Explosion of Warehouse during Storage of Expanded Polystyrene Beads

【August 23rd, 1982　Yokkaichi, Mie, Japan】

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At the dawn of August 23rd, 1982, the Namakawa Warehouse in Yokkaichi, Mie Prefecture which stored petrochemical products, exploded and burned down. The sound of the explosion was heard throughout the city area. The warehouse and the adjoining building were burned down, and the third ware house and the office building were also partially destroyed. The warehouse was located in a zone where factories and housing were intermingled, and several petrochemical factories and other plants of the Yokkaichi petrochemical complex adjoined the Namakawa Warehouse on the east. The north side was a densely housed area, and the explosion damaged over 330 buildings within a 1km radius the warehouse. The damage did not reach the petrochemical complex, because a machinery factory between the warehouse and the complex played the roll of a shield. The human damage was of 24 persons injured. The warehouse did not store any dangerous materials that could self-ignite and explode, but it is assumed that some light hydrocarbon gas such as propane and butane that was impregnated into expanded polystyrene (PS) beads was released, formed a combustible gas air mixture, and was ignited by some electrical spark.

The expanded PS bead is a raw material for making expanded polystyrene that is used for packaging material and heat insulating material, such as containers of the cup noodles. Light hydrocarbons such as propane and butane are impregnated into the beads as a foaming agent at about 6wt% by pressurizing when styrene is polymerized. This light combustible gas was gradually released during storage. At the warehouse where the accident occurred, the storage area was required to be kept below 5 ℃. However, the switch of the refrigeration unit, which was mounted inside the warehouse, was not of an explosionproof type, so the fire seemed to be caused by an electric spark due to electric discharge.

Until the year of the accident, 1982, many years had already passed since the use of the expanded polystyrene started. Didn't the manufacturer give any information about the danger of expanded PS beads or take some countermeasures during this period? If the expanded PS beads were distributed in the market without any information, the

main problem leading t o this accident woul d be the mass-distribution of the material with a possibility of generating a combustibl e gas or vapor to the market without a ny consciousness of danger.

1. Event

At dawn on August 23rd, 1982, a large explosion occurred at a warehouse, which had stored synthetic resin, at Yokkaichi in Mie Prefecture, Japan. Two out of the thr ee warehouses collapsed completely, and the other warehouse as well as an office building was parti ally destroyed. A large amount of d amage was also caused to the nea rby buildings, since the re were a larg e numbe r o f p rivate houses nearby . T wenty-four persons were injured in the explosion.

At first, some combustible gases s uch as butane and pentane were released from expanded PS beads stored in the warehouse. Then, the combustible gas was ignited by a sp ark of electric d ischarge of the refrigeration unit, resu lting in the exp losion. The expanded PS, which is synthetic resin used as packing ma terial or molding material after foaming, was impregna ted with a foaming agent at manufacturing. Combustible petroleum g ases such as p ropane, butane, and pentane are used as foaming agents. These gases were released into the atmosphere gradually after manufacturing, and the quantity of the released gas d ecreased with time. However , the foaming a gent remained, even after a l ong time passed, because the foami ng agent was necessary in order to foa m. Light ga s of the f oaming agent kept being released accumulated in the building, and caused a large gas explosion. Therefore, the accident like this may occur at anytime and any pl ace if the counterme asures against the re leased gas are not taken at all.

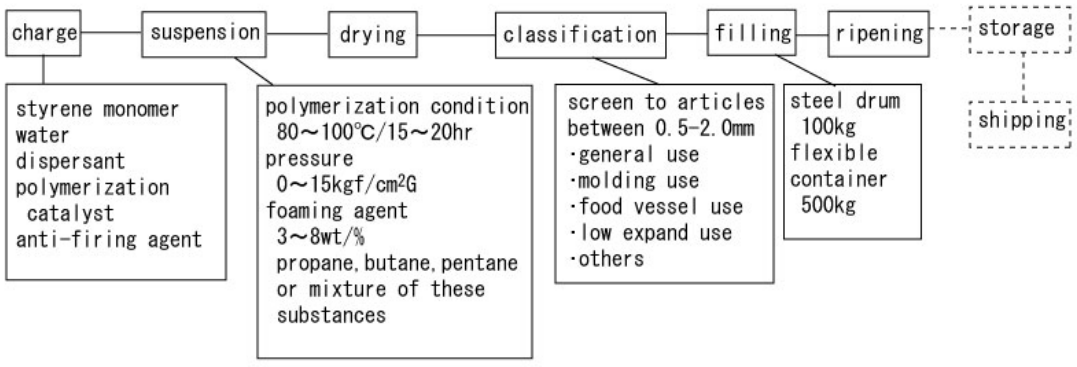

Fig.1 block flow diagram of expanded PS beads manufacture

Although there were many kinds of expanded resins used in those days, including

a copolymer of styrene, only for expanded PS beads, combustible gas was used as a foaming agent.

2. Course

In the Namakawa Warehouse, 30 tons of the expanded PS beads were stored in 100kg drum cans, and 120 tons of PS beads were received in 500kg flexible containers on August 19th and 20th.

At 17:00 on August 21st, the warehouse was opened once, and after that time the warehouse was subject to only, remote supervision by the security company; there was no personnel at the site.

Sometime after 03:10 on August 23rd, an explosion occurred in the warehouse, and the explosion shifted to the fire. After a short interval at 03:12, the display at the office of the security company showed the breaking of wire between the warehouse and the office. It may be considered by the accident.

At 13:54 on August 23rd, extinguishment of the fire was confirmed.

3. Cause

At the end of 1980, the warehouse where the accident occurred started being used as a constant temperature grocery warehouse. In June 1981, the stored goods were changed to petrochemical products. At that time, the temperature for the constant temperature storage was changed from 15℃ to 5℃.

Butane and pentane, which were released from the expanded PS beads that were stored in the warehouse, formed a combustible gas-air mixture due to the insufficient ventilation in the warehouse. The switch panel of the refrigeration unit for maintaining the constant temperature of 5℃ was mounted inside the warehouse, but the panel was not explosionproof, and it was estimated that a spark was caused by the electric discharge from the switch panel. When the usage of the warehouse was changed, the temperature setting of the refrigeration unit was changed, but the installation location was not changed and the switch panel was not changed to an explosionproof type. Similarly, no consideration was paid giving to ventilation.

The staff of the Namakawa Warehouse did not seem to realize that a combustible gas was released from the expanded PS beads. The manufacturer knew it, so usually the beads are stored in the warehouse of the manufacturer right after the production, when a considerable amount of gas is released. This is called "ripening". After that the ripening, the beads are shipped or stored in public warehouses. In the public warehouse, for quality maintenance, the beads are stored at a constant temperature.

Due to a certain report, some manufactures considered that there was no gas released from the beads if the beads were kept at 5℃ or less. However, by experiments conducted after the accident, it was confirmed that the release of the combustible gas continued, although the rate decreased even if the beads were kept at 5℃ or less. Besides, it is not known whether the beads that caused the accident had been ripened or not.

Another report indicated that changing the storage container from a drum can to a flexible container was a problem. Flexible containers can handle a much larger quantity at one time, can be used more easily and easily kept clean, compared with drum cans or paper bags. Therefore, presently in Japan, synthetic resin pellets are mainly handled using flexible containers. However, by changing to this flexible container, the possibility that released gas diffuses into the warehouse increased in comparison with the time when drum cans were used.

Another report suggested that though the temperature in the warehouse was 5℃, the contents of the flexible containers brought from outside in the summertime and those of paper bags that were piled up could not cooled down so easily, therefore the temperature remained high and release of the gas continued.

There is a report that claims that the accident was due to insufficient management and preliminary survey of the warehouse owner, but this seems to be an unreasonable demand for the warehouse owner. Warehouse owners cannot help depending on the information from manufacturer about materials, especially about chemical products, thus the stored materials will be handled in the way indicated by manufacturer. Moreover, in case of chemical materials handled for the first time at the warehouse, it is difficult for the warehouse owner to obtain more information than that was provided by the manufacturer.

Considering the points that have been mentioned above, the main cause of the accident is the management responsibility of the manufacturer who could not understand well the characteristic of the in-house product. The secondary cause was insufficient study of the warehouse owner at the time when the warehouse was remodeled in order to handle the chemical products, for example a lack of consideration of the location, the structure of the electrical items and ventilation.

There was not any regulation though the products were distributed in large quantity. Why was it? Ten years before this accident, there was an accident in which a polyethylene sheet exploded during replacement work of freight cars at the Aomori station. If the government regarded the explosion of polyethylene sheet as important, and some regulations were carried out, has the situation changed? From the view point

of the auth or, it is off the p oint to expect t he ad ministration t o carry out su ch regulations. In such a s ituation, a person who actually handles the materials cannot obtain as much knowledge and information as the manufacturer. It is necessary t hat the primary responsibili ty be taken by the ma nufacturer and that the manufacturer itself considers the dangers and countermeasures. It seems that a nonofficial rule that a manufacturer independently offers informat ion to person s who handle the materials such as warehouse owners should be established.

4. Process of cause elucidation

The type of the exp losion was immed iately judged to be a gas exp losion. The next step in the cause elucid ation was to d etermine the co mposition of the g as that caused the explosion. The following materials were considered as causative agents: CFC of the refrigeration unit and unknown ga s that was not included in the reg istration to the authorities. As a result of the field inspection, CFC was ruled out based on the fac ts that almost all of the CFC was recovered and the exist ence of unknow n gas was als o ruled out because any materials but PS beads were not stored in the warehouse. It w as known that the expanded PS bead s were im pregnated with a combusti ble gas. It was also confirmed by the investigation commi ttee that the gas was released ev en at temperatures below 5℃ by the experiment on the change with the lapse of time of the weight of th e exp anded PS bead s. Testing at the National Research In stitute of Fi re and Disaster verified this result. The results of the experiment are shown in Fig.2. As a result, the explosion th reshold was calculated to be 27.5 ℃ as the t otal quantity of butane and pentane.

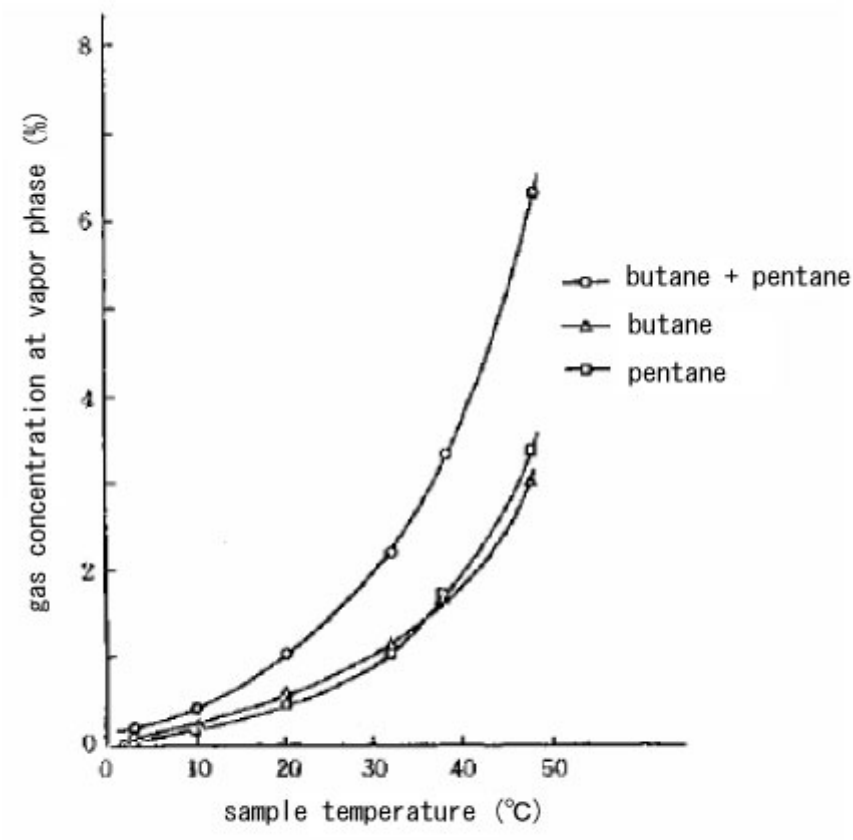

Fig. 2 gas consentration from expanded PS beads

5. Immediate action

Since the explosion occurred suddenly in an unmanned warehouse, no action was taken.

6. Countermeasure

After receiving the research results from the accident investigation committee, the vice president of the Fire and Disaster Management Agency sent a notification to the each prefectural governor showing the countermeasures.

The main contents of the countermeasures are as follows: a fixed gas detector should be installed in warehouses of expanded PS beads in order to detect combustible gas and an alarm should be sound if the concentration becomes over 1/4 of the combustion threshold, ventilation facilities should be installed for large scale warehouses or ventilating openings should be installed for small warehouses to assure sufficient ventilation, and electric devices of the explosionproof type must be used.

The measures described above were adopted based on the approval of combustible gas being generated, as it is impossible to compel the use of containers that will never leak or never will be damaged when the gas released, since a large amount of expanded PS beads have already been distributed in the market.

Although these countermeasures might be inevitable as they were taken after the accident, they were not fundamental countermeasures for preventing the similar accident. Basically, only manufacturers can know the properties of their products sufficiently, so adequate safety measures for handling and storing the products should be taken by the manufacturers. Moreover, manufacturers have a responsibility to offer the information they have to users and warehoused operators.

7. Knowledge

The real situation is not known until the accident occurs. However, the main cause of this accident appeared to be the result of sufficient examination of danger in spite of the knowledge about the generation of combustible gas. It is necessary to maintain an acute sense of danger and sense of how-to-act against the danger. Why didn't the actual condition become clear in spite of a large distribution of the products? It is too late after the accident occurred.

8. Influence of failure

Twenty-four persons were injured in the accident. The physical damage included the complete destruction of two warehouses and partial damage to one warehouse and one office building.

Since the warehouse was located close to a residential district, a total of 341 buildings were damaged and 170 telephone lines became out-of-service. According to one report, the total monetary damage including the damage to the neighborhood was 13.3 hundred million yen.

9. On the side

Accidents related to chemical factories that occur near a residential district cause damage to many inhabitants who do not have any relation with the factories. Because of a high density of Japanese cities, it is not easy to regulate the location of chemical facilities, which are often older than the residential buildings nearby. So, the chemical facilities that are located close to residential areas must be operated with far more attention and knowledge compared to the facilities in an industrial district, which are far from private houses. However, in fact, the opposite phenomenon seems to occur

often.

One of the causes of this explosion was insufficient ventilation. Although it is an old story, there was an aircraft carrier named “Ootori (Big bird)” that exploded and was sunk by the hit of only one torpedo in the World War Second. This explosion also appeared to have been caused by the accumulation of gasoline vapor due to insufficient ventilation. Considering these two accidents, there is a common cause of the accident, which is "insufficient ventilation", independent of the time and the place.

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