Lecture PA4

Explosion of Smokeless Gunpowder in a Temporary Storage House

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1. DESCRIPTION OF THE ACCIDENT

On 1st August 2000 at 22:09, a sever explosion occurred in a temporary storage house No.12 of Taketoyo Plant, in which total 7.7 tons of smokeless gunpowder was stored.

Weather data of the day recorded by Taketoyo Municipal Hall (22:00) was fine, temperature 26.3C, relative humidity 84%, average wind velocity 3.1m/sec and mean direction of wind south-east.

Considerable damage occurred throughout the whole plant. 29 buildings were completely destroyed, 39 buildings were half destroyed, 192 buildings were partially damaged and window glass was broken in 60 buildings. Since the plant was not in operation on that day, no employee was injured. Important damage also occurred outside the plant. 1 person was severely injured, 2 persons were injured and 76 persons were slightly injured. 12 houses were completely destroyed, 26 houses were half destroyed and 440 houses were partially damaged. Window glass was broken in 364 houses, and 46 cars and other items were damaged.

2. INVESTIGATION OF THE CAUSE OF THE ACCIDENT

The investigative committee of the ministry of international trade and industry was formed soon after the accident, and started the investigation of the cause of the accident.

2.1 FINDINGS

On Jury 31 at about 15:00, workers brought in and carried out smokeless gunpowder at temporary storage house No.12, and they noticed neither irregularity nor particular smell. On August 1st, no operation was done at temporary storage house No.12 since the plant was not in operation on that day.

Alarm system of Taketoyo Plant recorded following events of the accident:

22:09:10 Alarm system of temporary storage house No.12 began to operatesuggesting that doors and windows of the building were opened by pressure rise in the building due to combustion of smokeless gunpowder.

22:09:23 Alarm system of temporary storage house No.12 stopped to operate indicating that transmission line of the alarm system was broken by the effects of combustion or explosion.

22:09:29 Alarm systems of neighbouring buildings began to operate, which suggested that large scale explosion occurred in temporary storage house No.12.

The investigation on the site was performed by the investigative committee on August 4th and 11th. 13 craters were formed on the floor of temporary storage house No.12. Large and deep craters were formed in east part of the floor (size of largest crate was about 3m in diameter and about 1.3m in depth), and only small and shallow craters were formed in west part of the floor. Floor surface and steel frames in west part were severely burnt, which indicated that they were exposed to flame during considerable time. The record of

alarm system and findings of the investigation on the site suggested that smokeless gunpowder, which was stored in black electroconductive plastic container or wooden container placed in west part of temporary storage house No.12, was initially ignited and flame spread into whole building, and finally deflagration to detonation transition occurred.

2.2 MECHANISM OF IGNITION OF SMOKELESS GUNPOWDER

Following 5 factors were considered as the mechanism of ignition of smokeless gunpowder;

1) ignition by contact with hot body
2) ignition by impact of falling body or drop of container
3) ignition by static electricity
4) autoignition by degradation of stability
5) ignition by external factor such as lightning, external fire etc.

The results of detailed analysis of 5 factors suggested that the autoignition of smokeless gunpowder was most suspicious cause of the accident.

45 types of smokeless gunpowder were stored in temporary storage house No.12 at the time of the accident. Stability test was performed for 41 types of smokeless gunpowder stored in Taketoyo Plant after the accident. For 9 types of smokeless gunpowder within above 41 types of smokeless gunpowder, stability test was performed after loading high temperature, high humidity cycle test. The results of stability test suggested that one of 4 types of smokeless gunpowder had possibility to be initially autoignited.

The detailed analysis was performed for 4 types of smokeless gunpowder using microcalorimeter, chemiluminescence analyzer and NOx meter. The results of microcalorimetric measurements showed two most suspicious smokeless gunpowder; one was double base powder for commercial use and the other was ignition powder. The results of chemiluminescent measurements revealed that oxygen acceralated decomposition of the double base powder but not of the ignition powder. NOx evolution rate of the double base powder was very high and that of the ignition powder was low at a temperature of 65C. The results of calculation based on the thermal explosion theory suggested that the double base powder initially autoignited.

In temporary storage house No.12,window glass was painted with red paint without shading curtain and the measure to shade sunlight was insufficient. Temperature in black electroconductive plastic container which was exposed to sunlight through window glass was measured in similar temporary storage house. The results of temperature measurements showed that maximum temperature of 55C was attained in black electroconductive plastic container when the container was placed close to west window. It was recorded that 4kg of most suspicious double base powder, which was produced 4 years ago, had been stored during last 2 years in 2 black electroconductive plastic containers placed close to west window in temporary storage house No.12.

The results of the investigation suggested that stability of most suspiciou double base powder had been considerably degradated under the loading of high temperature and high humidity condition in summer season, and the double base powder finally autoignited.

2.3 ASSESSMENT OF THE EFFECTS OF THE ACCIDENT

To assess the effects of the accident, TNT equivalence of exploded smokeless gunpowder was evaluated. TNT equivalence of smokeless gunpowder, which was estimated using damage data of window glass in distant houses, was over 8tons. Explosion heat and detonation properties of smokeless gunpowder stored in temporary storage house No.12

were calculated using KHT and CHEETAH code. Total TNT equivalence of 7.7tons of smokeless gunpowder stored in temporary storage house No.12 was about 6.6tons according to the results of calculation. To investigate deflagration to detonation transition (DDT) possibility of smokeless gunpowder, DDT test was performed using 50/60 steel tube. Total TNT equivalence of smokeless gunpowder which had DDT possibility was about 2.2tons. TNT equivalence of exploded smokeless gunpowder was also evaluated from the size of craters using the results of 1/4 scale crater formation test. Total TNT equivalence estimated from the total volume of craters was about 4tons.

TNT equivalence estimated using various method was largely inferior to that estimated from damage of window glass in distant houses. This fact suggested that wood and aluminum used as container materials were pulverized into small particles by the explosion of smokeless gunpowder and began to react violently, and that high speed combustion of wood and aluminum enhanced blast wave. To verify the effects of combustion of container materials, small scale experiments and numerical simulation using hydro-thermodynamic code were performed. The results of the experiments and numerical simulation showed that blast wave could be enhanced particularly at far field, when container materials were reacted within 100msec after the detonation of smokeless gunpowder.

3. LESSON LEARNT AND ACTION TO PREVENT RECURRENCE OF THE ACCIDENT

The results of large scale experiments performed under the direction of the ministry of international trade and industry in the past showed that smokeless gunpowder, which was stored in wooden container or cardboard box, did not exhibit DDT behavior when smokeless gunpowder was exposed to fire. It is generally considered that smokeless gunpowder, which is kept in wooden container or cardboard box, has no DDT possibility. However, the results of the accident showed that smokeless gunpowder stored in large wooden container with inner aluminum plate, which contained more than 400kg of smokeless gunpowder, exhibited DDT behavior when it was enveloped in violent flame. Large scale experiments were performed after the accident to verify the effects of container size on DDT of smokeless gunpowder. DDT was not observed when smokeless gunpowder was stored in plastic container which contained less than 80kg of smokeless gunpowder, even when 2 containers were piled up. The results of the accident also showed the importance to control storage conditions.

To prevent recurrence of the accident, NOF Corporation took necessary action to improve the conditions of storage in temporary storage house of smokeless gunpowder ;

1) Installation of air conditioning equipment to control temperature and humidity.
2) Installation of recording thermometer and hygrometer.
3) Use of high quality curtain to shade sunlight.
4) Installation of automatic fire-extinguishing equipment such as sprinkler.
5) Use of smaller size container, material restriction on container and clarification of storage method.
6) Limitation of storage period.

Considering the importance of the accident, the administrative authority amended the safety distance of smokeless gunpowder stored in temporary storage house. The safety distance of smokeless gunpowder at temporary storage house is the same as that of high explosive. However, smokeless gunpowder and solid propellant, which are judged as having very low probability of explosion by DDT test (50/60 steel tube test), are exempted from the amendment of the safety distance.