On New Concepts, Applied Design and Core Management against Earthquake in the Complex Chemical Plants

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Abstract-The Earthquake is occurring more frequently in Korean Peninsula, where adjoins the circum-pan, Pacific Earthquake Belt being subjected to many Earthquakes. In 2009, Earthquakes in Korean Peninsula were occurred 60 times compared with 41 times on a yearly average of the last 10 years (1999~2008). And the Richter Magnitude (R.M.) records 6.9 of the maximum occurred in near DuMan River in Feb. 18, 2010. Inside their plant boundary, they have many kinds of processing equipment (P.E.) that are very high, huge and heavy. So, the stronger Earthquakes than 5.2 of R.M. in Mt. Sokri, 1978, will destroy these P.E. Then, these P.E. will be falling down, and hazardous materials will be leaked out and diffused. In the result, a great many people will be sacrificed; both neighboring county and city will be fallen into ruins. In general, according to the priority order, it is necessary to reinforce these P.E. on the Earthquake-design standards to be separately prepared by every plant. And upgrading of operation strategies is required to minimize total damages in the complex. Accordingly, this research shows what and how to protect and develop the processing equipment against Earthquakes.

Keywords- Earthquake; Korean Peninsula; Pacific Earthquake Belt; Richer Magnitude; Processing Equipment; Hazardous Materials; Earthquake-design Standards

I. INTRODUCTION

A. Research questions

More specifically, this study aims at investigating the following questions:

1. What and how to do for reinforcement of overall equipment and facilities against coming Earthquakes?
2. What can you suggest and develop for faster emergency shutdown than the existing process control system?
3. Why is required the establishing of an Earthquake Policy of the Earthquake Resistant Design Standards for Chemical Plants to construct so that Chemical Plants can be sustainably operated in safety against coming Earthquakes?

The philosophy of this research is on the basis of both Engineering Ethics and Beliefs in Experiences. And also it is to uphold the majesty of human being and to protect national properties. This research is claiming the fulfillment of the practicability of learning and experiences. In order to work out the countermeasures to minimize the losses on both human being and national properties, this research shows the preparations and methodologies/methods.

This research is supported on the basis of the Informal Education through Author's Hands-on Experiences from various Chemical Processes and Complex Chemical Plants, based on the following "Background of Research".

It is studied that Korean Peninsula is no longer safe from Earthquakes. According to the Metrological statistics, as mentioned in the above ABSTRACT, Earthquakes in Korean Peninsula in 2009 year, occurred 60 times compared with 41 times on the basis of yearly average occurred in the last 10 years (1999~2008). The record of 2009 year shows 19 times increment more than the yearly average of the last 10 years. And more concernedly, in Korean Peninsula, the Richter Magnitude (R.M.) records 5.2 of the maximum occurred in Mt. SokRi in 1978. On Feb. 09, 2010, an Earthquake on 3.0 of R.M. occurred in SiHeung area neighboring in the Seoul Metropolitan Area, and strong 6.9 of R.M. occurred near DuMan River on Feb. 18, 2010, respectively.

In connection with the Earthquakes, in their boundary of plants, those advanced complex and/or general chemical plants that have many kinds of Processing Equipment, that is to say, vessels, reactors, towers, columns, storage tanks, and stacks etc. that are very high, huge and heavy. These chemical plants have been producing intermediates and products as well as treating many kinds of materials to get their products through these Processing Equipments. More critically, these chemical plants have been running under the following serious conditions.

In brief, these materials including intermediates and products are mostly very toxic, extremely dangerous, fatally poisonous, easily inflammable, sensitively reactive and explosive, and environmentally hazardous etc. as most fine chemicals showing their special characters and properties in addition to high level of complexity and sensitivity. Worse than all, these plants have been running not only under the conditions of gradually aging (deteriorating) of facilities, but also potentially hidden risks in the manufacturing processes. In addition, most plants were not designed by Earthquake Resistant Design Standards (E.R.D.S). Unfortunately, this E.R.D.S. has not been established for chemical plants. More importantly, all processing and rotating equipment in the Chemical Plants are very sensible and weak by the vibration/shake. Therefore those major rotating equipment of these plants should be immediately and automatically shut down by interlock system of vibration shake. What are worse, any even slight vibrating shakes are caused crack on the gases duct lines, pipelines and those facilities, etc. Therefore, Earthquakes in the plants area and/or near plants will destroy these Processing Equipments by vibrating shake and call foundation crack/collapse. Then, these Processing Equipments will be fallen down. The consequence will show that enormous volume of dangerous materials will be leaked out along the stream and soaked to the ground, and also toxic

gases dispersed too far away areas by wind direction through the damaged equipments. Subsequently, conflagration and explosion will appear, and the toxic gases will be spread out which will seriously affect many residents.

Those toxic gases and hazardous materials caused by the Earthquakes not only result in serious ecological changes and destruction, but also affected human being, animals and plants, and even if other living things. In fact, most plants in Korea were constructed since 1950's which have been running with equipments and structures that are in the process of aging and deteriorating. Unfortunately, these plants have been designed in the subordinate concept on the Earthquake Resistant Design. In the worse case scenario, a great many people will be sacrificed because of the earthquake. Moreover, neighboring counties and cities will be fallen into ruins.

Obviously, it is the reason why author brings problems up against Earthquake and shows solutions in the following three categories of requirements. First category, it is required to reinforce weak points searched through safety evaluation of the equipments and its facilities etc such as processing equipments, piping facilities, and utilities' system in advance with the priority order, according to the Earthquake Resistant Design Standards (E.R.D.S.). This E.R.D.S. will be separately prepared by every plant on the mind of "Provide for the worst, the best will save itself." Second category, it is required to do develop and apply New Strategies for Faster Emergency Shutdown and Emergency Core Management. It is absolutely required to minimize total damages of both lives and properties from Earthquakes. Especially, it is necessary to consider so that those data provided by a Seismological Observatory, Korea Meteorological Administration (KMA) can be immediately utilized for faster emergency shutdown these plants. Those methods are searched on the following four classified fields: in process control side, in utilities system side, in storage system side, and in fire fighting facilities side, as shown on the following "Methods-2". Third category, it is required to do establish an Earthquake Policy of the Earthquake Resistant Design Standards (E.R.D.S.) for Chemical Plants in Korea. It should be applied to both existing chemical plants and newly-constructed plants to safely protect both lives and properties from Earthquakes. These requirements should be urgently prepared and fulfilled on time jointly by Chemical Engineers and other related fields of Engineers.

B. Necessity of this research

In order to timely prevent and minimize those losses on both lives and national properties caused from Earthquakes under the above-mentioned serious conditions of Chemical Plants, it is necessary that the above-mentioned three categories, mentioned to First, Second, and Third, of requirements should be urgently prepared and fulfilled on time through joint studies by chemical engineers, seismologist, and concerned R&D researchers. That is to say, this research requires the followings against Earthquakes and will answer the questions on the below in detail.

Firstly, doing reinforce weak points on the equipments and its facilities through Safety Evaluation.

Secondly, doing develop and apply New Strategies for Faster Emergency Shutdown and Emergency Core Management.

Thirdly, doing establish an Earthquake Policy of the Earthquake Resistant Design Standards (E.R.D.S.) for Chemical Plants in Korea.

C. Research Purpose

The purpose of this research is to minimize at the utmost efficiency those losses on both lives and national properties from Earthquakes by showing methodology and methods to make satisfy the above-mentioned requirements. Most importantly, author requests decision-makers and chemical engineers, and other fields of concerned engineers will do clarification what is their Philosophy against Earthquakes in Chemical Engineering.

In addition, author believes the above-mentioned these required activities and countermeasures could be successfully completed when they can put comprehensively their philosophical and ethical mind in practice in order to minimize both lives' sacrifice and losses of national properties.

D. Research questions

More specifically, this study aims at investigating the following questions:

1. What and how to do for reinforcement of overall equipment and facilities against coming Earthquakes?
2. What can you suggest and develop for faster emergency shutdown than the existing process control system?
3. Why is required the establishing of an Earthquake Policy of the Earthquake Resistant Design Standards for Chemical Plants to construct so that Chemical Plants can be sustainably operated in safety against coming Earthquakes?

E. Results

In those Complex Chemical Plants located in Taiwan and India where Earthquake occurs frequently, author had performed overall safety audit and evaluation for their Processes/Plants. Overall consultations on the audit and evaluation were performed for them in the fields of:

1. PSRME (Process Safety Risks Management with Evaluation).
2. Plants/Process Trouble-shooting.
3. Emergency Situation Control.
4. Evaluation of Process Safety.
5. Incidents Investigation.
6. Plant Construction & Engineering.
7. Initial Start-up and Performance Guarantee Test.
8. Production/Operation.
9. Overall Process Control.
10. Safety and Environmental.

These performances are included in those Overall Consultation Reports in detail for them.

In the view of overall Consultation Performance by hands on Experiences, Major Results against Earthquakes were resulted in as follows, based on Consulting Books prepared on the above overall consultations, which are written by author, Y.H.KIM (YHK) for Chemical Plants in Taiwan and India.

Firstly, doing reinforce weak points on the equipments and

its facilities through Safety Evaluation.

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Thirdly, doing establish an Earthquake Policy of the Earthquake Resistant Design Standards (E.R.D.S.) for Chemical Plants in Korea.

Accordingly, Author's Consultation Performance by overall safety Audit and Evaluation became to get an "Honored Service Award" from a company of Taiwan, in accordance with the satisfactory result and supply of the consulting books prepared on the overall Consultation Performance on the above.

II. BACKGROUND OF RESEARCH

This research is studied on the basis of the Informal Education through Author's both Hands-on Experiences and Technical Consultations which has performed in Korea, Taiwan and India as shown on the following "Figure 1, Background Diagram of this Research".

As a Chemical Engineer, author had worked for worldwide 4th and 7th Fertilizers and Chemical Plants in Korea that are joint-ventured with companies in the U.S.A. Author had very good chances to get many kinds of valuable hands-on experiences from many units of chemical plants belonged to the above complex chemical plants. After finishing works of the above two complex chemical plants, author as a Consultant had worked for Nan Ya Chemical Corp. in Taiwan, OSWAL Chemical & Fertilizers Co. and GNVFC Fertilizers Co. in India respectively, and DuPont in Korea. In the meantime, as a visiting professor since 2005 year, author has been teaching students who are majoring Chemical Engineering in Chunnam National University of Korea. And author has written to Korean language two kinds of textbooks in the field of Chemical Engineering, which are showing titled "Applied Design and Construction of Chemical Plants" and "Construction and Management of Chemical Plants". In the worldwide 4th and 7th Fertilizers and Chemical Plants, author has accumulated various fields of technical hands-on experiences in connection with the complex chemical plants. These accomplished hands-on experiences' fields are as follows. These fields become major factors for the purpose of preparation against Earthquakes.

Project engineering & management, technical feasibility studies, plant construction, pre-commissioning & commissioning, plant initial startup & performance guarantee test run, subsequent operation & plant normalization, plant & process trouble-shooting, incidents investigation, emergency situation control, plant engineering, development of manufacturing technology, process engineering & design, management of specification, evaluation on raw materials & chemicals, modification/revision on process and system, preventive maintenance management of plants, environmental studies, process safety management, safety audit & evaluation on process, preparing emergency planning program, preparing emergency operation total plan, and critical scenarios study with assumed serious situations, etc.

In the stage of consultation, author as a consultant for them has applied to these accumulated overall hands-on experiences to the worldwide above-mentioned plants and company. The performance on application was successful through author's consultation for these companies. As an example, in case of Nan Ya Chemicals Corp. in Taiwan, this plant was successfully constructed and initially started up successfully on the performance guarantee test on scheduled time, and subsequently normal operated in total safety. The result is that author received an "Honored Service Award" from this company. Other companies in India were satisfactory on the consultation reports. Moreover, special lectures for both students and professors of universities were upgraded very helpfully the evaluation of both lecture and teaching materials, and also international consultation know-how prepared on the basis of the above-mentioned hands-on experiences.

III. METHODOLOGY

A. Methodology 1

For "Firstly, doing reinforce weak points on the equipments and its facilities through Safety Evaluation." (Action to: Protect Equipment and its Facilities from Earthquakes)

The methodology of doing reinforce weak points of equipments and its facilities can be prepared and summarized as follows:

In order to do reinforce those weak points, in advance, they should find out whole weak points in detail through the whole systems of the plant. To find out and manage those weak points efficiently, it is desirable to classify those objects (equipment, facilities and structure, etc) according to the characters and severe specific operating conditions, etc. As an example, refer the classified Class-1 to Class-6 shown on the following. As tools to find out those weak points, there are the following conventional methods such as Piping Dynamic Analysis, Process Hazard Assessment, and Process Safety Risk Evaluation, etc. Through these tools, whole systems of the objects should be jointly inspected, checked, measured, and analyzed compared with designed conditions and safety allowance by all fields of concerned specialists: engineers and chemists. With overall collections of results that are accomplished the above-mentioned those conventional methods, they are examined and evaluated to judge reinforcement of those objects: equipments and facilities. Fundamentally, in order to analyze the room of the designed safety allowance, it is necessary to analyze aging and deterioration conditions of whole Equipment and Facilities. And the both influential range and impacts by dispersion toxic gases and leakage contamination, etc. should be evaluated to make decision the basis of the Richter Magnitude (R.M.) of classified objects to be reinforced. And also, the both scenario and simulation studies are required to find out more detailed methods/solutions in practice and hidden risks in the processes. Of course, these activities are in relation to minimize losses of lives and properties. For objects to be reinforced, they should decide what the Richter Magnitude (R.M.) is for the Earthquake Resistant Design Standard (E.R.D.S.) on each object.

As a reference, the following conditions of objects are suggested on the basis of R.M. for the E.R.D.S. as follows:

1. For general objects, 6.5 on the same level of the Standard of the Atomic Power Plant.
2. 7.0 for the objects operating under especially severe operating conditions.

The results of above-mentioned examination and evaluation should be reported to top management. Finally, top management should urgently make decision for fulfillment of the E.R.D.S.

B. Methods 1

Action to: Protect Equipment and its Facilities from Earthquakes:

1. Inspecting the inside of systems such as vessels/columns, towers, tanks, reactors, stacks etc in the process, according to the approved inspection procedure.
2. Checking whole equipment both battery limit and offsite areas in detail, according to the approved written checklist.
3. Analyzing the followings such as corrosion/erosion rate, carbonated conditions, pitting conditions, deterioration/aging conditions, defective conditions, and loosening status, etc on the equipment and facilities, according to the approved procedure.
4. Measuring thickness of equipment, vessels and various kinds of stacks, etc in especially corrosive areas.
5. Measuring and analyzing subsiding degree of pipe racks and whole equipments, according to the approved preventive maintenance procedure.
6. Analyzing soil conditions of piling and surrounding area of process equipments foundations.
7. Inspecting/ checking analyzing corrosion/ erosion conditions/ status of underground facilities: pipelines, concrete sewage, trench lines, and utilities cables.

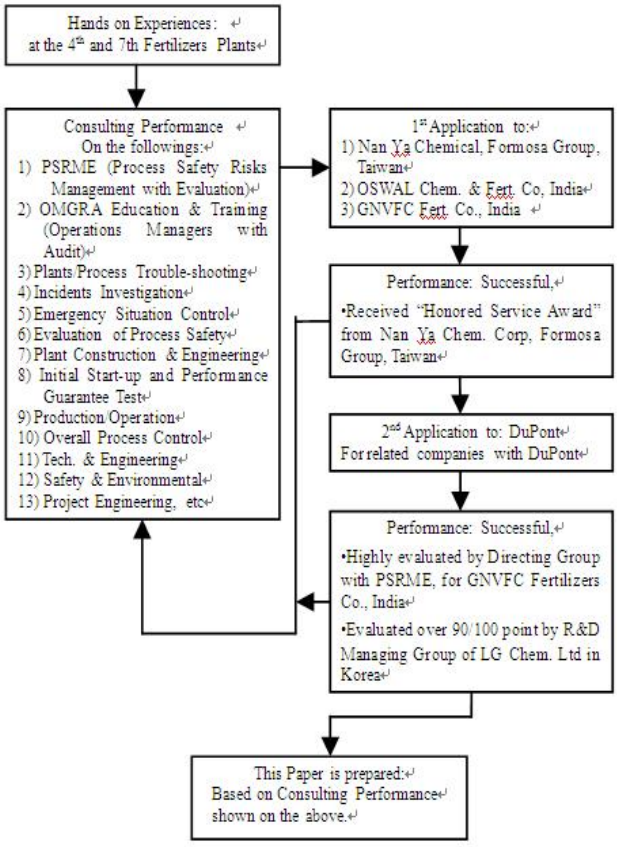

Figure 1 Background Diagram of this Research -Based on the Informal Education through Author's both Hands-on Experiences and International Consultation

C. Methodology 2

For "Secondly, doing develop and apply New Strategies for Faster Emergency Shutdown and Emergency Core Management." (Action to: Minimize both Lives and National Properties Losses from Earthquakes)

1. Fundamentally, the following systems and activities should be sustainably run under perfect management to be normal operation in ordinary times for sequentially faster shutdown.
2. Whole Utilities Systems.
3. Perfect Preventive Maintenance with high quality of spare parts.
4. Honest and Through Log Sheets/Books Recording.
5. Employee' Operation Education and OJT for Emergency Shutdown Skill Up.
6. Fire Fighting Drill.
7. Keeping full capacity of water reservoir in normal days, for 72 hours of usage. In advance, existing defective problems should be found out and solved in the following four fields of: (1) in process control side, (2) in utilities system side, (3) in storage system side, (4) in fire fighting facilities side, and others. More-efficiently, the sequence for Emergency Total Shutdown by pushing one-touch switch button is required and necessary to develop in the total process.

And also, it is necessary to on-lined so that the Earthquake Recorder of Seismological Observatory can be recorded on the control panel of central control headquarter. In addition, Wireless Communication System with the Korea Industrial Complex Corp. (KICC) is required to introduce to the central control headquarter for the information of utility status such as raw water.

To do immediately act faster emergency shutdown without any interruption, stock minimum level on hazardous materials should be decided and kept in normal operation. In order to absolutely minimize any losses on both lives and properties, it is required to develop and/or revise process so that extremely fatal toxic materials can't be stored in the process. And to do avoid any contaminated toxic gases according to the wind direction, it is necessary to decentralize plant air supply source to be cross four areas based on the plant orientation. Most importantly, both emergency generators' systems and neutralizing units should be perfectly managed according to the standard operating procedure, checklist and preventive maintenance program so that these systems and units can immediately be started up in any emergency cases. Moreover, faster shutdown sequential process should be sustainably studied and developed. Additionally, the related methods that connected to the faster shutdown sequential process should be found out through the critical scenarios and simulation study, etc.

D. Methods 2

Action to: Minimize both Lives and National Properties Losses from Earthquakes:

The following activities for improvements should be periodically performed to analyze in order to confirm the strength of equipment and facilities compared with the basis of designed conditions.

1. Methods On New Strategies For Faster

Emergency Shutdown is summarized on the following four managing sides: 1) In process control side, 2) In utilities system side, 3) In storage system side, 4) In fire fighting facilities side.

1) In process control side:

a) Managing both Reinforcement of Weak Points on Equipments and Doing project to establish the Earthquake Resistant Design Standards (E.R.D.S.).

b) Managing to keep Full Capacity of Water Reservoir all the times.

c) Keeping Minimum Level of Stock in ordinary times.

d) Splitting to get minimum stock level through modification of pipelines system.

e) Connecting power of Major Rotating Equipments to the Emergency Generators.

f) Keeping perfectly Toxic Gases Neutralizing and Recovery Systems against Emergency.

g) Testing periodically the Emergency Generators and keeping perfectly running.

h) Applying Interlock Shutdown Process Immediately when Excess Flow of Hazardous Materials occurs.

i) Applying Interlock Shutdown Process caused by Vibration Shake of Earthquake on the same level of designed conditions.

j) Applying Sequential Control Process for the Fastest Emergency Shutdown in the required shortest time against Earthquake.

2) In utilities system side:

a) Protecting underground piping and utilities cables against Earthquake.

b) Doing split instrument/plant air supply source to four areas, east area, west area, south area, and north area.

3) In storage system side:

a) Applying so that operation can be safely possible by splitting to be minimum storage volume on the following toxic, inflammable, explosive, and hazardous materials.

b) Applying so that operation can be possible in safety by keeping minimum volume of toxic and explosive materials in normal operation.

4) In fire fighting facilities side:

Designing tie-in and connecting hydrant water lines on both each process water tanks and treated water system of wastewater treatment facility.

The Critical Scenarios and Simulation Studies are applied to be possible troubles-shootings, to find out unexpected hidden problems, and to get many questions for discussion of further research study. For this study, making questions on worst cases of Assumed Serious Troubles are very important to approach to get solution on time. Cases on Assumed Serious Troubles can not only be provided on the following unit of sources, but also many suggestions can be got to solve critical problems from Earthquakes.

a) Each source of utilities including nitrogen supply system.

b) Raw water supply system from water reservoir dam to raw water pond.

c) Power supply system from power plant to plant power transformer station.

d) Explosion of major reactor/rotating equipments and vessels/towers, etc.

e) Rupture of storage tanks of toxic and hazardous materials.

f) Serious troubles of Emergency Generators.

g) Explosion of steam generating boilers.

h) Explosion of instrument compressors.

i) Contamination of utility steam and instrument, etc.

2. Methods for Emergency Core

Management against destroyable Earthquakes shows the following. Basically, this Emergency Core Management is to minimize both lives and national properties losses against Earthquakes. The following activities are necessary to thoroughly prepare and manage against Emergency Cases caused by the unexpected Earthquakes.

1) Preparing Total Emergency Plan for co-operation with the related companies' plants, of the complex industrial park, belonged to the Korea Industrial Complex Corp (KICC).

2) On lining with Recorder of Seismograph in "the Seismological Observatory", Korea Meteorological Administration (KMA).

3) Preparing Emergency Operation Total Plan for protection of each plant.

4) Forming Total Organization; so-called 'Crisis Overall Joint Committee'.

5) Preparing Emergency Planning Program.

6) Performing Critical Scenarios and Simulation Study on Critical Situation Cases.

7) Preparing How to do "fire-fighting drill" against Earthquake.

8) Preparing "Evacuation Plan and Drill" against Earthquake Attack.

9) Preparing Emergency Plan when is dispersed "toxic gas" toward neighboring community area.

10) Preparing Emergency Communication System with both neighboring plants and complex headquarters, and also neighboring community.

E. Methodology 3

For "Thirdly, doing establish an Earthquake Policy of the Earthquake Resistant Design Standards (E.R.D.S.) for Chemical Plants in Korea. (Action to: Protect Equipment Collapse and Lives/Properties Losses from Earthquakes)

Basically, the both frequency and strength of Earthquakes occurring in Korean peninsula should be analyzed to use as a basic data for establishing an Earthquake policy. And also, Earthquake circumstances in Korea and adjoining countries of Korea should be studied as a same purpose. Of course, those studies on scenario and simulation to minimize both lives and

properties losses should be timely performed. Process hazard assessment and process safety risk management with evaluation are required to get various data from whole processes and plants. And also, operational characters and severe specific operating conditions should be analyzed on time. Additionally, influential range and impacts should be evaluated on the basis of dispersion of toxic gases and contamination of leakage. And also, environmental impact assessment through the studies of critical scenarios and simulation should be performed on time. Impact analyses by "toxic gas" dispersing toward neighboring community are required. It is necessary to thoroughly examine aging/deterioration conditions for whole equipment and facilities above the ground and underground. Finally, they should make decision establishment of Earthquake policy of the Earthquake Resistant Design Standards (E.R.D.S.) for Korea on the basis of a report summarized with the above-mentioned methodologies.

F. Method 3

Action to: Protect Equipment Collapse and Lives/ Properties Losses from Earthquakes:

For establishing of the Earthquake Policy on Earthquake Resistant Design Standards (E.R.D.S.) for Korean Chemical Plants, it is suggested that the following improvements against Earthquakes should timely proceed on the following four fields: in process control side, in utilities system side, in storage system side, and in fire fighting facilities side. And author requires that these improvements will be included in the Earthquake Policy on the Earthquake Resistant Design Standards (E.R.D.S.).

1. Including process so that extremely fatal toxic materials can't be stored for the purpose of reserving stock in the process.
2. Including sequential control process for the fastest emergency shutdown in the required shortest time in case of Earthquake.
3. Including sequence of interlock emergency shutdown process caused by vibration shake of Earthquake on the same level of designed conditions.
4. Protecting underground piping and utilities cables against Earthquakes.
5. Connecting power of major rotating equipments, classified with priority number one in Emergency case, on power supply line of Emergency Generators.
6. Doing split instrument/plant air supply source to four areas, east area, west area, south area, and north area.
7. Applying so that operation can be safely possible by splitting to be minimum storage volume on the following toxic, inflammable, explosive, and hazardous materials.
8. Applying tie-in and connecting hydrant water lines on both each process water tanks and treated water system of wastewater treatment facility against Earthquakes.

In present time, author strongly suggests that Earthquake Resistant Design Standards (E.R.D.S.) for chemical plants will be urgently projected and established by KIChE (The Korean Institute of Chemical Engineers) jointly with EESK (Earthquake Engineering Society of Korea).

IV. DISCUSSION

Those objects to be reinforced and managed are classified as follows:

Class 1: Building and structures.

Class 2: Control room: emergency generator and transformer substation, electrical switch gear room, motor control center and lightening system and its facilities.

Class 3: Utilities: equipment and its facilities: steam generation boilers system, plant and instrument air production system, plant/potable water, nitrogen supply system.

Class 4: Process areas: steam generation boilers and other utilities, rotational and stationary equipment and its facilities processing and/or handling toxic, poisonous, inflammable, explosive and hazardous materials in the intermediate/total process, process piping system and pipe rack/structures, reactors and scrubbing system, processing column and vessel, whole stacks, flare stacks and vent stacks, toxic gas detecting system, and also whole storage tanks and pump stations/its facilities, etc.

Class 5: Offsite areas: neutralizing, scrubbing and recovery facilities of toxic gases and materials in highest priority, cooling towers and its facilities, waste water treating facilities, storage tanks farm, port areas for unloading and loading, etc.

Class 6: Fire fighting facilities: hydrant water pump station, chemical foam tank and foam extinguishers storing system.

In addition, author suggests that the Earthquake Resistant Design Standards (E.R.D.S.) to be applied to these chemical plants will be followed by the Richter Magnitude (R.M.) 6.5 on the same level of the Standard of the Atomic Power Plant. The reason is why these plants are not only running under very severe conditions as classified-below Class-4, Process areas, but also operating by both similar equipments and very toxic gases and materials in the complicate process. More importantly, It is strongly suggested that the Richter Magnitude (R.M.) 7.0 will be followed on the Equipments and its Facilities that running under specially severe operating conditions treating fatally Toxic and potentially Explosive Materials and Gases. In general, most existing chemical plants are old in aging conditions, and also operating under severely weak conditions because these most chemical plants were not designed on Earthquake Resistant Design Standard (E.R.D.S.).

In some cases of manufacturing process, most chemical plants are treating/handling acidic and alkaline materials in their boundary. Then soaking with acidic and/or alkaline chemicals leaked and spilled in the processing areas will make contaminate those plants foundation areas. Both process upset and emergency shutdowns have been occurred in extending over so many years caused weak conditions by leakage and soaking. And also, above ground processing equipment and facilities are running under some amount of corroded and/or eroded conditions compared with originally designed thickness. Accordingly, the above-mentioned equipment and facilities from Class-1 to Class-6 should comprehensively examine whole areas both battery limit and offsite areas through the activities such as the inspecting, checking, analyzing and measuring the followings in priority prior to reinforce those weak points.

The evaluation activities in order to make decision to reinforce various kinds of equipment are shown on the above-

mentioned methodology. These activities should be fulfilled on time to prevent any troubles from Earthquakes. And reinforcing activities are recommendable to decide through the courses of below-mentioned three steps of categories. That is to say, in first step, damage influential ranges should be reviewed through scenario and simulation studies on both lives and properties losses by toxic, poisonous, inflammable, explosive and hazardous materials treating in the process for the purpose of more correct decision-making by top management. In second step, helpful main facilities against Earthquake Emergency are classified to provide normally perfect maintenance in priority as well as periodically test running.

In particular, there are emergency generator system, reactors and its facilities, explosive process equipment and its facilities, neutralizing facility for toxic gas recovery, utilities and its supplying facilities, fire fighting facilities and the others. In advance, these facilities on the example should be reinforced on the basis of the Earthquake Resistant Design Standard (E.R.D.S.). In the third step, the results of the above-mentioned examination activities are summarized and reported to top management to provide wise decision-making in priority.

Secondly, doing develop and apply New Strategies for Faster Emergency Shutdown, Emergency Core Management. (Action to: Minimize both Lives and National Properties Losses from Earthquakes)

The basic concept against Earthquake is that Chemical Plants should be immediately shutdown when the sign of Earthquake is found out even minor vibrating shake. Doing apply New Strategies on the Core Management is required to minimize total damages of both people and properties against Earthquakes. Basically, managing activities process for minimizing damages from Earthquakes are shown on the below "Figure 2 YHK's Earthquake Damage Minimizing Flow Diagram". Chemical plants are running in very serious conditions potentially because they are treating/handling and controlling very toxic, extremely dangerous, fatally poisonous, easily inflammable, sensitively explosive, environmentally hazardous properties of materials on huge size of equipments and facilities. In case serious troubles are occurred by Earthquake, it is confident that the consequences will call disaster accompanying both unexpected lives' loss/sacrifice and unimaginable loss of national properties. So, chemical plants should be immediately shutdown when the sign of Earthquake is found. This action should be urgently done because those toxic and hazardous both gases and materials are leaked and flown along stream, and also diffuse too far away where are living residents.

In general, almost chemical plants are automatically shut down by some degree of vibration shake happened in mechanical condition. And unfortunately, Earthquakes go with vibration shake that will make shutdown those plants under emergency situation. Accordingly, it is required that the following New Strategies will be timely completed for the purpose of faster emergency shutdown. And Emergency Core Management should be perfectly run under Zero-Defect in order to minimize both lives' sacrifice and national properties loss.

In particular, on lining with Earthquake Prediction Data provided by a Seismological Observatory belonged to the Korea Meteorological Administration (KMA) will be very helpful for faster plants emergency shutdown. And also timely communicating with the Korea Industrial Complex Corp. (KICC) on Earthquakes Prediction will save time for safer plant shutdown and to reserve/distribute raw water.

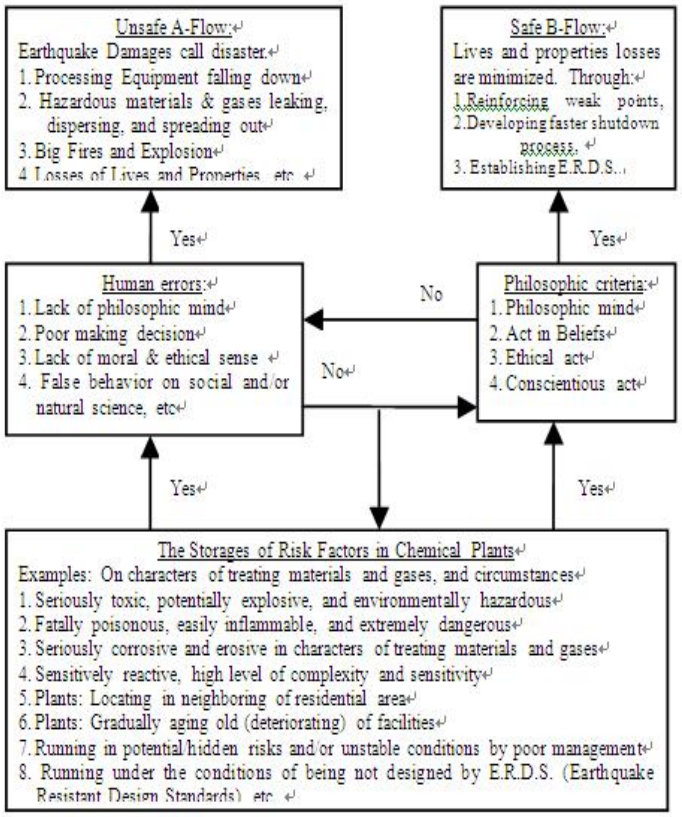

Figure 2 YHK's Earthquake Damage Minimizing Flow Diagram

Thirdly, doing establish an Earthquake Policy of the Earthquake Resistant Design Standards (E.R.D.S.) for Chemical Plants in Korea. (Action to: Protect Equipment Collapse and Lives/Properties Losses from Earthquakes)

Doing establish an Earthquake Policy for the Earthquake Resistant Design Standards (E.R.D.S.) should be urgently prepared and applied to both existing chemical plants and newly constructed plants for the purpose of safer operation against Earthquakes. To protect these chemical plants in safety from Earthquakes, the Earthquake Resistant Design Standards should be timely established to protect lives and national properties from serious Earthquakes. For a reference, the Earthquake Resistant Design Standards (E.R.D.S.) can be classified with from Class-1 to Class-7, according to the characters and conditions of each plant as shown on the above-mentioned "Firstly, of DISCUSSION".

Author suggests that the Earthquake Resistant Design Standards (E.R.D.S.) to be applied to these chemical plants will be followed by the Richter Magnitude (R.M.) 6.5 on the same level of the Standard of the Atomic Power Plant as already mentioned in the above "Firstly, of DISCUSSION". The reason is why these plants are not only running under very severe conditions as classified-below Class-4, Process areas, but also operating by both similar equipments and very toxic gases and materials in the complicate process. More importantly, it is strongly suggested that the Richter Magnitude (R.M.) 7.0 will be followed on the Equipments and its Facilities that running under specially severe operating conditions treating fatally Toxic and potentially Explosive

Materials and Gases. And it is absolute that owners of these chemical plants should follow the Earthquake Resistant Design Standards (E.R.D.S.) for both existing and newly-constructed plants.

Most these existing chemical plants are not still designed on the basis of the Earthquake Resistant Design Standards (E.R.D.S.) due to no Standards. And these existing plants have been running over 40 years in aging conditions. Most these chemical plants are operating with corrosive and erosive gases and materials. And also these chemical plants are treating/handling toxic and hazardous gases/materials. These chemical plants in Korea are apt to easily crack and/or collapse by some degree of Earthquakes. Moreover, the consequences due to the Earthquakes are disastrous and catastrophic on the side of both human being and national properties losses.

So, it is absolute for national destiny that an Earthquake Policy on Earthquake Resistant Design Standards (E.R.D.S.) for Korean Chemical Plants should be urgently established to protect human being and national properties from destroyable Earthquakes. In general, Earthquakes in Korean Peninsula have been frequently increasing as shown on the above introduction. Korean chemical plants are composed with high advanced technology producing toxic and dangerous fine chemicals. And also, their complex chemical plants are very close and compact in location. In capacity side, also their chemical plants are tremendously big and wide. In case Earthquakes are occurred in Korean Peninsula, those damages from these complexes chemical plants are unimaginable on the damages side both people and national properties loss. How about national grief and hopelessness on the consequence from the terrible Earthquakes? Accordingly, author suggests that the following Process Control Improvements to be newly applied will be included in the Earthquake Policy on the Earthquake Resistant Design Standards (E.R.D.S.) to minimize both lives and national properties losses from disastrous Earthquakes. And also, author strongly claims the Earthquake Policy on the Earthquake Resistant Design Standards (E.R.D.S.) will be established for advanced complex chemical plants as well as whole chemical plants.

V. CONCLUSIONS AND SUGGESTIONS

In this research, the three kinds of research questions were answered by showing many solutions through Methodology and Discussion. The followings in those solutions are summarized as Conclusions and Suggestions.

A. Conclusions

Firstly, those Weak Points found out through Process Hazard Assessment and Process Safety Risk Evaluation should be urgently reinforced. Recommendable: Based on the Richter Magnitude (R.M.) for the Earthquake Resistant Design Standard (E.R.D.S.)

1. Generally, 6.5 on the same level of the Standard of the Atomic Power Plant.
2. 7.0 for the equipments under especially severe operating conditions.

Secondly, those Methods for Faster Emergency Shutdown against Earthquakes require the following developments: as examples,

1. The Interlock Shutdown Control Process by Earthquake Vibration Shake,
2. Faster Shutdown Sequential Control Process in required shortest time,
3. The Sequence of Emergency Total Shutdown by one-touch switch button, etc.

Thirdly, the Establishing Earthquake Policy of the E.R.D.S. should be urgently accomplished through the followings: as examples,

1. Studying Earthquake Circumstances in Korea and adjoining Countries.
2. Evaluating Influential Range and Impacts by Dispersion of Toxic Gases and Contamination of Leakage.
3. Process Hazard Assessment and Process Safety Risk Evaluation.
4. Study on the Scenario and Simulation for Lives and Properties Losses.
5. Environmental Impact Assessment by the Critical Scenarios & Simulation Study, etc.

Most importantly, Chemical Engineers should be kept in mind that all solutions on the above are depending on your Philosophic Criteria: Philosophic Mind, Act in Beliefs, Ethical Act, and Conscientious Act.

B. Suggestions

Author suggests the followings so that these requirements can be fulfilled on time:

1. The Standard of Earthquake Resistant Design to be applied to these chemical plants will be followed by the Richter Magnitude (R.M.) 6.5 on the same level of the Standard of the Atomic Power Plant. And will be R.M. 7.0 for the equipments of especially severe operating conditions treating fatally Toxic Gases and potentially Explosive Materials.

2. For establishing of the Earthquake Resistant Design Standards (E.R.D.S.) for Chemical Plants in Korea, suggest it can be urgently prepared and proceed by KIChE (The Korean Institute of Chemical Engineers) jointly with EESK (Earthquake Engineering Society of Korea).

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