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137 – 141

Development of Components of Analog and Digital Gauges for Training Regulators Safety Check using Virtual Reality

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***Abstract*—**The inspection and check of the pressure regulation facility should be achieved, because it is mandatory item on law of gas safety management. It is more effective education using 3D virtual reality to enable injecting real combustible and toxic gas. Also it give immersion to trainee with virtual experience. In here, we reviewed education on the pressure regulating facility using virtual reality technology and designed a safety training scenario for decomposing and checking the pressure regulators on VR screen. And then we implemented components of an analog and digital pressure gauges using 3D Unity tool to visualize them on the VR education system. Trainee can be educated efficiently interacting their 3D virtual engine with components such as pressure gauges, pipelines, valves, and practical environments. Its effectiveness is demonstrated at the result through questionnaire. Its positive answer of three main inquiries is more 93%. We hope gas risks are reduced by using our virtual education contents at various industrial fields.

Keywords*-Virtual Reality; Regulator; Safety Training; Pressure Gauge*

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I. INTRODUCTION

The gas used in human dwellings and diets is one of very important energy sources. Gases can be obtained by adding higher heat to coals or directly from petroleum and cokes etc. Liquefied Natural Gas (LNG) is produced by making high pressure and heat to oil fields under the ground. In order to use the generated gases efficiently, above all the gases are stored in a larger tank, and the stored gases are supplied to gaseous appliances of every home, company, and factory through pipelines buried in the underground. For the sake of increasing the transportation capacity and efficiently using the supply equipment such as pipelines, the supply of gases is performed by using methods of high, medium, and lower pressure. A pressure regulator is a device that is used to reduce the supply pressure of gas from high pressure to medium pressure, from medium pressure to low pressure and to supply gases to customers by a proper pressure. The pressure regulator is not operated manually but maintains the secondary pressure automatically according to the pressure change such as fluctuation of the demand quantity. Usually, it is very important to maintain regulars because they are operated automatically in the unmanned state.

In Korea, by the end of 2014, 22,479 units of single regulators were installed nationally, and about 80 disassembled inspection companies were participated. In accordance with regulators of Na-mok 2), Article 2, the attached table 7 of the City Gas Business Law, a single regulator shall be decomposed and checked at least once every three years, and once every four years thereafter. If the pressure regulator is not disassembled and checked, or if an error is happened, the supply of city gas may be stopped, and inconveniences of consumers as well as risks of gas accident are occurred.

The Education Institute of Korea Gas Safety Corporation is conducting the training program for disassembling and checking on the pressure regulator to prevent its accident. The education on the pressure regulator is usually performed on the theory and practice with an artificially manufactured model. However, the education is unperfected because of not performing those practices that real gases are injected or toxic gases are used. Because that is dangerous if real gases are injected or toxic gases are used during the practice. On the other hand, virtual reality technology can be defined to a technology to provide a realistic and immersed experience to human beings in a 3D virtual environment by a computer simulation. That technology is widely used at the parts of education, manufacture, national defense, automobile, airspace, medicine, games, and sports [1].

In this research, in order to more effectively perform safety management and education on pressure regulator, we implemented contents enabling virtual reality experience on the pressure regulator with safety training scenarios and being injected real combustible gases to regulator using 3D and the virtual reality technology.

II. METHOD OF SAFETY CHECK OF REGULATOR

A. Definition and Classification of the Regulator

The pressure regulator is used to reduce gas pressure of pipeline required by consumers, in words, from the high to the medium pressure and the medium to low pressure where the higher supply pressure of the gas is restricted. And, the pressure regulator is a unit that is composed of a decompression device for reducing the supply pressure to a required pressure in accordance with changes of the gas demand in the hourly time, a monitoring device, a relief device, and a pressure recorder. It is classified as a district, a local and single regulator based on the usage. A district pressure regulator is used at the supply facilities of gas wholesaler for reducing pressure of 0.1MPa or more from pressure of 1MPa. Its regulator is installed and managed by the general city gas company. The local regulator is a regulator that adjusts pressure from the medium gas pressure to suitable pressure installed in a certain area for operating by a large number of users. Its regulator is installed and managed by the city gas provider. A single pressure regulator is installed and managed by a specific gas user in order to receive amounts of gas. The preliminary pressure regulator is for preparing disassembly, checking, and failure the main regulator. Also it is automatically switched and operated when pressure of the

 ISSN: 2454-4248
137 – 141

regulator outlet drops supplying for providing gases without stopping to consumers.

The other hand, depending on installed location and used purpose the pressure regulator is classified as a high pressure regulator, a district pressure regulator, and local and single pressure regulator. The high pressure regulator is currently used in Korea Gas Corporation which supported by government, power plants, and steel mills. The district and the local pressure regulator are mainly used in general city gas companies as shown in Fig. 1, and the single pressure regulator is widely used in buildings and houses. According to method of sensing pressure, pressure regulator is classified as direct-acting pressure regulator and pilot type regulator, and the pilot type regulators are classified in an axial flow valve and the fisher.

Figure 1. A local pressure regulator installed at on-site

B. *Standard on Facility, Technoology, Inspection of the Pressure Regulator.*

In the Republic of Korea, three Act on Gas Safety are enacted in order to manage handling of gas more efficiently and safely, and are recommended for being complied through distributing their acts to the gas safety management site. Three Act on Gas Safety are classified in detail to KGS Code, which subdivides described items on facilities, technology, and inspections specified by gas laws and regulations. And it supports three Act by obtaining an approval of the Ministry of Trade, Industry and Energy after the Gas Technical Standards Committee deliberates and resolves detailed gaseous standards.

Meanwhile, the technical standard to safely check the pressure regulating facility is shown in the standard (KGS FS552) on facility, technology, and inspection of general city gas provider of. The summary of the items of facility, technology and inspection standard is shown in Table 1 [2].

TABLE I. ITEM OF STANDARD ON FACILITY, TECHNOLOGY, AND INSPECTION OF GENERAL CITY GAS BUSINESS OF KGS FS552

Standard	Detailed Items
Safety Maintenance & Management	1) Basic Items 2) Storage Facilities 3) Gas Facilities 4) Pipe Facilities 5) Accident Prevention Facilities
Check	1) Whole Facilities 2) Basic Item 3) Storage Facilities 4) Gas Facilities 5) Pipe Facilities 6) Decomposing and Checking a Regulators 7) Accident Prevention Facilities
Inspection	Items and Method: 1) Intermediate 2) Construction & Supervision 3) Regular Inspection

Table 2 shows the standards, which is called KGS FS552, on the facility, technology, and inspection for disassembly and check of the pressure regulator used by general city gas provider. Also, periodically checking disassembly and operation on the pressure regulator is described in Table2 [2].

TABLE II. STANDARD AND PERIOD ON DISASSEMBLY AND CHECK FOR PRESSURE REGULATOR OF GENERAL CITY GAS PROVIDER IN KGS FS552

Standard	Explanation
Disassembly and Check standard	1) Ensuring the safety of city gas among the pressure regulator or safety management and supply facility 2) Periodically checking the disassembly and operating conditions for necessary facilities or facilities. 3) the necessarily measuring for maintaining the normal state and for normally operating if any abnormality is found,
Period of Disassembly and Check	1) Disassembly checking is at least once every two years 2) After gas supply is started the filter is inspected within one month, disassembling and checking the pressure regulator is performed with more than once every year, and operation status is checked at least once a week.

C. *Inspection Method of Regulator*

The decompression check of pressure regulator should be performed at least once per two years. In addition, the method of regularly general inspection on pressure regulating facility is detailedly described in KGS FS552 code. Procedure of functional tests for checking a pressure regulating facility as shown in Table 3.

TABLE III. PROCEDURE OF FUNCTION TEST IN KGS FS552

No	Procedure of Function Tests
1	Check operating pressure by measuring the secondary pressure. This only can be confirmed when it is made a trial run.
2	Check whether the preliminary regulator operates normally according to the pressure change of the main regulator. However, it can be confirmed at the time of commissioning.
3	Check the opening and closing performance of the gas shutoff device.
4	Confirm the function of the remote monitoring device connected to the gas leakage detection notification facility, abnormal pressure notification facility, whether the opening and closing of the gate of the regulator room, and whether the emergency shutoff valve is opened or closed according to the operation test.
5	Check the recording pressure error of the pressure gauge and pressure recorder.
6	If there is a forced ventilation facility, check according to the operating test.
7	Check the appropriate pressure setting of the abnormal pressure notification system, emergency shutdown device and safety valve, the size of the safety valve standard and the height of the discharge port according to the pressure at the inlet of the regulator and the design flow rate.
8	Check that the emergency power is working after shutting off the power supplied to the regulator.
9	Make sure that the light inside the regulator room installed in the basement is at least 150 lux.

 ISSN: 2454-4248
137 – 141

As shown as Table 3, functional test for checking a pressure regulating facility is verified through gauges to monitor operation conditions. In pressure regulating facilities, there are several gauges such as flow meters, pressure gauges, and thermometers. Their gauges play an important role in inspection of gas leak and decomposition in pressure regulating facilities [2].

D. Education for managing the Pressure Regulating Facility.

Decomposition check on the pressure regulator should be achieved at least once every two years. Gas risks during decomposing the pressure regulators are occurred, their enterprises need a certain qualification and a certification of education on the disassembly check program. On the other hand, the Gas Safety Education Institute is progressing education of basic and intermediate courses of the pressure regulating facility to foster their facility experts. Currently it is only educated on theory of the pressure regulator, but it is possible not only to perform more practical experience and iterative training but also to eliminate the risk of gas accident if virtual reality technology is utilized.

In this research as shown in Fig. 2, we are proposed the safety and training scenario for decomposing the pressure regulator and increasing secondary pressure. It is included with a procedure and a responding method for decomposing the pressure regulator.

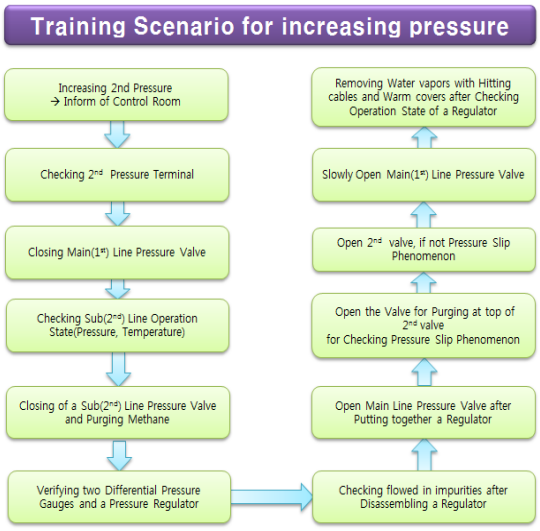

Figure 2. Safety and training scenario on the pressure regulator

III. IMPLEMENT OF A SIMULATION SYSTEM FOR CHECKING REGULATOR FACILITY

A. Development of a Component of a Digital pressure gauge

An individual software component is a software package, w web service, or a module that encapsulates a set of related functions. All system processes are placed into separate components so that all of the data and functions inside each component are semantically related [3]. In a broad sense, a component can be defined as an output of all units that can be reused among the products produced during the whole process of software development [4].

In this study, the virtual reality environment is implemented by the Unity solution used at 3D games and provided with the real time rendering. The UNITY engine is totally used to operate programming languages as C # and Java Script [6]. It can integrate dynamic virtual 3D objects with the development environment [5]. UNITY3D is mainly used to create components at 3D games. In this research, the analog pressure gauge component was developed to visualize a pressure state, to deliver the situation trainee, and to act a respondence on pressure facility when a pressure state is abnormal with warning sound. It is a part of software for developing contents of safety training platform.

Figure 3. A real and virtual digital pressure gauges

In the Fig. 3 left side shows a real pressure gauge in the pressure regulating facility and right side shows a virtual pressure gauge made by the Unity 3D solution. Unity 3D engine in the installed developing workstation can import the component package into the safety training platform, and then the digital gauge component is visualized after it is inserted in the list of Asset. Other components can be inserted and used through in this way.

B. Implement of a Simulation Education System

We first manufactured a simulation test module for educating the pressure regulating system using analog and digital pressure gauges in order to implement realistic virtualization and interact with trainees through wired UDP network as shown in Fig. 4.

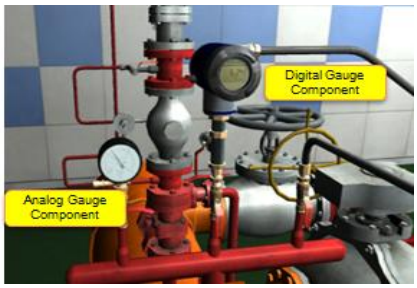

Figure 4. Visualization module for testing regulating facility

In the part of virtual education system, the model of the pressure regulating facility is implemented with 3D reality using an analog and digital pressure gauges. In here, we can achieve education of safety and disassembly on the pressure regulating facility according to scenario of Fig. 2. Based on scenarios of pressure regulators installed in the field, anomalies of high temperature and pressure are visualized through virtual reality components. In addition, it shows visualization of dashboard to indicate real time changeable values, position to display movement of trainees in virtual space using input devices and controllers, and manipulation of pressure valves through interacting the trainer with virtual environment shown

 ISSN: 2454-4248
137 – 141

in Fig. 5. Table 4 shows elements of virtual training system for the pressure regulating facility.

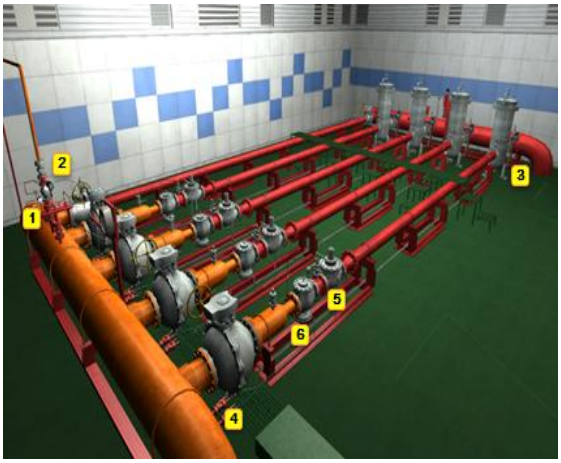

Figure 5. Virtual training system for the pressure regulating facility

TABLE IV. ELEMENTS OF THE PRESSURE REGULATOR

No	Elements
1	An analog pressure gauge
2	A digital pressure gauge
3	A main(first) line pressure valve
4	A sub(second) line pressure valve
5	An emergency shutoff valve
6	A pressure regulator

Finally, we developed the virtual education system with dome structure using a number of component such as pressure gauges, valves, flow meters, pipelines, and shut off valves system are real time operated with internetworking of upper described scenario. We made trainee work experience with virtual reality education of dome structure on the pressure regulating facility. Fig. 6 shows that constructed virtual reality education system with dome structure and are practicing education of the pressure regulating facility at dome screen.

Figure 6. The vitutal education of regulators on ome screen

IV. RESULTS OF VIRTUAL REALITY EDUCATION

We sent out a questionnaire with 10 questions for 30 trainee after accomplishing virtual reality education on the pressure regulating facility. Main questions are as Table 5.

TABLE V. MAIN QUESTIONS

no	Question
1	Do you think you need a virtual training system to education of the pressure regulators?
2	Do you think it is more effective if you train general education in parallel with virtual training system?
3	Do you think that training using virtual training systems is more effective than conventional theory and practice training?

In the first questions, 'Strongly agree' was twenty four (80%) and 'Agree' was five (16.7%). Totally positive answer was 96.7%. In the second, 'Strongly agree' was twenty three (76.7%) and 'Agree' was five (16.7%). Totally positive answer was 93.3%. In the third, 'Strongly agree' was twenty six (86.7%) and 'Agree' was three (10%). Totally positive answer was 96.7%. We demonstrated effectiveness of education using virtual reality system through questionnaire as shown in Fig. 7.

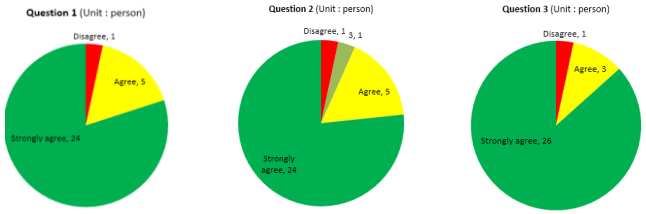

Figure 7. Answer for questions related with VR Education

V. CONCLUSION

It is necessary that education and training on the pressure regulation facility should be achieved by general and special courses, because it is mandatory item on law of gas safety management to protect gas risks. General education on the pressure regulator is performed by theory and simple practice without real input of gases due to risks of gas leak, explosion, and poisoning. But it is hard to say that complete education with real situation.

In this study, we reviewed education on the pressure regulating facility using virtual reality technology and designed a safety training scenario for decomposing and checking the pressure regulators on VR screen. And then we implemented components of an analog and digital pressure gauges using 3D Unity tool to visualize them on the VR education system. Trainee can interact their 3D virtual engine with components, which are pressure gauges, pipelines, valves, and practical environments. When a safety valve and a regulator are manipulated, the state data are changed in real time. Because those data are utilized to virtual reality education, it can be more effective training. Its effectiveness is demonstrated at result through questionnaire and its positive answer of three main inquiries is more 93%.

In the near future, we will make various education contents on gas safety management using virtual reality and apply to toxic and flammable gas plants to help prevent gas risks.

 ISSN: 2454-4248
137 – 141

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