generally, there is a comparatively complicated procedure for people to get in and out of the clean workshop (as shown in Figure 1^[2]). When the fire outbreaks, people tend to escape through entrances and exits due to their habits, thus they will pass the locker room, changing room and so on, which will prolongs evacuation time, and increases risk.

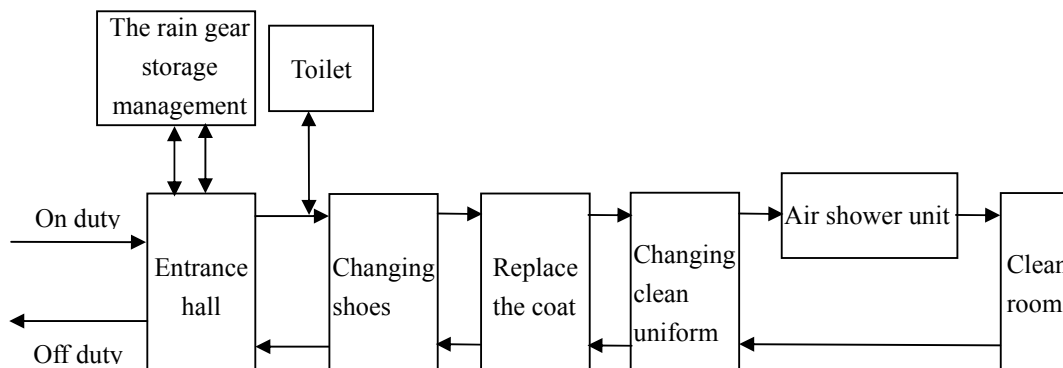


Figure 1 People purging program

Safe evacuation countermeasures of clean workshop

Safe evacuation refers to the process that all the personnel in a building evacuate the building and reach to a safe place in time when the fire starts to outbreak. Although it determined by many conditions to realize safe evacuation, in real life, it is mainly determined by safety evacuation facilities (such as the evacuation stairs, public pathways and doors, etc), safety evacuation supporting facilities (such as evacuation balcony, relieving device, and life pack, etc) and personnel escape kills.

Since most steps of the production process for the products manufactured in celan workshop are

completed in cleaning room with high requirement for airtight performance, and also there are special requirements for technical process and equipment layout in cleaning room which may lead to the failure of utilization of safety evacuation facility and its supporting facility and may not meet the requirements of standards like “Fire Prevention Code for Architecture Design”(GB50016-2006) (Hereinafter “Architecture Code”) and “Design Rules for Clean Workshop”(GB50073-2013) (Hereinafter “Clean Rules”) when the design and construction is under way. Therefore, it is quite necessary to formulate safe evacuation countermeasures for prevention of fire accident based on its characteristic of clean workshop and the fire hazard to solve the problem of safe evacuation of clean workshop. Besides, we need to conduct drills and make some improvement by PDCA (plan-do-check action) cycle which will not only help employees improve their skills and ability to deal with emergency fire accident, but also conducive to the safety evacuation of the reasonable layout of the facilities, so as to avoid or reduce the occurrence of casualties and major economic losses as effectively as possible.

Rational arrangement of safe evacuation exits and evacuation routes

According to the “Clean Rules”, the fire resistance class of the clean workshop should not be less than class II. The evacuation exits number in each fire prevention area or each cleaning area in each production floor of the clean workshop shall not be less than two, and the whole construction area of the cleaning area in each floor of the production workshop including type A and type B shall not exceed 50m². One safe exit shall be set up in dispersion for the cleaning room with no more than five producers during the same period of time. The door closer shall be open and added to the evacuation door connecting cleaning area and non-cleaning area as well as cleaning area and the outside along with the direction of evacuation. Safe evacuation door excludes hanging doors, revolving door, side sliding door, shutter doors and electronically controlled automatic door. Safe evacuation distance should be consistent with the provisions of the current national standard “Architecture Code 3. 7. 4”. In terms of the workshop design and technology equipment design setting up, evacuation routes should be simple, easy to recognize with obvious evacuation signs. Avoid arranging the evacuation routes into bag shape and try to combine the evacuation channel and the routes which are often be used. It is better that each evacuation channel has two or more than two evacuation directions for escape so that if one of the directions face with fire block, they may escape from the other one. Due to the needs of the special process, importers, exporters can not meet the evacuation, evacuation routes should be localized by the external walls, glass doors or windows closed as much as possible on the external walls of clean workshop, and a safety glass door or window at export lamps and shattered glass with a rubber hammer, when the fire broke out, these closed glass door or window can be used as emergency evacuation exits.

There are strict requirements when it comes to the material selection for evacuation aisle wall. According to the requirements specified in the “Architecture Code”, the fire resistance limitation of the wall on both sides of the evacuation walkways shall not be less than 1.00h and shall be separated with manufacturing and other areas. But in practical life, evacuation aisle wall is normally clean room wall with nonflammable plate as its material, the fire resistance of which may not reach 1.00h. Therefore, when selecting the material, the plate that has passed the fire resistance limit test shall be taken into consideration, meanwhile the material shall be with low smoke quantity or without toxicity or that will not produce asphyxiating gas after burning.

Appropriate arrangement of evacuation stairs

It is quite necessary to set up evacuation stairs appropriately for clean workshops with two or more than two floors. The location of the stairs shall be near the exterior wall, so that in the event of a fire, you may open the windows on the exterior wall to make the smoke inside dissipate naturally from stairs which to create favorable conditions for the safety evacuation and fire rescue job. Due to the limited conditions, if the evacuation stairs have to be set up in other areas of the workshop, positive pressure air supply facilities shall be set up as well. For the clean workshop with multiple floors, the evacuation stairs shall be set near the elevator because of people’s habit, which is to escape from the regular routes according to their first response. So it is in favor of evacuating

people fast and safely to set the evacuation stairs near the elevator.

Appropriate settings of the air shower door lock

The air shower room is an effective means for human purification and to prevent outdoor air from intrusion. Before the staff members going into the room, they shall be conducted with air shower to blow the dust on the surface of the uniform away with high speed air. Therefore, in order to reduce the staff contamination to the clean workshop, this room is a necessary place for them to pass through. Due to the inherent habit, when the fire breaks out, employees tends to escape from this route, which raises special requirements on the design and installation for the air shower door lock. From the aspect of current design of air shower room, the air lock, and magnetic lock or other special control method is normally adopted. But no matter which kind of lock you use, it shall be confirmed that once there is fire disaster or any other accident, there should be reliable ways to open closed air shower room fast to ensure the people safely evacuate and emergency rescue.

Sound layout of smoke control system and air conditioning system

Since most of the clean workshops are totally enclosed and some of them are not equipped with openable external window, thus when there is fire disaster, there will be no enough open space for smoke to discharge, and the smog will not be dissipated from windows. In that case, the air conditioning system will be closed down which will threaten to the safely evacuate of people. Therefore, we shall set up fire control system and smoke control system in rooms with a lot of staff members, evacuation walkways, and important control rooms. In particular, to set up individual smoke control system in cleaning room that is flammable, explosive, toxic and harmful. This system shall be capable of being switched between air supply system. When there is fire disaster, open the smoke outlet in the smoke proof area and close the air supply outlet. The allocation for the fire damper in central air conditioning system shall meet the requirements in the “Architecture code”, and besides, the fire damper shall be set up in the passing vertical air supply outlet or passing separated “General production area” and “Cleaning production area” and when the fire resistance of the wall between cleaning rooms is equal or more than one hour. The emergency shut off button shall be set up in the place where that there are a lot of people passing through in the cleaning rooms with central air conditioning system and air supply or returning system so as if there is any fire, the fire damper is able to be shut off immediately to prevent the fire to be spread rapidly so that the people can evacuate safely.

Rational distribution of emergency lighting, evacuation signs

When the fire breaks out, the power will be shut up firstly when the emergency lighting and evacuation signs are very important to safely evacuation. Therefore, the emergency lighting and evacuation signs shall be set up according to the requirements specified in the “Architecture code”.

Sound settings of fire detectors

The fire detectors shall be chosen and set up according to the property and development tendency of initial fire, combining with the factors as space, temperature, humidity, flow direction and speed of the air and so on. For the cleaning room, the major factors affecting the function of the detectors includes the flow direction and speed of the air, the more times the air is changed, the smaller probability the smoke ion reaches the detectors. According to American NFPA 72 standard, when the air changing times are 10 times per hour, the effective detection and protection area for the detectors are 0.833 of the standard parameter; when the air changing times are 30 times per hour, the effective detection and protection area is only 0.278 of the standard one^[4]. As a result, it is not suitable to choose a common smoke detector for detecting fire in a cleaning room. Instead, you shall choose an aspirating smoke detection alarm system with laser detection facility (which is also called as “very early smoke detection apparatus” or “Air sampling smoke detectors”) by which the fire may be found 30-120 minutes earlier than by using the common detection facilities, so as to earn more time for fire fighters and rescue and people evacuation.

To enhance fire education and training and regular fire fighting demonstration

The safety and relevant department of enterprises shall conduct fire fighting skill training for their staff members and strengthen the propaganda and education on fire fighting laws and regulations and escape knowledge. To compile emergency plan for fire fighting, safe evacuation and rescue, and conduct regular demonstration and drill based on the plan. To fulfill and perfect the content in the course by adopting the PDCA principle so as to enhance the skills and ability of fire fighting, self rescue, rescue each other, and self protection when they are in the site of fire.

To strengthen fire fighting facility management

The fire fighting facilities in the cleaning room are mainly used in the initial time of a fire. If the facilities are complete and reliable, and the fire is found in time, and the staff members may operate the facilities normally and neatly, most of the fire is able to be controlled effectively and even entirely put out. Therefore, the fire fighting facility is one of the most effective ways to prevent fire. The fire fighting facility management department of the enterprise shall strengthen the examination and testing job for these facilities while strictly strengthening management on fire fighting safety key part. It is better to ask units with professional skills and quality to make regular maintenance on fixed facilities to make sure that the fire fighting facilities in building are always available and the automatic alarm system, automatic spray system, emergency lighting system, safe evacuation system, smoke proof and purging system, and indoor and outdoor fire hydrant system can be directly adopted to fulfill the fire fighting and safe evacuation mission.

Conclusion

In conclusion, as long as the safe evacuation routes, evacuation stairs and other fire fighting assistant facilities may be used effectively, it can be realized that to strengthen the fire safe training and fire fighting and evacuation demonstration and drill for employees, enhance their fire fighting and rescue skills, to design and construct the plant building strictly in accordance with relevant regulation and rules, and make people to evacuate safely after the fire, and to reduce the fire loss.

Acknowledgment

Author would appreciate colleague's precious support and feedback from Environment and Safety Department of LG Philips LCD (Nanjing) Co., Ltd which he once worked. Appreciate Korea colleague Mr. Huang DaYuan during worked together with him and learned more professional knowledge and precious experience. Finally appreciate Jiangsu Natural Science Fund support (Grant No: bk2011892).

References

- [1] Li Xingrong. Large span factory fire safety management Exploration [EB/OL]. Jiangsu fire, November 3, 2006.
- [2] GB 50073-2013. "Lustration workshop design specifications" [S].
- [3] GB50016-2006. "Architectural design code for fire protection" [S].
- [4]Hu Dejun. Weak intelligent systems in a manufacturing plant which [EB/OL]. The international intelligent building network .2005 15 May.
- [5] Chen Hongfei talks about lustration workshop with early fire detection [J]. Sichuan Building, 23 (5) :76-77.
- [6] Xuming Ji, high Kam Tin rise buildings safety evacuation [J]. Shandong Fire, 2001, 12:45-46.
- [7] Liu Liu. Pharmaceutical industry clean potential fire and fire protection design [J]. Safety &

Supervision, 2005, 02:28-29.

[8] Wang Xu, Ko Wing atrium. Safety of high-rise building evacuation Countermeasures [J]. Safety Science, 1996, 03:6-10.

[9] Chen Baosheng, Zhou Jian safety evacuation of high-rise building design [M]. Shanghai: Tongji University, published in the February 1, 2004.

[10] Li Bing. Affect the safety evacuation of the thinking of a number of factors [EB/OL]. Safety culture network, January 10, 2005.