Explosion Damage in the Unit 4 Reactor Building of Fukushima Daiichi Nuclear Power Plant

Takashi Tsuruda
Akita Prefectural University
Yurihonjo, Akita, Japan

1 Introduction

The unit 4 reactor building of Fukushima Daiichi Nuclear Power Plant experienced a major explosion early in the morning on March 15, 2011. Tokyo Electric Power Company (TEPCO) reported a fire on the fourth floor of its reactor building from 9:30 to 10:00 on March 15, 2011. TEPCO also reported another fire of unit 4 on March 16, 2011. The unit 4 is outage and no fuel rod was in the reactor vessel at the explosion. The Nuclear Regulatory Authority (NRA), Japan set up the Committee on Accident Analysis of Fukushima Daiichi Nuclear Power Station on March 27, 2013[1]. NRA invited fire and explosion investigators to assess the building damage of the unit 4 reactor building. The author as a member of investigators visited the unit 4 reactor building on July 10-12, 2013. NRA released the official intermediate report on the explosion damage of the unit 4 reactor building on October 8, 2014. NRA also released pictures taken during the visit on its web site[2]. Nuclear reactor building employs a forced ventilation system, which exhaust air from the highest contaminated area and supply air to the least contaminated area. On the fourth floor of unit 4 reactor building two huge motor driven generators (MG set) locates. The height of the fourth floor is nearly two times higher than that of the third floor[3]. To dissipate heat from motor driven generators, ducts were also installed on the fourth floor. If the combustible gas spreads from the exhaust line, the combustible gas concentration decreases from the exhaust duct to the supply duct. In this paper, the damage of the unit 4 nuclear reactor building was examined with the pictures taken in the visit.

2 Equipment

All images taken during the visit were submitted to NRA for report preparation. NRA returned the submitted images, 36 frames of film pictures and 10 frames of digital images to the author in summer of 2014. Due to contamination control and high temperature, picture taking in unit 4 building was difficult. TEPCO carried out the contamination control of cameras by covering with plastic film. Camera lens was exposed to maintain high resolution of pictures. If the contamination of camera exceeded the control level, the contaminated ones were to be disposed in the site and the film and memory were to be recovered. In the visit, no significant contamination occurred. The illumination in the building is limited and flash photography was extensively employed. Due to limited flash capabilities of used cameras, only close flash photography was available. Film cameras were used as the main recording device. Date and time of each shot were printed at one corner of picture as orange

Correspondence to: TTsuruda@akita-pu.ac.jp

color characters. Digital cameras were also used as backups. Reference materials and notes are not used during this visit in unit 4 reactor building for contamination control.

3 Observed Explosion Damages

The first visiting area is the fourth floor where fires were reported. The visiting team walked from the entrance at the first floor to the fourth floor through a service stair with flashlights. After the fourth floor, the team visited the third, roof, and first floors. The stay on the roof was limited for the radiation exposure control from the unit 3 reactor building. All visits are limited where the radiation level is low.

3.1 Damage on fourth floor

After the explosion of the unit 4 reactor building, smoke was seen near the fourth floor. To see the fire damage, the team visited the north side on the fourth floor.

Figure 1 shows the north-west corner of the fourth floor. The ceiling panels are totally lost and panel supports are seen in this figure. The surface of ceiling concert is lost and steel mesh, which was embedded in concert, is exposed. The explosion blew the north wall and a large opening is formed. The remaining of the duct shows compression from the outside. This deformation indicates that the pressure on the fourth floor was much higher than the internal pressure of the duct. Connecting boxes of wirings are also compressed from outside. A rapid pressure buildup occurred in this area.

Figure 2 shows part of an MG set. A rectangular case in the center is slightly covered with soot. The north side opening is seen behind the case. The upper rim of the opening is covered with soot. Fragments are piled up high on the floor. Figure 3 shows blacken thermal insulators on the floor near the MG set. Leaked oil seemed to soak into thermal insulators and ignite by some ignition source.

Figure 1 Damaged Duct

Figure 2 MG set

Figure 3 Black colored insulators near an MG set

Figures 4 and 5 show ceiling. Part of ceiling surface concert is lost in fig. 4. Cracks run along the ceiling surface concert in fig. 5. Two ducts remain in the lower part of fig. 4.
Figure 6 shows the west side opening. A metal cover of thermal insulator was caught in a pole at the center of this figure. The direction of gas flow during the explosion was west at this point.

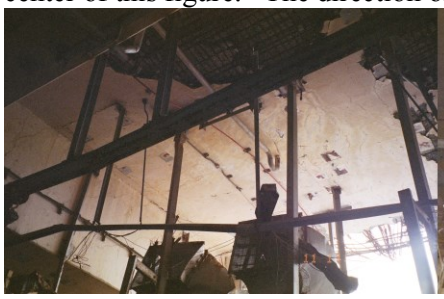

Figure 4 Ceiling near an opening

Figure 5 Ceiling near an MG set

Figure 6 West wall opening

3.2 Damage on first floor
Figure 7 shows a composite photograph of duct and cable rack on the first floor of the unit 4 reactor building. This is supply duct and damage is limited at the opening. The cable rack above the supply duct is damaged as seen in fig. 7.

Figure 7 Duct (lower) and cable rack (upper) damage

3.3 Damage on third floor

Figure 8 shows a composite photograph of K82E box on the third floor. Plastic sheets are seen upper part of the figure. Green fragments are on the left side of the picture. An exploded box K82E is at the center of the picture. A light green color box right of the exploded box is compressed slightly.

Figure 9 shows side view of the area in figure 8. A cable rack locates in the exploded box K82E. It seems that the gas flow from the upper floor conveyed fragments and gas into this section.

Figure 8 Front view of K82E

Figure 9 Side view of K82E

Figure 10 shows a composite photograph of fragments on pipes. Induced flow conveyed these fragments all over the floor. Figure 11 shows fragments on cable rack. Sharp fragments could damage coated cables. If a fire occurs after a gas explosion like unit 4 case, the surface coat damaged by sharp fragments might not withstand the designed heat stress of fire. Figure 12 shows heat damages on plastic materials. Green colored large fragment and small transparent one were caught in a red frame at the center of this figure. These plastic materials experienced a high temperature environment.

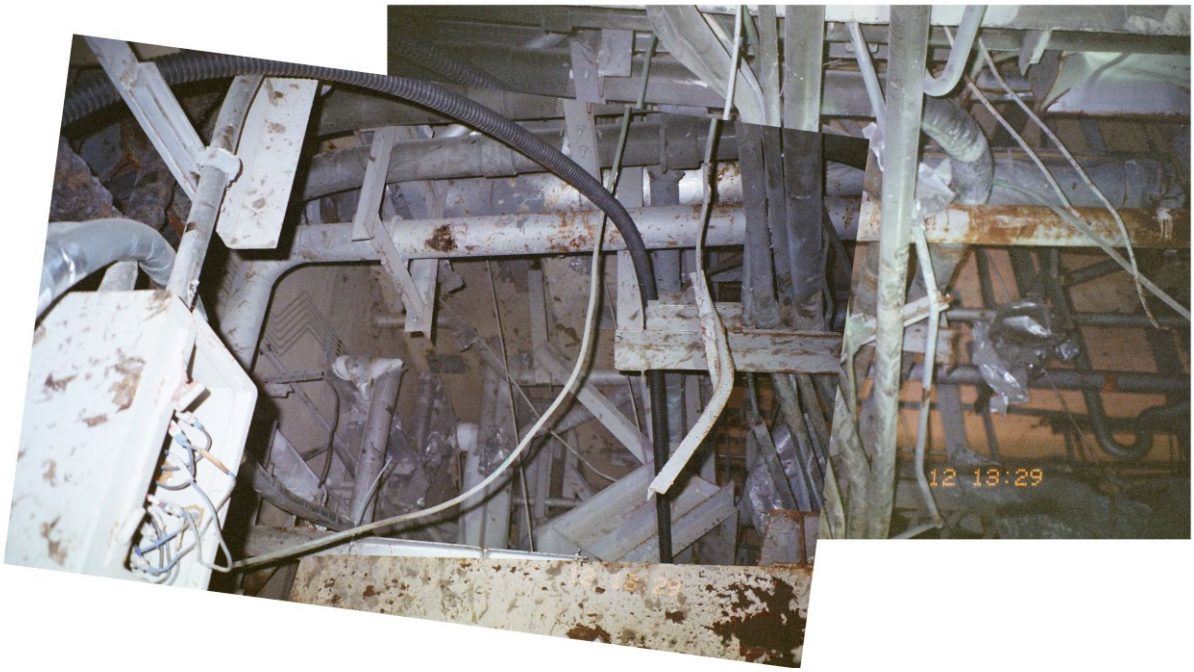

Figure 10 Fragments on pipes

Figure 11 Fragments on cable rack

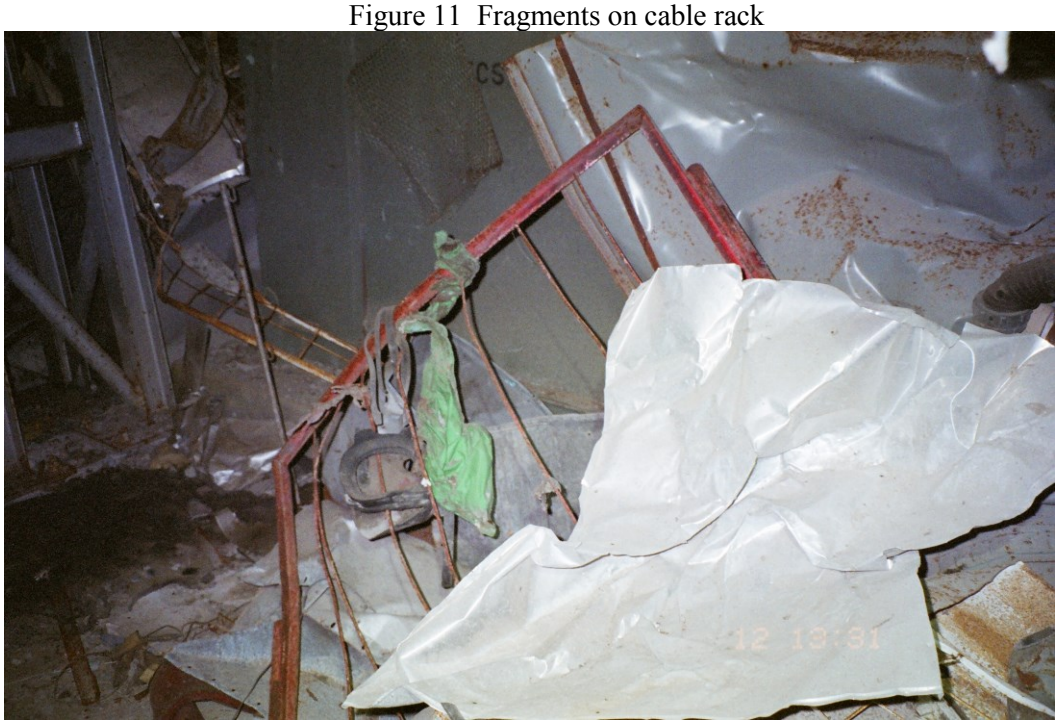

Figure 12 Heat damage on plastic materials

3.4 Non-uniform damage cause

The damages of these areas in unit 4 reactor building are not uniform. In a series of hydrogen deflagration tests [4] concerning the behavior of hydrogen, iodine and aerosols in the containment of water cooled reactors during severe accidents, a high steam content in the combustible gas mixture leads to an irregular combustion both for upward and downward burn direction with lower flame velocities and lower peak pressures as compared to "dry" mixtures. As reported by TEPCO[5], if wet hydrogen spreads in unit 4 reactor building and it contacts with walls, then various steam content mixtures in which flame propagate irregularly will form.

4 Conclusions

The damage of the unit 4 reactor building was examined with the pictures taken during the visit. Non-uniform damages of gas explosion are seen in the reactor building. Several local explosions seem to occurred like dust explosion case. Duct opening areas are heavily damaged on the first floor where the gas explosion damage is minor. The induced gas flow direction depends on where the opening was formed. Fragments are spread in a wide area of the building. Fragments could damage cables and other equipment. Heat damages are seen on plastic materials. This heat damages indicates a gas explosion in the reactor building of unit 4.

Acknowledgments

The author thanks for the invitation of this visit to the unit 4 reactor building of Fukushima Daiichi nuclear power plant by The Nuclear Regulatory Authority(NRA), Japan and the support of the visit by The Nuclear Regulatory Authority(NRA), Japan and Tokyo Electric Power Company.

References

[1] Nuclear Regulation Authority (2013). First Meeting of the Committee on Accident Analysis of Fukushima Deiichi Nuclear Power Station, http://www.nsr.go.jp/committee/yuushikisya/jiko_bunseki

/20130501.html .

[2] Nuclear Regulation Authority (2013). Walk down of unit 4 reactor building of the Committee on Accident Analysis of Fukushima Deiichi Nuclear Power Station, http://www.nsr.go.jp/committee

/yuushikisya/jiko_bunseki /20130710genchi.html.

[3] TEPCO (2012). Report on the Fukushima Daiichi Accident,http://www.tepco.co.jp/cc/press/ betu12_j/images/120620j0306.pdf.

[4]OECD/NEA (2010).THAI Project Hydrogen and Fission Product Issues Relevant for Containment Safety Assessment under Severe Accident Conditions, http://www.oecd.org/officialdocuments/ publicdisplaydocumentpdf/?cote=NEA/CSNI/R%282010%293&docLanguage=En.

[5]TEPCO (2011). Fukushima Nuclear Accident Analysis Report (Interim Report) , http://www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/111202e14.pdf, pp.99-104.