Report on the overview of the accident

Reference No.	Name of the Accident;
-	Explosion and fire at an acrylic acid production facility.

Date and time of occurrence:	Place of the accident:
Around 14:35 on September 29, 2012	Himeji-city, Hyogo Prefecture, JAPAN

Plant name:	Equipment name:	Main structural materials:	Summary of dimensions:
Acrylic acid production facility	Intermediate tank (V-3138)	Side plate: JIS SUS304 (t 3mm) Bottom plate: JIS SUS316 (t 4mm)	Inner diameter 4.2m Height 5.6m (Thermal insulation installed)

Contents:	Nominal capacity:	Normal operating pressure:	Normal operating temperature:
Acrylic acid, Inhibitors, etc.	70m^3	Atmospheric pressure	Not defined

Damage situation:

An intermediate tank (V-3138, Fig. 1) temporarily stored the bottom liquid of the glacial acrylic acid rectifying column in the acrylic acid production facility ruptured and exploded causing a fire in the surrounding area, which damaged an adjacent acrylic acid tank, a toluene tank, racks, piping, etc.(Fig. 2)

In this accident, 1 person (a fire fighter) was killed, 5 were severely injured (2 fire fighters, 3 employees), 13 were moderately injured (8 fire fighters, 1 police officer, 4 employees), 18 were slightly injured (14 fire fighters, 1 police officer, 3 employees), for a total of 37 people who were killed or injured.

Overview of the Accident:

Sep. 18 to 20	Total power shutdown in the facility for electrical and instrumentation maintenance work (total power shutdown work).
Sep. 20	
Approx. 21:00	After completion of the total power shutdown work, the intermediate tank (V-3138) was re-commissioned.
Sep. 21	
Approx. 11:00 to 14:00	Liquid was fed into the recovery column (T-6701) from the intermediate tank (V-3138) and T-6701 operation was started. Then, the operation of rectifying column (T-6108) was started and the bottom liquid of the column T-6108 was directly fed into T-6701.
Sep. 24	
Approx. 10:00	The rectifying column (T-5108) operation was started.
Approx. 14:10	Discharging of the bottom liquid of T-5108 was started by feeding to T-6701 via V-3138
Sep. 25	
Approx. 9:30	Liquid level built up in the intermediate tank (V-3138) was started by stopped feeding to T-6701 from V-3138.
Sep. 28	
Approx. 14:00	After the liquid volume in the intermediate tank (V-3138) reached 60m^3, feeding to V-3138 was stopped by switching T-5108 bottom liquid to T-6701 directly.
Sep. 29	
Approx. 13:17	The liquid level gauge of the intermediate tank (V-3138) triggered a 'liquid level high alarm'.
Approx. 13:20	White smoke emitted from the V-3138 vent was observed.
Approx. 13:25	The operators started spraying water onto V-3138 using private fire hydrant.
Approx. 13:40	The operation shift leader made the plant-wide announcement and alerted the company disaster prevention team. The V-3138 liquid level gauge reading exceeded the instrument indication limit value (84.8 m^3).
Approx. 13:48 to 13:49	Member of the disaster prevention section notified the situation to the fire station through the hot line.
Approx. 14:00	The company disaster prevention team started spraying water onto V-3138.
Approx. 14:02	The public fire brigade arrived at the scene and set a cordon.
Approx. 14:35	The V-3138 liquid level gauge reading dropped drastically and a 'liquid level low alarm' was triggered. V-3138 ruptured and exploded. The contents of V-3138 ignited and resulted in fire.
22:36	The fire was brought under control.
Sep. 30	
15:30	The fire was extinguished.

[Damage condition of the intermediate tank V-3138]

1. The roof plate broke and separated near the roof-to-shell joint. The roof plate has split into two and being thrown to a distance of about 50m (see Fig. 3).
2. The shell plate was vertically torn in a near straight line at 270° position and deformed into casement-type opening and left almost like a flat plate within the dike at the accident site. The bottom plate partly broke near the shell-to-bottom joint and remained inside the dike.
3. The cracks formed around the outlet nozzle of cooling water coil propagated and split the tank shell plate vertically in both directions at 270° position. The upwards crack broke into the roof plate and ran through it near the 135° position. The roof and bottom plates generally cracked in the circumferential direction near their joints with the shell plate.

Causes of the accident:

1. Even though high temperature T-5108 bottom liquid was building up in the intermediate tank (V-3138), the fact that the circulation of recycle to top was not commissioned has caused acrylic acid to remain stagnant for a significant long period of time at high temperature in the upper portion of the tank (Fig. 4).
2. Dimer formation of acrylic acid accelerated in the tank liquid with high temperature zones and the liquid temperature in the storage tank was elevated by the heat of dimerization. As a result, the polymerization reaction of acrylic acid starts to proceed and increased the liquid temperature further.
3. The abnormal condition was not possible to recognize due to the lack of thermometers and inadequate temperature monitoring, until the polymerization reaction of acrylic acid had proceeded. As a result, V-3138 exploded, followed by fire and caused enormous casualties and property damages (see Figs. 2 and 5).

Measures to prevent recurrence:

1. Measures to prevent recurrence for equipment causing the accident

(1) To prevent excessive heating in the tank feed liquid, specification of the T-5108 bottom liquid transfer pipe should be changed.

(2) To control the appropriate temperature of the stored liquid in V-3138, specifications of the intermediate tank (V-3138) and (new) associated equipment should be studied. The criteria and its response procedure for the abnormal status should be clarified.

(3) To clarify safety of the restored equipment and necessary matters for stable operation, documentation likes manuals, P&ID should be developed or revised.

(4) To operate the restored equipment safely and stably according to the manuals, education and training should be provided.

2. Measures for preventing similar accidents

(1) To ensure risk assessment is implemented whenever there are changes in non-routine works, procedures, methods, equipment, etc. and each work details are disseminated, basic rules for safe work management should be established, rules of Management of Change and practice of operating instructions should be reviewed.

(2) To enhance the emergency response capabilities when abnormal situations occur, crisis management manual should be developed, company disaster prevention manual should be reviewed and training on these manuals should be provided.

3. Horizontal deployment of disaster prevention measures

Review the above countermeasures and compare them against the current practices in other business facilities.

4. Fostering a safety culture promoting safe plants and enterprises

It should be made aware that safety is not something to be provided by others but rather need to recognize and achieve safety by themselves, and this concept should be reflected in the future behavior of organization and individuals.

Learned lessons:

1. The latest data of properties, reactivity and risks of handled chemicals (raw materials, intermediate products, additives, reactants, etc.) should be checked and reflected on their operational management, safety management and facilities management.
2. Risk assessment in the event of non- routine works, management of change and abnormal situations as well as risk assessment of facilities and processes should be conducted to enhance safety.
3. It should be confirmed that in facilities such as reactors, storage tanks and intermediate tanks with risks of polymerization reaction, decomposition reaction and runaway reaction in which cooling coil, U-tube or the like is installed to keep them at constant temperature and control the reaction, safety is secured

without causing abnormal reaction due to temperature elevation or impurities on the internal walls when the stored liquid volume is temporarily increased to above the cooling devices.

4. Operating standards and operation manuals in any abnormal, disaster and emergency situations should be developed in advance. Safe emergency responses such as stop the reaction or emergency stop should be clearly defined in the event in which it is beyond the scope of such standards or manuals, and they should be thoroughly informed through education and training.
5. Past troubles and abnormalities should be shared not only in the department where they occurred but also company-wide so that occurrence of similar accidents and recurrence of identical accidents can be prevented. It is important information on accidents and troubles which have occurred in other business facilities and departments is shared and used at our own workplace.
6. As a top and leading company, introduction of safety audits and safety assessment by a third party is recommended in order to achieve continuous safe operation.
7. Safety awareness should be shared from top management to all employees so that continuous stable production will not soften safety awareness and not become less sensitive towards danger. The corporate mission statement and security management policy should be understood and they should be reflected in the actions of organizations and individuals.
8. In this accident, an atmospheric tank ruptured, exploded and caused major damages due to a polymerization reaction. It is important to thoroughly inform the prevention and safety measures for accidents resulted in atmospheric tanks as well as rupture and explosion of high-pressure gas reactors, storage tanks .
9. Information sharing which include critical information of facilities, equipment, chemicals, affected areas, etc is important between the business facilities and relevant organizations (fire authorities, police, authorities concerned, etc.) which will enter the site in the event of accidents and abnormal situations.

Remarks:

Acrylic acid (CH_2=CHCOOH) is a colorless, transparent, flammable liquid with a pungent odor. Due to its unstable double bond, acrylic acid is readily converted into a dimer (DAA) via dimerization reaction and to polymerize through polymerization reaction.

The DAA forming reaction is not susceptible to the atmosphere and inhibitors. Typically, the atmosphere is controlled so that the oxygen concentration may be 5 vol% or more and inhibitors are added for the purpose of suppressing the polymerization reaction.

Reference;

Nippon Shokubai Co., Ltd. Himeji Plant Explosion and Fire at Acrylic Acid Production Facility Investigation Report, March 2013, Accident Investigation Committee, Nippon Shokubai Co., Ltd.

Further, matters that weren't written in previous report were written by KHK after consideration of Accident Investigation and Analysis Committee in KHK.

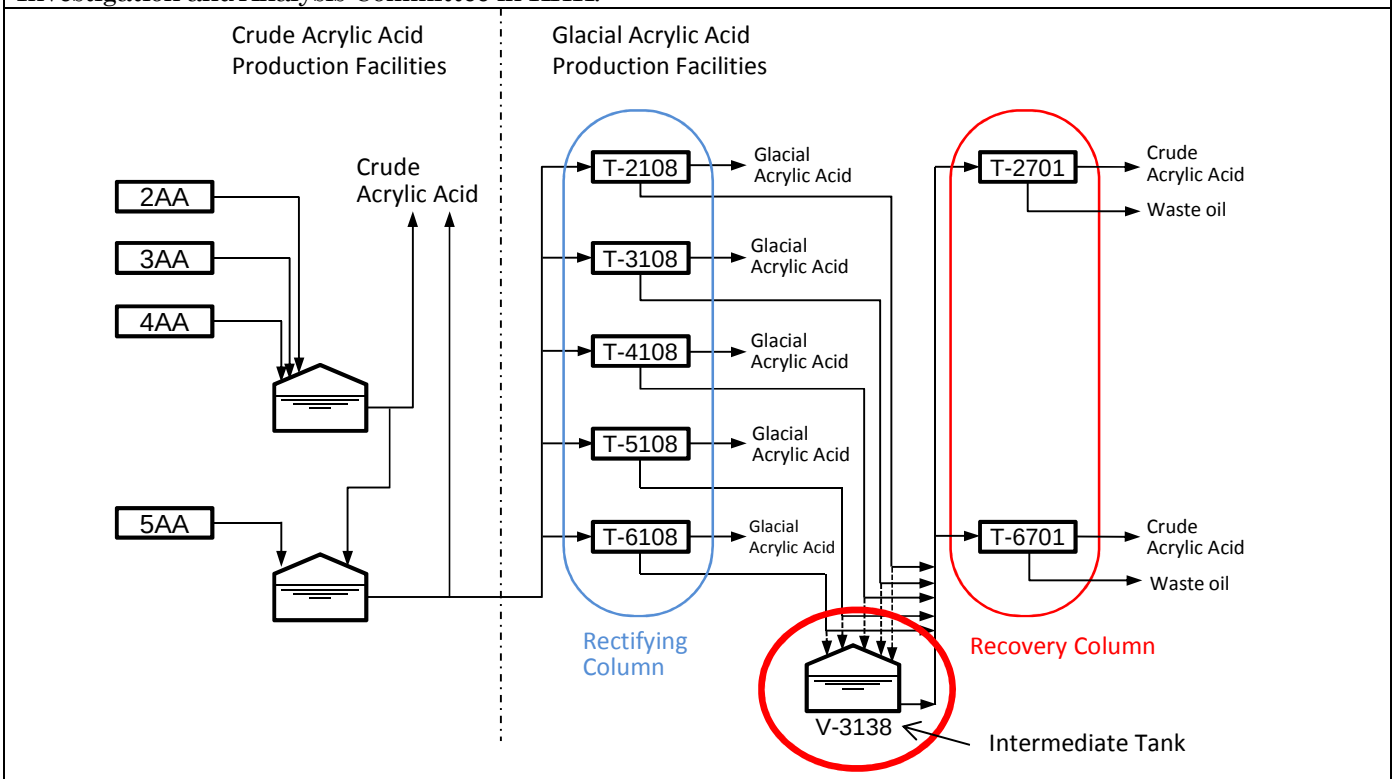

Fig.1 Configuration of acrylic acid production processes

Fig.2 Damaged Tank
(View from southwest and zoom in)

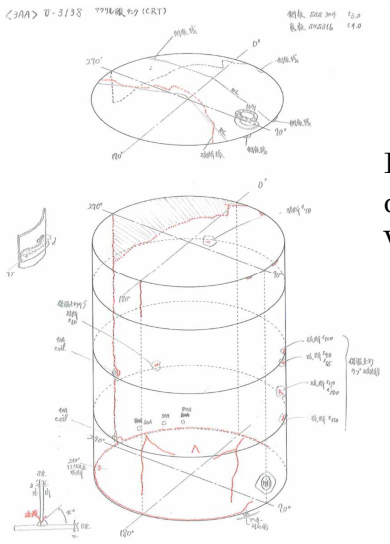

Fig.3 Reconstruction diagram (sketch) of V-3138 fragments

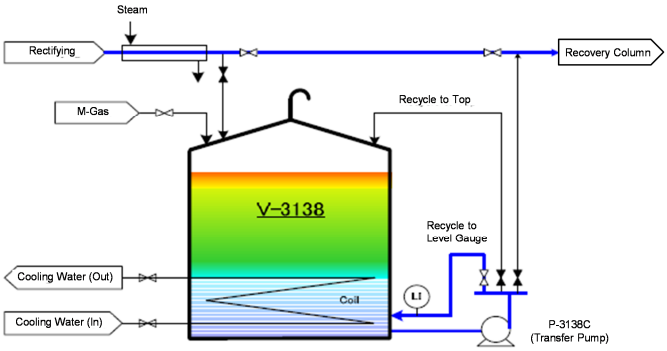

Fig.4 Status of tank V-3138 after liquid storing

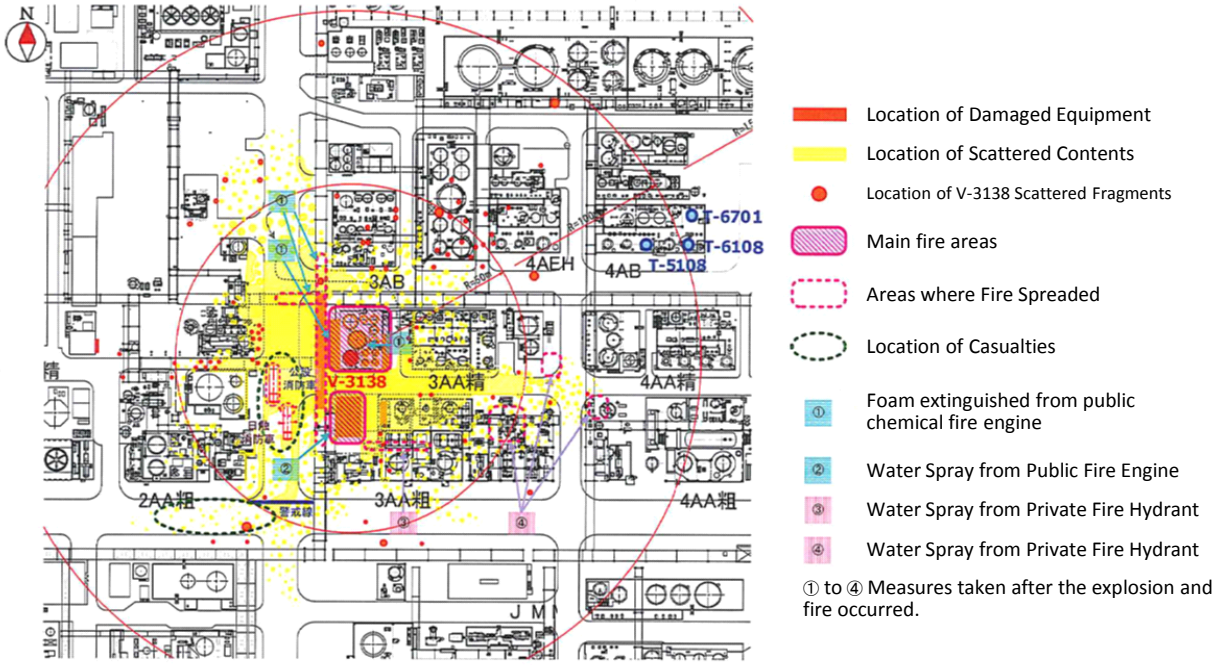

Fig.5 Fire areas around the intermediate tank

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