Hydrogen Gas Explosion in Non-industrial Refuse Incineration Facility

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Masahide Wakakura (Kanagawa Industrial and Technology Research Institute)
Mitsuo Kobayashi (Graduate School of New Frontier Sciences, University of Tokyo)
Masamitsu Tamura (Graduate School of New Frontier Sciences, University of Tokyo)

At around 10:00 on Thursday July 6th, 1995, an explosion happened at an incinerator of the environmental sanitation union incineration plant of Hatano and Isehara cities in Isehara City, Kanagawa. The incinerator had a processing capacity of 90 ton/day. Three workers got burnt by high-temperature gas that spouted from the inspection door, and one of them died after ten days. The accident happened during the inspection and repair work of the inside of the furnace for fixing an abnormality in the ash chute damper of the incinerator. In the repair work, the workers injected water to remove some blockage. The water reacted with incinerated ash of aluminum and other materials to generate hydrogen. This hydrogen seemed to cause the explosion.

Although the damage to the facilities was not very large, one incinerator of the other two in the plant was of the same type as the incinerator that exploded, so two incinerators of the three could not be used until the cause of the accident was made clear, and some part of materials to be incinerated had to be carried out to another incineration plant temporarily in the adjacent area.

The cause of the accident was the formation of hydrogen by a mechanism that no one could have imagined. Furthermore, the cause of the hydrogen formation was believed that non-industrial waste containing a large amount of aluminum was carried into the incinerator. Although there are many kinds of refuse which are not permitted to be treated by burning in non-industrial refuse incinerators, actually it is not possible to separate all of the refuse by the inspection at receiving. In this sense, the accident was inevitable, but a similar accident had also occurred in February 1983. After the court trial that continued for a long time, the causes of the accident and matters to be considered in operation of incinerators were reported in the journal of the Waste Society in 1994. If this report had been given sufficient consideration, and if it had been used for workers' education, this accident might have been avoidable. However, the report was about the incinerated ash that had accumulated in an electric precipitator, and it might be difficult to relate the two accidents though the causative agent in both cases was aluminum in the incinerated ash.

1. Event

At around 01:00, the ash chute damper of the No.1 incinerator, which was a continuous stoker type, showed an abnormality (Refer to Fig.1). The moisture in the refuse that is put into the hopper of the incinerator is removed in the drying zone. Then, the refuse is moved to the combustion zone. Hot air is supplied from below in the drying zone and the combustion zone. The monitor inside of the incinerator showed the accumulation of ash in the post-combustion part of the incinerator. So, the ash pusher in the post-combustion lower section was operated manually , but the ash pusher did not work well and the workers gave up combustion and stopped the combustion furnace. They stopped charge of refuse to the combustion furnace and started the operation called "fire burial", which finished at around 04:00.

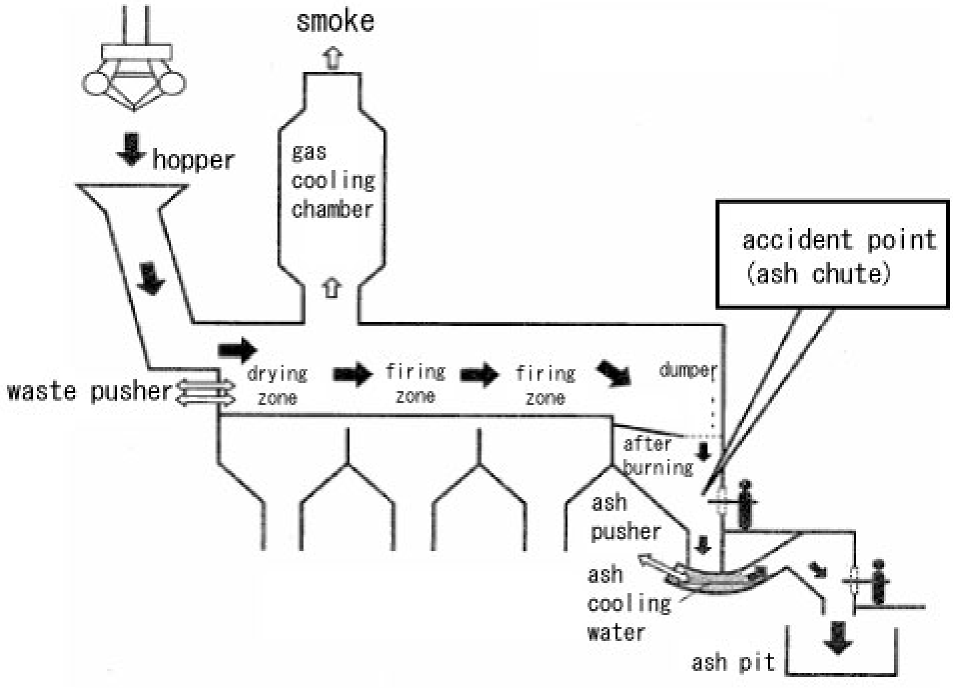

Fig.1 outline of the incinerator

After the day shift workers took over the operation, they started the inspection work. The operators saw that the ash was filled in the post-combustion zone when they opened the inspection door. They tried to remove the ash from the inspection door using a shovel, but they could only remove the ash slightly because there was a solid layer, which seemed to contain a clinker. A clinker is something like a volcanic rock, which is formed by the solidification of some molten material such as high temperature aluminum with adhesion of the incinerated ash. The explosion occurred inside the ash chute, when the operators were trying to crush the clinker with a long prodding chisel with injecting water intermittently. Besides, water injection was not carried out when this explosion occurred. Owing to exposure to high-temperature gas and ash which spouted out from the inspection door, the three workers received serious burns.

2. Course

At around 01:00 on July 6th, an abnormality was found in the ash chute damper. Immediately, workers checked the monitor mounted inside the incinerator and found an accumulation of combustion ash. The ash pusher, which is designed to push the combustion ash into the ash pit, was operated, but it did not operate well. The continuation of incineration was judged to be impossible. Charge of refuse was stopped at around 01:45, and in order to inspect the inside of the furnace, preparation of the fire burial work was started.

The work finished at around 04:00. The day shift crew took over the operation in this condition.

At around 08:20, they started an inspection and opened the incinerator. At 09:59, the explosion occurred.

3. Cause

The explosion was estimated to have occurred as follows: a combustible gas mainly containing hydrogen was formed in the ash chute and in the ash pusher, the gas mixed with the air from the inspection door to form a combustible gas-air mixture, and the mixture was ignited by hot clinker or some other ignition sources.

The hydrogen was supposed to have been generated by a chemical reaction between the water injected into the ash chute and the hot aluminum contained in the clinker and in the ash, and this hypothesis was confirmed by experiments. Although aluminum is not allowed to be put in the incinerator, a large amount of aluminum was contained in the non-industrial waste since the non-industrial waste was not correctly separated.

The water was injected into the furnace in order to help remove a blockage of the ash chute. A common reason why a blockage is produced in the ash chute is the generation of a clinker. The generation mechanism of a clinker is not sufficiently elucidated, but it is reported from experience that a clinker is easily formed when crushed material with high caloric value and a high content of aluminum is incinerated. The aluminum content the incombustible residue of the crushed material incinerated in this incinerator was as much as 24%, and its caloric value was high. There is no information on what is crushed material containing a large amount of aluminum.

Blockage in the ash chute and insufficient operation of the ash pusher were indicated as the indirect causes of the accident. The bulk density of the combustion ash at the time of the accident was several times larger than the designed value of the ash pusher. Although the reason why the bulk density was large was not clearly described, the refuse with a high aluminum content seemed to be one of the causes.

From the above, the true causes of this accident were following two; combustion processing of non-industrial waste contaminated with crushed materials of metal such as aluminum that should not be burned in an incinerator was conducted. Moreover, it was known that a clinker was easily formed from the material having a high caloric value and a high aluminum content, and in addition, there was a report of an explosion that was similar to the accident of this incinerator in the preceding year. If the managers and engineers had collected the information and conducted the management of the facilities with a sufficient safety consciousness, it seems that the accident could have been avoidable.

4. Process of cause elucidation

From the conditions of the explosion, the possibility of a steam explosion caused by a hot clinker and a gas explosion caused by generation of combustible gas were considered. It was concluded that it was not a steam explosion but a gas explosion based on the following reasons.

1) It was guessed that there was a combustion explosion because there were discoloration and peeling of anti-corrosive paint at the places that were damaged, and the steel plate itself burned. Discoloration is not caused by steam explosions, because steam explosions cannot generate a temperature high enough to cause oxidation.
2) The explosion occurred one and a half hours after the start of the water injection, and the water injection was not executed at the time of the explosion.
3) From the site investigation, the explosion seemed to have occurred in the ash chute. This position is higher than the water injection position, and it is also higher than the cooling section of the incinerated ash. Therefore, the direct contact of the ash with the injected water is considered to be difficult.

Beyond on the hypothesis above, the amount of gas generated inside the incinerator and caused the gas explosion was estimated. From general information from literature and other sources, the aluminum content in the ash was estimated. In the clinker, it was 11.6%, and in the incinerated ash, it was 9.0%. This value is higher than the reported value of 6 to 8%. It was confirmed through an experiment on the generation of hydrogen gas by injecting pure water to this incinerated ash that hydrogen is generated when the ash coexists with water of which pH value became 12 by the alkaline component in the incinerated ash. Considering a wide explosion range of hydrogen, there is a large possibility of the explosion by hydrogen gas.

5. Immediate action

Among the three incinerators operated by the plant, two incinerators were stopped until the investigation of the cause ended. One of the furnaces that were stopped was the one where the accident happened, and the other one was the same type as the one involved in the accident. The accident investigation committee was established the day after the accident to investigate the cause and to study the prevention measures for the accident. Besides, treatment of the waste that should be handled at these incinerators was entrusted to the waste incinerators in the neighboring area until the accident cause was cleared.

6. Countermeasure

From the operation perspective, incineration treatment of crushed material with a high aluminum content was stopped, nitrogen was introduced for purging a combustible gas generated when blockage was removed, sufficient cooling time and safety confirmation steps were executed prior to the removing work, water injection was stopped, etc..

At the facilities, an industrial camera and thermometer for early detection of blockage were prepared, and the capacity of the ash pusher was increased. Furthermore, for management aspects, a work standard was prepared.

As administrative countermeasures, a warning of the separation of refuse was issued using a citizen public relations magazine, and it emphasized the complete separation of non-combustibles and combustibles.

7. Knowledge

Accidents related to treatment of non-industrial refuse occur rather frequently. Although the separation of combustibles and non-combustibles is carried out, sometimes the separation may be insufficient and dangerous situations occur. At this plant, a large kettle was found in the incinerator, or pesticides contaminated and a poisonous and bad smell gas was generated at the non-combustible disposing facilities of the plant. It may be necessary for the persons concerned to recognize the non-industrial waste disposing facilities as dangerous material facilities.

There was an earlier accident that was similar although not completely identical with this accident. If the managers and engineers had been conscious that they were operating dangerous facilities, they could have taken more effective measures to prevent accidents by referring to the earlier accident. A positive attitude of learning from the mistakes of others and establishment of the systems for collecting outside information are important.

8. Influence of failure

The human damage from the accident consisted of three workers hospitalized for burns, and one worker died ten days later. Physical damage included deformation of the ash chute and damage to the humidifying cabin.

Damage to the administration occurred because the waste treatment capacity of the facilities decreased, and a request had to be made to the municipalities in the neighborhood to handle the excess wastes. It seems that the processing cost increased and the quality of the refuse collection service lowere.

9. On the side

Accidents at non-industrial refuse treatment facilities are unexpectedly frequent. Some accident examples are described in Table 1. In 1995, at treatment facilities in Saitama, a dust explosion occurred as a result of too much paper refuse being carried in. There are many accidents that can not be imagined at many places. A hydrogen gas explosion that is similar to the accident described here also occurred around 1983, and the court trial concerning this accident continued for 11 years. The person concerned described that he could not open any technical report about the causes of the accident during the court trial period. If the cause was announced earlier with sufficient PR, other accidents might have been prevented. Although each accident example is also important, by grasping the common or “upper” concept of the accidents, it becomes possible to contrast the knowledge in the examples with an individual case and therefore failure information can be utilized more effectively.

Again, it is important that the cause of the failure is communicated even if it is currently just speculation. It is better not to wait for the conclusion of the court trial and the formal accident investigation.

generation place	date	type of facilities	content of the accident
Higashi-Kurume, Tokyo	1981.1.14	Public, non-industrial refuse incinerators	fire in the operation and restart between an incinerator and an electrostatic precipitator
Asaka, Saitama	1995.3.7	Public, non-industrial refuse incinerators	Paper powder in corrugated fiberboard boxes caused a dust explosion in the refuse charge division
Kawasaki, Kanagawa	1997.8.15	Private, A General refuse incinerator	Crushed, and not cut refuse stops in the hopper, cause a fire.

Table. 1 Accident Example of Non-industrial refuse

Reference

・Kenji Yasuda, Hideo Tagota、Takashi Miyagawa and Yasuo Shimizu、" Hydrogen gas explosion in non-industrial refuse incineration facility in Kanagawa Prefect" , J.Japan Soc. for Safety Engineering, 36, 183-187(1997)

・Koh Takatsuki, "Lesson of collected dust bunker explosion" Waste Academic J., 5, 441-447 (1994)

・Health committee letter of the Isehara City, The No.10th, (1995)