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Development of Gas Accident Prediction Technique in the Area of Dense Energy Consumption by CFD Simulation

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Abstract

Accident likelihood is growing due to a correlation for gas and electricity installed in the area of dense energy consumption like traditional market and underground shopping center. In order to prevent accident risks related to gas and electricity in this area, it should be monitored and predicted for factors of gas leak or electricity. Accident risks related to gas and electricity are divided to two cases in the area of dense energy consumption. First case for accident risks is gas leak due to several factors. Then fire and explosion occur from a source of ignitions among many factors. The other case for accident risks is fire caused by several factors. Then gas leak due to damage of gas facilities causes fire spreading and explosion. In this study, gas leak CFD(Computational Fluid Dynamics) simulation was conducted to analyze accident risks related to gas leak. Because of no data for gas density, gas leak simulations were carried out to analyze gas density variation characteristic at gas detector position. Then, the gas accident prediction technique was developed based on variation characteristic of gas leak by using regression and statistic method.

Keywords: Statistic Method, Regression, Computational fluid dynamics, Gas leak Simulation, Accident prevention

1. INTRODUCTION

The areas of dense energy consumption are traditional market and underground shopping center etc. which have a large floating population with facilities of gas and electricity. Accident risks related to gas and electricity are explosion (35.6%), leak (16.8 %) and fire (26.1 %) during the most recent 10 years [Korea Gas Safety Corporation, 2015].

In order to prevent and respond accident risks related to gas and electricity in this area, it should be needed to develop safety management system based on internet of things (IOT) which executes sensor data collection and data analysis for accident prediction and safety control etc. [Tan and Zhang 2013, Zhou et al 2013].

In this study, the technique of gas leak prediction in the area of dense energy consumption was developed for safety management system. To obtain gas density variation data at gas detector position by using computational fluid dynamics (CFD), gas leak simulations were performed by flame acceleration simulator (FLACS) program [GexCon 2013]. The development of prediction technique was established through characteristic analysis for gas density data obtained from CFD simulations. Then, the algorithm of prediction technique was developed for safety management system.

2. ACCIDENT RISK SCENARIO IN THE AREA OF DENSE ENERGY CONSUMPTION

Accident risks related to gas and electricity are divided to two cases in the area of dense energy consumption. First case of A scenario in Figure 1 for accident risks of the area is gas leak due to several factors. Then fire and explosion occur from a source of ignitions among several factors. Areas of traditional markets and underground shopping centers are representative areas of dense energy consumption. In a survey of fire risk factors for the areas during the most recent 9 years (2007-2015), main factors are electrical factors(47.5%), carelessness(24.2%) and unknownness(12.0%) [Disaster Integration Management of Korea 2007-2015]. It recognizes that there is a correlation between gas and electricity. The other case of B scenario in Figure 1 for accident risks is fire caused by several factors. Then gas leak due to damage of gas facilities causes fire spreading and explosion. In order to prevent A scenario of Figure 1, it was studied about a technique of gas leak prediction in this paper.

Figure 1. Scenario of accident risk between gas and electricity

Two methods of prediction for gas leak risks are before and after gas leak in the area of dense energy consumption. In the case of before gas leak, deterioration models of wear, corrosion, fatigue and failure rate should be developed for gas facilities. But, it was reviewed that there is serious difficulty for prediction model development due to lack of accident cases and data related to deterioration models. In this study, method and model of risk prediction after gas leak was selected as development method. This prediction model can be obtained to analyze characteristic of gas density data according to time at gas detector position by using CFD analysis. It is needed to suppose trace leakage of the early time point and obtain gas density variation data according to time at gas detector position.

3. GAS LEAK CFD SIMULATION FOR THE AREA OF DENSE ENERGY CONSUMPTION

Because of no data of gas density data about trace leak of the early time point, gas leak simulations were carried out to obtain gas density variation data at gas detector position. Real accidental case was utilized as a place of gas leak simulation. Figure 2 shows target facility of the area of dense energy consumption for gas leak CFD simulation. Accident scene of Figure 2 is gas use restaurant in areas of traditional market. A position of gas leak is defined in the estimated position of accident investigation such as Figure 2. Gas leak automatic shut off device had installed near gas burner. But, this device had been turned off at the time of the accident.

Figure 3 represents photos of target facility for the scene of the accident. Figure 3 (a) is the presumed gas leak position at union part in top of the intermediate valve. Detector of gas leak automatic shut off device was installed in bottom of gas burner such as Figure 3 (b). Figure 3 (c) and (d) shows the photo

for the scene of the accident.

Figure 4 is CFD analysis model of target facility about gas leak. To analyze gas leak characteristic in target facility, FLACS program was used [GexCon 2013]. Type of gas in target facility is liquefied petroleum gas(LPG) which is composed propane 95 % and butane 5%. Inner pressure of gas pipe is defined as 25 kPa. Three cases for gas leak flow rate (kg/s) were performed for $10^{-3} kg/s$, $10^{-5} kg/s$, $10^{-6} kg/s$. Analysis cases were determined through several analysis of gas leak flow rate. It was assumed that CFD analysis was modeled in an enclosed space like real accident condition.

Detector of gas leak automatic shut off device should be installed in gas use facilities. Position of detector is a horizontal distance 4 m from center of gas burner in related code (under 0.3 m for LPG) [Korea Gas Safety Corporation 2016]. Figure 4 shows positions of monitor point and leak point. Monitor points are possible positions of detectors. By using CFD analysis for three cases, gas leak density data according to time were calculated at monitor points.

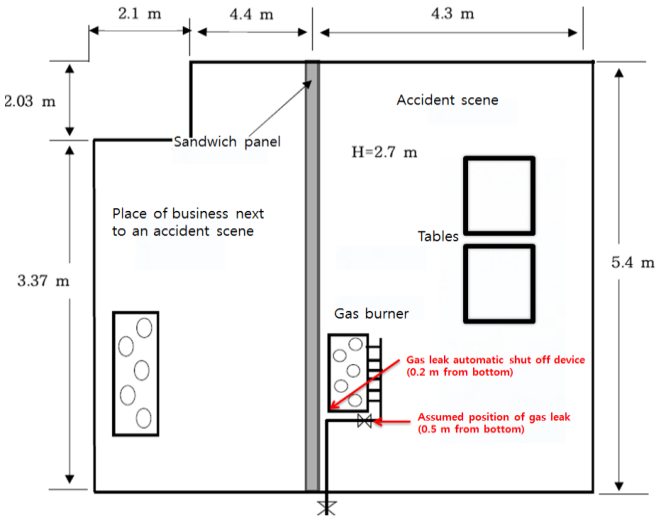

Figure 2. Target facility of the area of dense energy consumption for gas leak CFD simulation

Figure 3. Photos of target facility for the scene of the accident

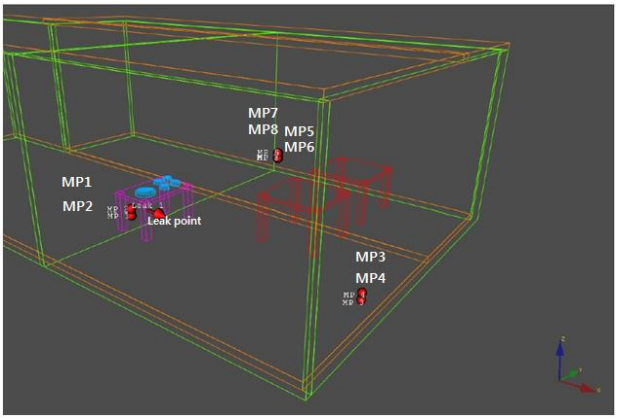

Figure 4. CFD analysis model of target facility about gas leak

4. METHOD OF GAS LEAK PREDICTION TECHNIQUE DEVELOPMENT THROUGH RESULTS OF GAS LEAK CFD SIMULATION

To perform preventive gas safety management, gas concentration and safety action according to 4 steps were proposed for LPG and NG such as Table 1. Existing gas leak automatic shut off device in wired form should be blocked at 25% of lower explosion limit for each LPG/NG. 0.45% of LPG and 1.25% of NG as the first values of 3 step(Warning) in Table 1 are the concentrations of gas shut out. As a part of preventive safety management, two steps (1 step(relief), 2 step(caution)) before 3 step of existing shut out/warning were added to gas safety management step.

Table 1. Step, gas concentration and safety action for safety management of LPG and NG

Division	LPG concentration (Lower explosion limit 1.8%)	NG concentration (Lower explosion limit 1.25%)	Safety action
1 step (Relief)	under 0.05%	under 0.05%	Safety (no action)
2 step (Caution)	0.05~0.45%	0.05~1.25%	Caution
3 step (Warning)	0.45~1.8%	1.25~5%	Warning/Shut off, Dispatch of related organization for gas and electricity
4 step (Danger)	1.8~8.4%	5~15%	Dispatch of related organization for gas and electricity, fire station, rescue center

Figure 5 shows LPG concentration according to time for LPG gas leak flow $10^{-6} kg/s$ and $10^{-3} kg/s$. It is identified that the relations between LPG concentration and time are nonlinear and linear for each Figure 5 (a) (small flow case) and (b) (big flow case). This relation can be utilized to develop gas leak accident prediction model.

In terms of low concentrations, gas concentration variation according to time was considered such as Figure 6. As LPG gas leak flow increases, variations of LPG concentration according to time increase. This characteristic of concentration data should be applied to accident prediction or gas leak decision.

In wide concentration range, gas concentration variation according to time was reviewed such as Figure 7. The small flow case ($10^{-5} kg/s$) and big flow case ($10^{-3} kg/s$) of Figure 7 have low and high growth rate respectively for gas concentration. All cases of gas leak flow can be predicted and controlled by data analysis of safety management system. The case of Figure 7 (b) is controlled at concentration 0.45 % by shut off function of detector device due to rapid gas leak.

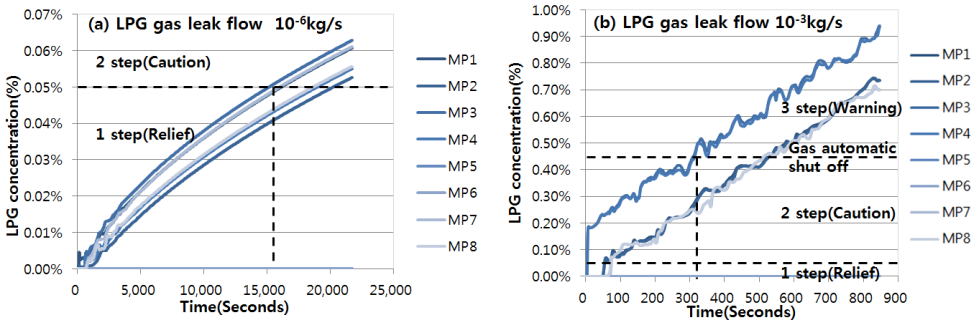

Figure 5. LPG concentration according to time : (a) LPG gas leak flow $10^{-6} kg/s$, (b) LPG gas leak flow $10^{-3} kg/s$

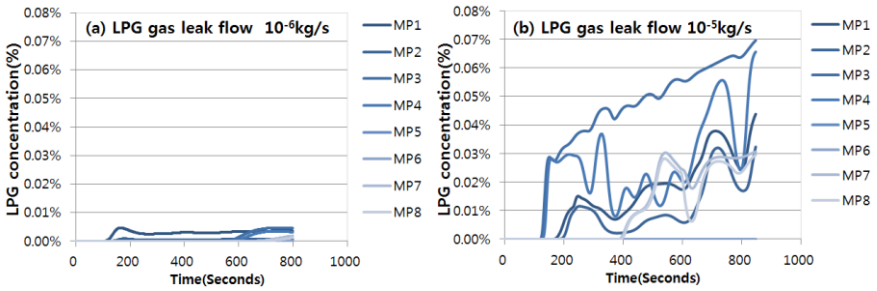

Figure 6. LPG concentration according to time : (a) LPG gas leak flow $10^{-6} kg/s$, (b)) LPG gas leak flow $10^{-5} kg/s$

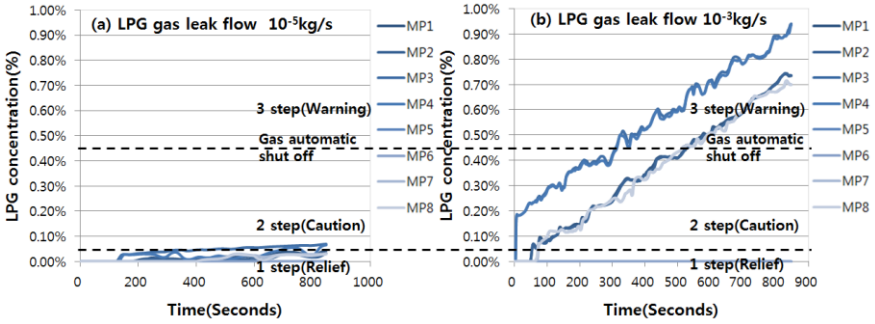

Figure 7. LPG concentration according to time : (a) LPG gas leak flow $10^{-5} kg/s$, (b)) LPG gas leak flow $10^{-3} kg/s$

5. DEVELOPMENT OF GAS ACCIDENT PREDICTION TECHNIQUE CONSIDERING CFD RESULTS

Two methods of prediction for gas leak risks are before and after gas leak in the area of dense energy consumption. In the case of before gas leak, there is serious difficulty for prediction model development due to lack of accident cases and data related to deterioration models. The technique of risk prediction after gas leak was developed considering CFD results. This technique can be applied to safety management system associated with real-time data of gas leak by using wireless sensors.

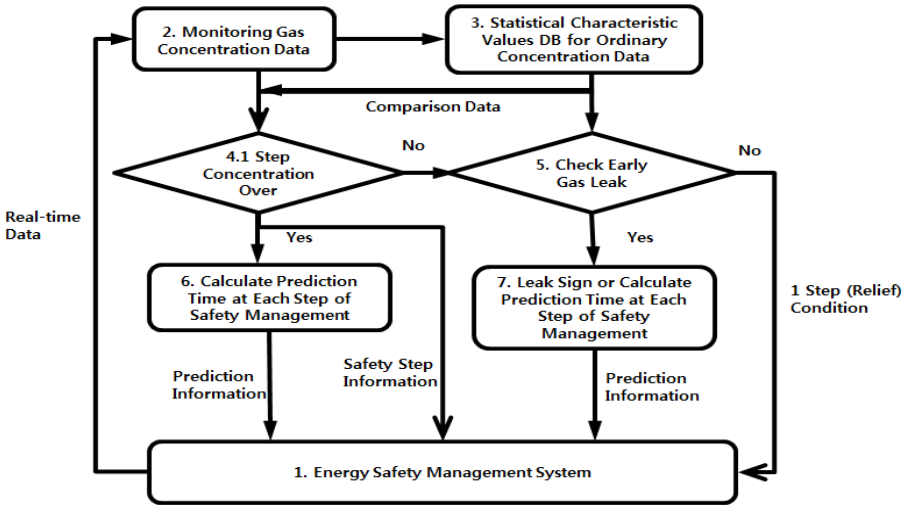

Figure 8. Gas Accident Prediction Algorithm based on Gas Leak Data

The gas accident prediction algorithm was developed considering gas variation data(slope of time-concentration), statistical characteristic variation such as Figure 8.
Energy safety management system is monitoring real-time data of gas concentration by using IoT sensors. Statistical characteristic values for ordinary concentration data as reference data are calculated during certain period. Standard deviation, moving average and gas leak frequency are utilized as statistical characteristic values.
In case of 1 step concentration over (a big rate of leakage) in safety management step of LPG and NG, the safety management system provides predicted information at each safe management step using regression model. In the case of objections (a small rate of leakage), early gas leak is checking through the comparison of statistical characteristic data variation. Also, if prediction model is generated by regression, this system provides predicted information at 1 step.

6. CONCLUSIONS

Accident likelihood is growing due to a correlation for gas and electricity installed in the area of dense energy consumption. To prevent and respond accident risks related to gas and electricity in this area, it should be needed to develop safety management system which executes sensor data collection and data analysis for accident prediction and safety control etc. In this study, the technique of gas leak prediction in the area of dense energy consumption was developed for safety management system. Gas leak simulations were performed to obtain gas leak concentration variation according to time by FLACS program. Main characteristics of gas leak data variation are linear/nonlinear relation and variability over gas leak flow rate which can be applied to accident prediction or gas leak decision. Then, the algorithm of prediction technique was developed for safety management system. The verification test of the algorithm for accident prediction technique will work in the future.

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REFERENCES

Korea Gas Safety Corporation (2015). Gas Accident Year book.
Z.L. Tan, and C.L Zhang (2013) “Construction of the safety management system for urban

underground business district with the application of IOT," Service Systems and Service Management (ICSSSM). Hong Kong, pp. 743-746, July 2013 [10th International Conference on Service Systems and Service Management].

C.A. Zhou, C. Chen, and H. Ren (2013). "Comprehensive Evaluation on Multiple Constraint Elements of City Underground Space Development and Utilization Based on Analytic Hierarchy Process and Fuzzy Comprehensive Evaluation Method," Applied Mechanics and Materials. London, vol. 357-360, pp. 2754-2758, August 2013.

GexCon AS (2013) FLACS v10.0 User's Manual, Accessed 12/08/13; Available from: http://www.flacs.com .

Disaster Integration Management of Korea (2007-2015). Statistical Yearbook of Emergency Management.

Korea Gas Safety Corporation (2016). Standard on Facilities·Technology·Inspection of the Liquefied Petroleum Gas Use Facilities for Containers.