PREDICTION OF THE HAZARD AREA CAUSED BY FIRE, EXPLOSION AND ACCIDENTS LEADING TO THE SPILL OF NOXIOUS GAS

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This paper introduce three software packages of prediction and their application. The prediction software regarding the fire or explosive index of danger is used to calculate the risks of fire or explosion of the production units, stock tanks or warehouses containing dangerous materials, to calculate the range affected by accidents to determine the coefficient of destruction and to further perfect the design of the relevant projects to strengthen the measures of safety and environmental protection according to the risk analysis. The prediction software regarding the hazardous range of the massive spill of the noxious gas, through computer simulation, is used to work out beforehand a prevention plan for the civil defence system. By using a vast amount of prediction data the fast estimation software is to fit out the corresponding formula suitable for the use in commanding at the time of emergency. This software can give out the hazard depth and area of 24 kinds of noxious gas (including the noxious fluid with high volatility) under different dose standards and time, and provide the map of gas diffusing. This paper also gives examples to show how to use the three software packages.

Key words: fire, explosion, noxious gas, accident, hazard, prediction

INTRODUCTION

With the rapid development of industry, the use of more complicated technology and the extensive adaptation of such techniques a high temperature, high pressure and hard vacuum the hidden danger of accidental disasters increases. At present there are more than six million types of known chemicals in the world, among them 60,000-70,000 types are widely used, and many new products are being put into use each year. These chemicals are produced in large quantities and fairly concentrated in storage. The volume of a large liquefied natural gas tank can be 6,000 cubic meters while the volume of a coal gas tank can be as large as 150,000 cubic meters. A warehouse of dangerous articles can store more than 40,000 tons of various kinds of dangerous articles, and nearly 10,000 tons of dangerous good and materials wait to be marshalled everyday at a large-scale railway marshalling yard. All these contain the hidden danger of the occurrence of major accidents. Accidents caused by fire, explosion and the spill of noxious chemicals pose a serious hidden threat to the society, the inhabitants and the environment. Though these accidents often cause mutual initiation and mutual intersection, there are great differences in the harming mechanism, the inhibition factor and the yardstick of time and space of the accidents. For the sake of taking preventive measures, the hazard prediction of possible accidents must be strengthened in order to lessen the losses. In the recent years the Research Centre of Environmental Sciences, CPLA has successively prepared three prediction software which have been applied and tested in the fields of working out a rescue plan beforehand, assessing the environmental risks, etc.

PREDICTION OF THE INDEX OF DANGER RELATING TO FIRE AND EXPLOSION

Origin of the method

It has been 20 years since the American Dow's Chemicals Corporation advanced its fire-explosion index assessment method. This method has been revised for five times, and its 6th edition was published in 1987. It makes use of the data of materials, equipment, quantity, etc. in the process of technology and calculates step by step to make a fairly objective assessment of the dangerous nature that is very much varied in the process of production, storage, transportation and usage. The method is highly valued by many countries. The data used in the process of assessment is taken from the data of the hidden energy of matter, past accidents and experiences obtained from the exiting disaster-prevention measures. Therefore almost all the factors affecting the assessment have been considered. Based on the relevant standards valid in our country we have programmed this assessment method and solved a series of curve's high-precision fitting to facilitate the continuous calculations of the computer.

Examples of prediction

For results see Table 1.

TABLE 1: Result of assessment of units such as acetylene gas manufacturing station

Units	1	2	3
Matter	Acetylene	Aviation Gasoline	Kerosene
State	manufacturing	storage	storage
Quantity (ton)	1.3	2400	2700
NEPA Nh	1	1	0
Nf	4	3	2
Grading Nr	3	0	0
Matter Coefficient	40	16	10
Flash point (^oC)	/	-43	38-72
Explosion limit (%)	2.2-80.7	1.4-7.6	0.5-0.7
F1	2	2.35	1.75
F2	2.27	2.85	2
F3	4.54	6.70	3.5
FE	181.6	107.2	35
Radius affected (m)	46.5*	27.5	8.97
Coefficient of destruction	0.88	0.60	0.18
Time for completing the assessment	92.10	93.10	93.4

* Exceed the border of the station
Unit 1: Certain Acetylene Gas Factory Gas Manufacturing Compression Station
Unit 2: Tank Area of Certain Airport Stock Tank of Aviation Gasoline
Unit 3: Kerosene Stock Tank of Certain Factory
F1: Coefficient of danger of ordinary technology
F2: Coefficient of danger of special technology
F3: Coefficient of danger of unit technology
FE: Fire-explosion index

Analysis of risks

(1). In the broad range of Acetylene gas infallibility Nf=4 grading and 2.2-80.7 % contained in the air, only a very small spark (energy 0.02 mj) can star ignition, which is extremely powerful. Data gathered from the investigation shows that most of the accidents occurring at the acetylene station are caused by wrong operation, not timely maintenance of equipment and equipment explosion or space explosion resulting from the ill ventilation of the room. Therefore, after the factory goes into operation, there will be grave danger of explosion caused by fire. The suggestion is that the factory management must put safety in production before everything else; properly raise the standard of quality relating to the operator's cultural level and charter when employing them; those who have not undergone safety training and examination must not be allowed to work; set up rigorous regulations concerning posts, tour of inspection and maintenance; key places such as gas manufacturing station must be installed with acetylene-gas concentration alarming system, which sound alarm immediately when acetylene exceeds 0.44 % in the air, and the station must be forcibly ventilated; an emergency plan should be worked out and drill be organised in the factory.

(2). For the storage tank of aviation gasoline in the tank area of a certain airport the fire-explosion index is 107.2, the radius affected is 87.5 m and the coefficient of destruction is 60 %. There are already fire walls in the area. We suggest that an oil emergency catch pool or a sealed channel be added. The floor should be designed to have a hard surface with a falling gradient over 1 %. We also suggest that liquid walls be added to the three sealed channel. Once oil-leaking occurs, leaking to the other areas of the airport can be avoided and the dissipation of large quantities of gasoline can be prevented so that the possibility of forming explosive gas can be reduced. Attention should be paid to the prevention of static electricity and prevention of being struck by lightning, especially by flank lightning in the tank area.

(3). Comparatively speaking the kerosene stock tank of a certain factory is not as dangerous and both the area affected or the coefficient of destruction are also smaller. Therefore, the original design has basically satisfied the demand for safety.

(4). After the three above-mentioned units go officially into operation, in the light of concrete equipment and safety measures, a re-examination should be again conducted to calculate the largest possible property loss, based on the investment in the affected area and in combination with the coefficient of destruction. Then in the light of safety measures. The coefficient should be revised and the actual possible property loss be worked out. On the basis of this a safety assessment should also be done.

THE SIMULATION PREDICATION OF HAZARD AREA CAUSED BY THE SPILL OF NOXIOUS GAS

Main technical norm

(1). The diffusing mode is based on the Gauss mode. It is better to use the local actual measuring value as the diffusing parameter. However, the international P-G curve can also be used.

(2). The accidental sources are divided into two categories: continuous source (spill) and instantaneous source (burst).

(3). There are 24 kinds of noxious gas (fluid) including phosgene, chlorine, ammonia, hydrogen sulphide, hydrogen cyanide.

(4). According to Pasquill classification the atmosphere stability is divided into 6 classes.

(5). The items of prediction include: distribution of the whole dose of the pollutant on the ground over the leeward of the accidental source, the hazard depth, width and area under a standard dose of severe, moderate and light injury and the probability of casualties of those without protection.

Method of prediction

Adopt the computer simulation, regard the random field as the flow field and take the diffusing formula as the model of probability. Wind velocity, wind direction, etc. are all random variable, and the concrete numerical value will be given out by the pseudo random numbers, the distribution of which will be decided by the theoretical results or be fitted according to data of actual measure. In the process of simulating whenever a wind direction angle is produced at random, the direction is determined as the direction of a favourable wind on the moving-co-ordinate system. Then the diffusing process is to be inspected on this moving-co-ordinate system. Thus, the problem of the effect of the pollutant diffusing on the flow-field non-steady state has better been solved.

The times of simulation in the statistical simulation are to be decided on the basis of the precision required of the subject of prediction, but not less than 500 times. In order to give out the standard deviation of the statistical simulation, each round of simulation must be repeated three times.

The prediction software will introduce the step length in the simulation area set-up to regulate the linear yardstick in this area so as to satisfy the demands of different size of the diffusing area under the conditions of different toxicity, different source strength and different meteorology. At the same time the attenuation coefficient of the different distances from the accidental source and the quality of different crowds. Before the software is set in motion, the data-document or data-bank of the topography and distribution of the population density (daytime and night) of the prediction area should be established.

Examples of results of the statistical simulation (see Table 2)

TABLE 2: Results of statistical simulation

Kinds of sources	Phosgene	Chlorine	Chlorine	Chloropene	Ammonia
Source strength (t)	1	50	50	20	60
Vertical stability	F	E	B	E	E
Wind velocity at a light of 16m (m/s)	2	1.2	2.34	2.51	1.2
Topography	City suburb	Hills	Hills	Industrial district	Industrial district
Standard deviation of wind direction (degree)	2	5	20	5	5
High of source (m)	10	3	3	3	3
Step length (km)	0.15	0.22	0.04	0.037	0.027
Severe hazard depth (km)	0.6	1.43	0.38	0.28	0.20
Moderate hazard depth (km)	1.2	2.31	0.54	0.43	0.31
Light hazard depth (km)	4.8	6.71	1.42	1.35	0.99
Severe hazard depth (km^2)	0.108	0.35	0.065	0.019	0.011
Moderate hazard depth (km^2)	0.234	0.83	0.131	0.039	0.024
Light hazard depth (km^2)	2.34	5.87	0.865	0.333	0.193

Severe injured population (individual)	215	744	201	59	33
Moderate injured population (individual)	461	1886	402	118	73
Light injured population (individual)	3926	16522	2670	1026	596
Time of completing the prediction	88.10	80.8	80.8	88.10	88.10
Cities concerned	Tianjin	Shenyang	shenyang	Zhuzhou	Zhuzhou

Some explanations

(1). The hazardous consequence of the spill of noxious gas has not only closely to do with the source strength and the toxicity but also to do with the conditions of meteorology. The prevention should be "all-weather" and "all-directions".

(2). The dose standard of injury to people caused by various kinds of toxic chemicals remains a problem not yet totally solved. This author has worked out a group of methods by inference. If the customers have more precise data, the data can be used as input parameter.

(3). In order to ensure the operation of the prediction software, one should at the same time consider the possibility of supplying the relevant diffusing parameter when selecting the diffusing mode.

FAST CALCULATION OF THE HAZARD AREA AFFECTED BY SPILL OF NOXIOUS GAS

Problem raised

The above-mentioned simulation prediction software is prepared for the working out of a plan beforehand in case of emergency. The precision of the computer simulation is in direct ratio to the square root of the simulation times. Therefore, longer computer time is needed and it is not suitable foe commanding on the spot. Besides, the simulation prediction software is aimed at the whole-dose distribution of the pollutant while the distribution of the dose or concentration of the pollutant at different times are often needed in emergency rescue. We started to prepare for the fast calculation software by the end of 1989. this software and the simulation prediction software are the same with regard to most technical norms. there are only two differences:

(a). Demand that one minute after the parameter is inputted into the computer, the software will give out the results of calculation, sound the alarm and show the diffusing map of noxious gas.

(b). Demand that the software well give out the dose value or concentration value of the continuos accidental source at different times.

Main technical ways

(1). The simulation prediction software is used to differentiate the continuous source and the instantaneous source and then select the diffusing mode and diffusing parameter suitable for the prediction area to do the computer simulation according to the multi-factor and multi-level experimental design so as to obtain enough basic data.

(2). Based on the above-mentioned basic data the hazard depth, the hazard area and the step length under 3 dose standards of injury making 7 dependent variables, which correspond to the 5 main variable (toxicity, source strength, wind velocity, atmosphere stability and source height), and the various relation of their possible combination will fitted.

(3). According to the theoretical fruits already gained in the process of diffusing the non-linear varied formulas of expression will be selected, and pertinence coefficient among them will be decided by the fitting of numerical value.

(4). Among several-dozen formulas of expression, though the comparison of the respective X^2 value, the fast calculation formula of expression which is simple in form and better for fitting will be optimised. Though test and verification the x^2 value of the formula of expression of the 7 chosen dependent variables is lower than 1-3 order of magnitude of the allowable value and the fitting degree is fairly high.

Example of application

We have used the fast calculation and on-the -spot commanding software successively in Shanghai District and Qi Lu Petrochemical District to predict the spill of fluid chlorine, fluid ammonia, etc. We have also used the software to assess the environmental risks. In October 1991 the former Changping Chemical Fertiliser Factory changed its production and needed fluid chlorine as raw materials. The problem is that the factory is near to Nankou County on the way to the main tourist line to Badaling (Great Wall), an environmental sensitive area. Therefore, an assessment of the risks of the possible spill or explosion of the fluid-chlorine cylinder was made. Figure 1 and 2 show the hazard area three-tons fluid chlorine under different wind velocities, wind directions and atmosphere stability. The maps were directly copied from the computer screen.

CONCLUSION

The emergency rescue of the sudden accidents of chemical is a complicated systematic project and prediction is only one link of lt. The most urgent task now is to establish and perfect the emergency rescue system, including detecting, forewarning, communicating, commanding, preventing and protecting, tackling and emergency, dealing with the aftermath, etc. to ensure the implementation of timely and effective rescue once accidents occur. The Environmental Detecting Technology Research Institute and Environmental Engineering Research Institute and some other units of the Research Centre of Environmental Science, CPLA enjoy fairly complete techniques and equipment of scout, prevention and disinfection to deal with the varied noxious chemicals. The equipment such phosgene alarm, organic phosphorus pest icicle detection tables, detection tube for carbon monoxide, chlorine and hydrogen phosphide, etc. have been widely used during Asian Games, the explosion accident of Shenzhen Qinshuihe Warehouse and other environmental protections. We hope to make concerted efforts with our colleagues from all walks of life to push forward the development of the prevention work of the district emergent accidents.

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