SAFETY MANAGEMENT FOR THE CITY GAS INDUSTRY

Theory and Practice in China

Peng Xu
Shuhui Zhan

Safety Management for the City Gas Industry

Safety Management for the City Gas Industry:

Theory and Practice in China

By

Peng Xu and Shuhui Zhan

Cambridge
Scholars
Publishing

Safety Management for the City Gas Industry:
Theory and Practice in China

By Peng Xu and Shuhui Zhan

This book first published 2022

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-5275-8170-5
ISBN (13): 978-1-5275-8170-8

TABLE OF CONTENTS

List of Figures

LIST OF TABLES

PREFACE

As a high-quality energy source, city gas provides great convenience for people's daily life and industries, but it also poses dangers and accidents. Gas safety management involves many fields such as engineering, planning, design, construction, supervision, inspection, operation, maintenance and emergency response. It is not only relevant to those working in the industry, but also the billions of gas consumers.

This book sorts out the important laws and regulations on safe production in force in China, and discusses the safety issues of city gas from a management perspective. It summarises China's practices and experiences in the city gas safety management, which will be of great benefit to the training of relevant enterprises, institutions and professionals across the globe.

There are seven chapters in this book, namely: (1) characteristics and accident hazards of city gas; (2) essential laws and regulations on safe production; (3) enterprise safety management and safety culture; (4) hazard identification and safety evaluation; (5) emergency plan management; (6) accident precaution and management; (7) safe operation and safe use.

ACKNOWLEDGEMENTS

The authors would appreciate the financial supports from **the Textbook Project Funding of Beijing University of Civil Engineering and Architecture**

CHAPTER 1

CHARACTERISTICS AND ACCIDENT HAZARDS OF CITY GAS

1.1 Types of City Gas

Gas generally refers to the gas used as a fuel, considering safety and economics. City gas must meet the quality requirements and supply to residential or commercial buildings or industrial enterprises as fuel.

We can classify gas according to its source or mode of production, or from the application's point of view, according to the calorific value of gas or combustion characteristics.

According to the source and mode of production, gas can be broadly classified as natural gas (including coalbed methane), manufactured gas, liquefied petroleum gas and biogas (artificial biogas). Natural gas, manufactured gas, and liquefied petroleum gas can be used as city gas sources. Due to its low calorific value and high carbon dioxide content; however, there are good application prospects as a clean energy alternative to straw and coal in rural areas. In recent years, the research and application of biogas processing and purification technology have been encouraged and supported by the policy in China, and we have used biogas as a vehicle fuel and regional energy in practice.

With the accelerating urbanisation process and the demand for clean energy, new gaseous fuels will continue to enter the urban energy system in various forms. The scope of city gas is also expanding.

1.1.1 Classification by source

1) Natural gas

Natural gas is commonly a gaseous fossil fuel, a mixture of hydrocarbon and non-hydrocarbon gases naturally occurring in the formation. It is a gaseous fossil fuel mainly composed of methane.

Natural gas is extracted from the earth at high pressure and easily transported over long distances. Natural gas has a high calorific value and is quickly and efficiently combusted, making it an excellent and economical natural resource.

We can generally classify natural gas according to its deposits or gas composition characteristics. The composition of natural gas varies depending on the origin, deposit structure, extraction season, and other factors. According to the features of the mineral deposits, conventional natural gas is mainly divided into three categories: gas field gas, condensate field gas, and oil-associated gas.

The gas field is the abbreviation of the natural gas field, which refers to the area rich in natural gas. Gas field gas presents a homogeneous gas phase in the stratum, and when it is extracted, it is called gas-phase natural gas. Its main component is methane, with a content of about 80% ~90%. It also contains small amounts of carbon dioxide, hydrogen sulphide, nitrogen, and trace amounts of helium, neon, argon, and other gases.

Condensate field gas refers to natural gas containing small amounts of light petroleum fractions (gasoline and kerosene components). After the gas is extracted, it is generally depressurised and cooled to separate the two phases of gas and liquid, transported, distributed, and used separately. The methane content of condensate field gas is about 75%.

Petroleum-associated gas refers to the natural gas that coexists with petroleum and is extracted with fat. Petroleum-associated gas is divided into gas cap gas and dissolved gas. Gas cap gas is insoluble in oil and is generally not extracted to maintain the necessary well pressure during the oil extraction process. Liquefied gas refers to the gas dissolved in grease obtained from oil extraction. The main components of petroleum-associated gas are methane, ethane, propane and butane, with small amounts of pentane and heavy hydrocarbons. The gas to oil ratio (gas m^3/crude oil ton) is generally between 20～500 m^3/t.

2) Manufactured gas

Artificially produced gas refers to the gaseous fuel produced by processing solid or liquid combustible materials. Generally, the gaseous fuel made from coal or coke is called coal gas, and the gaseous fuel made from petroleum and its by-products (heavy oil) is called oil gas.

Manufactured gas can be divided into many categories according to the raw materials, production and processing methods, and equipment.

When solid fuels (such as coal) are heated in isolation from the air, they decompose to the products such as combustible gases (dried distillate gas), liquids (coal tar), and solids (semi-coke or coke). This chemical process of solid fuels is known as dry distillation. The gas that escapes from the dry distillation of coal-based fuels is called dry distillation gas.

The process of converting solid fuels (such as coal or coke) into combustible gases through chemical reactions by interacting the solid fuels (such as air, oxygen, water vapour) with gasifying agents (such as air, oxygen, water vapour) at high temperatures is called gasification of solid fuels. The resulting gaseous fuel is called gasified gas.

Oil gas is a gas fuel made by cracking petroleum and by-products (heavy oil, light oil, naphtha) at high temperatures. The calorific value of high-temperature cracked gas with the participation of catalyst can be close to that of the distillate gas.

3) Liquefied petroleum gas

Liquefied petroleum gas (LPG) is a by-product of the oil extraction and processing process, and its main components are propane, propylene, butane, and butene. According to the number of carbon atoms in its molecules, it is often called C_3, C_4.

LPG is pressurised at room temperature or cooled down to atmospheric pressure to become liquid for easy storage and transportation as a mixture of hydrocarbons. Liquefied petroleum gas is a widely used type of gas source, which can be easily re-gasified into a gaseous state by depressurisation or warming.

According to its origin, liquefied petroleum gas is mainly divided into two. One is the natural petroleum gas, coming from the oil or gas field exploitation process, and the other is the refinery LPG from the refiner.

4) Other gas

With the development of science and technology and the gas mentioned above, some other gaseous fuels have been gradually developed and utilised, e.g., coalbed methane and mine gas, shale gas, methoxymethane, light hydrocarbon mixed gas, natural gas hydrates, and biogas.

Coalbed methane and mine gas are combustible gases associated with coal generation and metamorphosis.

Coalbed methane, also called coalfield gas, is a combustible gas produced in coal formation and gathered in a specific geological structure. Its main component is methane, but it also contains carbon dioxide, hydrogen, and a small amount of oxygen, ethane, ethylene, carbon monoxide, nitrogen and hydrogen sulphide, and other gases.

Mine gas is an explosive mixture of coalbed methane and air. During the coal mining process, when the coal seam is extracted and free space is formed in the shaft, the coal seam gas escapes from the coal seam and rock and moves into the distance, where it mixes with the air to create mine gas. Its main components are methane (30% ～55%), nitrogen (30% ～55%), oxygen, carbon dioxide.

Shale gas is an unconventional natural gas stored in organic-rich mud shale and its interlayer, mainly composed of methane. It exists in a free or adsorped state. Although shale gas is difficult to exploit, it is a promising unconventional gas resource with abundant reserves on the ground.

Natural gas hydrate, also known as *combustible ice*, is an ice-like crystalline material formed by natural gas and water under high pressure and low temperature in deep-sea sediments or permafrost of land areas. For its ice-like appearance and ignitability, it is also called *combustible ice*. Combustible ice has a high resource density and is widely distributed worldwide, making it precious.

Biogas is a combustible gas produced by the action of microbes (fermentation) under certain conditions of temperature, humidity, and acidity by isolating the air (such as a biogas digester) from some organic materials (such as straw, weeds, leaves, human and animal manure, municipal garbage, domestic sewage, and other wastes). It contains 60% ~70% carbon dioxide, hydrogen sulphide, nitrogen, and carbon monoxide, with a slight odour and a low calorific value of 20～25 MJ/m^3。

1.1.2 Classification by combustion characteristics

With the gas industry's development, more gas sources with broader variation in composition, resulting in changes in combustion characteristics, enter the city gas market. For gas distribution and appliance manufacturing companies to have a common guideline to follow, they must be classified

by gas source and its related combustion characteristics. The Chinese national standard GB/T 13611-2018 *Classification and essential attributes of city gas* are based on the high calorific value of gas and combustion heat load index (Wobbe index) to classify the city gas, as shown in Table 1-1.

The category and characteristic index of city gas (15°C, 101.325 kPa, dry) shall comply with the provisions of Table 1-1.

Table 1-1: Types of city gas and characteristic indicators

Category		High Wobbe index W_S /(MJ/m^3)		Gross Calorific Value H_S /(MJ/m^3)	
		Standard	Scope	Standard	Scope
Manufactured gas	3R	13.92	12.65~14.81	11.10	9.99~12.21
	4R	17.53	16.23~19.03	12.69	11.42~13.96
	5R	21.57	19.81~23.17	15.31	13.78~16.85
	6R	25.70	23.85~27.95	17.06	15.36~18.77
	7R	31.00	28.57~33.12	18.38	16.54~20.21
Natural gas	3T	13.30	12.42~14.41	12.91	11.62~14.20
	4T	17.16	15.77~18.56	16.41	14.77~18.05
	10T	41.52	39.06~44.84	32.24	31.97~35.46
	12T	50.72	45.66~54.77	37.78	31.97~43.57
Liquefied petroleum gas (LPG)	19Y	76.84	72.86~87.33	95.65	88.52~126.21
	22Y	87.33	72.86~87.33	125.81	88.52~126.21
	20Y	79.59	72.86~87.33	103.19	88.52~126.21
Mixture of LPG & air	12YK	50.70	45.71~57.29	59.85	53.87~65.84
Dimethyl ether (DME)	12E	47.45	46.98~47.45	58.87	59.27~59.87
Biogas	6Z	23.14	21.66~25.17	22.22	20.00~24.44

Note 1: The gas category, expressed as the high wobble index value of the gas in its original unit of kcal/m^3, divided by 1000 and rounded to the nearest whole number, e.g., 12T, so the high Wobble index value of the gas is approximately 12,000 kcal/m^3.

Note 2: 3T and 4T are mine gas or a mixed gas of air and light hydrocarbon, with combustion characteristics similar to natural gas.

Note 3: 10T and 12T natural gas includes dry well gas, oilfield gas, coalbed methane, shale gas, substitute natural gas, and biogas.

[a] Dimethyl ether gas should be used as a single source and not be blended.

1.2 Quality Requirements for City Gas

1.2.1 Basic requirements for city gas

High-quality gas should be supplied to the densely populated cities and towns as a matter of priority to meet energy conservation and environmental protection requirements. As a city gas source, it should meet the basic needs.

1) High calorific value

High energy density lowers the investment level in the transmission and distribution system. Only under particular circumstances, after technical and economic comparison reasonable, the use of the lower calorific value of gas as a city gas source is allowed. The calorific value of city gas should be more significant than 14.7 MJ/m^3.

2) Low toxicity

To prevent gas leaks from causing poisoning and ensure gas safety, we must strictly control the content of carbon monoxide and other toxic ingredients in city gas.

3) Low impurity content

The impurities and harmful components often affect the safety of the gas supply in the gas. Contaminants can cause equipment malfunctions in gas systems, instrument failures, pipeline blockages, improper use of gas appliances, and even accidents.

1.2.2 Effects of impurities and hazardous substances in gas

The impurities and harmful substances contained in the gas have a non-negligible impact on the safety of the city gas supply. The common contaminants and their possible hazards are as follows.

1) Tar and dust

The tar and ash content in dry distillation gas often accumulates in the valves and equipment, resulting in loose valve closure and blockage of pipes and gas equipment.

2) Sulphide

The sulfide in gas is mainly hydrogen sulfide. Besides, there are also small amounts of mercaptans (CH_3SH, C_2H_5SH) and carbon disulfide (CS_2). In natural gas, hydrogen sulfide is the main sulfide. Hydrogen sulfide is a colourless, rotten egg-smelling gas that burns to produce sulfur dioxide. Hydrogen sulfide and sulfur dioxide are both harmful gases.

3) Naphthalene

The content of naphthalene in coal gas is relatively high. At low temperature, gaseous naphthalene will precipitate in a crystalline state, attached to the wall of the pipe, so that the flow section of the tube becomes smaller or even blocked.

4) Ammonia

Ammonia has a corrosive effect on gas pipes, equipment, and appliances and generates nitrogen oxides (NO_x) and other harmful gases during combustion. However, ammonia has a neutralising effect on the acidic substances produced by sulfide, so the presence of a small amount of ammonia in the gas will help protect metal pipes and equipment.

5) Carbon monoxide

Carbon monoxide is a colourless, odourless, highly toxic, combustible gas. Generally, carbon monoxide content in city gas is less than 10% (volumetric component).

6) Nitrogen oxide

Nitrogen oxides are easily polymerised with double-bonded hydrocarbons to form gaseous colloids that can adhere to gas transmission equipment and gas appliances and cause malfunctions. When the concentration of nitrogen oxides in the air reaches 0.01%, it stimulates human respiratory organs, and prolonged exposure can endanger life.

7) Water

Water must be removed from natural gas before it enters long-distance pipelines. The local accumulation of water and other impurities can reduce the pipeline's capacity. Under high pressure, the water in natural gas also readily forms hydrides with the hydrocarbons inside. Acidic gases such as hydrogen sulfide and carbon dioxide dissolve in water, increasing the corrosion of metal pipes and equipment. The transmission and distribution system has to be improved in drainage facilities and pipelines' maintenance to transport water-bearing gas.

1.2.3 Quality requirements for city gas

1) Natural gas

The quality standard of natural gas shall conform to GB 17820-2018 Class I or Class II gas provisions in Table 1-2.

Table 1-2: Technical specifications of natural gas (GB17820-2018)

Items	Class I	Class II
High calorific value (MJ/m^3) ≥	34.0	31.4
Total sulphur (in terms of sulphur)(mg/m^3) ≤	20	100
Hydrogen sulfide(mg/m^3) ≤	6	20
Molar fraction of carbon dioxide (%) ≤	3.0	4.0

* The standard reference condition used in this standard is 102.325 kPa at 20°C.

2) Manufactured gas

The quality of manufactured gas should be under the provisions of GB/T 13612 in Table 1-3.

Table 1-3: Quality standards for manufactured gas

Items	Quality indicators	Impurity limits
Low calorific value [a] (MJ/m^3)		
Class I [b]	＞14	GB/T 12206
Class II [b]	＞10	GB/T 12206
Gas Properties Index (GPI) [c] fluctuation range compliance	GB/T 13611	
Impurities		
Tar & dust /(mg/m^3)	＜10	GB/T 12208
Hydrogen sulfide /(mg/m^3)	＜20	GB/T 12211
Ammonia /(mg/m^3)	＜50	GB/T 12210
Naphthalene[d] /(mg/m^3)	＜$50\times10^2/P$ (winter) ＜$100\times10^2/P$(summer)	GB/T 12209.1
Oxygen content[e] (volumetric fraction) /%		GB/T 10410.1 or chemical analysis methods
Class I	＜2	
Class II	＜1	
Carbon monoxide content [f] (volumetric fraction) /%	＜10	GB/T 10410.1 or chemical analysis methods

Note: a. This standard gas volume (m^3) refers to the book at 101.325 kPa at 15°C.
b. The gas of Category I is dry distilled coal gas. Category II is coal gasified gas, oil gasified gas (including liquefied petroleum gas and natural gas reforming).
c. Combustion characteristic index: Wobbe Index (W), combustion potential (CP);
d. Naphthalene system refers to naphthalene and its congeners α-methylnaphthalene and β-methylnaphthalene. When the absolute pressure (P) at the pipeline transmission point (P) is less than 202.65 kPa, the pressure (P) factor may be excluded from the calculation.
e. Oxygen content refers to the indicator required for the production process in a gas plant.
f. The carbon monoxide content shall be less than 20% by volume for the gas of Class II or Class I adulterated with Class II gas.

3) Liquefied Petroleum Gas

The content of sulphur, moisture, ethane, and ethylene in LPG should be confined. The amount of residual liquid (C_5 and above) should be under control, as C_5 and above components cannot be vaporised naturally at room temperature.

The quality standards for LPG as industrial and civil fuel are different from those for vehicles. Table 1-4 from GB 11174-2011 shows the quality standards for LPG as industrial and residential fuel.

Table 1-4: LPG quality standards

Items	Quality standard			Test method
	Commercial propane	Commercial propane-butane mixture	Commercial butane	
Density (15°C) /(kg/m^2)	report			SH/T 0221
Vapor pressure (37.8°C) ≤	1430	1380	485	GB/T 12576
Component%				SY0230
C_3 hydrocarbon fraction (volume fraction)/% ≥	95	—	—	
C_4 and higher hydrocarbon fractions (volume fraction) /% ≤	2.5	—	—	
(C_3+C_4) hydrocarbon fraction (volume fraction)/% ≥	—	95	95	
C4 and above hydrocarbon fraction (v/v)/% ≤	—	3.0	2.0	
Residue				SY7509
Evaporation residue/(ml/100ml)≤	0.05			
Oil stain observation	-			
Copper sheet corrosion (40°C, 1h)/grade ≤	1			SY0232
Total sulfur content/(mg/m^3)≤	343			SY0222
Hydrogen sulphide (subject to one of the following requirements)				
Lead acetate	None			SY0125
Chromatography /(mg/m^3) ≤	10			SY0231
Free water	None			visual assessmen*

* In case of dispute, visually check the presence of free water using SY0221 instruments and test conditions.

1.2.4 Odorisation

Gas is a flammable and explosive hazardous product. Therefore, it is required that the gas must have a distinctive, detectable, and warning odour. When a gas leakage occurs during customer use, it should be detectable by smell. The fragrance should be added to the gas, which is odourless or has a low odour. Gas concentration detection devices should also be installed on industrial and commercial users' premises to detect the presence of a gas leak.

Gas delivered to the city via long-distance pipelines is generally odorised at the city gate station.

The odorising agent should have the following characteristics.

1) The odorant should not be harmful to humans, pipes, or materials in touch within the usual concentration range.

2) The distinctive odour should be persistent, unpleasant, and distinctly different from ordinary gas odours.

3) Appropriate volatility.

4) Burning completely and the combustion products should not be harmful to the human respiratory system and should not rust or injure materials in regular contact with the combustion products.

5) Not chemically reacts with the components of the gas.

6) The degree of dissolution in water should not be greater than 2.5% (mass composition).

7) Low cost.

In China, the commonly used odorants are mainly tetrahydrothiophene (THT), ethyl mercaptan (EM). Also, non-alcoholic odorants are in use.

1.3 Forms and Features of the City Gas Supply System

The city gas supply system mainly has two forms: pipeline and bottled supply.

The supply system of the city gas pipeline is generally composed of gate stations, gas pipeline networks, gas storage facilities, pressure regulating devices, management facilities, monitoring systems. The received gas is delivered to the user through the transmission and distribution pipe network. The gas source is mainly natural gas or manufactured gas. Also, in some

areas, liquefied petroleum gas (LPG) mixed with air (i.e., the substitute natural gas) is supplied to users in the form of the pipeline.

The gas sources of the bottled supply system include liquefied petroleum gas (LPG) and liquefied natural gas (LNG), using special metal cylinders for commercial and residential uses.

1.3.1 Gas pipeline supply systems

Gas pipeline supply is the main form of city gas supply, with the following main features.

1) Multiple pressure levels

China" city gas pipelines are divided into seven levels according to their design pressure P (MPa), and the design pressure grading standards for pipelines are shown in Table 1-5.

Table 1-5: The design pressure of the city gas pipeline (gauge pressure)

Items		Pressure *P* (MPa)
High-pressure gas piping	A	$2.5<P\leq4.0$
	B	$1.6<P\leq2.5$
Sub-high pressure gas piping	A	$0.8<P\leq1.6$
	B	$0.4<P\leq0.8$
Medium pressure gas piping	A	$0.2<P\leq0.4$
	B	$0.01\leq P\leq0.2$
Low-pressure gas piping		$P<0.01$

Depending on the size of the city, the gas supply system can be a single-stage or multi-stage system to meet transmission and user pressure requirements. Gas power (thermal) plants, large industrial users, boiler houses usually require high or medium pressure gas; commercial and residential users generally use medium and low-pressure gas devices.

2) Wide range of pipe laying

Depending on the city planning and the distribution of gas users, city gas pipes are laid along streets and alleys. Underground gas pipes are usually laid on sidewalks, in green belts, on slow lanes, and under fast lanes. Customer gas pipes are laid on the facade of buildings and inside buildings.

3) Meet with the customers of different types and sizes

The gas supplied by pipeline can meet residential, commercial, industrial, heating and air conditioning, thermal power plants, and other users. The supply capability is guaranteed, and the gas supply is stable and safe.

4) System complexity

The gas system belongs to the city's infrastructure. There are many types and large quantities of equipment and facilities in the system, and the construction period is different. Therefore, systematic management is needed to ensure its integrity and safety.

1.3.2 Bottled supply systems

Bottled supply refers primarily to the LPG cylinder supply, which can be used alone or supplement the pipeline supply system. The features of the bottled supply system are listed below.

1) System scale and the investment controllability

The bottled supply plant's storage, filling scale, and investment can be adjusted and controlled as needed. The cylinders and transport vehicles can be purchased and used in phases. The supply area can be set and adjusted flexibly.

2) Low demands

Most residential household users use a single bottle gas supply, while commercial and small boiler plants and industrial users can use double bottles or groups of bottles for gas supply. It is not recommended to use the bottled gas supply for significant gas demand.

3) Safety and economy of the cylinders' transportation

As for the transportation of cylinders, the economy, safety, and other related factors should all be considered determining the transport modes and transport distance reasonably. The relevant departments shall develop and approve a transport safety management system.

1.4 Gas Accidents and Hazards

Every coin has two sides. As high-quality energy, the city gas brings us the convenience of production and life, but it also means danger when the gas system is abnormal.

In the gas production, storage, transportation and use process, once severe accidents, e.g., damaging leaks, fire and explosion occur, it will force the production system temporarily or longer-term to be interrupted and cause casualties and property losses, owing to the process continuity, high automation degree, technology complexity and the equipment variety.

Accidents have increased sharply with the continuous expansion of gas production and consumption, especially for natural gas. The consequences of accidents have become more and more serious, restricting the gas industry's development to some extent.

1.4.1 Features of gas accidents

Gas accidents have both general features and particularities.

1) Universality

There are wide ranges of gas pipelines and facilities in the city, and gas accidents may occur in and around any place with gas pipelines or gas facilities.

2) Emergency

City gas accidents generally occur suddenly. The damage to gas equipment or gas pipelines, including external damage by third parties, occurs typically without warning. Gas leaks often occur without people noticing.

3) Unpredictability

Some accidents can be predicted based on environmental and other factors. For instance, air and road traffic accidents may occur more frequently in bad weather. However, city gas accidents generally have little to do with factors such as climate and may appear in any season and under any weather conditions. Therefore, gas accidents are usually unpredictable and challenging to prepare for in advance.

4) Large influence range

When a gas accident occurs, not only does it affect the production, delivery, and use of gas, but certain surrounding areas are often affected by accidents as well. For example, if a gas explosion occurs in a residential building, it may cause the entire building to be damaged and affected. Once a gas explosion occurring in the residential building has caused damage to the building, it has to be dismantled as a whole after the explosion accident. Gas pipeline leaks may cause gas outages in a region of several kilometres.

5) Serious consequences

Many gas accidents can cause fires and explosions, resulting in injuries and property damage.

6) Secondary damage

In an earthquake, landslide, stratigraphic change, and flooding, damage to gas facilities may cause secondary damage. In many earthquakes, fires started after gas lines broke or leaked, which caused more severe damage than the earthquake itself and made it difficult to rescue people after the disaster.

1.4.2 Gas hazard and hazard analysis

1) Flammability and toxicity

The flammable and explosive characteristics of gas make it possible to meet air near the leakage point and mix to form combustible gas once the gas leaks. When it encounters fire, high temperature, electromagnetic radiation, radio and microwave, and other ignition sources, it may cause fire and explosion.

City gas must be purified before it reaches the town and must meet the requirements of the relevant standards. The toxicity of city gas is low, but it can still cause suffocation or poisoning at high concentrations. In particular, the manufactured gas contains colourless, odourless, highly toxic carbon monoxide (CO). Although the CO content is limited in the city gas quality requirements, the consequences of poisoning may still be serious when the leakage is significant.

2) Volatility and diffusivity

City gas leaks into the air and then spreads. High-pressure gas is ejected at high velocity from the pipe or equipment opening and spreads rapidly in the

air. If the gas cloud does not encounter the fire source, the harm will decrease with the gradual diffusion of the gas cloud and the decrease of pressure and concentration. However, fire and explosion accidents will occur if ignited, causing casualties and property losses.

When LPG leaks, the vapour cloud diffuses close to the ground, which is not accessible to volatilise and is easily ignited by ground ignition sources. When a large amount of LPG leaks, in the process of rapid gasification of LPG, it will quickly absorb the heat around it and form a low-temperature state locally, which may cause frostbite of personnel or failure of equipment and valve closure.

CNG, i.e., compressed natural gas and LPG, increased rapidly in Chinese cities and towns. Its characteristics of high pressure and low temperature make it more dangerous. A large leak of LPG calls for specialised response and disposal.

3) Flue gas hazards

When the gas combusts completely, the combustion products consist mainly of carbon dioxide (CO_2) and water. Once the gas cannot burn entirely, the flue gas contains CO. If it cannot be discharged in time and collects in a small space, it may cause suffocation or even death. Most poisonings and fatalities are because the indoor air was consumed, and the flue gas after combustion gathers indoor. It causes harm under the combined anoxic and toxic action.

4) Occupational hazards

City gas is a low-toxic gas that does not cause occupational hazards for employees under normal circumstances. However, in the places of gas production, storage and LPG filling, emergency repair of leakage accidents, attention should be paid to the protection of employees according to the monitoring of gas concentration.

The carbon monoxide levels and allowable operating hours in the work area are shown in Table 1-6. The relationship between airborne hydrogen sulphide (H_2S) concentrations and organism reflection is shown in Table 1-7.

Table 1-6: Carbon monoxide content in the working area and permissible working hours

CO concentration in the work area	Allowed working time
CO content not exceeding 30mg/m^3 (24 ppm)	Longer working hours
CO content not exceeding 50mg/m^3 (40 ppm)	No more than 1 hour of continuous work
CO content not exceeding 100mg/m^3 (80 ppm)	No more than 30 minutes of continuous working time
CO content not exceeding 200mg/m^3 (160 ppm)	Continuous working time should not exceed 15-20 minutes

Note: At least 2 hours between each work.

Table 1-7: Airborne hydrogen sulfide (H_2S) concentrations and organismal reflections

Concentration (ppm)	Symptoms
0.025	Sensitive people can feel odours
0.3	All can smell the unpleasant odour.
3-5	The smell is strong and very unpleasant.
20	It can be felt for a long time.
20-30	The odour is solid but tolerable, and people become dull to this odour.
70-150	The burning and painful feeling are expected with a long period of stimulation.
Above 200	Numbness and insensitivity to odours
170-300	Numbness is life-threatening for an hour or so.
400-700	Life-threatening numbness for 30 minutes to 1 hour is life-threatening.
Above 700	In minutes, people faint, stop breathing and even die.

5) Hazard and hazard analysis of city gas systems

The hazards and hazard analyses of the city gas system are shown in Table 1-8.

Table 1-8: City gas system hazards and hazard analysis table

Category	Hazards and hazards
Fire and explosion hazards	When gas leaks into the air and the concentration exceeds its lower explosion limit, the risks of fire and explosion appear once there are fire, electric spark, electrostatic discharge, and other sources of fire. The gas pipeline, pressure regulator station, pressure regulator box, storage tanks may cause gas leakage due to construction quality problems, pipeline corrosion, overpressure and sealing, improper operation, external damage, vandalism, and natural damage under pressure. In the process of engineering repair and gas replacement, the risk of fire and explosion may be caused by the operation with gas, illegal direction or procedure. Gas leakage, fire, and explosion may also occur in the terminal pipelines and equipment.
Physical explosion hazards	Gas pipelines, filters, high-pressure regulator devices, and other gas appliances under pressure result in physical explosion hazards in overpressure or ageing corrosion. The gas storage facilities of transmission and distribution stations and the LPG cylinders at terminal users under high pressure may cause a physical explosion in case of overpressure.
Poisoning and asphyxiation hazards	In the process of gas transmission, pressure regulation, if leakage occurs, especially in confined areas (such as pressure regulating stations, gate wells, storage tanks), it is easy to cause the accumulation of gas and cause personnel suffocation. The leakage of gas deodoriser of tetrahydrothiophene can also cause poisoning during filling and storage.
Vehicle injury hazards	Improper driving or other reasons may cause vehicle injury to the driver or other personnel when the inspection, testing, maintenance, and other staff drive engineering vehicles for transport, maintenance, and inspection operations.
Electric shock hazards	Poor wiring insulation of electrical equipment, lighting, and control systems or improper electrical protection may bring electric shock hazards. There exist dangers of direct contact with electric shock or indirect contact with electric shock in such places as substation and distribution rooms, distribution lines, workshop distribution boxes, all kinds of electrical dragging equipment, mobile electrical equipment, lighting lines, and lighting appliances in the workshop.
Lightning strikes	There is a risk of lightning damage when people contact metal pipes and metal equipment during a thunderstorm. There is also a risk of lightning damage to gas equipment and facilities installed in the open.

Falling injury	Personnel performing maintenance and repair work in areas with elevation differences may fall from a height in unforeseen circumstances to cause injuries and even fatalities.
Fire and electric burning injury	Personnel may suffer burns and electrical burns that could cause injury or death in the event of a gas flare, electrical fire, and other fires during operations.
Frostbite	There is a risk of frostbite injury to personnel in the event of unprotected contact with LNG pipelines and storage tanks or in case of an LNG leak or large LPG leak.

1.4.3 Typical gas accident cases

Gas accidents are reported frequently in the media worldwide.

In 2015, the WeChat public platform of *China Gas Explosion* recorded more than 350 gas explosion accidents in China, which resulted in 712 injuries and 127 deaths. There were 217 natural gas explosions, with 530 deaths and injuries; 88 LPG tank explosions, 236 deaths and injuries; and 19 gas pipeline leaks.

In 2016, according to www.gasshow.com, there were 805 gas explosions in China, resulting in more than 1,100 injuries and 95 deaths; 13 of these explosions occurred in Beijing. There were 531 gas explosions in residential households, accounting for 66% of the annual accidents, and 172 outbreaks in restaurants and businesses, accounting for 21% of the casualties.

Typical gas accidents in recent years are described and analysed below.

1) Gas explosion in Manhattan - an explosion caused by accidental construction sabotage

On 26th March 2015, at 15:17, a building exploded violently between Second Avenue and East Seventh Street in the East Village of Manhattan, New York City. The explosion sparked a fire, which quickly spread to the surrounding area with the wind, causing four buildings to be engulfed in flames.

Investigation revealed that construction personnel working in the building, which houses a Japanese restaurant called Sushi Park, improperly and accidentally damaged a gas line, causing a gas leak and an explosion. Three of the 12 injured people were severely hurt, and three buildings were reduced to rubble.

The mayor of New York City told a news conference that the once vibrant and bustling streets had changed beyond recognition.

Figure 1-1 Photos from the scene of the gas explosion in Manhattan

2) Nanchang pipeline gas explosion – the liability accident due to delayed repair

The Xihu District People's Court heard the dispute over property damages caused by a gas explosion accident in Nanchang City, Jiangxi Province. The court ordered the defendants, China Certain Property Insurance Company Limited, Nanchang Certain Gas Company, and Jiangxi Certain Construction

Company, to make economic compensation for losses caused by a gas explosion.

On the afternoon of 30th December 2012, in Nanchang City, near an intersection, the pipeline LPG deflagration accident occurred at a construction company construction site. Someone at the site smelled the gas and notified the construction company's site manager, dialling the gas repair phone.

Employees of the gas company visited the site to view the gas leak. They negotiated with the construction side to evacuate the people, set up a cordon, and strictly control the visible flames, but no shutdown measures were taken. After the dinner gas peak, repair crews arrived and prepared to begin repairs. Then they left the site without taking shutdown measures. At 18:30, a fire occurred and then an explosion near the gas leak location.

Over accident investigation, the safety supervision department affirmed that the gas company should be directly responsible for the accident. For it did not foresee the consequences of the development of the situation sufficiently, did not take decisive measures immediately to cut off the gas supply and organise an emergency rescue, and delayed the repair time. The construction company should be held indirectly responsible for the accident. It did not learn enough about the underground pipeline network, which resulted in the repeated crushing by the heavy vehicles on the pipeline and the accumulation of a large amount of residual soil on the medium-pressure pipeline, leading to the rupture of the LPG medium-pressure pipe.

3) Gas explosion in residence in Dalian - a significant liability accident caused by the illegal operation of gas company employees.

On 5th August 2015, a gas leak occurred in a residential building in Dalian City, Liaoning Province. The company responsible for gas supply assigned employees to find the leak. The employees allowed intermittent gas supply to the residential building, once by about 2 hours during the dinner cooking peak in the evening of the same day, without identifying the leakage point. The following day, during the three cooking periods in the morning, noon, and evening, the scheme of intermittent gas supply continued. The leaked gas constantly gathered. The employees on the site then all left, not identifying the warning area, not setting up warning signs, not detecting the gas concentration in the surrounding environment, and not identifying if the gas concentration dropped to a safe range in the warning area.

On 7th August 2015, the leaking gas met an electrical spark and then exploded. The explosion collapsed part of the building, killed five people, and injured more than 20.

In the first instance, the court sentenced the gas company employees to fixed-term imprisonment for the crime of serious liability accident.

Figure 1-2 A photo from the scene of a gas explosion in a Dalian district

4) Beijing Jimenqiao gas pipeline leak - the incident of the third-party drilling sabotage successfully disposed of by the gas company

Beijing Gas Group received a report of a gas smell 100m east of the Jimen Bridge on the Third Ring Road auxiliary to Haidian District at 3:25 a.m., 3rd June 2016. According to the investigation, the subway construction personnel accidentally drilled the gas pipeline during the drilling construction implementation, causing the medium pressure gas pipeline damage in the concrete street ditch. The incident affected 29 pressure regulator boxes, 12,000 residential customers, and 42 public service users.

Receiving the alarm, the local company immediately starts the response following the emergency plan, and the personnel and vehicles rush to the scene for disposal and emergency repair. Measures such as restricting traffic, evacuating personnel, confirming the air leakage point, and controlling pressure repair are taken. The pipeline repair was completed by noon, and the surrounding traffic was restored.

The traffic management department started the high-level disposal plan and the regional personalised traffic command and guidance measures. Personnel from relevant government departments went to the scene to direct and coordinate the emergency work.

Under the unfavourable conditions of large gas leakage volume and the handling process coinciding with the morning traffic rush hour, the gas company adopted high-level emergency response, quick judgment, and decisive disposal. It successfully prevented the expansion and deterioration of the situation without causing casualties. The disposal process, successful experience, emergency procedures, and methods can be used as a reference for dealing with gas emergencies.

Figure 1-3 Photograph of the damage to the medium pressure DN500 gas line

Figure 1-4 Photograph of the gas line rehabilitation process

5) Beijing Changying gas leak and fire incident – the widespread social concern events of the leaked gas from the broken welding joint being ignited by overhead wires above the pipeline

At about noon on 23rd December 2016, the welding joint of the medium pressure gas pipeline broke suddenly at the junction of Changying Road, Chaoyang District, Beijing, resulting in a large amount of gas leakage, and the high voltage wire above the gas pipeline ignited the leaked gas. The fire department had taken steps to isolate the fire area from the surrounding area and controlled the fire in a relatively steady state. Relevant departments have done excellent personnel evacuation in time and prevented casualties. The gas company quickly repaired the damaged gas pipeline. Consequently, the leak and fire incident did not cause serious consequences.

This incident calls for us to further think about the relationship between gas pipelines and facilities and other facilities in the city and to re-examine whether the relevant provisions in the codes and standards meet the safety requirements. The concept of "intrinsically safe" should run through all stages of planning, design, construction, and operation and become the essential requirement to ensure the safety of gas facilities and cities.

Figure 1-5 Fire at the incident scene

Figure 1-6 Gas pipeline weld defects.

6) Xiamen "11-25" gas explosion - a significant liability accident for gas violations

At 8:27 on 25th November 2014, a gas explosion occurred at a Sichuan-style restaurant in Xiamen. The accident caused four deaths, three injuries, four shops damaged to different degrees, with a direct economic loss of 266,000 RMB.

The investigation revealed that at the end of 2012, the owner of the Sichuan-style restaurant had remodelled the restaurant's kitchen and was using 50 kg YSP118 LPG cylinders without setting up a dedicated gas cylinder room. Subsequently, the safety management system for gas use was not set up despite gas leakage. No particular person was designated to manage gas facilities and equipment safety, resulting in a long-term safety risk of the Sichuan restaurant, which evolved into a significant accident.

On the day of the incident, the LPG cylinder valve in the kitchen and the valve connected to the cylinder was in the open state, and the LPG leaked and mixed with air to form an explosive mixture, which exploded after meeting a fire source.

The District People's Court held that the restaurant owner was responsible for organising, directing, and managing the production and operation, but violated the safety regulations, resulting in an accident that killed four people, injured many others, and damaged property. The court ruled that the restaurant owner was mainly responsible for the accident, and the circumstances were so dire that it constituted a crime of significant liability accident. However, considering that he has voluntarily turned himself in and actively compensated for the victims' economic losses, a lighter punishment could be appropriate. In the end, the court sentenced the restaurant owner to a fixed term of imprisonment for the crime of significant liability for the accident.

Figure 1-7 Scene of the accident at Xiamen gas explosion

CHAPTER 2

ESSENTIAL LAWS AND REGULATIONS FOR SAFE PRODUCTION

Safe production refers to the production and business activities, which avoid accidents, injury to people, and property damage. It takes corresponding prevention and control measures to carry out the production process following the prescribed conditions. Additionally, safe production ensures that production and related business activities can be carried out smoothly, i.e., employees' safety and health, equipment facilities, and the environment from damage.

Laws and regulations refer to the laws, administrative regulations, judicial interpretations, local regulations, local rules, departmental regulations, and other normative and compulsive documents, including the amendments and additions. As an essential part of the national legal system, safe production laws and regulations are the general terms that stipulate and adjust safe production relations.

Safe production laws and regulations originated in the late Industrial Revolution of the 18th century, which was the need for the technological development of industrial production and the promotion and struggle of the workers' labour movement. The human safe production laws and regulations have gone through a long process of non-existence, then a single rule that only applies to a specific scope (industry, region, workers) to a comprehensive system with a broader range of application and perfection.

2.1 Overview of Chinese Safe Production Laws and Regulations

Following the guiding principle of "safety first, prevention first, and comprehensive management" established in *Safe Production Law of the People's Republic of China*, China has developed a series of product safety laws, regulations, and standards and has formed a relatively complete system of production safety laws and regulations.

2.1.1 Concept of safe production laws and regulations

Safe production laws and regulations refer to the sum of laws and regulations governing the various social relations arising from the production process, including those relating to the safety and health of workers or production personnel and the safety of the means of production and social wealth. All of these compose an essential part of the state's legal system. They regulate social relations by stipulating the rights and duties among people to ensure the stability and development of society and safeguard the fundamental interests of the state and people. Safe production laws and regulations first adapt to the various relationships and behaviours associated with safe production that occur in the company's production and operating activities. It includes the relationship between production units and their employees; the relationship between production units and the safe production intermediaries, which provide the technical services; and the relationship between employees of production units and the relevant state organs and social organisations. Laws, rules, regulations, statutes, decisions, ordinances, and standards issued by *the Standing Committee of National People's Congress*, *the State Council of the People's Republic of China* and the relevant ministries and commissions, and the local people's congresses and local governments concerning safe production, occupational safety and health, and labour protection, all these fall within the scope of safe production regulations.

Safe production laws and regulations stipulate the behaviours rules of production, which are legal and could be done, illegal and forbidden, which must be done under what circumstances and which should not be done. They use the compulsory power of the state to maintain the regular order of safe production in enterprises. Therefore, with various safe production laws and regulations, the state can make the safety management work, which aimed to "possess laws to follow, guarantee laws to be followed, enforce the law must be strict, against laws must be traced". Violation of legal requirements will be subject to specific legal responsibilities and sanctions following the laws.

2.1.2 Forms of Chinese safe production laws and regulations

The primary forms of safe production laws and regulations include laws, administrative regulations, local regulations, rules, and various professional and technical norms and regulations.

The *Constitution* has the most substantial legal effect among all the laws and regulations about safe production. All laws, administrative regulations, local regulations, autonomous regulations, and single-row regulations and rules shall not contradict the Constitution. The administrative regulations have a higher effect than local regulations and rules, and local authorities have a higher impact than local government regulations on their level and lower levels. Departmental regulations have an equal effect among themselves and between the departmental and local government regulations and shall be applied within the limits of its authority. When the inconsistency appears between the special and general provisions of laws, administrative regulations, local ordinances, autonomous ordinances, and individual ordinances and regulations made by the same authority, the special provisions shall be applied. When the inconsistency between new and old provisions appears, the new provisions shall be applied. When the inconsistency appears between local ordinances and departmental regulations of the relevant state agencies on the same matter, and uncertain how to use them, the State Council shall issue the opinion. When the State Council deems that local regulations should be applied, it shall propose that the judgment of *the National People's Congress Standing Committee* should be applied in that place. When departmental regulations should be applied, it shall submit them to *the Standing Committee of the National People's Congress* for a ruling. When the inconsistency appears between departmental regulations or between the departmental and local government regulations on the same matter, *the State Council* shall make a ruling.

Professional and technical specifications and procedures are legal documents that adjust the relationship between people and product safety in production and business activities. According to the natural laws and scientific and technological research results, people formulate them to engage in effective and safe production and operation activities. They stipulate the primary forms of human behaviour, material status, and environmental factors in the production and operation activities. Violating the technical norms and regulations may endanger the personal safety of the workers, and threaten the production and living environment, as well as the social environment. Furthermore, it may cause individual casualties, property losses, and environmental damage.

2.1.3 Roles of safe production laws and regulations

In the production process, safe production laws and regulations play an essential role in ensuring the smooth progress of production and construction and promoting the development of productive forces. China's

safe production laws and regulations reflect the fundamental interests of the broad masses of people represented by the *Party* and the *State* on behalf of the public.

The main functions of safe production laws and regulations include:

1) Safeguarding workers' legitimate rights and interests in safety and health. Chinese safe production laws and regulations set out administrative norms for safe behaviour and the material conditions required to achieve safe production and ensure the safety and health of workers in terms of production technology and equipment. Through safe production legislation, the safety and health of workers are guaranteed, and employees can work under conditions that satisfy the safety and health requirements.

2) Strengthening the legalised management of safe production. The safe production laws and regulations stipulate the responsibilities of relevant departments, enterprises, and leaders at all levels in safe production management and strengthen the importance of labour protection work.

3) Guiding and promoting the process of safe production. The safe production laws and regulations reflect the objective rules that must be followed to protect the regular progress of production and the safety and health of workers. The safe production work is promoted through the law's binding force and the state's coercive power.

4) Ensuring the smooth progress of production and national economic construction career. Safe production is directly related to the immediate interests of enterprises. Through the compliance and implementation of the safe production technical regulations and standards, the safety of the production process can be effectively improved so that the efficiency of production can be guaranteed and improved, finally improving the production efficiency and effectiveness of enterprises.

5) Promoting the improvement of social productivity. The safe production laws and regulations put forward mandatory requirements for the safety and health conditions of production in line with production and construction, which forces leaders at all levels to take corresponding measures in production and management decisions, technical equipment. To improve labour conditions, enhance safety, accelerate technological transformation, and ultimately promote general social productivity.

2.2 Interpretation of Essential Laws and Regulations on Safe Production

2.2.1 Interpretation of *Labour Law of the People's Republic of China*

The *Labour Law* is a fundamental law that focuses on regulating labour relations, safeguards human rights, and reflects the concern for the human person. The content of the *Labour Law* mainly includes the principal rights and obligations of workers, labour employment policies and the provisions of employing workers, the requirements of labour contract conclusion, change and termination procedures, the signing and implementation measures of collective contracts, working time and rest time system, labour remuneration system, labour health and technical safety procedures.

Labour Law of the People's Republic of China (from now on referred to as *Labour Law*) was enacted based on the *Constitution* to protect the legitimate rights and interests of workers, to regulate labour relations, to establish and maintain a labour system adapted to the socialist market economy, and to promote economic development and social progress. *Labour Law* came into effect on 1st January 1995 and amended some clauses on 27th August 2009.

For the first time, *Labour Law* elevated labour policy to the level of a legal norm, established the basic framework of the labour legal system, adapted to the needs of the reform of the market economy, and, to a certain extent, played a role in regulating labour relations and safeguarding the rights and interests of workers under the conditions of the market economy. The implementation of this law has played an essential role in protecting the legitimate rights of workers, harmonising labour relations, stabilising social order and promoting the reform process of various labour systems.

The basic principles of *Labour Law* include three aspects: the principle that labour is both right and duty, protecting the legitimate rights and interests of workers and the principle of a reasonable allocation of labour resources.

Labour Law provides for the rights comprehensively enjoyed by workers in terms of the right to equal choice of employment, the right to remuneration for labour, the right to rest, social insurance and welfare. It further protects workers' rights by stipulating the responsibilities of the *state* and employers, such as promoting employment and providing vocational training.

Labour Law also stipulates the rights enjoyed by the employer, including the right to establish and improve rules and regulations under the law, the right to set reasonable labour quotas, the right to conduct occupational skills assessment of workers, the right to establish safe production operating procedures, the right to set lawful working hours, the right to set standards of labour discipline and professional ethics and the right to submit labour disputes, and the right to conclude labour contracts on an equal footing.

2.2.2 Interpretation of *Safe Production Law of the People's Republic of China*

Safe Production Law of the People's Republic of China (from now on referred to as *Safe Production Law*) came into effect on 1st November 2002 and has been amended twice, on 27th August 2009 and 1st December 2014. *Safe Production Law* consists of chapters and 114 articles, including the general provisions, safeguards for the safe production of production units, rights and obligations of employees in the safe production, supervision and management of safe production, emergency rescue and investigation, and treatment of safe production accidents, legal responsibilities, and by-laws.

Safe Production Law is a comprehensive law on safe production, with rich legal connotations and normative functions. Its adoption, amendment, and implementation have played an essential role in establishing the rule of law in safe production, preventing and reducing production accidents, and safeguarding the lives and property of the people.

According to *Safe Production Law*, the concept of people-oriented and safe development should be established in safe production. The safety management model should be innovated. The primary responsibility of enterprises should be implemented. The capacity of supervision and law enforcement and emergency response should be improved. The enterprises should prioritise prevention and strictly enforce the responsibility for safe production. Both the symptoms and the root causes should be addressed. People's lives and property should be safeguarded by eliminating the potential dangers.

The *Safe Production Law* aims to strengthen safe production and prevent and reduce safe production accidents, safeguard the lives and property of the people, and promote the sustainable and healthy development of the economy and society.

In the general provisions of *Safe Production Law*, it is clearly stated that safe production should be people-oriented, that it should be based on secure development and that it should be based on the "red line awareness". This "red line awareness" reflects the high attached to labours' lives.

Safe Production Law clarifies the critical status, main tasks, and fundamental means of achieving safe production. It proposes that the working principles of safe production are "safety first, prevention first, and comprehensive management". The addition of "comprehensive treatment" as one of the guidelines for safe production summarises Chinese practical experience in safe production and a deep understanding of the common laws governing safe production. Safe production is a systemic project that requires coordination and concerted efforts on all fronts. It is a comprehensive approach that addresses both the symptoms and the root causes, the use of legal, economic, administrative, technical, and managerial means, and the total mobilisation of the forces of society as a whole for group prevention and control to achieve the desired goal.

Safe Production Law requires "establishing a safe production mechanism in which production and operation units are responsible, and employees participate, the government supervises, the industry self-regulates, and the society supervises."

Safe Production Law sets forth the "three imperatives", requiring that industry administration charge the safety, operation, production, and management. It is a concrete manifestation of the "comprehensive management" approach to safe production.

The requirements of the *Safe Production Law* concerning safe production supervision and law enforcement are as follows. Firstly, it stipulates that the *State Council* and the local people's governments at or above the county level shall establish a sound mechanism for coordinating work on safe production to coordinate and resolve significant issues in the supervision and administration of safe production on time. Secondly, it stipulates that safe production supervision and administration departments at all levels of government shall carry out comprehensive management and administration. Within the scope of their respective functions and duties, the relevant departments shall supervise and administer safe production in the appropriate "industries and fields". Thirdly, it is clear that production safety supervision and management departments at all levels and other departments with production safety supervision and management responsibilities, as administrative law enforcement departments, carry out administrative law

enforcement work in production safety following the law. The executive law enforcement departments supervise and inspect the implementation of laws, regulations, national standards, or industry standards by production and operation units.

At the legislative level, *Safe Production Law* clarifies the responsibilities of townships and streets in the work of safe production. In response to the practical problems in the local safety regulatory system, it makes clear that the people's government of township and the organs of local people's governments, such as neighbourhood offices and development zone management agencies, should strengthen their supervision and inspection of the workplace safety of production and management units within their administrative areas and assist the relevant departments of the people's governments at higher levels in carrying out their workplace safety supervision and management duties under the law.

Safe Production Law clarifies the establishment, staffing standards, and work responsibilities of safe production management bodies and personnel in production and management units. It specifies that mines, metal smelting, building construction, road transport units, and units for the production, operation, and storage of dangerous goods shall set up safe production management bodies or deploy full-time safe production management personnel. Other production management units with more than 100 employees shall set up specialised bodies or deploy full-time personnel. The seven duties of safe production management bodies and managers are stipulated, including the formulation of safe production rules and regulations, operating procedures and emergency rescue plans for the unit, organising the promotion and implementation of safe production laws and regulations, organising education and training in the safe production, stopping and correcting unregulated commands and violations of operating procedures, and supervising the implementation of corrective measures for safe production in the unit. It requires that production and operating units listen to the views of safe production management bodies and managers when making business decisions involving safe production.

Safe Production Law emphasises the strengthening of primary prevention and the investigation and treatment of the potential dangers. It requires that production and operating units establish a system of analysis and management of the potential risks and take technical and management measures to eliminate them. Relevant government departments must develop and improve a system for supervising the significant potential dangers and urge production and operating units to eliminate the potential risks. Administrative penalties must be imposed for failure to establish a

plan to investigate and manage the potential dangers and take adequate measures to eliminate them.

Safe Production Law clarifies that production and operating units shall promote the standardisation of safe production and raise the level of intrinsic safe production.

Safe Production Law stipulates that production and storage units of dangerous goods and mining and metal smelting units shall have registered safety engineers engaged in safe production management and encourage others to employ registered safety engineers.

To increase the source of funds for emergency relief and compensation for victims of accidents other than those employed in the accident units, the government encourages production and management units to take out safe production liability insurance. Insurance is not only a form of financial compensation; it is also an economic system of risk-sharing and risk prevention.

2.2.3 Interpretation of *Law of the People's Republic of China on Response to Emergencies*

Law of the People's Republic of China on Response to Emergencies (from now on referred to as *Law of Response to Emergencies*) came into effect on 1st November 2007. *Law of Response to Emergencies* consists of 7 chapters and 70 articles, including the general provisions, prevention, emergency preparedness, monitoring and early warning, emergency response and rescue, post-emergency recovery and reconstruction, legal responsibilities, and by-laws.

The Law of Response to Emergencies is a vital law to standardise the working principles of emergency response and the work requirements of all stages of prevention and emergency response. The purpose of the legislation is to improve the ability of all aspects of society to respond to emergencies under the law, timely and effectively to control, mitigate and eliminate the severe social hazards caused by emergencies, to protect the safety of people's lives and property, and to safeguard national security, public security, environmental security and social order.

The Law of Response to Emergencies grants the government several emergency responses powers, the following main provisions.

(1) In the event of a natural disaster, accident or public health incident, the people's government shall exercise unified leadership and take emergency response measures. Those measures include organising rescue and treatment of victims, evacuating and properly relocating the threatened persons and taking other relief measures, controlling the danger sources rapidly, marking danger zones, cordoning off dangerous places, designating warning zones, exercising traffic control and other criteria. Immediate repair of damaged public facilities such as transportation, communications, water supply, drainage, electricity supply, gas supply, heat supply; provision of shelter and necessities of life to persons exposed to hazards; implementation of medical care and epidemic prevention and other safeguards; prohibition or restriction of the use of relevant equipment and facilities, closure or regulation of the use of appropriate places, suspension of activities with a high concentration of people or production that may lead to the expansion of hazards; the people's governments at this level shall take other protective measures; activate the financial reserves and emergency relief materials set up by them, and call on other urgently needed materials, equipment, facilities and tools when necessary; organise the participation of citizens in emergency relief and disposal work, and request the services of persons with specific expertise; and ensure the supply of necessities of life such as food, drinking water and fuel.

(2) After a social security incident has occurred, the relevant people's government shall: immediately organise the relevant departments to take measures such as compulsory isolation of the parties concerned, blocking off the appropriate places and roads, controlling the relevant areas and facilities, and strengthening the guarding of core organs and units under the law; in the event of an incident that seriously endangers the social security order, the public security authorities may also take corresponding compulsory measures under the law in the light of the situation at the scene.

- *Law of Response to Emergencies* authorises the *People's Government* the following powers:

The Emergency Response Law also empowers the People's Government to: punish severely, following the law, acts that disrupt the market order, such as hoarding, price hiking and counterfeiting, stabilise market prices and maintain market order. According to the law, the government shall severely punish acts that disturb the social order, such as looting property, disrupting emergency response work, and maintaining social security. The government takes necessary measures to prevent secondary and derivative incidents.

- *Law of Response to Emergencies* bind the government to perform its duties with eight high-pressure lines:

Where local governments at all levels and relevant departments of the people's government at or above the county level violate the provisions of this law and fail to perform their statutory duties, the supervisors and other persons directly responsible shall be punished under the law. The scope of the sanctions includes those:

1) Failed to take the required precautions that lead to an unexpected event or failure to take the necessary precautions that lead to the occurrence of a secondary or derivative event.

2) Delayed, false, concealed, or omitted information about the emergency, or notified, reported, or published incorrect information, resulting in damage.

3) Failed to issue emergency alerts and failed to take measures for the warning period on time, resulting in damage.

4) Failed to take timely measures to deal with an emergency or improperly handled an emergency, resulting in damage.

5) Disobeyed the unified leadership, command, and coordination of the people's government at a higher level in handling emergencies.

6) Failed to organise timely self-help production, rehabilitation and reconstruction, and other rehabilitation work.

7) Intercepted, misappropriated, or privately treated the emergency relief funds and materials.

8) Failed to return the expropriated property on time or failed to compensate the units and individuals as required.

- To protect civil rights significantly, the *Law of Response to Emergencies* stipulates clearly:

The measures to respond to an emergency taken by the government and its departments shall be commensurate with the nature, extent and scope of the social harm that may result from the emergency. The maximum protection of citizens' rights and interests

According to the *Law of Response to Emergencies*, the government concerned and its departments may expropriate the property of units and individuals to respond to emergencies. "However, the expropriated property shall be returned promptly after it has been used or after the emergency

response work for an emergency incident has been completed. If the property is destroyed or lost after being expropriated or expropriated, compensation shall be paid."

- Establishing a unified national information system for emergencies, the *Law of Response to Emergencies* stipulates that：

The local People's Governments at or above the county level shall establish or determine a unified emergency information system for their region. At all levels, the local People's Governments shall report emergency information to the People's Government at the higher level following the relevant national regulations. The relevant authorities of the People's Government at or above the county level shall notify the relevant departments of the People's Government at this level of the emergency information. Professional organisations, monitoring networks, and information reporters shall report emergency information to the local government and relevant authorities on time. Citizens, legal persons, or other organisations informed of emergency incident information shall immediately report it to the local People's Government, the relevant competent department, or the designated professional body. Any unit or individual reporting information on emergencies should be timely, objective, and truthful and should not be late, misrepresented, concealed, or omitted.

Law of Response to Emergencies stipulates that the People's Government performing unified leadership duties or organising the handling of emergency events shall, following the relevant provisions, release unified, accurate, and timely information on the development of emergency events and the emergency handling work. Decisions and orders made by the appropriate people's governments and their departments in response to emergencies shall be made public on time.

A particularly significant emergency occurs and poses a substantial threat to the safety of people's lives and property, national security, public security, environmental security or social order. The *Standing Committee of the National People's Congress* or the *State Council* shall decide to enter a state of emergency, following the authority and procedures stipulated in the *Constitution* and other relevant laws if the government fails to eliminate or effectively mitigate its severe social hazards.

(1) Classification and grading of emergencies

Law of Response to Emergencies classifies emergencies into four major categories: natural disasters, accidents and disasters, public health events,

and social safety events.

According to factors such as the degree of social harm and the scope of influence, the *Law of Response to Emergencies* classifies natural disasters, accident disasters, and public health events into four levels: particularly significant, significant, large, and general.

(2) Management mechanism for emergencies

Law of Response to Emergencies stipulates that the state shall establish a mechanism for emergency management based on unified leadership, comprehensive coordination, classified management, hierarchical responsibility, and territorial management. In responding to emergencies, the People's Governments at all levels must provide unified leadership and establish an emergency response command structure, which is composed of the main person in charge of the government, the persons in charge of the relevant departments, and the appropriate persons in charge of the resident *Chinese People's Liberation Army* and the *Chinese People's Armed Police Force*, to exercise unified command of the response.

To clarify the responsibilities of governments at all levels, the *Law of Response to Emergencies* stipulates that: the People's Governments at the county level are responsible for responding to emergencies within their administrative areas; when an emergency occurs, the People's Governments at the county level in the place where the emergency occurs shall immediately carry out advance treatment; natural disasters, accidents and catastrophes, and public health incidents at the level of general and large shall be under the unified leadership of the governments at the county level and the municipalities in which they are located, respectively; natural disasters, accidents and catastrophes, and public health incidents at the level of significant and particularly significant shall be under the unified leadership of the governments at the county level and the municipalities in which they are located, respectively. In the case of social safety incidents that affect the entire country, span provincial administrative regions, or exceed the capacity of provincial governments to handle, the People's Government shall exercise the unified leadership of the State Council at the provincial level where the incident occurred. Social safety incidents are to be handled by the People's Government at the county level where they occur, while the People's Government at a higher level may, if necessary, organise the handling directly.

Implementing the "primary management in the territory" principle requires local governments to respond promptly and handle the situation on time.

However, local management as the mainstay does not exclude the guidance of higher-level governments and their relevant departments in their work, nor does it exempt other departments in the area of occurrence from their obligation to cooperate.

(3) Emergency Prevention and Emergency Preparedness

Law of Response to Emergencies stipulates that: governments at all levels and relevant government departments shall formulate and revise emergency response plans at the appropriate time and strictly implement them; urban and rural planning shall be consistent with the need to prevent and deal with emergencies and to safeguard national safety, public safety, environmental safety, and social order; county-level governments shall strengthen the monitoring and control of dangerous sources and areas within their administrative regions and order the relevant units to take adequate safety measures; the People's Governments at the county level shall take all necessary measures to prevent and deal with emergencies. The preventive measures should be taken, supervised and inspected. All units should establish and improve their safety management systems. They will equip themselves with alarm devices and the necessary emergency rescue equipment and facilities, eliminate the potential dangers on time, and grasp and handle any problems that emergencies may cause in their units. Grassroots organisations and units, such as neighbourhood committees, village committees, and autonomous organisations, should regularly investigate and settle disputes to prevent conflicts from intensifying. At or above the county level, people's governments shall establish and improve a training system for relevant government staff and its departments on emergency management knowledge and laws and regulations. Relevant departments shall integrate emergency resources, establish a sound system of comprehensive, professional, full-time and part-time, volunteer emergency rescue teams and strengthen training and drills. The *Chinese People's Liberation Army* and the *Chinese People's Armed Police Force* and militia organisations shall organise special training in emergency rescue knowledge and skills in a planned manner.

The People's Governments at the county level and their relevant departments, the People's Governments at the township level, street offices and grassroots mass self-governing organisations, and appropriate units should organise and conduct publicity and popularisation activities, and necessary emergency response exercises and the news media should carry out public-interest publicity on emergency response knowledge free of charge. The schools and other educational institutions at all levels and in all categories

should make emergency knowledge an essential element of quality education for students.

At or above the county level, the People's Governments should guarantee the funds needed for the emergency response work. The *State* should establish and improve the supervision, production, storage, allocation, and emergency distribution of essential emergency supplies and improve the emergency supplies of the reserve guarantee system and the emergency communications guarantee system.

(4) Monitoring and Early Warning of Emergencies

The Law of Response to Emergencies stipulates that the local People's Governments at or above the county level shall establish a unified information system for monitoring and early warning of emergencies in their regions. They should develop a system of full-time or part-time information rapporteurs in residents' committees, villagers' committees and the relevant units to obtain the related information from various sources.

The state shall establish a sound early warning system for emergencies. The early warning levels for natural disasters, accidental disasters and public health events that can be warned of are classified into Level I, II, III and IV according to the degree of urgency, development situation, and possible harm caused by the unexpected event. They are indicated in red, orange, yellow and blue, respectively, with level I being the highest level.

(5) Emergency response and rescue measures for unexpected events

After an emergency incident, the government shall immediately organise emergency disposal and rescue work, mobilise emergency rescue teams and social forces, and take emergency disposal measures to mitigate and eliminate the damage it causes to people's lives and property.

(6) Post-incident recovery and reconstruction

After the threat and harm caused by a sudden incident have been controlled or eliminated, post-incident recovery and reconstruction work should be organised immediately to mitigate the losses and effects as soon as possible and appropriately resolve the contradictions and disputes.

Requirements for the gas industry under *Law of Response to Emergencies*:

1) When an emergency occurs, the source of the danger should be quickly controlled, the danger zone marked, the place cordoned off, the area

cordoned off, traffic control and other control measures implemented. The damaged public facilities such as gas supply should be immediately repaired. The collection of fuel and other necessities of life should be ensured.

2) Following a social security incident, the supply of fuel and gas in a specific area should be controlled.

2.2.4 Interpretation of *Management Measures for Emergency Response Plan*

Management Measures for Emergency Response Plan (referred to as *Measures*) came into effect on 25th October 2013. *Measures* have nine chapters and a total of 34 articles, including general provisions, classification, and content, preparation of emergency plans, approval, filing and publication, emergency drills and exercises, evaluation and revision, training and propaganda and education, organisation and safety, and by-laws.

China has been promoting emergency preparedness since the fight against SARS and has achieved remarkable results. Emergency plans have played an irreplaceable role in strengthening emergency preparedness and responding effectively to emergencies. However, there are still pertinence problems, practicality, operability, and insufficient training and exercises. *The Management Measures for Emergency Response Plan* is an important measure to implement the *Law of the People's Republic of China on Response to Emergencies*, strengthen emergency management and further promote the construction of an emergency response plan system. *Measures* clarify the concept of emergency preparedness and related requirements for the first time at the national level.

The emergency plan refers to the work plan formulated in advance by the People's Governments at all levels and their departments, grassroots organisations, enterprises, institutions, and social groups to respond to emergencies lawful, rapid, scientific, and orderly.

An emergency plan is a necessary complement to laws and regulations, a specific implementation plan within legal norms according to the needs of a particular region, sector, industry, and unit in response to an emergency. It is a program of work designed to improve the speed of emergency response in a shift from the normal to the extraordinary.

The emergency plan is an essential carrier of the institutional mechanism and is a response plan based on the available resources. In the emergency plan, pre-arrangements should be made for the emergency organisation

system and responsibilities, personnel, technology, equipment, facilities and equipment, materials, rescue operations and their command and coordination to clarify responsibilities, disposal methods, and resources preparation. It is a list of tasks, working procedures, and linkage agreements formulated in advance for responding to emergencies.

The emergency plan focuses on regulating the post-incident response work and extends forward and backwards appropriately. The forward extension mainly refers to the necessary monitoring and warning. The backward extension refers to the recovery of the emergency required, including effective prevention and response to secondary and derivative events.

For the first time, *measures* put forward requirements on the management principles of emergency preparedness plans at the national level, making it clear that emergency preparedness plans should follow "unified planning, classification and guidance, graded responsibility and dynamic management".

Measures divide emergency plans into two main categories according to their formulation: emergency plans for the government and its departments and emergency plans for units and grassroots organisations.

1) Emergency preparedness of the government and its departments

The government's emergency plans and departments are divided into general, unique, and departmental emergency plans.

The general emergency plan is the general outline of the emergency plan system, which mainly stipulates the basic principles, organisation system, operation mechanism, and available arrangements for emergency response and specifies the responsibilities and tasks of all parties concerned.

The particular emergency plan involves the responsibilities of several departments, which are formulated in advance to deal with a specific type or several types of emergencies or to deal with particular crucial work such as important target protection, significant activities, and emergency resources.

The departmental emergency plan is a work plan formulated in advance to deal with an emergency of the department (industry or field) or to protect essential targets, significant activities, emergency resources, which involves the work of several departments.

The emergency plans of the *State Council* and its departments focus on national-level response actions, reflecting both policy and guidance. The

provincial government's emergency plans and departments focus on provincial-level response actions, reflecting direction. The emergency plans of municipal and county People's Governments and their departments focus on municipal and county-level response actions, reflecting the main functions of emergency response. The emergency plans of the township People's Governments focus on regulating response actions at the township level and reflect the characteristics of pre-emptive disposal.

2) Emergency preparedness of units and grassroots organisations

Emergency plans for units and grassroots organisations are formulated by legal persons and grassroots organisations such as organs, enterprises, institutions, social groups and neighbourhood and village committees. The emergency plan focuses on rescue work at the scene, e.g., clarifying the responsibility for emergency response, monitoring risks and hazards, reporting information, responding to early warning, organising evacuation and requesting emergency resources and assistance. The emergency plan should reflect self-help, information reporting, and pre-emptive disposal features.

***Measures* recognises city gas supply as a lifeline project.**

1) Confirm city gas supply as one of the lifeline projects. Clarify that the emergency plan to protect essential infrastructure, lifeline projects, and other essential targets should focus on risk and preventive measures, monitoring and warning, information reporting, emergency disposal, and emergency recovery.

2) Large enterprise groups can establish their emergency planning system following relevant standards and norms and actual working needs concerning international practices.

3) The emergency plans of enterprises and institutions focus on clarifying who is responsible for emergency response, monitoring risks and hazards, information reporting, early warning response, and emergency disposal. Emergency plans should also focus on evacuation organisation and routes, emergency resources that can be called upon or requested and how they will be implemented. The emergency plan reflects self-help features, information reporting and pre-emptive disposal.

2.3 Interpretation of Relevant Laws and Regulations in the City Gas Industry

The city gas industry, like other industries, should first abide by the national laws and regulations, especially pay attention to the content related to the production and management of the industry. At the same time, the planning and design, construction, completion acceptance, operation management, maintenance, testing, and inspection of city gas systems have also formulated relevant technical specifications, procedures, and standards.

1) In terms of planning and design, there are GB/T 51098 *Code for Planning of City Gas*, GB50494 *Technical Code for City Gas*, GB50028 *Code for Design of City Gas Engineering*, NB/T1001 *Technical standard for vehicle liquefied natural gas fuelling station*, GB 50016 *Code for Fire Protection Design of Buildings*.

2) In construction and completion acceptance, there are technical norms including CJJ33 *Code for Construction and Acceptance of City and City gas Distribution Works*, CJJ94 *Code for Construction and Quality Acceptance of City Indoor Gas Engineering*, CJJ63 *Technical Standard for Polyethylene(PE) Gaseous Fuel Pipeline Engineering*, GB 50156 *Code for Design and Construction of Filling Station*, CJJ/T147 *Technical Specification for Trenchless Rehabilitation and Replacement Engineering of City Gas Pipe*, CJJ12 *Specification for Installation and Acceptance of Domestic Gas Burning Appliances*.

3) In operation management and maintenance, there are CJJ51 *Technical Specification for Safety of Operation, Maintenance and Rush-Repair of City Gas Facilities*, GB/T50811 *Standard for the Operation Safety Assessment of Gas System*, CJJ61 *Technical Specification for Detecting and Surveying Underground Pipelines and Cables in City*, CJJ95 *Technical Specification for External Corrosion Control of Buried Steel Pipeline for City Gas*.

4) In terms of facility testing and inspection, there are GB16914 *General Safety Technique Conditions of Gas Burning Appliances*, GB/T16411 *Universal Test Methods of Gas Burning Appliances for Domestic Use.*

These norms and regulations provide a basis for the healthy and orderly development of China's city gas industry. There are "laws to follow" within the industry, and a code of conduct for enterprises and technical personnel should be formulated. However, as China's town gas industry is undergoing rapid development, technology, equipment, and facilities are changing

rapidly, and the level of construction, operation and management is gradually improving. Therefore, there is an urgent need to establish and strengthen the system and content of applicable regulations, further standardise the industry codes and regulations, and improve their theoretical and operability.

2.3.1 Interpretation of *The Regulations on the Administration of City Gas*

The Regulations on the Administration of City Gas (referred to as the "*Administrative Regulations*") came into force on 1st March 2011.

The problems existing in China's city gas industry are listed as follows. The division of responsibilities among government departments is overlapping, the administrative management system needs to be rationalised, and the industry's regulatory mechanism is imperfect; the gas development planning is lagging behind, with duplicate construction, arbitrary gas supply stations and mismatched facility construction; the gas emergency reserve and emergency dispatching system is not sound, with insufficient supply capacity and weak emergency guarantee capacity; the development of upstream, midstream and downstream is not coordinated, with a single source of gas, low trunk pipeline capacity and the prominent contradictions between supply and demand; the gas management system is imperfect, with illegal operation, disorderly competition and unregulated service behaviour; the construction of peaking facilities such as underground gas storage lags behind, lacking seasonal peaking capacity; the safety management system is not sound, safety measures are not implemented, and gas accidents occur repeatedly; the necessary gas safety accident prevention and handling mechanisms are lacking.

The purpose of the legislation of the *Administrative Regulations* is to strengthen the management of city gas; to ensure the supply of gas; to prevent and reduce gas safety accidents; to protect the lives of citizens, property safety, and public safety; to safeguard the legitimate rights and interests of gas operators and gas users; to promote the healthy development of the gas industry. The main thread running through the legislation of the *Administrative Regulations* is "highlighting safety regulation".

The *Administrative Regulations*' application scope includes the development planning and emergency safety of city gas, gas operation and services, gas use, protection of gas facilities, prevention and handling of gas safety accidents, and related management activities. The provisions of these

Administrative Regulations govern gas management in rural areas.

(1) The principles and functions of the gas management system

The functions of the People's Government are: to strengthen the leadership of gas work and incorporate gas work into the national economic and social development plan; to approve the gas development plan for this administrative region; to increase investment in the construction of gas facilities and encourage social funds to invest in the construction of gas facilities; to establish and improve the gas emergency reserve system, organise the preparation of gas emergency plans, and take comprehensive measures to enhance the ability of gas emergency safety. The use of reserves and emergency dispatch following emergencies like severe gas supply shortages and supply disruptions.

The functions of the construction authority under the *State Council* are: to be responsible for gas management in the country, organise the preparation of the national gas development plan and organise its implementation.

The functions of the gas management departments of local People's Governments at or above the county level are: to be responsible for gas management within the administrative region; to organise the preparation of the gas development plan for the administrative region, report it to the People's Government at this level for approval and then manage its implementation, and report it to the gas management department of the People's Government at a higher level for the record; to monitor, forecast and provide early warning of the gas supply and demand situation; to issue gas operating licenses; to delineate the protection scope of gas facilities and announce it to the public; to approve the alteration of municipal gas facilities.

The functions of other relevant departments of the People's Government at or above the county level are: to be responsible for the management of gas following these regulations and other applicable laws and regulations within their respective spheres of responsibility.

(2) Gas emergency reserve system

The local People's Governments at or above the county level shall establish and improve the gas emergency reserve system; gas operators shall strengthen the daily peak reserve and emergency reserve of gas to ensure a continuous, stable, and safe supply of gas.

(3) Gas emergency planning system

Local people's governments at or above the county level shall organise the preparation of gas emergency plans. Local people's governments at or above the county level shall take comprehensive measures to improve the emergency protection capacity of the gas. The gas emergency plan shall specify the gas emergency sources and types, emergency supply methods, emergency disposal procedures and emergency rescue measures.

(4) Gas emergency monitoring, forecasting, and early warning system

The gas management department of the local People's Government at or above the county level shall, in conjunction with relevant departments, monitor, forecast, and provide early warning on the gas supply and demand situation.

(5) Gas emergency measures system

After the occurrence of an emergency such as a severe shortage of gas supply or interruption of gas supply, the local People's Government at or above the county level shall promptly take emergency measures such as the use of reserves and emergency dispatch. The gas operator and other relevant units and individuals shall cooperate and undertake appropriate emergency tasks.

(6) Gas operating license system.

Clarify the conditions and approval procedures for obtaining a gas operating license. Individuals are prohibited from engaging in piped gas business activities. Individuals engaging in bottled gas business activities shall comply with the relevant provisions of provinces, autonomous regions, and municipalities directly under the central government.

(7) Obligations of gas operators

The obligations of gas operators are: to provide gas users with a continuous, stable, and safe supply of gas that meets national quality standards; to guide gas users on the safe and economical use of gas; to conduct regular safety inspections of gas facilities; to publicise information on business processes, service commitments, tariffs, and service hotlines; and to provide services following national gas service standards.

(8) Prohibited acts of gas operators

Prohibited acts of gas operators include: refusing to supply gas to units or individuals within the coverage of the municipal gas pipeline network who meet the conditions for gas consumption; selling, mortgaging, leasing, lending, transferring or altering the gas operating license; stopping the gas supply, adjusting the amount of gas supplied, or suspending or closing the business without approval without fulfilling the necessary notification obligations; providing gas operating licenses to units or individuals who have not obtained gas operating permits for the purpose of business; storing gas in premises that are not in a safe condition; requiring gas customers to purchase products or receive services specified by them; filling gas for non-owned cylinders without authorisation; selling bottled gas filled by unauthorised filling units or selling bottled gas filled by filling units without permission for non-owned cylinders; impersonating the name or logo of another enterprise to engage in gas business or service activities.

(9) Liability of piped gas operators

Pipeline gas operators shall be responsible for the operation, maintenance, repair, and renewal of municipal gas facilities within the scope of their gas supply, as well as the gas facilities outside the owner's only part within the building zone. The piped gas operator shall assume responsibility for managing the gas facilities of unit gas users following the agreement of the gas supply and consumption contract.

(10) Regulatory responsibilities of the gas management department in the operation and service sector

The gas management department shall take measures to protect the regular gas supply of gas users in the following cases: the piped gas operator temporarily adjusts the gas supply or suspends the gas supply without resuming the normal gas supply on time. The piped gas operator fails to take emergency measures due to unexpected events affecting the gas supply. The gas operator ceases or ceases business without permission, and the gas management department withdraws, revokes, cancels or revokes the gas business permit following the law.

(11) Management of the cessation of gas supply, adjustment of gas supply, and suspension or closure of the piped gas enterprise

If the piped gas operator needs to temporarily adjust the gas supply or suspend the gas supply for reasons such as construction or maintenance, the

operating hours and the area affected shall be announced 48 hours in advance, or the gas users shall be notified writing. The regular gas supply shall be resumed on time following the relevant regulations.

Emergency measures should be taken if the gas supply is affected by an emergency, and gas users should be notified on time.

If a gas operator ceases or closes its business, proper arrangements should be made in advance for the routine use of gas-by-gas users within its supply area. Also, it must report to the local gas authority 90 working days in advance for approval to suspend or close the business.

(12) Legal system of gas transportation regulation

Commercial entities transporting gas by road, waterway or railway shall comply with laws and administrative regulations relating to the safety of transporting dangerous goods and the relevant rules issued by the *State Council*'s transport department and the *State Council*'s railway department. They shall also obtain a permit for the road transport of dangerous goods or a license for the waterway transport of hazardous goods following the provisions of the relevant laws and administrative regulations on road transport and waterway transport, respectively.

(13) Obligations of gas users

The obligations of gas users are: to comply with the rules of gas safety; to use qualified gas-burning apparatus and gas cylinders; to replace on time gas-burning apparatus and connecting pipes that have been eliminated by state orders or have reached the end of their service life; to pay for the gas following the agreed period; unit gas users should also establish and improve the safety management system and strengthen the training of gas safety knowledge and operational skills for operation and maintenance personnel.

(14) Prohibited acts of gas users and related units and individuals

The following actions by gas users and related entities and individuals are prohibited: operating public gas valves without authorisation; using gas pipelines as load-bearing supports or grounding leads; installing or using gas-fired appliances that do not meet the requirements of the gas supply; installing, modifying or removing household gas facilities and gas metering devices without authorisation; using or storing gas in places that do not have safe conditions; stealing gas; changing the use of gas or diverting gas supplies.

(15) Rights of gas consumers

Gas users have the following rights under the law: to obtain gas products and contractual services that comply with national standards; to inquire with gas operators on matters such as gas charges and services, and gas operators shall respond to such inquiries within five working days from the date of receipt of the application; to file complaints on such issues as gas charges and services with the price departments of local People's Governments at or above the county level, gas management departments, and other relevant departments, and the relevant departments shall deal with such complaints within 15 working days from the date of receipt of the complaints.

(16) Marking system for gas burning appliances

The gas management department shall publish public information on the type and composition of the gas in the administrative region. Gas apparatus manufacturers shall mark the kind of gas to which they are adapted on the gas combustion apparatus.

(17) Prohibited activities within the protection of gas facilities

Within the protection zone of gas facilities, the following activities that endanger the safety of gas facilities are prohibited: constructing buildings, structures, or other facilities that occupy underground gas pipelines; blasting, earthmoving, or other operations or use of open flames; dumping or discharging corrosive substances; placing flammable and explosive hazardous substances or planting deep-rooted plants; other activities that endanger the safety of gas facilities.

(18) Restricted activities within the protection of gas facilities

Within the protection area of gas facilities, the relevant units engaged in laying pipelines, piling, jacking, excavation, drilling and other activities that may affect the safety of gas facilities shall work with the gas operator to formulate a gas facility protection plan and take appropriate safety protection measures.

(19) Protection obligations of gas operators and other units and individuals

Gas operators shall set up protective devices and safety warning signs for gas facilities following the relevant national engineering construction standards and safety management regulations, such as anti-corrosion, insulation, lightning protection, voltage reduction, isolation. Moreover,

conduct regular inspections, testing, repair, and maintenance to ensure the safe operation of gas facilities.

No unit or individual shall infringe upon, dismantle or move gas facilities, destroy, cover, alter, or remove or move safety warning signs of gas facilities without authorisation.

Any unit or individual who discovers those behaviours endangering gas facilities and safety warning signs owns the right to discourage or stop it. In case of any difficulties, the gas operator or even the gas management department, the safety production supervision, the management department and the public security authorities should be informed immediately.

New, extended, or altered construction work must not affect the safety of gas facilities.

The construction unit shall ascertain the underground gas pipeline's relevant conditions within the construction project's construction scope before the commencement of construction; the gas management department and other relevant departments and units shall provide relevant information on time.

There are essential gas facilities such as underground gas pipelines within the construction area of a construction project. The development organisation shall work with the construction unit and the piped gas operator to develop a protection plan for the gas facilities. The development organisation and the construction unit shall take appropriate safety protection measures to ensure the operational safety of the gas facilities; the piped gas operator shall send professional personnel to provide on-site guidance. Where laws and regulations provide otherwise, the provisions of the relevant laws and regulations shall be implemented.

(20) Legal system for the prevention and handling of gas safety accidents

Gas safety accident of contingency plan system: the gas management department shall, in conjunction with the relevant departments, formulate gas safety accident of contingency plans, establish a statistical analysis system for gas accidents, and regularly report the results of accident handling. Gas operators shall prepare their emergency plans for gas safety accidents, equip emergency personnel with the necessary equipment and devices, and organise regular drills.

(21) Notification and reporting system of gas safety accidents or potential dangers

Any unit or individual who discovers a gas safety accident or a potential gas safety accident should immediately inform the gas operator, or report to the gas management department, the fire-fighting agency of the public security authorities, and other relevant departments and units.

(22) Gas safety accident potential hazard disposal system

Gas operators should establish a sound gas safety assessment and risk management system and take timely measures to eliminate the potential gas safety hazards if they are identified.

Gas management departments and other relevant departments and units shall, following their respective responsibilities, supervise and inspect gas operations and the safety conditions of gas use. Where hidden gas safety hazards are found, gas operators and gas users shall be notified to take timely measures to eliminate the hidden risks. The gas management department and other relevant departments shall eliminate the potential danger if the gas users do not fulfil their responsibility. The relevant units and individuals shall cooperate.

(23) Gas safety accident of handling system

After the occurrence of a gas safety accident, the gas operator shall immediately activate its emergency plan for gas safety accidents and organise emergency rescue and repair work.

After the occurrence of a gas safety accident, the relevant departments and units, such as the gas management department, the safety production supervision, and management department, and the fire-fighting agencies of the public security authorities, should, according to their respective responsibilities, immediately take measures to prevent the expansion of the accident and activate the emergency plan for gas safety accidents according to the relevant circumstances.

(24) Responsibilities for gas safety accident supervision

Gas management departments, safe production supervision and management administration, public safety organs and fire-fighting agencies of general security organs have supervisory responsibilities for gas safety accidents under the law.

(25) Gas accident liability determination

Suppose a gas safety accident is determined to be a liability accident after investigation, the cause of the accident shall be ascertained and the responsibility shall be clarified. The case shall be pursued under the law. The gas safe production accidents shall be reported, investigated, and handled following the laws and administrative regulations on safe production accidents.

(26) Role and legal status of the gas industry association

The gas industry association should strengthen industry self-discipline and management and promote gas operators to improve their service quality and technical standards. Industry associations are responsible for organising the drafting and formulation of industry constitutions, formulating and organising the implementation of industry codes of ethics, promoting the construction of industry integrity systems, providing members with training services in human resources, technology, management and law, assisting in the formulation of relevant national standards, developing industry standards and service specifications, promoting gas operators to improve their service quality and technical standards, strengthening the cultivation, regulation and supervision of the gas market, and promoting industry self-discipline and healthy development.

2.3.2 Interpretation of *The Administrative Measures for Gas Business Permits*

Following the relevant provisions of the *Regulations on the Administration of City Gas*, the *Ministry of Housing and Urban-Rural Development of the People's Republic of China* issued a notice on 19th November 2014 regarding *the Administrative Measures for Gas Business Permits*.

The Administrative Measures for Gas Business Permits clarifies that any person engaged in gas business activities shall obtain a gas business permit under the law and operate within the scope specified in the permitted matters. The application and acceptance, review and approval, issuance of documents and related supervision and management of gas business permits shall comply with the provisions of the *Administrative Measures*.

The Administrative Measures for Gas Business Permits makes it clear that the conditions to be met in applying for a gas business permit are:

1) Complying with gas development planning requirements

The gas business area, type of gas, mode, and scale of supply, layout, and construction sequence of gas facilities align with the gas development plan approved and filed under the law.

2) There are gas sources that meet national standards.

The gas supply contract or letter of intent shall be signed with the production and supply enterprise. The gas supply shall comply with the relevant national standards on city gas quality.

3) There are gas facilities that conform to national standards.

There are facilities and equipment for gas production, storage, transmission and distribution, supply, metering, and safety following national standards; the construction of gas facilities complies with the statutory procedures, and the completion and acceptance are qualified and filed under the law.

4) There is a complete safety management system and a complete business plan.

The safety management system mainly includes a safe production responsibility system, facilities, and equipment (including user facilities), safety inspection, testing system, gas quality testing system, post operating instruction, gas emergency contingency plan, gas safety propaganda system.

The business plan mainly includes the enterprise constitution, development plan, engineering construction plan, customer development business process, fault reporting, complaint handling, safe gas consumption, and other service systems.

5) The three types of people in charge of the enterprise, including the main person in charge, safety management personnel, and operation, maintenance, and repair personnel, should attend professional training and be qualified by the gas management authorities.

2.3.3 Interpretation of GB50494 *Technical Code for City Gas*

Technical Code for City Gas is currently the only code in China's city gas industry that contains all mandatory provisions. The *code* targets the basic functional and performance requirements of town gas facilities. It sets out critical technical requirements directly related to safety, personal health,

conservation of resources, protection of the environment, and public interest, which are essential technical provisions that must be strictly implemented. It applies to the construction of city gas facilities, including new construction, alteration, expansion, and technical renovation works, including planning, design, and construction.

The Technical Code for City Gas principle*s* is also the basic principle to be followed in constructing, using, and maintaining city gas facilities, namely "safe production, guaranteed supply, economic rationality, conservation of resources and protection of the environment". The focus is on performance objectives for the construction, use, and maintenance of city gas facilities. At the same time, specific technical requirements in engineering practice should also be implemented following the relevant national and industry standards and specifications. The main technical content includes eight chapters, including general provisions, terminology, introductory performance provisions, gas quality, gas plant stations, gas pipelines and pressure regulating facilities, gas vehicle transport, fuel appliances, and gas-burning equipment.

The crucial contents include:

1) The siting and alignment of city gas facilities should follow the principles of land conservation and effective use of land and space. It shall be determined following engineering and geological, hydrological, meteorological, and surrounding environmental conditions.

The siting and alignment of gas facilities should consider natural conditions and the surrounding environment to prevent significant damage in a natural disaster and avoid or reduce the risk to the protected objects.

There are extensive gas facilities in city gas systems, gas source plants, gate stations, storage and distribution stations (natural gas, LPG, CNG, and LNG stations). These extensive gas facilities should be set up at the edge of cities or relatively independent and safe areas. They should be located away from places where people gather, such as urban residential areas, villages, schools, theatres, and gymnasiums, to prevent nasty accidents causing loss of life and property.

2) Gas plant stations, transmission and distribution systems, pressure stations, gas pipelines, and other essential gas facilities, as well as dangerous operating places, should have standardised and visible safety warning signs.

Following gas's flammable and explosive nature, there should be warnings for internal and external personnel in important places and locations.

3) Measures to effectively ensure personal and public safety should be taken in the construction, operation, and maintenance of city gas facilities and their use. Prevent the mere pursuit of economic benefits from reducing the investment in safety during construction and operation, thereby posing a severe threat to personal and public safety.

4) Activities that are likely to damage or endanger the safety of gas facilities shall not be carried out within the safety protection area of the gas facilities.

Within the scope of ground and underground safety protection of gas facilities, the construction of buildings (structures) and activities that endanger the safety of the gas supply facilities, such as piling up objects and digging pits for soil, is prohibited.

5) The operation and maintenance of city gas facilities should have a sound safe production and operation management system and a corresponding organisational structure.

The safe production and operation management system developed by city gas supply enterprises should include emergency rescue plans for accidents and work permits entering dangerous gas facilities and carrying out gas-operated operations. A full-time repair agency should be set up according to the supply scale. It should be equipped with the necessary repair vehicles, repair equipment, repair facility, communication equipment, protective gear, fire-fighting equipment, testing equipment, and other equipment and ensure that the equipment is in good condition.

The development of the specific safety, operation, and maintenance management system shall be under the current national standards CJJ 51-2016 *Technical Specification for Safety of Operation, Maintenance, and Rush-Repair of City Gas Facilities*.

6) The design life of the gas plant and station shall be determined by the design and construction units and comply with the relevant national regulations. The design life of the main buildings (structures) in the plant and station shall not be less than 50 years; the safety level of the construction of the buildings (structures) shall not be less than Grade II.

7) The fire spacing between the buildings (structures) inside the station and those outside the station should meet the requirements of the current national standards. The boundary of the station should be fenced or guarded.

The fire protection spacing mainly considers the impact of heat radiation

from the flames on buildings such as residential areas in the event of an accident at the plant and station where a large amount of gas (liquid) leaks into the atmosphere and encounters an ignition source that explodes and causes a fire. Specific fire spacing should be under GB 50028 *Code for Design of City Gas Engineering* and GB 50016 *Code for Fire Protection Design of Buildings* and other implementation norms.

8) The station's production and support areas should be separated; the entrances and exits should be designed to facilitate access and evacuation in an emergency.

The general layout of a gas plant station should be divided into production and auxiliary areas. To facilitate safety, production management and reduce the threat to the auxiliary site in the event of a gas leak, the production area should typically be laid out on the upwind or upwind side of the station area in the direction of the least frequent wind throughout the year.

In addition to production needs, the entrances and exits should be designed to ensure the smooth evacuation of personnel and the passage of rescue vehicles and fire engines in the event of a fire.

9) The production area of LPG and LNG plants and stations should be s provided with a non-combustible solid enclosure of not less than 2.0 m in height.

Considering the need for safety precautions, government departments require LPG and LNG plants and stations to set up non-combustible solid walls with a height of not less than 2.0m in the production area.

10) The equipment and pipelines in the plant and station shall be set up with dispersion and cut-off devices according to process and safety requirements. The dispersion device shall be installed to ensure safety and sanitation during operation.

When for some reason, the pressure at the control point exceeds the set value, the system shall automatically cut off the gas source or discharge the overpressure gas to the atmosphere to protect the equipment, pipelines, and users. The height of the dispersion pipe and the distance to the building should be under the corresponding provisions of GB 50028-2006 *Code for Design of City Gas Engineering*.

11) Gas pressure feeding equipment should meet the pressure and flow requirements and have an alarm and automatic stop function for abnormal working conditions; a manual emergency stop device should be installed

near the equipment.

The manual emergency stop is mainly required for safety purposes. The manual emergency stop is used to stop the gas press in place in the event of an abnormality to avoid possible property damage and casualties.

12) LNG tanks and LPG storage tanks with a volume greater than 100m3 should be set high and low liquid level alarm devices; LNG tanks and LPG storage tanks over 50m3 should be equipped with an emergency shut-off valve the liquid phase outlet pipe.

The liquid level in the LNG and LPG tanks should be kept under normal conditions to prevent and reduce personal injury and property damage due to tank leakage.

13) The plant and station should develop operating procedures and accident contingency plans according to the media characteristics and process requirements.

Gas plant stations should emphasise the institutionalisation of safe operation management and clarify their responsibilities and obligations through operating procedures and emergency plans to reduce accidents and deal with accidents scientifically.

14) Combustible gas leak detection and alarm devices should be installed in places with a risk of gas leakage and explosion. The alarm concentration should not be higher than 20% of the lowest limit of the explosion of combustible gas. Cryogenic gas storage areas, gasification areas, and other areas where cryogenic gas leaks occur should be equipped with cryogenic detection and alarm interlocking devices.

15) Where underground gas pipes cross drainage ditches, heat ditches, cable ditches, joint ditches, tunnels, and other trenches, measures should be taken to prevent gas leakage into the channel.

Underground gas pipelines should not pass-through underground structures to avoid adverse effects on each other. When the crossing is necessary, protective measures should be taken for underground gas pipes passing through structures to not leak into drainage ditches, heat ditches, cable ditches, joint ditches to harm other public facilities and public safety.

16) Effective measures should be taken for the out-of-service or abandoned gas pipelines to ensure their safety.

Make it clear that the owner or user of a disused or abandoned gas pipeline should take responsibility for managing the disused or abandoned gas pipeline. Decommissioned and abandoned gas pipes that cannot be removed immediately should be sealed with effective pressure retention and inert gas replacement; no fire should be started on abandoned gas pipes without permission.

17) Gas pipes in the building should not pass through the bedrooms, flammable and explosive warehouses, power distribution rooms, transformer rooms, elevator shafts, cable (well) ditches, flue ducts, air intake refuse ducts.

To ensure the gas supply's safety and facilitate maintenance and management, ventilation and gas leakage alarms should be installed in basements, semi-basements, and poorly ventilated areas.

18) There should be appropriate safety procedures and management systems for using gas transport vehicles and loading/ unloading.

The use and loading/ unloading of gas-fired vehicles shall be carried out by *Regulations on the Safe Management of Hazardous Chemicals in China* and *Provisions on the Administration of Road Transport of Dangerous Goods*, which shall be observed by enterprises transporting dangerous chemicals.

2.3.4 Interpretation of GB50028 *Code for Design of City Gas Engineering*

GB 50028 *Code for Design of City Gas Engineering* is the primary basis for the design of city gas engineering in China, which plays a vital role in regulating the design, construction, and acceptance of work to ensure the safety, reliability, and standardisation of city gas projects.

GB50028-2006 *Code for Design of City Gas* is divided into ten chapters and six appendices. Its primary contents include general provisions, terms, gas consumption and quality, gas production, purification, gas transmission and distribution system, CNG supply, LPG supply, LNG supply, gas application.

According to the development needs of the city gas industry and standard preparation plan, the GB50028-2006 *Code for Design of City Gas* is to be split into six individual standards. The six corresponding essential chapters

of the original standard include the production and purification of manufactured gas, gas distribution, compressed natural gas (CNG) supply, liquefied petroleum gas (LPG) supply, liquefied natural gas (LNG) supply and gas applications. Three codes have been now issued, namely GB 51142-2015 *Code for Design of Liquefied Petroleum Gas (LPG) Supply Engineering* (replacing Chapter 8 of the original code); GB 51102-2016 *Code for Design Compressed Natural Gas (CNG) Supply Station* (replacing Chapter 7 of the original code); GB51208-2016 *Code of Design on Plant of Producing Man-Made Town Gas* (replacing Chapter 4 and 5 of the original code).

Code for Design of City Gas Transmission and Distribution Engineering (replacing Chapter 6), *Code for Design of Urban Liquefied Natural Gas (LNG) Supply Station* (replacing Chapter 9), and *code for design of City Gas Engineering of User* (replacing Chapter 10) have been completed. The draft has not yet been sent for review. The submission drafts have been formed. Accordingly, the corresponding part of the former GB50028-2006 *Code for Design of City Gas Engineering* has been gradually abolished.

CHAPTER 3

ENTERPRISE SAFETY MANAGEMENT AND SAFETY CULTURE

Safety management science is an essential branch of science in the safety science and technology system. It endeavours to control accidents, eliminate hidden dangers and reduce losses through management so that the workers have a safe and comfortable working environment, the enterprises and equipment reach a safe level, and the objective set in which the public lives is safe and secure. Safety management can be defined as decision-making, planning, organisation, and control for safety.

The primary task of safety management is to prevent accidents through the combination of management and technical methods, eliminate potential dangers of accidents, control unsafe factors and behaviours, and ensure the safety of the production system, workers, and people.

Accidents are inevitable due to several factors such as technology, economic conditions, and people's quality and level of operation. Therefore, the second task of safety management is to take effective emergency measures to control the spread of the accident, reduce casualties, and minimise the loss of the accident when an accident occurs.

At the same time, since property losses and casualties generally accompany accidents, insurance compensation is also a necessary safety management task. Although insurance compensation cannot directly affect the consequences of the accident, it can balance the economy, provide financial support for the injured, and help recovery.

In summary, safety management uses management activities that organically combine accident prevention, emergency measures, and insurance compensation to ensure safety.

3.1 The basis of modern safety management

3.1.1 The evolution of safety management

Safety management emerges with industrial production and continues to develop with production technology and enterprise management levels.

The history of human development has always been accompanied by the challenges of man-made or accidental accidents and natural disasters. From passive suffering to learning to "mend the fold" and cope with the experience, to the awareness of "accident prevention" in recent times, to the new safety concepts, views, knowledge, strategies, and behaviours in modern society, people have turned the decadent understanding of "accident worries" into their careful thinking of safety science with safety system engineering and intrinsic safety. The science and technology of accident prevention have transformed the decadent awareness of "accident worries" into careful consideration of safety science; the self-disturbing emotion of "accident peak" and "survival crisis" in the real society into a struggle and realisation of safety. We will turn our self-disturbing feelings about "accident peaks" and "existential crises" in the real world into the motivation to fight and achieve peace and happiness and ultimately create a world of safety and well-being for human beings. This process of human history contains the development and progress of the philosophy of human security—the epistemology and methodology of human security activities.

(1) Fatalism and passive security

In ancient times, people had no choice but to resign themselves to accidents and disasters. They believed that fate was ordained by heaven and that the gods were the masters of humankind. Therefore, we can only pray for God's blessings and God's shelter. Until the 17th century, agriculture, animal husbandry, and handicrafts had developed rapidly, but people's understanding of security was still backward and ignorant. Fatalism and passive suffering were the salient features determined by the ancient security culture of humankind.

Table 3-1: Evolution of the epistemology of safety

No.	Period	Technical characteristics	Epistemology	Methodology
1	Pre-industrial revolution	Agriculture and handicrafts	Submit to fate	Impotent
2	17th to early 20th centuries	Age of the steam engine	Partial safety	Ex post facto
3	Early 1900s to 1950s	Age of Electrification	System safety	Prophylactic
4	Since the 1950s	Astronautics and nuclear power	System safety	Comprehensive countermeasures and systems engineering
5	Since the 1990s	Age of the information	Concept of general safety	Safety management

(2) Empiricism and hindsight safety philosophy

With the change of production methods, humankind entered the early industrialised society from agriculture and animal husbandry into the steam engine era. In the early stages of the development of capitalist industry, due to the development of science and technology, people's safety epistemology was raised to the level of empiricism. With the complexity of accidents and disasters, human beings have entered the understanding of partial safety. The philosophy aspect is reflected in understanding human security based on the experience of accidents and disasters, the awareness of fighting accidents, the learning of "remedy", and the characteristics of "remedial after the event" in the strategy of accidents. This kind of activity that changed from passive to active, from unconscious to conscious, was already a significant improvement at that time. People equated accident management with safety management and only focused on the accident. Therefore, the effect of safety management was minimal.

(3) System theory and preventive safety philosophy

From the beginning of the 20th century to the 1950s, with the development of industrial society and the continuous progress of science and technology, humankind's understanding of safety has entered the stage of system theory and recognised that accidents were possible to prevent. The methodology emphasises the overall safety of the production system, and various technical methods were used to avoid accidents. The accident strategy has moved from "remedy after the fact" to the stage of "prevention first".

Especially in the industrial production system, accident prevention measures have been considered in the design, manufacturing, processing, and production processes. The control of potential dangers has been strengthened, and the effectiveness of safety management has been improved.

(4) Essentialism and comprehensive safety philosophy

Since the 1950s, humankind's understanding of security has entered an essentialist phase due to the continuous application of high technology. People have established a comprehensive understanding of the accident system. They realised that man, machine, environment, and management are the broad elements of accidents and advocated comprehensive engineering technology, education, and management measures to promote safe production and life in methodology. Comprehensive countermeasures emphasise the importance of starting with the essential safety of people, machines, and the environment and implementing comprehensive safety management and the principle of unity of security and production technology. Safety management has entered the stage of modern safety philosophy.

(5) A big safety concept with proactive and preventive approaches

Since the 1990s, human society has entered the information era. With the rapid development and application of high-tech, people pay more attention to the value of life and health and gradually realise that safety management is one of the three effective countermeasures for humankind to prevent accidents. The preventive "big safety" concept and the comprehensive safety management model have gradually become the trend of safety management development in the 21st century. This kind of safety thought and methodology in the high-tech field has extensively promoted the progress of safety measures in traditional industries and technical areas, announced the development of safety science and technology in modern industrial society, and improved the methods for humankind to conquer accidents.

The main characteristics of modern safety philosophy are comprehensive safety management, the principle of the unity of safety and production technology, safety-oriented man-machine design, system safety engineering, advanced and active safety methodology. These are demonstrated by the following. The essence of human safety means that people should have the quality of knowledge, skills, and awareness and start from the human

qualities of human concepts, ethics, emotions, attitudes, cognition, and morals, thus building a safe culture. The essential safety of things and the environment means adopting advanced safety science and technology and promoting self-organising, adaptive, automatic control, and lockout safety techniques. It needs to study the modern industrial safety principles such as safety systems theory, safety control theory, and safety information theory for people, things, energy, and information. Technical projects must follow the "three simultaneous" principles of designing, constructing, and putting into production simultaneously as safety measures and technical facilities. Safe production must be synchronised when enterprises consider economic development, mechanism conversion, and technological transformation. Planning, simultaneous development, and simultaneous implementation are the so-called "three synchronisations" principle, also the "three no-harm" activities of not hurting others, not hurting oneself and not being hurt by others, the "5S" activities of tidying up, tidying up, cleaning up, clearing away and attitude, the fixed management of the logistics of tools, equipment, materials and workpieces on the production site and the flow of workers on-site, the "three points" control project of "danger points, hazard points, and accident-prone points" on the production site, and other preventive safety activities. Safety system engineering methods, such as safety target management, hazard-free management, safety, economic analysis, hazard foresight activities, and accident determination techniques, should be implemented.

3.1.2 Principles of safety management

As a branch of management, safety management follows the universal regularity of control and obeys the basic principles of management. However, safety management has its particularities with its management principles.

(1) Prevention principle

Safety management should focus on prevention, through effective management and technical methods, to prevent unsafe behaviours and unsafe conditions of things from appearing, to minimise the probability of accidents. This is the principle of prevention.

Prevention takes advanced measures to prevent accidents where accidental personal injury or health damage may occur. Prevention and aftercare are two approaches to safety management. Aftercare is for the measurements and treatment work taken after an accident has occurred, in which case, no

matter how well the treatment work is done, the injuries and losses caused by the accident have already occurred, and this improvement can only be relative. The preventive approach is proactive and optimistic and is the primary approach that should be taken to safety management.

The primary starting point for safety management is prevention, which stems from the idea that accidents in the production process can be prevented. Except for natural disasters, all-hazards caused by human activity always have a cause-and-effect relationship, and by exploring the causes of accidents and taking effective countermeasures, it is possible in principle to prevent accidents from occurring.

Since prevention is a pre-work, correctness and effectiveness are very important. Production systems are generally more complex systems. Accidents occur for physical and human reasons and are difficult to assess adequately in advance. Sometimes, the critical prevention issues do not happen, but the under-recognised problems lead to catastrophes. To make the prevention work effective, on the one hand, we must pay attention to the accumulation of experience, carry out statistical analysis of existing accidents and unhappened accidents (dangerous accidents), and discover the laws from them.

On the other hand, we must adopt scientific safety analysis and evaluate technology to make accurate judgments on the unsafe factors and consequences of people and things in production to implement effective countermeasures to prevent accidents. It is tough to avoid all accidents, so it is impossible to reduce the probability of accidents to zero. Therefore, it is necessary to take adequate emergency and after-treatment countermeasures to be prepared. Safety management should adhere to the scientific management method of "prevention first, followed by aftercare".

1) Accidental contingency

The consequences of an accident (personal injury and death, health damage, material loss, environmental impact) and the magnitude of the products are random and difficult to predict. Repeated accidents do not necessarily produce the same consequences. It is the contingency of accident losses. Taking an explosion accident as an example, the number of casualties during the explosion, the degree of losses, the type and extent of equipment destroyed, and whether concurrent fires after the explosion are determined by chance and cannot be predicted.

Some accidents did not cause any loss. This type of accident is called a near miss (or near accident, quasi accident). However, if an utterly similar accident happens again, the loss it will cause can only be determined by chance and cannot be predicted in advance. According to the contingency of accident losses, the principle of accidental losses in safety management can be obtained. Regardless of whether the accident has caused casualties, to prevent accident losses, the only way is to avoid the accident from recurring. This principle emphasises that, in the practice of safety management, attention should be paid to all kinds of accidents, including near misses; only by controlling near misses, the occurrence of accident losses can be indeed prevented.

2) Accident causality

Cause-and-effect is the relationship between things that one thing is the cause of another thing. Accidents result from a series of causes and effects of many factors. One factor is the former factor's result, and the latter factor's cause is linked together, leading to accidents. The causality of an accident determines the certainty of the accident. Accident factors determine that the accident will happen sooner or later. By grasping the cause of accidents, blocking the chain from accident factors to accidents, eliminating the inevitability of accidents, it is possible to prevent accidents from occurring. All these are the principle of causality to recognise the certainty of the causal relationship between accidents, discover the law of accidents, turn unsafe conditions into safe conditions, and eliminate accidents in the early causal stage.

3) The 3E principle of prevention

The main reasons for the unsafe behaviour of people and the unsafe state of things can be attributed to four causes: technology, education, body and attitude, and management. Technical reasons include poor working environment (lighting, temperature, humidity, ventilation, noise, vibration), messy material stacking, small working space, defective equipment lacking maintenance, and technical defects in maintenance protection and alarm devices. Education includes a lack of necessary job skills, knowledge and experience in safe production and unskilled operation techniques and abilities. The reasons for the body and attitude include poor physical state or health, e.g., poor vision or hearing, physical dysfunctions of unresponsiveness, lack of strength, disease, drunkenness and fatigue, emotions of neglect, resistance, and dissatisfaction, negative or exciting work attitude.

Reasons for management include the lack of attention to safety by key business leaders, inadequate staffing, inappropriate operating procedures, and lack of safety procedures or poor implementation of enforcement. Thus, the so-called 3E principle will be adopted, namely engineering, education, and enforcement.

The engineering countermeasures only use engineering techniques to eliminate unsafe factors in production facilities and equipment, improve operating environmental conditions, perfect protection and alarm devices, and achieve safety and hygiene in production conditions.

The education countermeasures provide education and training at various levels, in multiple forms and contents, so that employees can firmly establish the "safety first" idea and master the knowledge and skills necessary for safe production.

The enforcement countermeasures use laws, regulations, standards, and other necessary compulsory methods to restrain people's behaviour from achieving the goal of eliminating the phenomenon of not paying attention to safety and illegal operations.

When applying the 3E principle, three countermeasures are applied comprehensively and flexibly in response to the four causes of unsafe human behaviour and insecure state of things. It should not unilaterally emphasise one of the countermeasures. The specific order of the improvement is first engineering and technical measures, then education and training, and finally legal management measures.

4) The principle of intrinsic safety

The principle of intrinsic safety is derived from the theory of intrinsic safety. The meaning of this principle refers to the realisation of safety from the beginning, and in essence, the possibility of accidents can be fundamentally eliminated to prevent accidents.

The so-called intrinsic safety means that the equipment, facilities, or technical processes have inherent functions that can fundamentally prevent accidents. Specifically, it means that there will be no accidents and injuries even if the operator makes mistakes. Alternatively, the equipment and facilities have the function of automatically preventing people from unsafe behaviours-safety (Fool-Proof). Equipment and facilities fail or damage Fail-Safe function that can temporarily maintain regular operation or automatically change to a safe state. The two safety functions above should

be inherent to the equipment and facilities. They should be included in their planning and design stage rather than compensated afterwards.

Intrinsic safety is the fundamental manifestation of the safety management and prevention principle, and it is also the highest state of safety management. Although it is still challenging to achieve, we should stick to this principle. The meaning of intrinsic safety is not limited to the intrinsic safety of equipment and facilities. Still, it should be extended to various fields such as new construction projects, transportation, new technologies, new processes, new materials, and even people's daily lives.

(2) Coercive principle

Mandatory management is adopted to control people's wishes and actions so that individual activities and behaviours are subject to safety management requirements to achieve adequate safety management. This is the principle of compulsory management.

Generally, management is mandatory to some extent. The critical need for security management is based on the following three reasons:

1) The contingency of accident loss

Due to the contingent nature of accidents and the damage they cause, unsafe acts of people or hazardous conditions of things do not necessarily have immediate catastrophic consequences. Thus, people may feel that safety is not crucial and can be dispensed. It can lead to further neglect of safety and allow the unsafe behaviour and unsafe conditions to continue until too late.

2) People's "adventure" psychology

"Adventure" means that some people are willing to take the risk of being harmed to obtain some benefit. People with this kind of psychology misestimated the potential of the accident. They took a chance and made the wrong choice between avoiding risks and gaining benefits. The meaning of "benefit" includes saving trouble, saving time, saving energy, being comfortable, wishing to appear beautiful, and showing off one's ability and bravery, improving money gains. Taking risks always leads to conscious unsafe behaviours.

3) Irretrievability of accident losses

It is arguably the fundamental reason security management needs to be mandatory. Once the accident loss occurs, it will cause permanent damage,

especially to human life and health, and it is irreparable. Therefore, when it comes to security issues, experience is generally indirect, for people cannot accumulate expertise and raise awareness by making mistakes. The realisation of mandatory safety management is inseparable from strict and reasonable laws, regulations, and all levels of rules, which constitute the norms of safety behaviour. At the same time, there must be a strong management and supervision system to ensure that the managed person always conducts activities by the code of conduct. Once his behaviour exceeds the constraints of the code, there must be severe penalties.

The opposite of compulsory management is democratic management. Due to the particularity of safety management, it tends to be mandatory. Of course, there is a fundamental difference between imperative management and dictatorship based on the will of the chief executive. Although both make the managers obey, compulsory management emphasises normalisation, institutionalisation, and standardisation. In contrast, dictatorial management is based entirely on the personal will of the top leaders of the enterprise, which has been confirmed by a great deal of practice not good for safety work.

The principle of coercion mainly includes the "safety first" code and supervision.

"Safety first" requires safety work to be the top priority of all work when carrying out production and other activities. When there is a conflict between production and safety, safety should be given priority. The production and all others should obey safety. The principle of "safety first" can be the primary safety management principle. As an essential part of the safe production policy, it has been written into the "*Safe Production Law*" in China.

We are implementing the "safety first" principle, which requires leaders of all economic sectors and production enterprises to pay attention to safety and consider safety a top priority. It is necessary to ensure safety as a prerequisite for accomplishing all the tasks. When planning, arranging and implementing various tasks, we should first think about safety and prevent accidents in advance. This principle emphasises that safe production must be regarded as the primary content of measuring the quality of the work of an enterprise, as an indicator of the "veto power", and no production activity is allowed unless safety conditions are met.

As a principle in the category of the critical tenets, "safety first" should become the company's unified understanding and code of action. Leaders at all levels and staff should be people-oriented and safety-oriented in all their work. People who violate this principle should be punished accordingly. It has nothing to do with whether the individual understands it or not. Instead, this principle should be followed unconditionally and unwaveringly.

Adhering to the principle of "safety first", we must establish and improve the safe production responsibility system at all levels by putting safety work in the first place in terms of organisation, ideology, and strategy. Constantly pay attention to forming a standardised and institutionalised working system.

To urge production management departments at all levels to strictly implement safety laws, regulations, standards and rules, to protect employees' safety and health and to achieve safe production, the specific departments and personnel must be authorised to perform supervision, inspection, and punishment duties expose safe work. To supervise and urge the resolution of the problem, investigate and punish violations of regulations and dereliction of duty, this is the supervision principle of safety management.

Safety management is compulsory. It only requires the execution system to implement safety regulations automatically. Without solid supervision and a strategy to supervise the execution, the mandatory power of rules is difficult to exert. With the development of the socialist market economy, enterprises have become independent legal persons and are responsible for their profits and losses. Safety management will also reflect the difference in interests between the state and enterprises and between business operators and employees. It is manifested as the contradiction between production and safety, benefit and safety, partial and social benefit, immediate and long-term profit. Business operators are often prone to the one-sided pursuit of quality, profit, output while ignoring the safety and health of employees. Under this circumstance, it is necessary to establish a particular supervisory agency, allocate qualified supervisors, and give the essential coercive powers to ensure that they perform their supervisory duties to ensure that safety management is implemented.

3.1.3 Features of modern safety management

With the practice of safety management and the progress of science and technology, safety management can be roughly divided into two stages, traditional safety management and modern safety management. Modern safety management further enhances, improves, and refines conventional safety management.

Traditional safety management is also called conventional safety management. After an accident is analysed and dealt with, lessons are learned, and measures are taken to prevent similar accidents. The analysis and handling of various safety issues in production are based on experience and perception. There are many qualitative concepts in analysing and evaluating safety issues, i.e., more "safe" or "unsafe" and fewer quantitative concepts.

Traditional safety management has accumulated much valuable experience and effective management methods, such as "three simultaneous", "five simultaneous", "three-level safety education", "four do not let go", and so on. The practice has proved that those experiences, methods, and systems are practical. However, traditional safety management also has serious shortcomings.

1) Due to traditional safety management's "post-mortem" prevention methods, safety work always runs behind the production, lacking systematic analysis and unable to solve the problem comprehensively. Therefore, it is difficult to prevent problems before they happen, and accident prevention work fails to keep up with product development.

2) Dealing with safety issues in production based on experience and intuition often does not allow for in-depth analysis from surface to surface, so it is not easy to identify potential hidden dangers and effectively control accidents and implement safety target management.

3) There are many qualitative concepts and few quantitative concepts. It is challenging to conduct a practical risk assessment and propose corresponding safety measures. There is no idea how safe the production process is, how likely an accident will occur, and the degree of consequences.

In short, to adapt to the development of production and technological progress, traditional safety management must undergo relevant improvements to adapt to the rapidly developing level of production technology.

Modern safety management is the intersection and synthesis of management and safety science. Modern safety management is developed and improved based on traditional safety management. It applies advanced scientific knowledge and engineering techniques to study and analyse the inherent and potential unsafe factors in production systems and operations. It conducts qualitative and quantitative safety and reliability evaluations. It takes effective countermeasures to control and eliminate these potential

hazards, effectively predicting, forecasting and preventing system safety from obtaining the best possible safety production results.

Scientific tools are applied to hazard prediction to achieve the goal of prevention. Analysing and predicting the unsafe factors, possible failures, and accident risks in the system, conducting safety and reliability assessments on production, construction, mechanical equipment, production installation, all these efforts aim to turn post-accident handling into the prevention of accidents.

1) Implementation of system safety management. Modern safety management starts from the system, observes, analyses, and studies problems comprehensively to formulate countermeasures and overcome the situation of "treating the head when it hurts and treating the foot when it hurts", running behind the production circling accidents. The system makes logical predictions and masters the rules and methods for eliminating accidents before they occur.

2) Quantitative analysis of safety. The so-called "quantitative" transform safety from an abstract concept into a "quantitative" indicator. So, people can predict the risk of accidents and provide a scientific basis for choosing the best solution.

The continuous development of safety management is promoted under the guidance of information flow. A decision concerning safe production in implementing the objective situation may encounter changes, which should be adjusted according to this dynamic information. A new decision will be made following feedback after implementation. All these promote the continuous improvement of safety decisions.

Modern safety management places particular emphasis on the "four all" management:

1) There should be all staff safety management. People-centred safety management fully mobilises the initiative and consciousness of every manager, practitioner, and all relevant personnel in the system, with everyone participating in safety management. Safety management is not just a matter for full-time safety management personnel. It is difficult to manage safety well if the general staff and population remain reactive. In terms of the safety concept, "make me safe" should be changed to "I want to be safe." In the city gas system, it has often been seen that the unsafe behaviour of one person leads to many people being put at risk, even with the consequences of injury or death.

Therefore, it should be emphasised that everyone must consciously pay attention to safety management and take the initiative to ensure the system's overall safety.

2) There should be safety management in the whole process. Safety management starts from the planning, design, and construction stages. Moreover, it runs through the entire system's life until scrapped or stopped. Although there are some differences in the probability of accidents in different scenarios, we should always adhere to scientific and effective safety management to minimise accidents and losses. Similarly, unsafe factors in any link may lead to potential safety hazards and cause safety accidents.

3) There should be comprehensive safety management. Safety management must be done in all aspects of work from beginning to end. Although the degree of danger varies from one part of the system to another, any small piece of equipment or component is a possible accident point, and nowhere is safe. It has also been seen that Many accidents are the result of small component failures or damage, minor faults in massive systems, which, when not handled properly, transform and cause significant accidents.

4) There should be all-time safety management. Attention is always paid to safety, 24 hours a day, 365 days a year, whatever the weather and conditions. Some accidents are directly related to the weather, climate. It is natural to pay special attention to safety issues in bad external conditions. However, this does not exclude those accidents that can still occur under relatively good external conditions. In other systems, accidents are less dependent on external conditions, such as weather, making it more critical to implement the principle of all-time safety management. This way can ensure the system is constantly under safety supervision.

In short, the elemental spirit of the "four all" management means that safety should be placed first for everyone, everything, everywhere, and all time.

Overall, the basic idea of modern safety management is seven changes, namely: change the vertical single-factor management to horizontally integrated management, change accident management to event analysis and hidden danger management (change after-the-fact type to prevention type); change the traditional, passive safety management object to modern safety management dynamics; change the traditional static safety management to modern dynamic safety management; change the safety auxiliary management,

which only focuses on production efficiency in the past to the efficiency, environment, safety, and health integrated effect management; change the traditional passive, auxiliary and lagging safety management program to active, essential and advanced safety management program; change the traditional externally forced safety index management to be dynamic, intrinsic and progressive safety management program.

3.1.4 Situation of safety management

In recent years, safety management has received more and more attention, especially in dangerous industries such as petrochemicals. The relevant state departments have emphasised and requested, by various means, that enterprises should establish a modern enterprise system, promote the transformation of the shareholding system and strengthen the scientific management. They should do an excellent job in managing safe production and resolutely reverse the backward safety management, lax discipline, and disorder.

For the town gas system, many new companies and personnel have entered the field as the industry is in a period of unprecedented development. Implementing many projects such as the "West-East Gas Transmission" and the import of liquefied natural gas has expanded the variety and quantity of gas sources. Natural gas for power generation, the "triple-supply" energy system, the delivery of gas to the countryside and the conversion of rural coal to gas projects have led to a dramatic increase in gas users. As a result, city gas safety management is severe, and the task is arduous, both for the industry internally and for the public.

Safety management is closely related and mutually infiltrated by other management tasks. Solid supervisory and governance measures are among the most critical actions to ensure safety in production. They are the fundamental means of implementing the national legal system for safe production. Otherwise, the safety regulations promulgated will be just a piece of paper.

3.2 China's safe production supervision system and institutions

3.2.1 China's safe production supervision system

The *China National Safe Production Supervision and Administration* is abbreviated as the *Safe Production Supervision Bureau*. It is a government functionary in charge of safety products and related policies and regulations,

with administrative and enforcement powers. The supreme level safe production supervision agency is the *National Administration of safe production*.

The safe production management system is based on the five levels of "unified government leadership, departmental supervision under the law, full responsibility of enterprises, public participation and supervision, and social supervision and support" to build a work pattern of safe production.

These five levels of safe production management mechanisms are indispensable and cannot replace each other, and each has its responsibilities and characteristics. They are interlinked, mutually reinforcing, and a complementary unified, organic whole. They must coordinate and form a synergy between them to promote and develop an overall supervision system for safe production under market economy conditions and make the supervision and management of safe production more standardised.

According to the *Safe Production Law* provisions, the current national safe production supervision system implemented in China is a system that combines comprehensive national safe production supervision and special supervision by relevant functional departments at all levels of government. The comprehensive supervision department for safe production is the *National Safe Production Supervision Administration*. The particular supervision departments are the *Fire Department of the Ministry of Public Security* for fire safety. The *Transportation Administration of the Ministry of Public Security* for motor vehicle supervision. The *Coal Mine Safe Production Supervision Bureau* for coal mine safety supervision.

Moreover, the *Ministry of Transport for Maritime Affairs* is charged with ship and water transportation safety supervision. The *Quality and Technical Supervision Bureau* is responsible for special equipment safety supervision. A reasonable division of labour and coordination between the relevant departments of the State's safe production constitutes China's safe production regulatory system. This regulatory system demonstrates that the central enforcement bodies of China's *Safe Production Law* are the state's comprehensive safe production management departments and the corresponding specialised supervisory departments.

At the beginning of 2000, China established the *National Coal Mine Safety Supervision Bureau*. Moreover, at the beginning of 2001, the *National Safe Production Supervision Administration* was established, and then in 2003, it became an agency directly under the *State Council*. It provides an

institutional guarantee to strengthen the comprehensive supervision of safe production further and improve the safety supervision system. The State Work Safety Supervision and Administration function and administrative enforcement to guarantee the effective implementation of the State Work Safety Supervision Administration has put forward a basic general working idea. They aim at one goal, build an active pattern, focus on three major events, establish six support systems and promote five innovations.

1) One goal is to adapt to the overall requirements of building a moderately prosperous society in all aspects. We are committed to establishing a long-term mechanism for production safety, relying on local governments and all relevant departments. Through the efforts of several years, we will form an efficient safety supervision system, a sound legal system for production safety and a self-improvement and restraint mechanism for enterprise production safety, as well as a public opinion atmosphere of "caring for life and concern for safety" in the whole society. The total number of accidents in industrial and mining enterprises has decreased year by year, achieving national safety. The production situation has stabilized and improved. The work pattern is a safe production pattern with unified leadership by the government, supervision by the people and the departments under the law, full responsibility for enterprises and support by social care.

2) Three significant events: the first is to promote the construction of a safety supervision system and working mechanism, the formation of a flexible, lean and efficient safety supervision system and effective operating mechanism following the requirements of deepening the administrative system reform. The second is to strengthen a safe production legal system as soon as possible. Form a safe production legal system with the *Safe Production Law* as the mainstay and supporting relevant laws, regulations, rules, and standards, and at the same time strengthen the administrative work according to law. The third is to reinforce the team development to build a "political firm and professionally proficient". The security supervision and executive law enforcement team are particularly capable of fighting.

3) Six supporting systems: While improving the national safe production supervision system, speed up the establishment of six systems of safe production law, information, technical equipment, publicity and education, training, and emergency rescue, forming strong support for comprehensive safety supervision work and practical protection.

4) Five innovations: The first is safe production ideology, strengthening basic theoretical research and constructing a safety system. Secondly is the innovation of safe production supervision systems and mechanisms. Then is the creation of safe production supervision methods. Fourthly is the invention of safety technology. The fifth is the innovation of safety culture, based on improving the quality of safety culture of the whole people and promoting the socialisation and industrialisation of safety culture construction.

3.2.2 China's safe production supervision and management agency

(1) *Safe Production Committee of the State Council*

The *Safe Production Committee of the State Council* was established in October 2003 to strengthen the unified leadership of safe production across the country, promote the steady improvement of the safe production situation, and protect national property and people's lives. The safety committee members are composed of the principal persons in charge of the *Economic and Trade Commission*, the *Ministry of Public Security*, the *Supervision Department*, and the *China Federation of Trade Unions*.

The primary responsibilities of the safe production committee include: under the leadership of the *State Council*, it is responsible for researching, deploying, guiding, and coordinating national safe production work; researching and proposing significant guidelines and policies for national safe production work; analysing the national safe production situation and studying and solving meaningful problems in safe production work; coordinating with the *General Staff Headquarters* and the *Armed Police Headquarters* to mobilise troops to participate in emergency rescue work for major safe production accidents when it is necessary; completing other safe production tasks assigned by the *State Council*.

(2) *Ministry of Housing and Urban-Rural Development*

As the competent authority of the city gas industry, the *Ministry of Housing and Urban-Rural Development* has the following responsibilities.

1) Implement supervision and management of the safe production of construction projects nationwide under the law. Responsible for formulating and supervising the implementation of construction safe production policies, rules, and regulations. Investigate and punish the violations of construction

safe production laws and regulations. Supervise and manage the installation and use of hoisting machinery and special motor vehicles on housing construction sites and municipal engineering sites.

2) Organise the formulation and implementation of urban and rural planning under the relevant laws. Link it with safe production and pipeline development planning and strengthen the safety control of related construction project planning links. Instruct local urban and rural planning authorities to incorporate plans for selecting the pipeline construction route into local urban and rural planning management under the relevant and issue planning permits for pipeline construction projects based on urban and rural planning. Guide the preparation and implementation of town, township, and village planning. Guide rural housing construction, rural housing safety, and the renovation of dilapidated houses.

3) Guide the construction, safety, and emergency management of urban municipal public facilities. Guide urban water supply, gas, heat, gardens, urban appearance, environmental governance, urban planning area greening, urban sewage treatment facilities and pipeline networks, urban underground space development and utilisation, scenic spots. Work with relevant departments to strengthen the guidance, supervision, and inspection of the construction and management of underground pipelines, and guide the local housing and urban-rural construction departments to be responsible for the comprehensive management of urban underground pipelines in conjunction with relevant departments. Guide the safety supervision and management of urban subway and rail transit planning and construction.

4) Responsible for the safe production supervision and management of the construction industry, such as construction engineering, construction and installation, building decoration, survey and design, construction supervision, real estate development, property management, house acquisition, and demolition. Responsible for guiding and supervising the safe production access management of construction enterprises under the responsibility of the provincial construction authority. Responsible for conducting the safe production education and training of employees in construction enterprises.

5) Responsible for the statistical analysis of safe production in the construction industry, real estate industry, and housing urban-rural construction system, organising or participating in the investigation and handling of related accidents under the law. Supervise and inspect the accident occurrence unit's implementation of prevention and rectification measures according to the division of responsibilities.

(3) *National Health Commission of the People's Republic of China* and *Ministry of Emergency Management of the People's Republic of China*

In March 2018, the *National Health Commission of the People's Republic of China* and *the Ministry of Emergency Management of the People's Republic of China* were formed, and the *National Safe Production Administration* was no longer retained.

The primary responsibilities of the *National Health Commission of the People's Republic of China* are formulating national health policies, coordinating, and deepening the reform of the medical and health system, organising the formulation of the national essential drug system, supervising and managing public health, medical services, and health emergencies, being responsible for family planning management and services and formulating policies and measures to deal with the ageing of the population and the integration of medical care and elderly care.

The *Ministry of Emergency Management of the People's Republic of China* is primarily responsible for preparing general national emergency plans and planning, guiding the work of all regions and departments in responding to emergencies, and promoting the construction of emergency plan systems and plan exercises. It establishes disaster reporting systems and unifies the release of disaster information, coordinates the construction of emergency forces and material reserves and unifies their dispatch in disaster relief, organises the building of disaster relief systems, directs emergency relief in the production safety category and natural disaster category, and undertakes the work of the *National Command for Response to Special Major Disasters*. It guides the prevention and control of fire, flood and drought disasters, and geological disasters. It is responsible for the comprehensive supervision and management of production safety and production safety in the industrial, mining, and trade industries.

3.2.3 Basic principles of safe production supervision and management

(1) Adhere to the principle of "the laws must be followed, law enforcement must be strict, and violations must be investigated".

The laws that must be followed include two aspects, i.e., enforcement and compliance. Firstly, it means that occupational safety and health supervision agencies and personnel must strictly abide by the act under the law. As far as judicial organs are concerned, they must take facts as the basis and the law as

the criterion when trying cases. For employers and workers, it is necessary to strictly abide by occupational safety and health laws, regulations, and systems.

Strict law enforcement means that law enforcement agencies and personnel must act in strict accordance with the law and maintain the dignity and authority of the law. For the judiciary, it is necessary to strictly abide by the law regarding conviction and sentencing and the severity of penalties in the trial of cases. Another layer of strict law enforcement means that it will not be illegally interfered with by other administrative agencies, groups, or individuals in the judgment activities.

Violations must be investigated, which means that all illegal and criminal acts must be seriously investigated and punished under the law. No one can be above or beyond the law, and no one can enjoy privileges beyond the provisions of the law. It is an essential principle of the socialist legal system to insist that law violations must be punished and that everyone is equal before the law. Only by strictly implementing this principle can we effectively ensure the unity and seriousness of the socialist legal system.

(2) Adhere to the principle of taking facts as the basis and law as the criterion

The illegal facts are the objective basis for handling or punishment. When supervising and enforcing the inspections or reported cases, it is necessary to conduct in-depth investigations, collect reliable evidence, and ascertain the facts. Identify and check the facts of the offence in a factual manner so that the facts found to be in breach of the law are fully substantiated and can stand the test of history.

The provisions of laws and regulations are the only criterion for punishment. When imposing penalties, the occupational safety and health supervisory authority must do so accurately and appropriately under the specific provisions of the laws and regulations.

In the process of law enforcement, occupational safety and health supervision departments must respect the objective facts and carry out proper law enforcement in strict accordance with laws and regulations at the same time.

(3) Adhere to the principle of combining behavioural supervision and technical supervision

State supervision of occupational safety and health not only implements behavioural supervision (supervision and inspection of the management

behaviour of the employer and its leading personnel, including whether the regulations and management activities comply with the requirements of product safety legislation). It also carries out technical supervision, i.e., through technological means, in-depth control and inspection of the safety and health conditions of production processes, equipment, raw materials and the working environment, and the technical conditions of their protection. Only by combining behavioural and technical supervision and highlighting the role of behavioural surveillance can the purpose of the national charge of occupational safety and health be effectively achieved through the legal system under the conditions of continuous progress in science and technology.

(4) Adhere to the principle of combining supervision and service

The occupational safety and health supervisory body should conduct supervision and inspection seriously and make timely requests to strengthen preventive measures and expose and correct deficiencies and deviations in occupational safety and health. It also has to help employers with publicity, education and technical training with enthusiasm, provide relevant information and scientific and technological intelligence, and guide and help employers do an excellent job in occupational safety and health to achieve unity between safety and production.

(5) Adhere to the principle of combining education and punishment

The principle of combining punishment and education means that punishment is a weapon to punish violations of the law and plays an educational role. Its educational role is mainly manifested in the learning, understanding and mastering of the law, on the one hand, and the punishment of responsibility for the offence, on the other hand, to educate others not to commit similar crimes and the person concerned to repeat similar offences.

3.2.4. Safe production supervision procedures

Supervision agencies generally carry out supervisory inspections of companies planned, lining them up and focusing on different situations. The United States has formulated the *Principle of Priority Inspection Order*, which places companies with hazardous jobs at the forefront of inspections. The inspected unit is generally not notified in advance before the inspection. The regulations stipulate that anyone who reveals information about the assessment will be punished. Supervisors should show their credentials

(with photos) when entering the unit under investigation, and the employer or its representative must conduct verification. Then convene a meeting with employers or their representatives, union representatives or workers, and the supervisor will explain the reason and intention of the inspection. The regulations and provisions that should be followed are sent to the management, and the inspection route is proposed, and the management and labour representatives will accompany the inspection. Once any illegality is found during the inspection, immediately make a record and inform the management accompanying personnel (if the labourer has violated the law, notify the labourer). After the examination, a summary meeting was held, and the supervisor puts forward his own opinions and suggestions and discussed them with the participants simultaneously. The safe production supervisor inspector may also put forward specific views on the *Improvement Notice* or *Prohibition Notice* to be issued by the superior. After the safe production supervisory inspector returns, if the enterprise receives the *Improvement Notice* or the *Prohibition Notice*, it shall handle it according to its requirements. Otherwise, they shall be punished under the law. If there is any disagreement, it can file a complaint to the Industrial Court (or other arbitration institution) within the time limit specified by the safe production regulations. If the employer refuses to execute, the supervisor also has the right to complain, and the court shall make a final judgment and ruling.

Safe production supervision procedures refer to the steps and sequence of supervision activities, including supervision preparation, hearing reports, on-site investigations, making opinions or suggestions, issuing *Safe Production Supervision Instruction* or *Safe Production Supervision Penalty Decision*.

To ensure the implementation of national laws, regulations and standards relating to safe production, the People's Governments at all levels have set up agencies for the comprehensive management of safe production and exercise state supervisory powers. All relevant departments, trade union organisations, and most enterprises also have functional departments to manage safe production. An excellent supervisory and management team provides the fundamental guarantee for effective prevention of casualties and reducing occupational hazards.

The state supervisory inspectors have extraordinary powers and, upon presentation of their documents, have the right to enter any production and business unit, accompanied by the police if necessary, to inspect its implementation of safety regulations and standards. The inspectors have the

right to inspect the documents, accounts, information, take photographs, measurements, records and samples. They can question the persons concerned and request the writing of statements. They have the right to remove or exclude objects deemed to pose an imminent danger to the safety and health of the persons employed. With the approval of his superior, they have the right to issue a restrictive order to the operator to rectify a breach of the safe production regulations or prohibit the enterprise from continuing with its operations.

Safety supervision, primarily industrial and specialised safety supervision, requires the results of technical inspections as evidence. China has established safe production testing and inspection institutions, carried out a safety inspection of equipment and occupational hazard testing, and quality supervision and inspection of labour protection supplies. They have initially formed three levels of national, provincial and local (municipal) level testing systems with different responsibilities, which have completed much work for the supervision and management of safe production and the safe production of enterprises.

3.2.5 Scope of safe production supervision and management

The powers of the national safe production supervision and management are to carry out regular maintenance and inspection of compliance with and implementation of the provisions of safe production laws and regulations; to conduct special checks on new, renovated, and expanded projects, special equipment, severely hazardous workplaces, and special operators. For significant potential dangers, severe occupational hazards and those companies unqualified for safe production, the related functions will stop and improve the dangerous (hazardous) operations by forced approach. They will penalise the companies, institutions and those directly responsible for the accident and participate in and supervise the investigation of casualties.

There are two types of state safety supervision: behavioural supervision and technical supervision.

The content of behavioural supervision includes organisational management, construction of rules and regulations, staff education and training, and the implementation of the safe production responsibility system at all levels. The purpose and role of behavioural supervision are to raise safety awareness and implement safety measures effectively in the workplace, in which unsafe behaviours that violate rules and regulations, operation rules

and labour discipline are to be seriously corrected and dealt with. According to a survey, casualties caused by unsafe acts of non-compliance account for about 80% or more of the total number of accidents.

Technical supervision refers to the supervision of material conditions. They include the "three simultaneous" supervision of new construction, expansion, reconstruction, and technological transformation projects, the supervision of the integrity and utilisation rate of the existing protective measures and facilities of the employers, the supervision of the quality, equipment, and function of personal protective equipment and the supervision of dangerous equipment, severely hazardous workplaces, and particular types of work operations. Technical supervision is characterised by solid professionalism and high technical requirements, and it often requires special testing agencies to provide data. Technical supervision, mainly based on "intrinsic safety", is an essential element of supervision.

From the perspective of professional supervision, the types of national safety supervision are divided into general supervision, specialised supervision, and accident supervision.

1) General supervision of safe production is comprehensive supervision of the routine production activities of an enterprise. There have been clear regulations on the specific contents, methods, and frequency of general supervision in recent years. For example, some provinces and municipalities have formulated general supervision assessment standards. They compiled into a supervision procedure table and identified dozens of contents according to safety management, safety technology, labour hygiene, labour protection for female and minor workers, working hours and leave, training and education, accident investigation. It enables general supervision to achieve clear objectives and uniform standards of assessment.

This irregularly organised supervision and enforcement activity carries out systematic health inspections and assessments following occupational safety and health inspection and evaluation standards. It runs in many specific forms, ranging from comprehensive occupational safety and health inspections to focused reviews of particular industries and units where severe casualties or occupational hazards exist. According to relevant national laws and regulations and system engineering principles, some regions have comprehensively proposed inspection items for employers regarding safety management, safety technology, labour hygiene, and safety effects, and stipulated specific inspection content and scoring coefficients. According to these standards, the occupational safety and health supervision

agency conducts regular inspections and employers' assessments. It will award the employers' safe production advanced units, qualified units, or unqualified units, respectively, indicating the existing defects and problems and determining if they are safe. Production work played a role in promoting. Supervision activities were carried out based on reports. The supervisory agency shall dispatch personnel to investigate and deal with employees' complaints on safe production and labour protection incidents and the statements and disclosures made by trade union organisations. By promoting the economic contract responsibility and labour contract systems, labour protection disputes between employers and employees have gradually increased. Supervision based on reports can effectively protect the legitimate rights and interests of the employees.

2) Specialised supervision of safe production, i.e., management of particular issues, including the charge of productive construction projects, control of special equipment, care of labour protection products, and supervision of special operators.

The "three simultaneities" supervision is a type of safe production supervision established by summing up the safe production experience and the lessons of China's decades of industrial construction. We should proceed from the following three aspects to do this work well. First, it is necessary to strengthen the formulation of the "three simultaneous" management regulations and occupational safety and health design regulations for construction projects and clarify the implementation of the "three simultaneous" occupational safety and health measures with capital construction projects. Secondly, improving the supervision procedures and control the three barriers of design, construction, and acceptance. During the preliminary design stage, sending and reviewing orders and audit notices for construction project labour safety and health facilities is implemented. The expanded design information and documents are carefully reviewed and not delivered for construction without review and approval. In the construction design and site construction stage, follow-up supervision is carried out to prevent the reduction of labour safety and health facilities. At the completion and acceptance stage, the pre-acceptance is grasped。 The problems are found to be improved by a deadline, and those not meeting the safety production regulations cannot be put into operation. Some places also actively participate in project feasibility demonstration activities and conduct investigation and supervision in the early stage of construction. Third, strengthen law enforcement. According to the "*Administrative Punishment Measures for Violation of the Labour Law of the People's Republic of China*", the unit shall be ordered to rectify the situation where

the labour safety and health facilities of its new construction, alteration, expansion and technical transformation projects fail to be designed, constructed, put into production and used with the main project. It may be fined not more than 50,000 yuan. If the safety and health facilities do not meet the national standards, the employer shall be ordered to rectify the situation and fined up to RMB 50,000. Therefore, employers who violate the "three simultaneous" regulations should be given a warning, fined, or recommended to the relevant competent authorities not to issue a construction licence.

Special equipment refers to mechanical equipment, such as cranes, elevators, that are hazardous and likely cause personal and equipment accidents. Special equipment is inspected to fundamentally ensure that it is produced and created following norms and standards. Regular inspections and tests are carried out during use and operation to ensure that the equipment is always in good working order and prevents accidents.

Labour protection equipment is a kind of defensive equipment necessary to protect workers' safety and health in the production process. Due to the relatively poor production technology and low level of automation in China, the labour conditions in many enterprises cannot be improved fundamentally. The use of labour protection products plays a crucial role in reducing occupational hazards. Under certain conditions, when the safety and health of employees cannot be fully guaranteed after safety measures are taken, particular labour protection products play an essential role. They are an indispensable auxiliary measure in labour protection measures.

Special operations refer to operations that are prone to casualties during the labour process and have a significant hazard to the operator, especially to the safety of others and surrounding facilities. The government has introduced a uniform training syllabus, assessment materials, and documents to prevent injuries and fatalities caused by a lack of safety education and the necessary technical safety skills training. Special operators must undergo specialised safety training and obtain a certificate before they are allowed to work. Credentials are generally reviewed once every two years, and those operating certificates which fail to renew on time or fail to pass the review will be invalidated.

3) Accident supervision

Accident supervision is the reporting, registration, statistics and investigation of casualties and occupational poisoning for processing. The *Labour Law*

stipulates that the administrative departments, relevant departments, and employers of the People's Governments at and above the county level should, under the law, collect statistics, report and deal with casualties that occur during labour time. According to the *Regulations on Reporting and Handling of Accidents of Enterprise Employees* issued by the *State Council*'s, the person in charge shall immediately report to the competent department of the enterprise and the administrative department after receiving a report of serious injury, death, or significant fatality. When the capable department of the enterprise and the executive department gets a report of a fatal or significant fatal accident, they should immediately report it up the hierarchy according to the system. They shall report fatal accidents to the competent departments of enterprises and administrative authorities of provinces, autonomous regions and municipalities directly under the Central Government. They shall report major fatal accidents to the relevant competent departments and executive authorities of the State Council. For severe or minor injuries, the person in charge of the enterprise or its designated personnel shall organise an accident investigation team involving production, technical, safety and other relevant personnel and trade union members to conduct the investigation. For fatal accidents, the competent department of the enterprise, together with the local administrative department of the municipality, the public security department and the trade union, shall form an investigation team to investigate the accident. After the accident investigation team has ascertained the circumstances of the accident, if the analysis of the accident and the handling of the accident cannot be reached, the administrative department has the right to issue a conclusive opinion. The supervision of the accident should be done following "four not-to-go". It refers not to let go the unclear cause of the accident, not to let go the responsible and the masses without education, not to let go the implement preventive measures and not let go the responsible person.

3.2.6 Labour protection supervision of labour union

The employees are the leading power in the enterprise's economic development and the main force to improve safe production. It is essential to fully understand the importance of relying on the working class from a political point of view, realise its mastery, and give full play to mass supervision of labour protection by trade unions. The No. 36 document of the *General Office of the State Council* points out that it is necessary to give full play to the supervisory role of the trade union organisations. The trade union organisations are actively supported not to let go of the mass activities for employees.

The masses supervision of trade unions has a complete system—federations of trade unions at or above the county level set up labour protection supervision and inspectors. The basic-level trade unions in enterprises set up basic-level labour protection supervision and inspection committees or inspectors, and workshop teams set up labour protection inspectors for labour union groups. The mass supervision organisation system of the grassroots trade unions represents the legitimate rights and interests of workers, supervises and assists the unit in implementing national laws and regulations on labour protection, implements the responsibility system for safe production, supervises the solution of problems in occupational safety and health, improves labour conditions and the working environment, and participates in the investigation and treatment of casualties, conducts analysis and research, and stops violations of rules and regulations, such as command and operation.

The primary tasks of the labour protection work of enterprise trade unions are: trade unions publicise the Party's production safety guidelines and policies and the national product safety regulations to workers. Trade unions educate workers on safety and labour discipline. Trade unions urge and assist the administration of enterprises in improving the safety performance of various equipment and safety devices. Trade unions educate workers on the proper use and care of the safety devices of different equipment. Trade unions carry out mass supervision and inspection activities through workers' congresses and urge the administration to formulate plans to implement solutions to the proposals made by workers' representatives concerning labour protection. Trade unions regularly inspect the implementation of labour protection measures plans of administrative departments. The trade unions supervise the correct proposal and reasonable use of funds for labour protection measures by executive departments. They manage and review whether the "three simultaneous" projects of new construction, alteration and expansion are carried out. They incorporate labour protection work into labour competitions and conduct practical safety culture-building activities. To supervise and assist the administrative departments in the control of dust and toxins and labour hygiene, to prevent the occurrence of occupational diseases, and to supervise the executive departments in the active treatment and proper placement of occupational disease patients; to participate in the investigation, analysis and handling of casualties; to supervise and assist the administrative departments in the special protection of female workers; to supervise and assist the executive departments in the supply of labour protection supplies under regulations; to help the administrative departments of enterprises in the conscientious implementation of the policy of combining work and rest, and act under the labour law; implement the rights

of workers to protect their safety and health in the course of labour, and have the right to stop unregulated command and unregulated work.

Mass safety supervision can be achieved through the following ten channels:

1) Online supervision, through the team of the trade union masses, such as labour protection supervisory inspectors, employee representatives, and safety liaison officers of employee family members, forms online supervision.

2) Two-way supervision, active management carried out by trade union cadres and group supervisors and mutual leadership by the passive control of enterprise administration.

3) Democratic supervision supervises the corporate administrative department through the employee representative assembly.

4) Political supervision, participate in the formulation of local government safety regulations and supervise new construction, reconstruction, expansion, and ongoing construction projects.

5) Supervise under the law, relying on the *Labour Law*, *Trade Union Law*, and *Mine Safety Law* to conduct adequate supervision.

6) Scientific supervision, using safety science theories for effective management and supervision.

7) Public supervision, using public opinion tools such as news and propaganda to conduct exposure supervision.

8) Special supervision, special investigation and research on more typical problems, analysis, and suggestions, and supervising the relevant departments to solve the issues.

9) Information supervision, establishing an intelligence information system, obtaining reliable data and materials, conducting dynamic analysis, and proposing countermeasures to control accidents.

10) Joint supervision, work closely with labour and health departments and jointly conduct regular and irregular safety and health inspections, link the inspection results to the company's awards and promote the company to strengthen labour protection.

3.2.7 Safety supervision and management of special equipment

Boilers and pressure vessels are equipped with explosion hazards. Once an explosion occurs, it will damage the equipment itself and damage nearby equipment and buildings, endangering life and property safety and causing significant losses to the national economy. Special equipment must be designed, manufactured, installed, used, inspected, repaired and modified from seven aspects of supervision and inspection.

1) Design review. The design review can only determine the product's safety and reliability when the design's rationality is ensured. The design unit should have the technical ability and plan appropriate to the type and variety of equipment it designs, and a sound design management system and technical responsibility system.

2) Manufacturing review. On the premise of good design, examine whether the units' manufacturing products and varieties have the appropriate technical strength and design means and whether they have a sound design management system and technological system.

3) Product inspection and review system. On the premise of good design, all the links from material acceptance, processing finished products to the various aspects of the equipment leaving the factory should be strictly inspected. For the manufacture of products, there should be a strict quality assurance system to implement the licensing procedure. The manufacturing plant should have the technical ability appropriate to the equipment manufactured, complete design drawings, strict raw material acceptance system and process, quality inspection agencies. The inspection system should be implemented to ensure that new products must be supervised and inspected by the competent administrative department (*Economic and Trade Commission*) before leaving the factory. Only after passing the inspection, they can leave the factory.

4) Installation review. The installation unit must be approved to ensure quality. In addition to the necessary technical ability, construction process and installation equipment, the installation unit must also have a complete quality acceptance system.

5) Registration and license. To ensure the safe operation of the equipment, the user must register and obtain the permit.

6) Regular inspections, including internal, external, and water pressure tests, identify problems on time and eliminate potential issues through experimental review.

7) Review of repairs and transformations. Major repair and transformation plan for boilers and pressure vessels must be reported to the safety supervision agency for review and approval, and equipment that is too severely damaged to ensure operation should be scrapped.

3.3 Safety management of gas companies

A production enterprise with modern technology inevitably needs a modern science of safety management to go with it. Safety management principles are the basis, strategy, and programme for modern enterprise safety scientific management. Through continuous innovation and progress, modern safety management can meet the needs of contemporary enterprise safety management. Gas management should adhere to integrated planning principles, ensuring safety, securing supply, standardising services, energy-saving and efficiency. To safeguard gas supply, prevent and reduce gas safety accidents, protect the lives and property of citizens and public safety, and promote the healthy development of the gas business, city gas enterprises should strengthen the safety management.

3.3.1 Fundamentals and principles of business management

The business management principles are the laws of business management derived from scientific analysis, synthesis, abstraction and generalisation of the substance of business management from the commonalities of business management. Business management principles are the general rules that guide business management activities based on business management principles. Safety management is an integral part of enterprise management. Thus, it should follow the universal laws of enterprise management and obey the fundamentals and principles.

(1) System principle

System principle is one of the most basic principles in modern management science. It means that while people are engaged in management work, they use systematic viewpoints, theories, and methods to conduct an adequate systematic analysis of management activities. To achieve the optimisation goals of management and to understand and deal with the emergence of business management from the perspective of system theory problem.

Any management object can be considered a system that contains several subsystems. At the same time, it is subordinate to a more extensive system

and has various horizontal connections with other systems outside.

As a system, production enterprises transform and organise elements such as materials, energy, personnel, capital, equipment, and information to form products, labour, and services that meet the needs of society and the market. The interrelation and interaction of the essential elements in the enterprise system shape the three most fundamental movements in the enterprise system, i.e., material, capital and information.

The business management, auxiliary services, information processing and other departments and related management systems and working methods set up by enterprises for production and business activities or the direction of the above three basic movements are collectively referred to as corporate management systems. Thus, the enterprises can fully play the various enterprise management functions to organise and fully utilise those essential elements and ultimately achieve more significant economic benefits with less labour.

The safety management system is a subsystem of the enterprise management system. Its composition includes full-time and part-time safety management personnel at all levels, safety protection facilities and equipment, safety management and accident information, safety management rules and regulations, and safe operation procedures. Safety runs through all the primary activities of the enterprise. Safety management prevents the consumption of spontaneous labour (human, financial, and material) and ensures the enterprise's system operating goals.

For enterprise safety management, the first step is to treat the whole enterprise as a system and study it entirely from a safety perspective, rather than limiting it to the safety of a particular department, link or process. Secondly, identify what elements are relevant to security, what subsystems these elements form, what risk factors exist in these subsystems, how these risk factors are interlinked and interact with each other, under what circumstances accidents can occur. Thirdly, to distinguish the hierarchical structure of safety management, i.e., the levels of safety management from the company (factory), workshop to shift and the management responsibilities and rights of each group. Fourthly, conduct qualitative and quantitative evaluations of potential safety hazards in enterprises, including statistics and analysis of past accidents, to determine the management focus of safety work and formulate overall management goals and partial goals at all levels and links. Finally, implement the functions and tasks of safety management at all levels and choose the best work plan to realise safety management goals.

Principles for applying system principles include:

1) The principle of dynamic relevance

The various elements that make up the enterprise management system are developing and interrelated. They are both complementary and mutually restrictive. This principle means that the regular operation of any enterprise management system is restricted by the system's conditions and affected and restricted by other related systems and changes with time, place, and people's different efforts. The dynamic correlation of each part of the enterprise management system is the fundamental reason for developing the management system. Therefore, to improve the effectiveness of management, it is necessary to grasp the dynamic correlation characteristics between the elements of management objects and make full use of related factors.

To master the dynamic correlation between people and equipment, between people and the operating environment, between people, between funds and facility equipment transformation, and between safety information and users is a prerequisite for effective safety management.

2) Principle of integration, division, and synthesis

Modern, efficient management must be a clear task division under the overall planning and practical synthesis based on the division, which is the principle of integration, division, and synthesis. The essential requirement of this principle is to give full play to each element's potential and improve the enterprise's overall function. Firstly, it requires a comprehensive understanding and planning of the management object from the overall objective. Secondly, it implements a clear and necessary division of labour or decomposition under the overall planning. Finally, based on the task division to establish internal horizontal links or collaboration, the system can operate in a coordinated, integrated and balanced manner. In this regard, division of labour or decomposition is the key, and integration or coordination is the guarantee.

The principle of integration, division and synthesis also has an essential significance in safety management. Integration means that when business leaders formulate overall goals and make macro decisions, they must include safety as a critical part of the comprehensive plan. Division means that safety management must achieve a clear division of labour and implementation at all levels. It must establish a sound safety organisation and a safety production responsibility system. It makes the objectives and responsibilities clear to each person; together, it means strengthening the

safety management department's functions and establishing its authority to ensure strong coordination and control in achieving effective integration.

3) Feedback principle

Feedback is one of the basic concepts of cybernetics and system theory. It refers to the reaction of the controlled process to the control mechanism. Feedback presents in abundance in all kinds of systems and is a common phenomenon in management, being the primary condition for the management system to achieve the desired goals. The principle of feedback means that successful and efficient management cannot be achieved without sensitive, accurate and rapid feedback.

Modern enterprise management is a complex system engineering, and its internal conditions and external environment are constantly changing. Therefore, for the management system to achieve its objectives, it must be informed of these changes based on feedback to adjust its state and ensure that the goals are met.

Management feedback is based on information flow. The timely and accurate feedback relies on a complete management information system. Effective safety management should promptly capture and feedback various safety information and take timely actions to eliminate or control the unsafe factors so that the system can maintain a safe state and achieve safe production.

With the development of computer technology, modern information systems should be well-matched human-machine systems composed of humans and computer systems.

4) The principle of closure

In any management system, management methods and processes must form a continuous closed circuit to form practical management activities, the closure principle. The fundamental spirit of this principle is that there must be a relationship of mutual restraint between the various management bodies within the enterprise and between the multiple management systems and methods for management to be effective. This restraint relationship includes the restriction between the different management functions and the restraint of superiors on subordinates. The leaders themselves must also be subject to corresponding constraints. Otherwise, they will contribute to a culture of subjectivity and irresponsibility. It will be challenging to ensure that all enterprise decision-making and management activities are based on science.

(2) Humanistic principle

The principle of humanism means that the human factor must be put in the first place in business management activities, embodying the guiding ideology of humanism. People-oriented has two layers of meaning: all management activities are carried out with people as the main body. People are both the subjects and the objects of management. Each person is at a certain administration level, and there is no management without people. Therefore, people are the main object of management activities and essential resources. The other, in the management activities, as the management object of the elements (funds, materials, time, information) and management system of the links (organisation, rules and regulations), are required to be in charge, operation, promotion and implementation of people. Therefore, according to human thinking and behaviour laws, we should use all kinds of incentives to give full play to human enthusiasm and creativity and explore people's inner potential.

It directly manifests the humanistic principle by improving enterprise safety management, avoiding work-related accidents and occupational diseases and fully protecting the workers' safety and health.

Applying humanistic principles include:

1) Motivation principle

The fundamental force driving management activity is the people, and management must have the motivation that stimulates people's ability to work, which is the principle of motivation. The motivation can be generated from material, spiritual and informational sources. Accordingly, there are three basic types of motivation: ① material motivation, i.e., appropriate material benefits to stimulate human behavioural motivation. ② spiritual motivation, i.e. the use of ideals, beliefs, encouragement and other spiritual forces to boost people's behavioural motivation, to achieve the purpose of stimulating people's motivation. ③ information motivation, that is, through the acquisition and exchange of information to generate the behavioural push to catch up with or pull ahead of others, to achieve the purpose of stimulating people's motivation.

Proper application of the principle of motivation can enable management activities to proceed continuously and effectively. Failure to apply the principle of motivation reduces management efficiency and has a negative effect. Firstly, attention should be paid to the integrated and coordinated use

of the three kinds of motivation, not just the isolated use of a particular type of motivation. Secondly, the dialectical relationship between individual inspiration and collective motivation should be correctly understood and handled. The collective advancement is the fundamental of management and under this premise. The individual should be able to develop freely fully. Thirdly, the relationship between temporary motivation and lasting motivation should be handled. Fourthly, it is vital to master the thresholds of the various stimulus amounts to avoid the opposite result.

2) Energy level principle

The concept of energy level comes from physics and means that the electrons in the atom have specific energy and are distributed in the corresponding orbit according to the energy size and revolve around the atom's core. The energy values corresponding to these orbits are discontinuous and arranged in magnitude, called 'energy levels'. Modern management has introduced the concept that all units and individuals in an organisation have a certain amount of energy and can be arranged in order of energy magnitude to form the energy levels in modern management. The principle of energy levels means that a reasonable set of energy levels can be established in a management system. Thus, the position and tasks of each unit and individual are arranged in terms of their energy levels. The stability of the structure and the effectiveness of management can be ensured.

Management level is not an artificial assumption but an objective existence. When applying the principle of competency levels, three things should be achieved: firstly, the determination of competency levels must ensure that the management system has stability; secondly, the staffing and use of talents must correspond to the competency levels; thirdly, different competency levels should be given additional powers and responsibilities and various incentives, so that their duties, powers and benefits are in line with their competency levels.

3) Incentive principle

Motivation in management means using the stimulation of some external trigger to mobilise people's inspiration and creativity. The principle of motivation uses scientific means to stimulate people's inner potential to give full play to their intention, initiative and creativity.

When using the principle of motivation, enterprise managers should adopt various effective motivational measures and means in line with the laws of human psychological and behavioural activities. The inspiration of

enterprise staff comes from three primary sources, namely the internal motivation, which refers to the enterprise staff's spirit of struggle; the external pressure, which refers to some external force imposed on the team, such as salary increase, demotion, praise, criticism, information; and the attraction, which refers to some power that can make people interested and hobby. These three kinds of motivation are interlinked, and managers should understand and guide them. They should adopt various motivation methods and motivation intensity scientifically and reasonably according to people's differences to maximise the inner potential of employees.

(3) Principle of flexibility

Business management must remain sufficiently flexible, i.e., it must be highly adaptable and flexible, adapting in time to all possible changes in objective things and implementing effective dynamic management, which is called the principle of flexibility in business management.

The need for flexibility in management is due to the external environment in which the business system is located, the internal conditions and the specificity of the business management movement.

The external environment is complex, with national guidelines, policies and regulations, political, military and economic changes at home and abroad, and competitors' factors. All these factors are difficult to control, and the analysis and forecasts made by enterprises based on past information will always differ from the current reality. Therefore, rigid management should be abandoned, and flexible management should be implemented.

The internal conditions are relatively controllable, but there are limits to how they can be controlled. Internal constraints are limited both by the company's resources and the external environment, subject to many uncertainties and unpredictable situations. The human factor, in particular, as a thinking being with free will, is subject to change. If business management does not pay enough attention to this and starts from an ideal state without leaving any room for error, it will often be in a very passive situation.

The specificity of the enterprise management movement itself requires the principle of flexibility in management. First of all, the problems encountered by enterprise management always involve many inextricably linked factors. It is difficult to be thoughtful in a comprehensive investigation, so we must grasp the law and constantly improve the management. Secondly, enterprise management can only leave room for a total balance since it should focus

on the primary factors and not ignore the details. Thirdly, enterprise management faces many uncertainties, so no method or system can be effective and adaptable in the long term and must be adjusted frequently. Finally, enterprise management is the science of action. There are consequences, as the saying goes, "one wrong move leads to all lose", so there must be timely and flexible countermeasures to cope with it.

The principle of flexibility is a fundamental principle generally applicable to enterprise management. As long as it is appropriately used, the management effect of the enterprise will be significantly improved. The following points must be noted when applying the principle of flexibility to management practice.

1) Correctly handle the relationship between the whole and the part. The whole contains the local, and the local is relative to the whole. Overall, resilience is a significant part of the resilience of business management, so problems must be dealt with on the premise that overall resilience is considered. Only on this premise can local issues be solved, coordinated or adjusted.

2) It is necessary to distinguish the boundary between positive and negative flexibility strictly. Positive flexibility means leaving space when formulating goals and plans and preparing a few more plans when dealing with problems. At the same time, negative flexibility places too much emphasis on leaving space and conservatively shrinks. Distinguishing between the positive and negative aspects of resilience issues is essential in applying flexibility.

3) The enterprise flexibility is limited. The flexibility of enterprise management is confined and cannot be expanded and relaxed in an unlimited way. The kind of enterprise management where management ideas, organisations, methods and systems are constantly changing, where requirements vary, and where there is too much scope for dealing with problems and solving them is doomed to failure. Therefore, the principle of flexibility should be applied in just the right way.

The principle of flexibility has tremendous significance to safety management. Safety management is confronted with complex environments and conditions, especially the causes of accidents, which are difficult to anticipate and grasp fully, so safety management must remain as flexible as possible. On the one hand, we must continue to promote the scientific and modernisation of safety management, robust system safety analysis and risk assessment as far as possible to identify, eliminate and control dangerous

factors. On the other hand, we must adopt all-around and multi-level accident prevention countermeasures and implement comprehensive, entire staff, the whole safety management process, from people, materials, environment, and other aspects of prevention layers. In addition, in safety management, attention must be paid to coordinating the relationship between the upper and lower, left and right, internal and external parties, and obtaining the understanding and support of personnel at all levels as far as possible. In this way, safety management can be carried out smoothly.

3.3.2 Requirements for safety management of gas companies

Enterprises should follow the "safety first, prevention first, and comprehensive management" policy to carry out safe production. The investigation and management of potential dangers will improve safe production, reduce accidents, ensure personal safety and health, and ensure smooth operation. Enterprises should establish and improve safe production rules and regulations and distribute them to relevant jobs to standardise production and operation behaviour.

Enterprises should set up safe production management institutions and personnel following regulations. The main person in charge of the enterprise shall be fully responsible for the safe production work and fulfil the safe production obligations, following the duties assigned by the safe production laws and regulations. Enterprises should establish a safe production responsibility system and clarify units, departments, and personnel at all levels. Enterprises should establish a safe production input guarantee system, perfect and improve production conditions, withdraw safety expenses following regulations, and use them exclusively for safe production.

Enterprises should abide by safe production laws, regulations, standards, and norms and promptly translate relevant requirements into the unit's rules and regulations. Moreover, they should implement them in all tasks. All functional departments of the enterprise shall timely identify and obtain the applicable safe production laws and regulations, standards and regulations applicable to their departments. They shall grasp the revisions of relevant laws and regulations and provide them to the enterprise responsible for identifying and obtaining the applicable safe production laws and regulations on time. Enterprises should promptly communicate applicable safe production laws and regulations, standards, and other requirements to the practitioners. Enterprises should prepare job safety operating procedures based on their production characteristics and distribute them to the relevant positions.

Enterprises should establish safety record files of major safe production processes, events, activities, and inspections and strengthen effective safety records management.

(1) Operating conditions for gas companies

The state implements a licensing system for gas operation. Gas operators shall be selected for gas facilities invested in and constructed by the government through a tender process. Investors may operate independently or choose other gas operators for gas facilities financed by social funds. An enterprise engaged in gas business activities shall meet the following conditions:

1) Meet the requirements of the gas development plan.
2) Have gas sources and gas facilities that meet the national standards.
3) Have a complete safety management system and a sound business plan.
4) The main person in charge of the enterprise, safe production management personnel, and operation, maintenance and repair personnel have been professionally trained and qualified.
5) It should meet the other conditions stipulated by laws and regulations.
6) Individuals are prohibited from engaging in the pipeline gas business. Individuals involved in bottled fuel gas business shall abide by relevant provinces, autonomous regions, and municipalities directly under the *Central Government*.

(2) Safety supervision of gas companies

City gas enterprises shall provide services under the national gas service standards. Gas companies must not have the following behaviours:

1) It refuses to supply gas to units or individuals that meet the gas usage conditions within the municipal gas pipeline network coverage.
2) Resale, mortgage, lease, lend, transfer, or alter the gas business license.
3) Failure to perform the necessary notification obligation to stop gas supply, adjust gas supply without authorisation, or suspend or close business without approval.

4) Gas applies for business purposes to entities or individuals who have not obtained a gas business licence, is prohibited.

5) It is storing gas on premises that are not in a safe condition.

6) Require gas users to purchase their designated products or accept the services they provide.

7) It was filling gas for non-owned cylinders without authorisation.

8) We sell bottled gas filled by unlicensed filling units or bottled gas filled by filling units for non-self-owned cylinders without authorisation.

9) It uses the name or logo of other enterprises to engage in the gas business, service activities.

(3) In any of the following situations, the gas management department should take measures to ensure the regular use of gas.

1) The pipeline gas operator temporarily adjusts the gas supply or suspends the gas supply and fails to resume the regular gas supply in time.

2) Due to unexpected gas supply incidents, pipeline gas operators fail to take emergency measures.

3) The gas operator suspends business or goes out of business without authorisation.

4) Under the law, the gas authority withdraws, revokes, cancels, or revokes the gas business permit.

3.4 Safety culture construction in gas companies

3.4.1 Introduction to safety culture

In a broad sense, culture is the sum of the material and spiritual wealth created in human social and historical practice. Culture refers to society's ideology and the institutions and organisational structures that correspond to it in a narrower sense. Culture is a historical phenomenon, and every community has a culture that fits it and develops with the development of its material production. Culture, as an ideology, reflects the politics and economy of a society and gives tremendous influence and effect to the politics and economy of a given society.

Safety culture in a broad sense refers to the process of human survival, reproduction and development, in all areas of human production, life and survival practices. It ensures the people's physical and mental/health safety and enables them to engage in activities comfortably and efficiently. It helps to avoid and eliminate casualties and deadly diseases and establish a safe, reliable and harmonious system of human-machine-environment to make human beings healthier and the world more peaceful.

The construction of a safety culture includes different levels of artefacts, institutions, spiritual intelligence and value norms.

1) Artefact's level includes all kinds of tools, instruments and objects made and used by human beings for safety and protection and the protection of human physical and mental safety (including health) for production, living, survival and knowledge.

2) Institutional level includes all institutionalised forms of social organisation and social network of people in terms of safe production, labour safety and health, traffic safety, disaster reduction safety, environmental safety.

3) Spiritual intelligence level includes philosophical thought on safety, religious beliefs, aesthetic awareness of safety (safety aesthetics), e.g., safety literature and art, safety science, safety technology and experience and theories on safety science or safety management in the natural sciences and social sciences.

4) Value norms level includes people's values and behaviour norms for safety.

3.4.2 Safety culture model

The safety culture of an enterprise is the accumulated values of the safety philosophy of the entire staff, the safety features reflected in the employees' professional behaviour and the enterprise's safety atmosphere. The safety culture of an enterprise is the material and spiritual wealth formed by the employees in preventing accidents, resisting disasters and creating a safe and civilised working environment.

The manifestations of company safety culture include:

(1) The general and unique requirements of the company in terms of safety and safety science and technology in production.

(2) The company-wide consensus on safety in production.

(3) The company's management level of safe production, including the implementation of laws and regulations on safe production, the development and implementation of safety regulations and various technical standards.

(4) The knowledge of general safe production and safety techniques mastered by all staff.

3.4.3 Safety culture construction

The safety culture construction mode generally covers the material culture, the system culture, the spiritual culture, and the behaviour culture on safety.

Cultivating and establishing employees' safety concepts is the primary task of safety culture construction. The safety concept is the precursor of safety culture construction. Construction requires improving the employees' safety concept to strengthen the culture. Thus, they are aware of their responsibility and obligation for safe production, consciously participate in the management of safe production, strengthen the accidents prevention and strictly implement safety regulations to guarantee the safe production of the enterprise.

Safety means responsibility, and the most crucial thing in building a safety culture is to develop a culture of accountability. The role of safety culture is to cultivate the employees' safety responsibility through various ways, e.g., *safety month*, *fire day*, *100 days without accident* and other safety competition activities. Through management tools such as rewards or punishments, employees are guided to love the company and their jobs, gradually turn the requirements of product safety laws and regulations into habitual work behaviour and put safety responsibility into each work process. Accountability for everything lies with the person, accident control measures with the person, safety supervision positions with the person, and responsibility for the pursuit of accidents with the person, thus promoting the construction of the company safety culture and improving the level of the company safety culture.

Building a culture of safe behaviour is an important landing point for constructing a safety culture and is also the main objective of developing a safety culture. To create a culture of safe behaviour is to encourage employees to form good safety habits. The typical demonstrations, case education, safety lectures and other ways and means should be fully used to prompt the majority of the employees to desire safety from their minds and

ensure protection from their actions.

A safety system culture must be implemented in every post and every person. It makes employees aware of the importance of complying with rules and regulations, consciously abiding by them, constantly following procedures to complete every job, and raising their awareness of self-protection. It is essential to nip safety hazards in the bud and minimise safety risks on time.

CHAPTER 4

HAZARD IDENTIFICATION AND SAFETY EVALUATION

4.1 Hazard Identification

A hazard is a source or condition that may cause injury or death, occupational injury, property damage, or environmental damage.

To distinguish between the characteristics and effects of the adverse impact of an object on the human body, we usually divide harmful factors into risk factors (emphasising sudden and instantaneous or so) and hazard factors (emphasising cumulative effects within a specific practical range). When no detailed distinction is made between the two, they can be collectively referred to as risk factors. The manifestations of risk factors and hazard factors are different. However, in terms of the nature of the accident, they can be attributed to the accidental release of energy or leakage of harmful substances, can cause casualties to people, sudden damage to things or affect the human body and can lead to chronic disease damage.

Generally, the more energy a system has and the greater the number of hazardous substances present, the greater the potential danger to the system. On the other hand, a corresponding amount of energy and substances (including hazardous substances) is required whenever a production activity occurs. Therefore, danger and hazard factors exist objectively in production sites and certain living places.

All energy sources and energy carriers that generate and supply energy can be dangerous under certain conditions. For example, the shock waves, temperature and pressure of pressure vessels, explosive and hazardous substances, the potential power of working at heights (or of lifting heavy objects), the electrical energy of charged conductors, the kinetic energy of moving vehicles (or of moving mechanical parts of any kind, workpieces), the acoustic energy of noise, the light energy of lasers, the thermal energy of high-temperature work and process devices with severe thermal reactions, radiation energy of any kind, can cause all sorts of accidents under certain

conditions. The angles of stationary objects, burrs, the ground can hurt the human body and movement, fall kinetic energy, and potential energy caused by. These are all dangerous factors formed by the accidental release of energy.

Under certain conditions, harmful substances can also damage the human body's physiological functions and normal metabolic functions and destroy the effectiveness of equipment and objects is also the most fundamental hazard factor. For example, toxic substances, corrosive substances, dust, asphyxiating gases and other harmful substances in the workplace, when they come into direct or indirect contact with human bodies or objects, can lead to casualties, occupational injuries, property damage or damage to the environment.

It can be said that the danger and hazards are almost everywhere, but the degree of danger varies. Therefore, the first step in preventing hazards and risks is identifying them and their extent.

Whether due to lack of knowledge or carelessness, accidents and injuries occur when people fail to recognise the dangers around them and act recklessly. As the saying goes, "the ignorant are fearless". For example, people who have not been exposed to LPG the first time they see an LPG cylinder often do not realise its danger. Some people, out of curiosity, will open the cylinder valve and even put their faces to smell. Some people use a hose to refill large cylinders of LPG into small cylinders privately, resulting in leaks and explosions. The lack of knowledge about LPG and the relevant expertise has them unable to recognise its danger. Normally, a professional would not conduct as that under any circumstances.

4.1.1 Hazard identification

Although hazards and hazardous factors are everywhere, in safety management, we pay more attention to identifying risks at the production site, especially the identification of significant threats, because the hazards and hazardous factors involved in production are concentrated. If hazards and accidents occur, the consequences will be more serious. Identifying hazards and risk factors in life requires awareness and knowledge of safety and the accumulation of life experience.

(1) Classification of hazard sources

The classification of hazards is based on the likelihood and severity of their transformation into accidents. Hazard source classification is essentially the assessment and evaluation of the hazard source.

In terms of the likelihood of an accident occurring, they can be classified qualitatively as: very likely to occur, likely to occur, more likely to occur, not likely to happen, challenging to occur, tough to occur.

According to the degree of harm caused by accident, they can be classified as negligible, critical, dangerous, destructive.

The classification is based on a single indicator, generally a quantitative one. For example, work at height is based on height difference indicators to classify fall hazards into four classes: Class I 2~5m, Class II 5~l5m, Class III 15~30m and Extraordinary 30m or more.

(2) Analysis of potential hazards

The transformation of a hazardous source into an accident is manifested by releasing energy and hazardous substances. Therefore, the potential danger of a hazardous source can be measured by the energy intensity and the number of hazardous substances. The energy includes electrical energy, mechanical energy, chemical energy, nuclear energy; the greater the energy of a hazardous source, the greater its potential danger. The two main categories of hazardous substances include incendiary, explosive, and toxic substances. The former generally refers to substances that can cause a fire or explosion, such as flammable gases, flammable liquids, flammable solids, dust, explosive compounds, spontaneous combustion substances, mixed hazardous substances. The latter refers to the chemical substances which directly harm the human body and cause poisoning, disease, teratogenicity and carcinogenicity. The danger of a hazardous source can be described according to the quality of the hazardous substance used.

(3) Analysis of conditions and triggering factors for the existence of hazardous sources

Depending on the conditions of its presence, a certain amount of hazardous material or certain intensity of energy reveals different dangers. It has different levels of potential to be triggered into an accident. Therefore, analysing existential conditions and triggering factors is essential in identifying hazard sources.

The analysis of the existing conditions includes the storage conditions and physical parameters of the hazardous materials, the state of the equipment, the protection of personnel and the operational management conditions.

Triggering factors can be divided into human factors and natural factors. Human factors include personal factors (such as operating errors, incorrect operation, carelessness, carelessness and psychological factors) and management factors (incorrect management, incorrect training, command errors, errors in judgment and decision-making, design errors, wrong arrangements.). Natural factors are the various natural conditions and their changes that cause the transformation of hazard sources, such as changes in climatic conditions, lightning, earthquakes, floods.

(4) Hazard identification procedures

To identify the scope of hazard identification, we must first identify which processes and sites need to be recognised for risks and hazards and determine which areas need to be prioritised. The scope of identification must be scientific, relevant and precise.

Hazardous sources are the premises for accidents and are the subject of energy and material releases during accidents. Once the system has been identified, the situation of the hazards in the system being analysed should be investigated. The investigation mainly includes several aspects, such as production process equipment and materials, operation environment, operation, accidents and safety protection.

It is also essential to delineate the hazard range of the source point. Generally, systems should be divided first: subsystems can be divided by equipment, production units and facilities, or operating units. Then to analyse the hazard source points in each subsystem. Generally, the equipment and containers that produce or have energy, substances, an operator working space, or produce aggregated hazardous substances are considered as hazard source points. The dangerous area is defined as the core point plus the protection area, which is the area of the source. In determining the source area, it may be defined as follows:

1) According to the hazard source is a fixed or mobile definition: such as transport vehicles, transport equipment in the workshop for mobile, its hazardous area should be determined with the mobile space of the equipment; and boilers, pressure vessels (tanks), compressors are fixed, the scope is also fixed.

2) Defined by whether the hazard source is a point source or line source: generally, the hazard range caused by a line source is more extensive than that of a point source. For example, gas pipelines are mostly line sources when corrosion cracks and leaks occur.

3) According to the hazardous workplace, delineate the area of the source of danger, e.g., explosions, fire, vehicular injury, electrocution, poisoning and asphyxiation.

4) Define the area as a source of danger according to the location of dangerous equipment, such as boiler room, oil depot, oxygen station, substation, storage tank area, liquefied petroleum gas filling area, steel cylinder storage area.

5) Define the danger source by energy forms, such as chemical, electrical, mechanical, radiation, and other sources.

The procedure for hazard identification at a production site is shown in Figure 4-1.

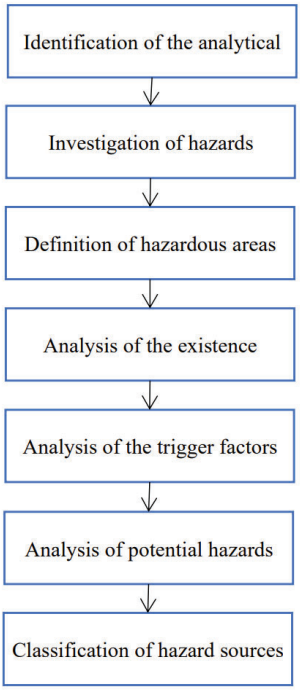

Figure 4-1 Hazard identification procedures

4.1.2 Main elements of hazard identification

In the process of hazard identification, the principle of "horizontal to the edge, vertical to the end, no dead corner" should be adhered to, and the identification results should be scientific and accurate. It requires safety management knowledge and familiarity with the identification system and place, such as the process, material, and equipment characteristics. If it does not understand the plan and the site, it is difficult to focus and identify critical areas in the identification process; the results may not be accurate and clear enough to provide a reliable basis for effective safety management. The identification and analysis of hazards and risk factors generally include:

1) Plant (station) site and environmental conditions: It is generally necessary to analyse the engineering and geological conditions of the plant (station) site, the geographical topography, natural disasters, the surrounding environment, meteorological conditions, resources and traffic, rescue and relief support conditions. For example, the analysis of the plant (station) area layout should pay attention to functional partition (production, management, auxiliary production, living area) layout: high temperature, harmful substances, noise, radiation, flammable, explosive, dangerous goods facilities layout; process layout; buildings, structures layout; wind direction, safety distance, health protection distance.

2) Transportation routes and terminals: roads in the plant (station) area, railways in the plant (station) area, dangerous goods loading and unloading areas, docks in the plant (station) area.

3) Buildings (structures): building structure, fire prevention and explosion-proof measures, building orientation, lighting conditions, (operation, safety, transport, maintenance) access, doors and windows, production health facilities.

4) Production process: material properties (toxicity, corrosiveness, flammability), temperature, pressure, flow rate, operation and control conditions, accidents and uncontrolled state.

5) Production equipment and devices, including production equipment, devices (high temperature, low temperature, corrosion, high pressure, vibration, back-up equipment in critical areas, control, operation, maintenance and emergency abnormalities in case of failure or malfunction); mechanical equipment (moving parts and workpieces, operating conditions, maintenance operations and malfunction); electrical equipment (power outages, electric shock, fire, explosion, malfunction, static electricity, lightning); hazardous equipment, equipment working at high places; special individual equipment

and devices (boiler rooms, storage tanks, LNG loading and unloading facilities, LPG filling equipment).

6) Dust, toxins, noise, vibration, radiation, high temperature, low temperature and other hazardous work sites.

7) Management facilities, accident emergency rescue facilities, auxiliary production and living health facilities.

8) It includes labour organisation physiological and psychological factors and ergonomic factors.

4.1.3 Hazard identification methods

A hazard is a material, object, system, process, facility or plant that has the potential to cause harm to people, property or the environment. Hazard identification, in turn, is the identification of the characteristics of a material, system, process, or plant that could cause an accident leading to adverse consequences.

There are two critical tasks in hazard identification: the first is to identify the likely consequences of an accident when it occurs, and the second is to identify the characteristics of the materials, systems, processes or plants that could cause an accident. The former is relatively easy and defines the latter's scope by which it is crucial to identify the possible consequences of an accident.

The consequences of an accident can be divided into three main categories: injury to people, damage to property and damage to the environment. They can be subdivided into various specific types of injury or damage. Once the possible accident consequences have been identified, the characteristics of the materials, systems, processes or plants that may produce these consequences can be further identified.

The risk factors requiring further evaluation can be identified based on the hazard identification. The scope and complexity of the hazard evaluation are proportional to the number/ type of the identified hazards and the depth of the problem to be understood.

Commonly used hazard identification methods include analysis of material properties, production processes and conditions, production experience, organisational and management measures, and the development of interaction matrices and the use of safety evaluation and analysis methods.

The selection of hazard identification method should be based on the characteristics of the place, hazard, and hazards to be identified. At the same time, the information and data should be collected by various means, using the experience and the results of the same industry or similar situations.

4.1.4 Issues in hazard identification

In the process of hazard identification, the following points should be noted.

1) Use hazard identification forms correctly. According to the different identification sites, some fixed-format forms can be recommended to facilitate hazard identification, avoid the difference of identification results due to the diverse identification personnel, and make the identification results as objective and practical as possible. In the process of using these pre-made forms for hazard identification, attention should be paid to the appropriate selection and supplementation of the contents according to the specific identification site. At present, there are few fixed forms for hazard identification in the city gas industry, most of which are based on the records of hazardous chemicals and the petrochemical industry. To provide a reference basis for safety management, we should gradually establish and improve the unique hazard identification and evaluation forms for various places in the city gas system.

2) The risks and hazards are identified in the order of their distribution. For an orderly and convenient way to avoid omission, it suggests analysing the existing threats to obtain a complete list of dangers and their distribution generally, according to the plant (station) site, layout, buildings, materials, production process and equipment, auxiliary production facilities (including public works), operating environment hazards.

3) Identify ways and means of harm (hazard)

Injury (danger) methods refer to causing injury to the human body and damage to human health. For example, mechanical injury by crushing, biting, collision, shearing, poisoning of target organs, physiological dysfunction, forms of damage to physiological structures (e.g., mucosal erosion, vegetative nerve disorders, asphyxia, retention of dust in alveoli, fibrosis of lung tissue, carcinoma of lung tissue).

Most risk and hazard factors cause injury through direct contact with the human body. The explosions are caused by shock waves, flames and splashing objects within a particular spatial range. Poisons act on the body

through direct contact (respiratory tract, oesophagus, skin mucous membranes) or air from the respiratory belt within a particular area. Noise is caused by air within a certain distance that damages the sense of hearing.

4) Determine the main hazards and hazard factors. It is essential to analyse the direct and induced causes of the conditions leading to the accident, to provide a basis for setting evaluation objectives and priorities, dividing evaluation units, selecting evaluation methods and adopting control measures and plans. The priorities should be clearly distinguished so that the safety management work can be targeted and focused.

5) Clarifying the analysis of significant hazards and hazard factors to prevent omissions, especially those that can lead to significant accidents, should be given special attention and not ignored. Not only should we analyse the hazards and risk factors of regular production and operation, but more importantly, we should also analyse the hazards and risk factors of equipment and device damage and operational errors that may have serious consequences.

4.1.5 Results of hazard identification

The results of hazard identification activities, usually a list of materials or production conditions that may lead to hazardous conditions, are shown in Table 4-1. The analyst can use these results to determine the appropriate scope and select the proper safety evaluation or risk assessment method. In general, the scope and complexity of a safety evaluation depend directly on the number and type of hazards identified and the extent to which they are known. If the range of some risks is not clear, additional specialised studies or tests will be required before conducting a safety evaluation.

Table 4-1: Results of hazard identification

No.	Result
1	List of combustible materials
2	List of toxic materials and by-products
3	Hazard response list
4	List of chemicals and monitorable releases into the environment
5	List of systemic hazards, e.g., toxicity, flammability
6	List of contaminants and production conditions leading to runaway responses
7	List of significant sources of danger (risk factors)

4.2 Basis for Safety Evaluation

Safety evaluation is also known as hazard evaluation, risk evaluation or risk assessment. The safety evaluation of the city and city gas system aims to achieve the safe operation of the whole system. It requires applying the principles and methods of safety engineering to identify and analyse the dangerous and harmful factors, determine the likelihood and severity of accidents and occupational hazards, and provide a scientific basis for developing preventive measures and safety management. At present, safety evaluation is mainly carried out for artificial gas source plants, natural gas and LPG storage and distribution stations, CNG and LNG field stations, transmission and distribution pipeline systems.

4.2.1 Purpose of safety evaluation

Safety evaluations can provide a basis for reducing accident rates, reducing economic losses and optimising safety investments. The objectives of safety evaluation should include at least the following aspects.

1) It aims to discover the potentially hazardous and harmful factors in the entire system design, construction and installation, inspection and testing, operation and management, maintenance, repair and renovation to realise the whole safety control process. It analyses and determines the engineering technology conditions that may cause system disasters and proves the reasonableness of technical safety measures. Evaluation before preliminary design can avoid using unsafe processes or unsuitable equipment and facilities and improper selection of materials; when specific processes and equipment and facilities must be used, countermeasures to reduce or eliminate hazards can be proposed. Evaluation after construction design can check for defects and deficiencies in the specific construction design, and early improvement and preventive measures can be taken. After the system has been built and is in the operational phase, evaluation can explain the natural hazards of the overall system operation and provide a basis for further identifying risk reduction measures.

2) Establish the optimal safety solution and provide a basis for decision-makers by analysing the hazard sources in the system and their distribution parts and numbers, predicting the probability and severity of accidents, and proposing the safety technology and management countermeasures and measures to be taken. Decision-makers can choose the best solution for system safety based on the evaluation results.

3) It creates conditions for the standardisation and scientific nation of safety technology and safety management by evaluating whether the safety of equipment, facilities or systems in the production process conforms to the relevant laws, regulations, standards and norms, and identifying problems and deficiencies against industry technical standards and norms.

4) Promote the realisation of intrinsically safe production. Through safety evaluation, the company will scientifically analyse the accident and propose technical measures and programs to eliminate the danger because of various causes and conditions of the accident. By taking corresponding steps in design, we strive to make sure that the risk factors existing in the system will not lead to accidents even in the event of desperation or equipment failure, and finally realise the intrinsically safe production process.

4.2.2 Safety evaluation process

The General Principles of Safety Evaluation issued and implemented by the *State Administration of Safe Production* on 1st April 2007, makes it clear that safety evaluation procedures generally include: preparation stage, identification and analysis of hazardous and harmful factors, safety evaluation, proposing safety countermeasures, forming safety evaluation conclusions and recommendations, and compiling safety evaluation reports.

1) Preparation stage includes site investigation and preliminary data collection. It clarifies the object and scope of the evaluation, collects relevant domestic and foreign regulations and standards, understands the production and accident situation of similar equipment, facilities or processes, and the geographic and meteorological conditions and social, environmental conditions of the object of evaluation.

2) Identification and analysis of hazardous and harmful factors. According to the geographical and meteorological conditions of the evaluated equipment, facilities or places, engineering design, construction plan, process flow, equipment layout, leading equipment, instruments and meters, physical and chemical properties of raw materials, intermediates and products. It identifies and analyses the possible accident types, causes and mechanisms of accidents.

3) Select the safety evaluation method. Based on the above hazard identification and analysis, the evaluation unit is divided, and one or more specific evaluation methods are selected according to the purpose of evaluation and the complexity of the evaluation object.

Conclusion: there are many evaluation methods. It is essential to choose evaluation methods that are targeted, operable, and safe, starting from conditions that are suitable for the actual situation of the construction project. These methods can be both quantitative and qualitative.

4) Safety evaluation. The possibility and severity of accidents are evaluated qualitatively or quantitatively. The risk is graded according to the standard values of accident risk to determine the priorities for safety management. The safety evaluation should express the danger and harmful scope and degree of various dangerous and detrimental factors as far as possible. The choice of model in the assessment is also crucial. Only by establishing a scientific, mathematical model can the real situation encountered in the actual project be better simulated.

5) Safety countermeasures and recommendations. According to the evaluation and grading results, safety countermeasures and suggestions are put forward: for the risks higher than the standard value, engineering technology or organisational management measures must be taken to reduce or control the risk; for the risks lower than the standard value, which are acceptable or permissible, monitoring efforts should be established to prevent changes in production conditions leading to an increase in the risk value; for the risks that cannot be excluded, preventive measures should be taken; for the preparation of contingency plans to provide reference.

6) Safety evaluation conclusion. The safety evaluation agency shall make the safety evaluation conclusion rigorously and clearly according to the principles of objectivity, fairness and truthfulness. The contents of the safety evaluation conclusion shall include a summary of the evaluation results, a judgment on the conformity of the evaluation object with the laws, regulations, standards, rules and norms of the state related to safety products from the perspective of risk management, a predictive conclusion on the possibility and severity of the accident, and the safety state after taking safety countermeasures.

7) Safety evaluation report. The conclusion of the safety evaluation is a summary of the evaluation work. It should briefly list the assessment results of the main hazardous and harmful factors and point out the major dangerous and detrimental factors that the construction project should focus on preventing. It should specify the essential safety countermeasures that should be noted. It should conclude whether the construction project complies with the relevant national and industry laws, regulations, technical standards, and codes from the perspective of safe production. The safety

evaluation report should reflect the safety evaluation process comprehensively and generally. The text should be concise and accurate, the information presented should be precise and reliable, and the arguments should be clear and easy to read and review. The safety evaluation report should be adequate in content, apparent in organisation and conclusions, prepared according to requirements, and organised for evaluation by experts.

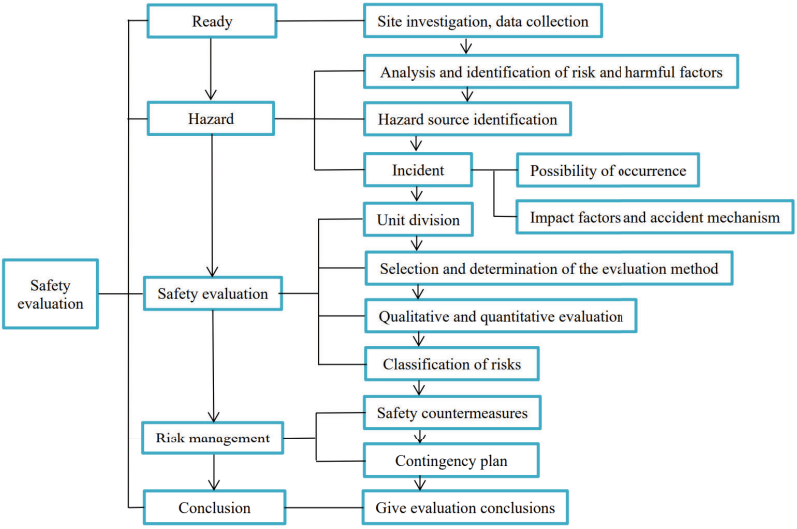

Figure 4-2 General procedures for safety evaluation

4.2.3 Types of safety evaluation

There are many forms of safety evaluation depending on the purpose of the assessment, and different industries and systems have to choose to use them with their characteristics. The more commonly used types of evaluation are those based on the project's life cycle. According to the project implementation time, safety evaluation can be divided into pre-evaluation of safety, safety acceptance evaluation, safety status evaluation, and safety-specific evaluation.

(1) Pre-evaluation of safety

Pre-evaluation of safety is to apply the principles and methods of safety evaluation for the predictive assessment of the danger and hazard of the system before the project starts construction and implementation. Safety pre-evaluation should be carried out for major and large investment projects

to ensure funds' scientific and reasonable investment.

Pre-evaluation of safety is generally based on the national and industry policies and regulations, project feasibility studies. It analyses and predicts the types and degrees of hazardous and harmful factors existing in the project, evaluates the overall safety condition of the project, and proposes reasonable and feasible safety technical countermeasures, measures and suggestions.

Takes the proposed project as the research object, safety pre-evaluation studies the inherently dangerous and harmful factors of the system according to the production process, medium, leading equipment and operation conditions. It conducts a qualitative and quantitative analysis of the danger and hazards of the system. It determines the dangerous and harmful factors of the system and their danger and hazard degree with system safety engineering methods. Then, it proposes technical countermeasures and management measures to eliminate, prevent and reduce the danger because of the foremost dangerous and harmful factors and their danger and hazard consequences. Finally, it evaluates whether the system can meet the safety requirements stipulated by the state and industry after taking countermeasures. The project's design and management can be concluded as to whether or not the project has met the safety requirements and how to improve the system to meet the safety requirements.

The safety level of the system depends first on the safety design. The safety pre-evaluation, as an essential basis for the safety design of the project, will identify the inherent or potentially hazardous and harmful factors in the operation of the system, as well as the main conditions and consequences of the dangers and hazards, and propose the best techniques, measures and solutions to eliminate the hazardous and harmful factors and their trigger conditions. By implementing these measures in the design, the system can be operated in an intrinsically safe manner without danger or detrimental consequences, even if dangerous and harmful factors are still present or if malfunctions or equipment failures occur.

Pre-evaluation proposes the type, distribution and degree of danger and hazard of the project's hazardous and harmful factors and the conditions that cause the danger and hazard consequences and should clarify which accidents and hazards are mainly dependent on management measures to prevent. The possible effects of unsafe human behaviour and the management measures to be taken; point out which places and operating positions are the most hazardous, and focus on monitoring and management.

In addition, it should also be put forward in the event of personnel failure, faulty operation, equipment failure. These all put forward goals and foundations for the safety management of the system after it is put into operation. They provide a basis for the supervision and management of the enterprise by the safety supervision and management department.

Projects that fail the safety pre-evaluation cannot be approved for construction; for projects requiring design modifications to meet the requirements, a new safety evaluation should be carried out after the changes are determined to be complete. The construction can only be done approved for implementation after passing. In the city gas system, the fire safety veto system currently in place is an important measure to ensure that projects meet safety requirements during the project safety pre-evaluation stage. When the project's design results do not meet the fire safety requirements, the project cannot start construction.

Pre-evaluation of safety is the most widely used form of evaluation. The importance of safety pre-evaluation cannot be underestimated. It can prevent blind investment, fundamentally limit the implementation of projects with safety deficiencies, and prevent the occurrence of safety accidents by eliminating the inherent safety hazards of the system.

(2) Safety acceptance evaluation

Safety acceptance evaluation is also called "post-evaluation". It is also known as inspection safety evaluation, a safety evaluation of the actual operation of the project facilities, equipment, devices and management conditions after the completion of the project and regular trial operation. To find the dangerous and harmful factors that exist after the project is put into operation, determine their extent and put forward reasonable and feasible safety countermeasures and suggestions.

Safety acceptance evaluation applies system safety engineering principles and methods to examine the hazardous and harmful factors presented in a system qualitatively and quantitatively. It determines the safety compliance of the system and the effectiveness of the supporting safety facilities, thus concluding the safety evaluation. It proposes remedial or compensatory measures for systems or units that do not meet the safety objectives to improve the intrinsic safety of the system and meet the requirements of safe production.

The safety acceptance evaluation provides technical preparation for the safety acceptance of the system. The safety acceptance evaluation report of

the construction project will serve as the basis for the construction unit to apply to the government safety supervision and management agencies for the approval of the safety acceptance of the construction project.

Whether the safety acceptance evaluation is satisfactory or not is directly related to whether the system can operate appropriately after completion. The project should first be accepted as completed in the city gas system following the construction acceptance specifications. After the gas has been turned on and the trial run is typical, a comprehensive safety acceptance evaluation should also be organised to judge the actual operation of the whole system. It examines whether it meets the safety regulations and proposes remedial and compensatory measures when the areas need to be improved and perfected. The safety acceptance evaluation report should be kept as the primary technical data for the system's operation.

(3) Evaluation of the safety status situation

Safety status evaluation, also known as safety state evaluation, is generally to evaluate the safety status of the overall or local production and operation activities of the system in operation, to find out the existing danger and harmful factors and determine their extent, and to propose reasonable and feasible safety countermeasures and suggestions.

According to the relevant laws, regulations and regulations on occupational safety, health and environmental protection, the evaluation confirms the safety status of production installations, equipment or facilities in service and whether they are acceptable or not. The proposed measures for the evaluated accident hazards serve as a basis for the enterprise's accident hazards management and a reference for the enterprise's safety investment and capital use.

In China, the method of a safety checklist operates. Fire, explosion and toxicity index sums to give quantitative values of safety parameters. For potential accidents with significant consequences, we use the corresponding mathematical models to carry out accident simulations, predict the scope of impact in extreme situations, analyse the maximum damage and the probability of an accident occurring. Then rectification measures and suggestions are proposed.

The city gas enterprises in operation should be regularly evaluated on the safety status to continuously find out the problems and take effective corrective measures to eliminate the potential safety hazards and ensure regular operation. Each evaluation report should be kept as important safety

management information to continuously check the implementation of safety corrective measures and understand the safety operation status.

(4) Special safety evaluation

Special safety evaluation is for the production in a particular activity or station (field) and the specific production process or equipment. It aims to find hazardous and detrimental factors, determine their extent and finally put forward reasonable and feasible safety countermeasures and recommendations.

Special security evaluation is generally based on an assessment of the current security situation, through the need for further thematic analysis and evaluation of specific equipment, a part of a technical link, using professional technical inspection, testing, research, experiments and other means to carry out thematic security analysis of a security evaluation. The unique safety evaluation report is generally used as an annexe or supplementary document of the comprehensive assessment of the safety status.

Special safety evaluation of the inspection, testing, analysis and experiments, is generally performed jointly by the evaluation unit and the unit owners. The evaluation unit should find professional testing organisations and research units to complete if necessary.

In the city gas system, in recent years, there have been many new supply systems and new equipment, new materials, in the early application of these technologies, equipment and special safety evaluation to help improve the technology, equipment and promotion. For certain types of accidents occurring frequently or causing significant social impacts, the management can also request to focus on the safety evaluation of specific equipment, facilities, and certain types of places or systems. It helps to discover the potential safety hazards and prevent similar accidents. Within the enterprise, professional organisations and personnel can also be hired to conduct individual evaluations of specific equipment and facilities based on those problems exposed in actual operation. They arrange maintenance, repair and replacement plans and capital preparation and learn the safety status of the system in a timely and accurate manner.

4.2.4 Safety assessment methods

1. Safety evaluation method classification

The safety evaluation method analyses and evaluates a system's hazard and harmful factors and their degree. At present, there are dozens of evaluation methods used in production processes or facilities. According to the quantitative degree of evaluation, safety evaluation methods can be divided into qualitative and quantitative safety evaluations. Sometimes, the two methods are used jointly, i.e., the so-called semi-quantitative evaluation methods.

Qualitative safety evaluation is a method to analyse and judge things scientifically with the help of experience, knowledge, observation and understanding of the law of development and change. There are the safety checklist method, Preliminary Hazard Analysis (PHA), failure type and impact analysis method, Hazard and Operability Analysis (HAZOP). Their simplicity, ease of operation characterises these evaluation methods and intuitive evaluation process and results and are therefore widely used in the safety management of domestic and foreign enterprises. Such methods can identify hazardous and harmful factors in the system and derive a qualitative hazard level. However, this method has a largely artificial and empirical component and lacks depth in describing the system's hazards.

Quantitative safety evaluation is based on statistical data, testing data, similar and similar systems data, and scientific methods to construct mathematical models and carry out quantitative evaluation according to relevant standards. At present, there are mainly three types of methods: first, probabilistic risk evaluation method, according to the accident rate of the fundamental causal factors of the accident, the application of probability statistical analysis methods, to obtain the correlation degree of the primary causal factors of the accident or the whole evaluation system accident probability of safety evaluation methods, such as accident tree method; second, hazard index evaluation method, the application of the system of accident risk index model, according to the fundamental nature and state of the system and its material equipment (facilities) and process, using the method of extrapolation, step by step to give the possible loss of the accident, the equipment that caused the accident or make the accident expand, the risk of the accident and the effectiveness of taking safety measures of safety evaluation method, such as the DOW's fire, explosion hazard index evaluation method, etc.; the third is the injury (or damage) range evaluation method, according to the mathematical model of the accident, the

application of calculation mathematical methods, to obtain the scope of injury to people or damage to objects of the accident safety evaluation methods, such as pool flame and radiation intensity evaluation model.

There is also a selection of hazard evaluation software for significant hazards or specific sites, which can be used as required.

In comparison, qualitative and quantitative evaluation methods have their advantages and disadvantages: qualitative evaluation methods can determine various types of hazardous and harmful factors on time and give them a corresponding rating. The ways are simple and easy to implement. However, the classification criteria of qualitative methods are relatively loose. Moreover, the evaluation process is prone to be mixed with more human subjective factors. The quantitative evaluation methods can give a clearer picture of the harmful range and degree of hazardous and toxic elements. However, the operation is complicated, and it requires the collection of a large amount of original and historical data and information. These methods are limited by the mathematical models used, and it is difficult to summarise the comprehensive effect of harmful factors. It is difficult to draw reliable conclusions, especially when insufficient data is accumulated.

2. Common methods for safety evaluation

There are many existing evaluation methods. It is generally necessary to select a suitable method for safety evaluation, considering the purpose of the assessment, its content, the available information, and the financial input.

For example, the following safety evaluation methods are commonly used in pipeline construction: Work Condition Hazard Evaluation (Graham Kinney Method), Preliminary Hazard Analysis (PHA), Fault Tree Analysis (FTA), Hazard and Operability Study (HAZOP), W. Kent Muhlbauer Pipeline Risk Evaluation, Safety Checklist Method, and Dow's Fire and Explosion Hazard Index Evaluation.

(1) Hazard evaluation method for operating conditions

The operating conditions hazard assessment method is a simple and easy semi-quantitative method of evaluating the hazards of the working environment, which Graham and Kinney proposed in the United States. The risk factors affecting the operating conditions are the likelihood of an accident (L), the frequency of personnel exposure to the hazardous environment (E), and the possible consequences if an accident occurs (C). The product of these three factors is used to evaluate the hazard D, i.e., $D =$

LEC. The higher the value of *D*, the more hazardous the operating conditions are.

1) Likelihood of an accident score L

It is used to express quantitatively the probability of an accident occurring. The likelihood that an accident will necessarily happen is 1, which is assigned a score of 10, while the probability that an accident will not occur is 0.1. On this basis, the range of values based on the probability of an accident is shown in Table 4-2.

Table 4-2: Accident probability score L

Numerical value of a point	Likelihood of an accident	Numerical value of a point	Likelihood of an accident
10	Entirely predictable.	0.5	Conceivably, very unlikely.
6	quite possible	0.2	Highly unlikely
3	Maybe, but not often.	0.1	Not really.
1	Unexpected. Very unlikely.		

2) The frequency of exposure of personnel to the hazardous environment score E

The greater the amount of time a person is exposed to the environment, the greater the likelihood of injury and the greater the corresponding risk is. A score of 10 is assigned to continuous personnel exposure to a hazardous environment, with a minimum score of 0.5. The range of values is shown in Table 4-3.

Table 4-3: Personnel exposure to hazardous environment frequencies score E

Numerical value of a point	Frequency of exposure to hazardous environments	Numerical value of a point	Frequency of exposure to hazardous environments
10	Continuous exposure	2	One exposure per month
6	Exposure during daily working hours	1	Several exposures per year
3	Weekly or occasional exposure	0.5	An infrequent exposure

3) Score C for possible consequences of the accident

Due to the wide range of injuries caused by accident, a score of 1 was established for minor injuries requiring treatment and 100 for simultaneous deaths of 10 or more persons, as shown in Table 4-4.

Table 4-4: Possible consequences of accidents C

Numerical value of a point	Consequences of the accident	Numerical value of a point	Consequences of the accident
100	Ten or more deaths	7	Severely disabled
40	Several deaths	3	Disabled
15	One death	1	Minor injuries requiring medical attention

4) Hazard classification criteria

This method specifies that a hazard score of 20 or less is a low hazard, slightly lower than the hazard of daily cycling to work, between 70 and 160. There is a significant hazard that requires corrective measures; between 160 and 320, there is a high hazard that must be corrected immediately; if it is greater than 320, there is an abnormal hazard that should be immediately stopped and wholly corrected. See Table 4-5 for the hazard classification according to the hazard score.

Table 4-5: Hazard classification criteria

Numerical value of a point	Risk level	Numerical value of a point	Risk level
≥320	Extremely dangerous to continue operations	≥20~70	More dangerous and needs attention.
≥160~320	Highly dangerous and in need of immediate corrective action.	＜20	A slight risk is acceptable.
≥70~160	Significant risk requiring correction		

As can be seen from the above steps and scoring criteria for implementing the operational condition hazard evaluation method, the method is relatively simple. It can be used to make a preliminary determination of the degree of risk of hazardous and harmful factors in each unit. This method is widely used in various evaluations of construction projects and can provide a

simple and intuitive overview of the construction project (system).

(2) Preliminary Hazard Analysis (PHA)

Preliminary Hazard Analysis (PHA) is a system safety analysis method to analyse macroscopically and roughly the various risk factors existing in the system and the possible consequences of the accident before the construction project. PHA requires the evaluator to understand the evaluation content fully. First, the potential hazards of the system are analysed from the energy point of view. The hazardous substances, process equipment and operators and other influences, then the trigger events (factors) that may generate hazards are deduced along with these hazards. The hazardous and harmful events (elements) are graded and dealt with. Finally, appropriate measures are formulated to prevent these events from occurring. The preparation of a hazard analysis table is the main task of the Preliminary Hazard Analysis, and Table 4-6 shows the items of a typical hazard analysis table.

Table 4-6: Hazard analysis tables

Hazard and risk factors	Trigger event	Phenomena	Cause of accident	Circumstances of the accident	Consequences	Hazard level	Initiatives

Trigger events are directly linked to the phenomenon of hazardous and harmful factors and are events that can be directly predicted by methods such as observation and measurement. The cause of an accident is some factor that leads to the trigger event and is to be derived through causal analysis. Consequences are the consequences of the actual accident or the inferred possible consequences of the accident.

Hazard levels are classified according to the following: level 1, safe, negligible; level 2, critical, on the verge of an accident, likely to develop further into an accident; level 3, dangerous, causing injury to people and property damage; level 4, destructive, likely to cause a severe accident. The measures are the prevention methods proposed by equipment control and safety management for the events that cause accidents.

Preliminary Hazard Analysis is a relatively simple analysis method, which can quickly find a series of accident factors and is a simple and easy-to-use evaluation method to carry out preliminary evaluation work.

(3) Fault Tree Analysis (FTA)

Fault Tree Analysis is a directional "tree" describing the causal relationship between accidents and is one of the most important analytical methods in safety systems engineering. It can be used to identify and evaluate the hazards of various systems, both qualitatively and quantitatively. It features simplicity and visualisation, reflecting the systematic, accurate and predictive nature of a system engineering approach to safety.

The functions and characteristics of the FTA method are as follows: it can describe and analyse the multiple factors leading to accidents and their logical relations in a comprehensive manner; it is easy to discover and identify the inherent and potential risk factors in the system and provide the basis for safety design, designating technical measures and taking safety management countermeasures; it can analyse the causes of the accidents that have occurred; it enables the operators to fully understand and master the methods and points for preventing and controlling accidents; and it is helpful for logical operation, quantitative analysis and evaluation.

The FTA method is a block diagram of the possible accident conditions and possible consequences of a disaster in an established production system or operation, plotted in a process flow, sequence, and cause-and-effect relationship to show the logical connection between the various factors leading to a disaster or injury. The fault tree consists of event symbols, logic gates and transfer symbols. It is used to analyse the system's safety or the operational function of the system and provide a visual and concise form of expression for determining the pathway of occurrence and the relationship between disasters and injuries.

The basic procedure for Fault Tree Analysis is as follows.

1) Identify and familiarise itself with the system. Determine the boundary and scope of the analysis system, get a detailed understanding of the system state and various parameters, and draw a process flow diagram or layout diagram.

2) Investigate accidents. Collect accident cases, conduct accident statistics and envisage possible accidents for the system.

3) Determine the top event. The object event to be analysed is the top event. The accident under investigation is analysed comprehensively, from which the accident with severe consequences and more likely to occur is identified as the top event.

4) Determine the target value. Based on lessons learned and accident cases, after statistical analysis, solve for the probability of the accident occurring as the target value of the accident to be controlled.

5) Investigate causal events. Investigate all causal events related to the accident. The definition of causal events should be clear and not ambiguous.

6) Draw an accident tree. Starting from the top event and working up to the depth of the analysis, the direct cause event is identified, and the accident tree is drawn in a logical relationship.

7) Qualitative analysis. The minimum set of cuts and the minimum set of paths are worked out according to the structure of the accident tree to determine the degree of influence of each virtual event on the top event and provide a basis for formulating the sequence of safety measures and priorities.

8) Quantitative analysis. It means determining the probability of all causes, marking them on the accident tree, and determining the likelihood of the top event (accident). It requires stating the degree of influence of each important event on the top event quantitatively and developing an economical and reasonable accident control scheme to achieve the purpose of optimal safety of the system.

The gas transmission stations and storage and distribution stations have a lot of equipment, a high personnel density, and many hazardous and harmful factors. The FTA method applies in the safety evaluation of them. It requires the evaluators to have a good understanding of the project (system) and its operation process and to be able to recognise the potential risk factors so that the top event and other level events will not be missed as far as possible. The professional quality of the evaluators plays a vital role in compiling and demolishing the accident trees

(4) Hazard and operability study (HAZOP)

Hazard and operability study is a qualitative safety evaluation method. The basic process is to use leading words as a guide to identifying possible deviations in the process or process state, identify the causes, analyse the consequences, and propose safety countermeasures for these deviations.

1) Introductory words

HAZOP specifies seven leading terms and 16 process parameters to prevent omissions or excessive questioning. The names and meanings of the guide words are listed in the table, and the commonly used analytical process parameters are listed in the table. The guide words are combined with the relevant process parameters and applied to each point to identify the various deviations.

Table 4-7: HAZOP guide words and meanings

Introductory phrase	Implication
NO OR NOT	Complete negation of the design intent. No part of the intention is achieved, e.g., no flow.
MORE	The value is immense with the standard value ratio, such as low temperature and pressure values.
LESS	The same standard value ratio, the values are small, such as high temperature and pressure values.
AS WELL AS	Quantitative modification/increase. Impurities present, simultaneous execution of another operation/step.
PART OF	Quantitative modification/decrease. Only some of the intention is achieved, i.e., only part of an intended fluid transfer occurs.
REVERSE	the occurrence of something or anything precisely opposite to the design requirements, such as a reverse flow of fluid.
OTHER THAN	Complete substitution. A result other than the original intention is achieved, i.e., transfer of inappropriate material.

Table 4-8: Commonly used HAZOP analytical process parameters

Volume flow	Time	Number of times	Mix
Pressure	Component	Viscosity	By-products (side reactions)
Temperature	PH value	Voltage	Separation
Fluid level	Speed	Data	Reactive

2) Analysis flow chart

Firstly, the process area to be analysed is selected, the nodes or operating steps of HAZOP are defined, the relevant process data, equipment performance and process flow are collected, and the individual process indicators or operating measures are explained. Then, according to the typical value of a design or operating parameter, the fundamental

deviations are set, and the possible consequences and their causes are analysed item by item. Meanwhile, the protection devices in existing systems are identified to perform deviation avoidance operations. Finally, other measures to avoid deviations are proposed based on the consequences, the causes and the estimated risk of protection. After the HAZOP analysis of one process parameter has been completed, the analysis of the other process parameters is carried out, and if the entire selected process range has been analysed, the following process range is selected. HAZOP for large projects is time-consuming, and research into expert systems has been initiated abroad to improve efficiency and level.

(5) Kent pipeline risk evaluation method

The W. Kent. Muhlbauer method of pipeline risk evaluation is based on finding the relative risk number magnitude of the pipeline to determine the level of danger. In other words, the higher the relative risk number, the lower the risk and the safer the pipeline is. Analysing the independent influencing factors of each section of the pipeline, finding the exponential sum, then analysing the hazard and influence coefficient of the medium, finding the leakage influence coefficient, and finally finding the ratio of the exponential sum to the leakage influence coefficient, all these results in a magnitude of the relative risk number. The relative risk number can be calculated according to the following formula.

$$Relative\ risk\ number = \frac{index\ sum}{Leakage\ impact\ factor} \tag{4-1}$$

Where,

$$index\ sum = the\ third\ party\ damage\ index + corrosion\ index + design\ index + error\ index$$

$$Spill\ Impact\ Index = \frac{Medium\ Hazard\ Index}{Impact\ factor} \tag{4-2}$$

Third-party damage refers to the accidental pipeline damage caused by non-pipeline operating unit personnel. It relates to the minimum burial depth of the pipeline, the level of activity in the territory through which the pipeline passes, above-ground pipeline equipment, public education, line condition and patrol frequency, but does not include intentional human damage.

Corrosion is one of the most common destructive factors in metal pipes. Corrosion index refers to the atmospheric corrosion index, inner wall corrosion index and buried metal corrosion index. Internal wall corrosion is mainly related to the pipeline transport medium, and external corrosion is the main factor of gas pipeline corrosion damage. It is related to the pipeline corrosion protection method, the quality of the protective layer, the soil's corrosiveness, the pipeline's age, the pipeline near the presence of other metal buried objects, and many other factors.

The design is closely related to the risk profile of the pipeline. Simplification models sometimes have to be adopted to select certain factors in the design, and differences from the actual situation due to simplification can directly affect the safety of the pipeline. The design index comprises six components: the pipe safety index, the system safety index, the fatigue index, the water strike index, the hydraulic test index, and the soil movement index.

Errors include errors in design, construction, operation, and maintenance. Improper design or errors are errors in safety design, such as poor consideration of the causes of accidents, inadequate fire protection measures, and wrong selection of materials. At the design stage, the hazardous and harmful factors of the pipeline should be taken into complete account to analyse the causes of various failures and to eliminate or mitigate the hazards. The selection of materials meets the requirements of the specification standards; construction errors mainly refer to failure to operate following the technical specifications of the design; operation and maintenance errors include human behaviour and errors in the system monitoring and data acquisition system.

The media hazard index is related to the flammability, chemical activity and toxicity of the media; the leakage impact factor is associated with the rate of leakage of the media and the population density.

(6) Safety checklist

The safety checklist method is the most commonly used qualitative evaluation method. It is a method of safety inspection and judgment based on a detailed analysis and discussion of the project or system by some experienced safety technicians familiar with the process, equipment, operation and management process, and make a table of inspection items and contents.

The safety checklist method is widely used in safety evaluation because of its simplicity, ease of use, and intuitiveness. The *Safety Acceptance*

Guideline clearly states that the safety checklist method should be used for acceptance evaluation. Depending on the project, the safety checklist can be compiled in Table 4-9.

Table 4-9: Safety checklist

Item	Content	Technical requirement	Results	Remarks

The term *item* refers to the target of this safety checklist method. The content is a series of safety measures that should be in place. The technical requirements refer to the technical specifications and standards related to these safety measures. The result is answered with "Yes" or "No" or "Not involved". "Yes" means that the conditions are met, which is indicated by "√". "No" means that there are problems to be further improved, which is indicated by "x". "Not involved" means that the project is not involved in this clause, which is indicated by "○". The remarks include other contents that need additional explanation.

4.3 Hazard Management

4.3.1 Classification of hazard sources

A hazard source is a site, area, place, space, position, equipment, and location in a system with a potential energy and substance release risk. It can be transformed into an accident under certain triggering factors. In other words, a hazard source is the core of a concentration of energy and hazardous substances and is the place where the power comes out or explodes. Hazard sources exist in defined systems, and the area of the head varies from system to system in scope. For example, a specific factory is a hazard source for a hazardous industry (e.g., petroleum, chemical). For instance, on a national scale, a particular enterprise in a hazardous industry (e.g., petroleum, chemical) may be a source of hazard. In contrast, an enterprise system might be a workshop or warehouse source of hazard or a piece of equipment in a workshop system. Therefore, the analysis of hazard sources should be performed at different system levels.

According to the above definition of a source of hazard, a source of hazard should be composed of three elements: potential hazard, present conditions and triggering factors.

Potential hazard refers to the magnitude that could be caused if an accident were triggered or the intensity of the energy or mass of hazardous material that the source of the hazard could release.

Existing conditions are the physical, chemical and constrained states of the hazard source, such as the pressure, temperature and chemical stability of the substance, the solidity of the container, and the surrounding environmental obstructions.

Triggers refer to the external factors that transform a hazard source into an accident, and each type of hazard source has a corresponding sensitive trigger. For example, heat is a sensitive trigger; increased pressure is another sensitive trigger in pressure vessels. Although the trigger is not an inherent property of the hazard source, it is an external cause of the transformation of the hazard source into an accident. Therefore, a particular source of danger is always associated with a corresponding trigger. Under the influence of a trigger, a hazard source is transformed into a hazardous condition; if this condition is not improved, it may be transformed into an accident.

A source of danger is a potentially unsafe factor that may lead to an accident. There are many and very complex dangerous factors in production and life processes. They play a very different role in causing accidents, injuries and property damage, and accordingly, the principles, techniques and methods of controlling them are different. According to their role in the occurrence and development of accidents, the sources of danger can be divided into two main categories: the first category and the second category.

(1) Analysis of Category I hazards

According to the principle of accidental release of energy, an accident is an unintentional release of energy or a hazardous substance. Excess energy acting on people and objects or substances that interfere with the exchange of energy between the human body and the outside world is the direct cause of injury. Thus, the first hazard category is energy or hazardous substances in a system where an accidental release occurs. Generally, energy is interpreted as the ability of an object to do work. The ability to do work is invisible and only visible when work is done. In practice, therefore, energy sources that produce energy or energy carriers that possess energy are often treated as Category I hazards. Examples include electrically charged conductors, running vehicles.

The common types of injury accidents in industrial processes that can be listed with the first category of hazards are shown in Table 4-10.

Table 4-10: Injury accident types and hazard sources of Category I

Type of accident	Generation, storage of energy sources or hazards	Energy carriers or hazardous materials
Object strike	Equipment, places and operations where objects are dropped, thrown, broken or scattered.	Dropped, thrown, broken, scattered objects
Vehicle injuries	Broken or scattered.	Vehicles in motion
Mechanical damage	Vehicles, traction equipment to move vehicles, ramps.	Moving parts of machinery, human body
Crane damage	Mechanical drives.	Lifted object
Electric shock	Power supply unit.	Charger, step voltage region
Scalding	Heat source equipment, heating equipment, furnaces, stoves, heat generators.	High-temperature objects, high-temperature substances
Fire (that burns)	Combustible.	Flames, fumes
Falling	Facilities and equipment for elevating people in places with significant height differences.	Human body
Collapse	Slopes, stockpiles, silos, buildings, structures for earth and stone works.	Slope soil (rock), materials, buildings, structures, loads
Gang of pop-ups	Surrounding rock bodies in mine excavation spaces.	Top plate, two gang cofferdam
Gunfire, gunpowder explosions	Dynamite.	
Gas explosion	Combustible gases, combustible dusts	
Boiler explosion	Boilers.	Steam, hot water
Pressure vessel explosion	Pressure vessel.	Contents
Drown	Rivers, rivers, lakes, seas, ponds, floods, water storage containers.	Water
Poisoning by asphyxiation	Devices, containers and places where toxic and hazardous substances generated, stored or gathered.	Toxic, hazardous substances

1) Devices and equipment that generate or supply energy, such as power substations, heating boilers, supply or generate high energy when they operate.

2) Devices, equipment and places that make the human body or objects have higher potential energy, such as cranes, hoisting machinery, and significant height differences.

3) Energy carriers, such as charged conductors, moving vehicles.

4) Devices, equipment, premises that could generate significant energy if out of control. Some devices, equipment, places where energy is converted, work is done as intended under normal circumstances, and considerable energy may be generated under unexpected circumstances. Examples include chemical installations with strong exothermic reactions, spaces filled with explosive gases.

5) Devices, equipment, premises where a build-up or sudden release of energy may occur in the event of loss of control. Devices, equipment and places where excess energy is released under normal circumstances and is in a safe state, but where a considerable accumulation of energy occurs in the event of a loss of control, the result of which may lead to the accidental release of large amounts of energy. For example, various pressure vessels pressurise equipment, devices, and places where static electricity accumulates.

6) Hazardous substances. In addition to harmful substances that interfere with energy exchange between the body and the outside world, they also include dangerous substances with chemical energy. Hazardous substances with chemical energy are divided into combustible, explosive hazardous substances and toxic, hazardous substances. The former refers to substances that can cause fires and explosions and are classified according to their chemical properties into eight categories: flammable gases, flammable liquids, flammable solids, flammable specks of dust, explosive compounds, spontaneous combustible substances, water-resistant substances and mixed hazardous substances; the latter refers to chemical substances that are directly harmful to the human body and cause poisoning, disease, deformity and cancer in people.

7) Devices, equipment and places for the production, processing and storage of dangerous substances that may cause fire, explosion or leakage of hazardous substances under unexpected circumstances. For example, explosive production, processing, storage facilities, petrochemical production equipment.

8) An object with which contact with the human body would result in an unintended release of energy from the body. Angles of objects, workpiece burrs, sharp blades, once a moving human body comes into contact with

them, the body's kinetic energy is accidentally released, and injuries occur.

The risk of a Class I source is mainly expressed in the accident. The magnitude of the risk from a Class I source depends primarily on the following: the amount of energy or hazardous substance; the intensity of the accidental release of the energy or hazardous substance; the type of energy and the hazardous nature of the hazardous substance; and the extent of the effects of the accidental release of the energy or hazardous substance.

(2) Analysis of Category II hazards

In production and life, to use energy and allow it to flow, convert and do work in production processes as intended, it is necessary to take shielding measures to constrain and limit energy, i.e., the sources of danger must be controlled. The shielding that constrains and limits energy should reliably control the energy and prevent it from being released accidentally. However, reliable shielding does not exist in actual production processes. Under the influence of many complex factors, the shielding to restrain and limit energy can fail or even be broken, and an accident can occur. We, therefore, refer to the various unsafe factors that lead to the failure or breakage of restraint and energy-limiting shielding as Class II hazards, which include human, physical and environmental aspects.

1) When it comes to human factors in safety work, the terms *unsafe act* and *human error* are used. An unsafe act generally refers to an apparent violation of safe operating procedures, which leads directly to an accident. For example, an electric shock may occur when the electrical circuit is repaired with power on. A human error means that the result of a human action deviates from a predetermined standard, e.g., closing the wrong switch to electrify a line under maintenance, opening a valve by mistake to release a harmful gas. Unsafe acts and human error may directly undermine the control of the first category of hazards, resulting in the accidental release of energy or hazardous substances. It may also cause problems with the unsafe elements of things resulting in accidents.

2) The unsafe condition of an object can be summarised as unsafe condition and malfunction or failure of an object. The unsafe state is when the mechanical equipment or material does not meet the safety requirements, e.g., unprotected drive gears, exposed live bodies. For safety management practice in China, the unsafe condition of an object is often called a potential hazard. Malfunction or fault refers to the

phenomenon that mechanical equipment, parts and components cannot achieve the intended function due to low performance. The unsafe condition and fault may directly cause the failure of measures to restrain or limit energy, or hazardous substances and accidents may occur, e.g., destruction of wire insulation and leakage of electricity.

3) Environmental factors mainly refer to the system's environment. These include the physical environment of temperature, humidity, lighting, dust, ventilation, noise and vibration, and the environment of the business and society. A poor physical environment can cause physical unsafe factor problems or human factor problems. For example, a humid environment can reduce the strength of a structure or container by accelerating metal corrosion; intense noise in the workplace affects people's emotions, distracts them, and causes them to make mistakes. The management system, interpersonal relationships or social environment of an enterprise affect the human psyche. It may result in unsafe behaviour or human error.

Category II hazards are often random occurrences surrounding category I hazard, and the circumstances of their occurrence determine the likelihood of an accident occurring. The more frequent the occurrence of category II sources, the greater the likelihood of an accident.

(3) Linkage between hazard sources and accident occurrence

An accident occurs from the joint action of two types of hazard sources. The existence of a category I source is a prerequisite for the event of an accident, without which there would be no accidental release of energy or substances. On the other hand, if the category II source had not destroyed the control of the category I source, no release of energy or dangerous substances would have occurred. A category II source is necessary for a category I source to cause an accident. The two types of hazard sources are interdependent and complementary in accident occurrence and development. The energy released from the category I source in the occurrence of an accident is the main body of energy that causes injury to people or damage to property and determines the severity of the consequences of the accident; the difficulty of the appearance of the category II sources determines the possibility of the accident. The two types of hazard sources together determine the danger of the source of the hazard.

Category II hazards should be based on the control of category I hazard, which are phenomena that occur randomly around category I hazard and are more difficult to control than category I hazard.

4.3.2 Hazardous source control approaches

Hazardous source control eliminates and controls hazardous sources and prevents them from causing accidents, injuries, and property damage using engineering technology and management tools. Hazardous source control can be carried out from technical control, human behaviour control, and management control.

(1) Technical control

Control of hazardous sources is mainly achieved through technical means. Hazard source control technology includes safety technology to prevent accidents and safety technology to reduce or avoid accident losses. When taking technical measures to control the sources of danger, the former should prevent accidents before they occur. On the other hand, adequate preparations should be made to prevent the accident from expanding or causing other accidents in a malfunction or accident and limit the damage caused by accident to the smallest possible extent. The main techniques of hazard source control are elimination, management, protection, isolation, monitoring, retention and transfer.

(2) Human behaviour control

Human error should be controlled and reduced. Human error is mainly manifested as operational errors, command errors, incorrect judgment or lack of judgment, carelessness, boredom, laziness, fatigue, tension, disease or physiological factors, the improper use of protective equipment and protective devices. The control of behaviour is firstly to strengthen education and training to make people safe; secondly, operational safety should be achieved.

(3) Management control

Scientific safety management is also a vital means of controlling the sources of danger. Through a series of planned and organised safety management activities, maintaining the sources of risk can also be achieved. Generally, the following management measures can prevent the danger source.

Establish and improve the rules and regulations of the management of dangerous sources. They are enhanced after the hazard sources are identified. These include the system of job safety production responsibility, implementation rules for crucial control of hazard sources, safety operation procedures, operator training and assessment system, daily management

system, shift handover system, inspection system, information feedback system, approval system for hazardous operations, emergency measures for abnormal situations, assessment awards, and the reward and punishment system.

1) Clear responsibilities and regular inspections

The responsible persons at each level should be identified according to the level of each hazard source, and their specific responsibilities should be clarified. In particular, the responsibility for regular inspection of hazardous sources at all levels should be clarified. In addition to the daily self-inspection by operators, the leaders should be required to participate in the regular inspections. The company's general manager (factory director, institute director) should do a semi-annual inspection, branch factory director monthly review, workshop director (room director) weekly inspection, and section and team leader daily inspection for the vital hazard sources. A detailed inspection arrangement plan should also be made for low-level sources of danger.

According to the specified methods and standards, the inspection of dangerous sources should be carried out against the checklist item by item, and records should be kept. If hidden hazards are found, the information feedback system should be followed to be eliminated on time. According to the law, anyone who fails to receive a request to perform the inspection duty and causes an accident should be held accountable. Requiring at all levels to participate in regular inspections helps to enhance their sense of responsibility for safety and reflects the principle of managing safety when managing production. It also helps significant accident hazards to be identified and resolved on time.

Dedicated safety technicians should regularly inspect, supervise and strictly evaluate the implementation of inspections by personnel at all levels to achieve management closure.

2) Strengthen the daily management of dangerous sources

Operators are strictly required to implement the rules and regulations on the daily management of hazardous sources. They should do an excellent job of safety duty and changeover, operate by safety operation procedures, carry out daily safety inspections according to safety checklists, and approve their dangerous operations. All activities should be carefully recorded as required. Leaders and safety and technical departments regularly conduct strict inspections and examinations, find problems,

give timely guidance and education, and reward and punish according to the review and examination.

3) Strengthen the daily management feedback of danger sources and rectify the hidden danger on time. To establish and improve the information feedback system of danger sources, formulate the information feedback system and strictly implement it. For the accident hidden thoughts found in the inspection, according to their nature and severity, information feedback and rectification should be implemented and recorded under the provisions of the hierarchy. The discovery of significant hidden dangers should be immediately reported to the safety technology department and the first leader of the administration. The responsibility for information feedback and rectification should be implemented to the person. Information feedback and rectification should be regularly assessed, rewarded and punished by leaders and safety technology departments at all levels. The safety technology department shall periodically collect and process information and provide it to the leaders at all levels for research and decision-making to continuously improve the control and management of hazard sources.

4) Improve the preparatory work of controlling and managing dangerous sources. In addition to establishing sound rules and regulations, the essential work of hazard source control management should also include establishing sound safety files and installing safety signage for hazard sources. Hazardous source files should be set by the relevant content of safety file management and designated to be kept by a dedicated person and collated regularly. Safety signs should be prominently displayed at the source of danger, indicating the level of risk, indicating the person responsible, indicating the main hazards according to the national standard safety signs, and outlining the preventive measures.

5) Improve the assessment, evaluation, rewards, and punishments for controlling and managing dangerous sources. Assessment criteria should be established for all aspects of hazard control management and should seek to quantify and grade them. Regular and rigorous appraisal and evaluation of rewards and penalties are required. The requirements can be increased yearly to promote continuous improvement in hazard source control management.

4.3.3 Hierarchical management of the hazard sources

Since the 1980s, many Chinese enterprises have implemented a classification system to manage hazard points, which has produced good results. It enhanced the sense of responsibility for safety among leaders at all levels, improved the safety awareness, safety knowledge and accident prevention ability of the operators, strengthened the primary work of enterprise safety management, and improved the overall control level of hazard source points.

The so-called hazard source point refers to the production equipment, facilities, production posts, operating units that contain the hazard source of Category I. In terms of safety management, hazard point grading management focuses on managing these hazard 'points'.

Hazard source points grading management is the specific application of systematic safety engineering in hazard identification, control and evaluation in production site safety management, which reflects the characteristics of modern safety management. Compared with traditional safety management, the grading management of hazard source points has the following features: reflecting "prevention first"; comprehensive and systematic management, highlighting key management. The hazard source points grading management regarding their degree of danger can highlight the focus of safety management and limited human, financial and material resources on solving the most critical safety problems. Seizing the key points can also drive the general and promote the general improvement of the enterprise safety management level.

Hazards in the city gas industry can be classified according to the following criteria:

(1) A site that meets one of the following conditions is a significant hazard source and is defined as the primary prevention target.

1) Stations with terminal receiving, loading and unloading functions (LNG ports and terminals)

2) City gas gateways (natural gas)

3) Important gas pipelines determined by the local people's government (city gas transmission trunklines, critical consumer gas supply pipelines, essential section pipelines)

4) Major gas source's reserve function stations (municipal strategic gas source reserve function natural gas, LPG storage and distribution stations,

LNG, CNG stations)

5) Municipal gas dispatch centre (gas supply's control management system)

(2) Places that meet one of the following conditions are secondary prevention targets.

1) Regulation stations of High-pressure A.

2) CNG refilling stations.

3) CNG cylinder supply stations.

4) LPG refilling stations.

(3) Pressure-regulating stations, bottling supply stations and bottle supply stations that do not belong to the primary or secondary prevention targets are tertiary prevention targets.

4.4 Gas System Operational Safety Evaluation

In December 2012, *the Ministry of Housing and Urban-Rural Development of the People's Republic of China* and *the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China* jointly issued GB/T50811-2012 *Safety Evaluation Standard for Gas System Operation*.

This standard applies to the safety evaluation of the status of city gas systems that have been officially put into operation. Essential provisions of the standard are extracted below.

Gas operating enterprises should conduct regular safety evaluations. Accident hazards identified during the evaluation process should be rectified immediately, or a treatment plan should be drawn up for a limited period. A safety evaluation must be carried out directly on the gas system where the accident occurred when a major accident occurred.

The safety evaluation of gas operating enterprises can be carried out by an evaluation team of personnel familiar with the production technology and safety management, or a third-party professional service provider for safety production can be commissioned.

The procedure of gas system safety evaluation shall include four main procedures: preliminary preparation, on-site inspection, rectification and

review, and the preparation of safety evaluation report.

The content of the gas system safety's evaluation report should include basic information, identification and analysis of hazardous and harmful factors, division of evaluation units, qualitative and quantitative evaluation, safety countermeasures and recommendations, and conclusions of the safety evaluation.

Quantitative safety evaluation methods are appropriate for gas system safety evaluation. When qualitative safety evaluation methods are used, the safety checklist method should be the primary method, supplemented by other safety evaluation methods.

When the safety checklist is used for evaluation, the facilities and operations checklist and the safety management checklist shall be used to score the evaluation separately. The total score for the evaluation shall be calculated according to the following formula.

$$\begin{aligned} &Total\ evaluation\ score \\ &= 0.6 \times score\ of\ the\ facilities\ and\ operations\ checklist \\ &\quad + 0.4 \times score\ of\ safety\ management\ checklist \end{aligned} \tag{4-3}$$

Following the formula, 60% weight is given to the facilities and operations checklist, and 40% is allocated to the safety management checklist.

The evaluation scores and conclusions are divided into four levels.

1) When the evaluation score is ≥90, the evaluation concludes that the safety conditions are good and the operational requirements are met.

2) When the evaluation score is ≥ 80 and < 90, the evaluation concludes that the safety conditions meet the operational requirements. Daily management and maintenance need to be vital to improve the safety conditions gradually.

3) When the evaluation score is ≥ 70 and <80, the evaluation concludes that the safety conditions meet the operational requirements, but the potential hazards need to be corrected in a limited period.

4) When the evaluation score is <70, the evaluation concludes that the safety conditions do not meet the operational requirements and the operation should be stopped immediately. After carrying out hidden rectification and improving the safety conditions, a re-evaluation is

required. The operation may only continue once the safety conditions have been met.

The standard also provides safety checklists for different site facilities and users in an appendix, which gas operators can use according to the actual production situation.

CHAPTER 5

EMERGENCY PLAN MANAGEMENT

An emergency plan is a predetermined programme of work for responding to emergencies in an orderly, rapid, scientific and legal manner and minimising emergencies and the damage they cause. The management of emergency plans should follow the principle of "unified planning, classification and guidance, graded responsibility and dynamic management", including the planning, preparation, approval, release, filing, exercise, revision, training, publicity and education of emergency plans.

Governments should formulate and manage the government's emergency plans and various departments at all levels and relevant departments. The plans include three categories, such as overall emergency plans, unique emergency plans and departmental emergency plans. The emergency plans of production and operation units can be divided into three categories: comprehensive emergency plans, individual emergency plans and on-site disposal plans. Concise and practical emergency disposal cards can also be prepared. Large enterprise groups can refer to international practice and establish a group-level emergency plan system.

The emergency plan should generally include prediction, identification and evaluation of possible accidents, identification and preparation of resources such as workforce, materials and tools, guidance on the establishment of a rational and practical emergency organisation on and off-site, design of emergency action tactics and procedures, development of training and exercise plans, development of post-accident site clearance plans, tidying up and recovery steps.

When an accident or disaster is unavoidable due to natural or man-made causes, effective emergency rescue action is the only effective measure that can counteract the spread of the accident or disaster and mitigate the consequences of the hazard. A well thought out emergency response work plan before an accident or disaster occurs and timely and effective emergency response action when a disaster occurs can save lives, protect property and protect the environment.

5.1 Basis for Contingency Planning

Emergency plan work shall be carried out following the state's requirements, the industry and the safety production department, under relevant laws, regulations and systems, and in conjunction with the actual production, the plan management work plan shall be formulated and carried out.

The national and local standards for the emergency planning work in the city gas industry are mainly based on the *People's Republic of China Safe Production Law, Law of the People's Republic of China on Emergency Response, Emergency Pre-plan for the Incidents of Foreign Experts, Measures for the Administration of Contingency Plans for Safe Production Incidents, the Guidelines for the Preparation of Emergency Plans for Safe Production Accidents of Production Operators, Regulation on the Administration of City Gas, Safety Technical Specification for Operation, Maintenance and Rush-repair of City Gas Facilitie*s; the provincial, municipal and local regulations on management, general plans for emergencies, and the measures for the management of emergency plans for safe production accidents.

The Measures for the *Administration of Safe Production Accident Emergency Response Plans*, which was promulgated and came into effect by the *State Administration of Safe Production* from 1st July 2016, set out new requirements for safe production emergency response plans. Among them:

Article 3, the management of emergency plans shall be based on localisation, hierarchical responsibility, classification guidance, comprehensive coordination and dynamic management.

Article 6, the emergency plans of production and operation units are divided into comprehensive emergency plans, unique emergency plans and on-site disposal plans.

The comprehensive emergency plan refers to the comprehensive work plan formulated by the production and operation units for dealing with various safe production accidents. It is the general outline of the unit's overall work procedures, measures and emergency plan system for dealing with safe production accidents.

The particular emergency plan refers to the specific work plan formulated by the production and operation units to deal with one or more types of safe production accidents. It prevents safe production accidents by targeting essential production facilities, primary hazard sources and significant activities.

On-site disposal plan refers to the emergency disposal measures formulated by the production and operation units for specific places, installations or facilities according to different types of safe production accidents.

Article 7, the preparation of emergency plans should follow people-oriented, law-based, practical and pragmatic principles, with emergency disposal as the core, clear emergency responsibilities, standardised emergency procedures, and detailed safeguard measures.

Article 19, the production and operation unit shall prepare emergency plans, concise, practical and effective emergency disposal cards for the workplace and the post's characteristics.

The emergency disposal card should specify the procedures and measures for critical positions and personnel and the relevant contact person and contact details and be easily carried by practitioners.

5.2 Preparation of Contingency Plans

The emergency plan should be prepared based on risk assessment, emergency resource survey and emergency capability assessment, and the content should be reasonably determined. Attention should be paid to improving its relevance, practicality and operability.

Risk assessment refers to identifying hazard factors in the production system and evaluating the possibility of safe production accidents and their possible consequences regarding the degree of harm and the scope of influence to explore measures to control risks and manage potential hazards. The risk assessment content mainly includes the types of accidents that various types of safety risks may cause, the consequences of accidents, the scope of influence.

The emergency resources refer to the sum of human resources, materials, facilities, information, and technology that the region and the unit can call up at the first time of safe production accidents, mainly including emergency response teams, experts, equipment and materials. Investigation of emergency resources can provide a basis for formulating emergency response measures. If necessary, a survey should also be conducted on the emergency resources in the cooperation region that can be requested for assistance and the social emergency resources in the area.

The emergency response capability for safe production accidents refers to the ability necessary for emergency management activities such as

performing emergency management duties, performing emergency rescue tasks, and achieving emergency management objectives. By assessing emergency response capability, it is possible to understand whether the existing emergency response capability can meet the emergency response needs of an accident and promote the improvement and construction of emergency response capability.

5.2.1 Requirements for the preparation of emergency response plans

The preparation of an emergency plan shall meet the following basic requirements.

1) Comply with the provisions of relevant laws, rules, regulations and standards.

2) Conform to the actual situation of safe production in the region, department and unit.

3) Based on the risk assessment and risk analysis of the region, department or unit.

4) The responsibilities of emergency organisations and personnel are divided, and there are specific implementation measures.

5) Clear, and specific emergency procedures and disposal measures are compatible with their emergency response capabilities.

6) There are clear emergency safeguards in place to meet the emergency needs of the region, department and unit.

7) The essential elements of the emergency plan are complete, and the information provided in the annexes to the emergency plan is accurate.

8) The contents of the emergency plan are connected with appropriate emergency plans.

5.2.2 Contingency planning steps

Specific steps in the preparation of emergency plans are as follows.

1) Set up a contingency plan preparation team. The main person in charge of the production and operation unit shall be responsible for organising the preparation and implementation of the unit's emergency plan and is responsible for the authenticity and practicability of the emergency plan; the

team should also include personnel from departments and units related to the emergency plan, as well as personnel with experience in on-site disposal.

2) Gather information. Collect and research the information on laws, regulations, accidents and regulatory documents, including information on associated emergency response plans.

3) Identify hazards and evaluate risks. Evaluate the hazard sources, danger degree. Or make use of the existing safety evaluation reports.

4) Evaluate the emergency response capabilities and resources. Evaluate emergency response personnel, equipment, rescue forces and resources, and rescue capabilities, and examine whether they meet the needs of emergency rescue.

5) Select the appropriate type of emergency work plan. Make emergency work plans for different systems and places, and scope of work, emergency measures.

6) Prepare and complete emergency plans at all levels. Prepare and complete the emergency plan, consult with relevant emergency rescue teams, citizens, legal persons or other organisations; organise relevant departments and experts to comment on and review the plan and improve it.

5.2.3 Key elements of the emergency plan

The emergency plans of the government and related departments shall clarify information reporting, response classification, transfer of command and alert evacuation under the actual situation of the region and the department.

The emergency plans of production and operation units should reflect the features of self-help, mutual rescue and early disposal. They stipulate the emergency response organisation and its responsibilities, emergency response system, accident risk description, early warning and information report, emergency response, safeguard measures, emergency plan management and other contents.

1) Organisational structure and its responsibilities: Specify the emergency response organisation, participating units, personnel and their roles; specify the general person in charge of the emergency response and the person in charge of each specific action; list the relevant organisations outside the region that can assist; specify the respective responsibilities of the government and enterprises in the emergency response to accidents.

2) Hazards identification and risk assessment: Analyse the hazards and identify the type and location of the accident; determine the scope of the accident and the number of people who may be affected; classify the risk and the level of the emergency response in terms of the severity of the accident.

3) Alarm and information report: Determine the alarm system and procedures, including the alarm methods; determine the communication and contact methods with the government and competent departments; clarify the mutually recognised forms and contents of announcements and alarms (to avoid misunderstanding); clarify the ways for emergency responders to call for help; clarify the standards, methods and signals for alerting the public; explain how the emergency response command centre can ensure the relevant personnel to understand and respond to the emergency alarm; clarify the information reporting requirements and forms.

4) Emergency equipment, facilities and resources: Identify the facilities available for emergency response, such as offices, communication equipment, emergency supplies; list the emergency equipment available to relevant departments, such as corporate site, armed police, fire, health, epidemic prevention; describe the relationship with the appropriate medical institutions, such as first aid stations, hospitals, ambulance teams; describe the available hazard monitoring equipment; list the available personal protective equipment (such as respirators, protective clothing); list the mutual assistance agreements signed with relevant agencies.

5) Emergency response capability and response: Specify the person responsible for determining the level of risk for each emergency event; describe the procedure for evaluating the level of risk; describe the capability of the evaluation and emergency response team; determine the responsibilities of the external assistance professionals and personnel.

6) Procedures for protective measures: Specify the person responsible for authorising the issuance of orders for the evacuation of the population; describe the procedures for deciding whether to take protective measures; identify the agencies responsible for implementing and verifying the evacuation of the population (including announcements, transportation, traffic control and alerts); describe the safety and protection measures for special facilities and groups of people (such as schools, kindergartens, disabled persons); describe the reception centres or shelters for evacuated people; describe the conditions under which the decision to terminate protective measures is made.

7) Dissemination of information and public education: Identify the spokespersons of emergency response organisations to the media and the public during the emergency response process; describe the methods used to make decisions about releasing accident emergency information to the media and the public; describe the periodic communications and safety awareness measures taken to ensure that the public understands how to face an emergency.

8) Post-accident recovery procedures: Identity of the person responsible for deciding to terminate the emergency response and restore regular order; describe the measures taken to ensure that unauthorised access to the accident scene does not occur; describe the procedures for announcing the termination of the emergency response; describe the procedures for restoring normal conditions; describe the methods for continuous testing of the affected area; describe the methods for investigating, documenting, and evaluating the emergency response.

9) Training and drills: Train emergency personnel and ensure that those who are employed meet emergency requirements; describe the annual training and exercise plan for the emergency plan; describe the conditions under which the emergency plan is evaluated periodically; describe the frequency and extent of communication system testing; describe the frequency and extent to which public notification tests are conducted and their effectiveness evaluated; describe the frequency and extent to which on-site emergency personnel are trained, and safety information materials are updated.

10) Maintenance of emergency plans: Identity of the person responsible for updating and maintaining the emergency plan; describe the methods for evaluating, updating, and revising the emergency plan; improve the emergency work plan according to the drill and test results.

5.2.4 Requirements for unique emergency plans and on-site disposal plans for production and operation units

The particular emergency plan refers to the unique work plan formulated by the production and operation units to prevent production and safety accidents by targeting necessary production facilities, primary hazard sources, and significant activities. For one or more types of accident risks, the production and operation units may prepare corresponding unique emergency plans or incorporate the special emergency plans into the comprehensive emergency plans. The individual emergency plans shall

provide emergency command agencies and responsibilities, disposal procedures and measures.

The on-site disposal plan refers to the emergency disposal measures developed by the production and operation unit for specific sites, installations or facilities according to different types of production safety accidents. For the more dangerous places, devices or facilities, the production and operation units shall prepare the on-site disposal plan; the on-site disposal plan shall stipulate the responsibilities for emergency work, emergency disposal measures and precautions and other contents.

The various types of emergency plans prepared by the production and operation units shall be linked to each other and the emergency plans of the relevant people's governments and their departments, emergency rescue teams and other units involved.

5.2.5 Emergency response cards

Production and operation units can prepare simple, practical, and effective emergency disposal cards for workplaces and positions based on emergency plans. The emergency disposal card should stipulate key positions, personnel emergency disposal procedures and technical measures, and the relevant contact personnel and contact information so that employees can readily inquire and carry.

The emergency disposal card of the gas supply unit can be divided into outdoor events, indoor events according to the location of the event. The outdoor gas pipelines, including the steel pipe and PE pipe, are divided into third-party sabotage, pipeline corrosion and other emergency disposal card according to the type of ordinary events. It is also possible to prepare job emergency response cards according to commanders, operators, inspectors. In conjunction with the construction of "smart gas" and "intelligent gas", attempts can also be made to develop emergency cards quickly and intelligently queried.

5.3 Review, Publication and Filing of Emergency Response Plans

After the emergency plan is prepared, the working group or the lead unit shall submit the draft of the emergency plan for review and other relevant materials to the emergency plan approval unit. If it is necessary to publish a shortened version of the emergency plan for confidentiality and other

reasons, the shortened version shall be submitted together for approval. After completing the approval, it needs to be filed and published within a specified time following relevant regulations.

Local safe production supervision and administration departments at all levels shall organise relevant experts to validate the departmental emergency plans prepared by their departments.

The production and operation unit shall review the emergency plan prepared by the unit and form a written summary of the review. The review or demonstration of the emergency plan shall focus on the completeness of the essential elements, the rationality of the organisational system, the pertinence of the emergency disposal procedures and measures, the feasibility of emergency safeguard measures, the convergence of the emergency plan and other content.

After the evaluation or demonstration of the emergency plan of the production and operation unit, the main person in charge of the unit shall sign and publish it and promptly distribute it to the relevant departments, positions and relevant emergency rescue teams of the unit. Suppose the accident risk may affect other units and personnel in the vicinity. In that case, the production and operation unit shall inform other units and personnel in the vicinity of the nature of the accident risk, the scope of influence and the emergency precautionary measures.

The emergency plans of the local safe production supervision and management administration at all levels shall be reported to the people's government at the same level for the record and copied to the safe production supervision and management administration at the next higher level.

Production and operation units shall make informative filings with the safety production supervision and management administration and relevant departments by the principle of territoriality.

5.4 Training and Drilling of Emergency Response Plans

The emergency plan preparation unit should organise emergency plan training for managers and professional rescuers closely related to the implementation of the emergency plan by compiling and distributing training materials, holding training courses and conducting work seminars.

Governments at all levels and their relevant departments shall make emergency preparation training an essential part of emergency management training and bring it into the training of leading cadres, civil servants, and emergency management cadres' daily training.

The safe production supervision and administration departments at all levels shall include training their emergency plans in the work plan of safe production training and organising and implementing emergency plans for crucial production and operation units in their administrative regions. They shall organise regular drills of emergency plans to improve the ability of their departments and areas to handle emergencies in production and safety accidents.

The production and operation units shall organise and carry out training activities on their emergency plans, emergency knowledge, self-help, mutual rescue and evacuation skills. Thus, the person concerned may understand the contents of the emergency plans and be familiar with their emergency duties and disposal procedures and measures. They shall formulate and practise their emergency plans. It is required to organise at least one comprehensive emergency plan practice or particular emergency plan practice every year and at least one on-site disposal plan practice every six months, as per the characteristics of their accident risks. The operation and management units of lifeline projects such as municipal water supply, power supply, gas supply, and heat supply shall organise and carry out emergency drills on a targeted and regular basis.

5.4.1 Purpose of emergency plan training and exercises

As major accidents often occur suddenly, the standard order of production, work and life is disrupted. Effective rescue measures might not be implemented if no prior emergency rescue plan is in place due to panic and confusion. When the initial preparation is not sufficient, it may result in emergency personnel not being in place timely, delaying the rescue of personnel and accident control, or even the expansion of the accident.

These can be avoided by formulating an accident rescue plan in advance and an emergency plan for all kinds of accidents, especially significant accidents. However, to ensure that the emergency procedures and methods can be adopted accurately and promptly when an accident occurs, and to react and deal with the accident quickly. It is also necessary to train and rehearse the accident emergency plan. The commanders of emergency agencies at all levels, emergency response teams and enterprise employees

can understand and be familiar with the requirements and their duties in an accident emergency. Only when this step is taken can the rescue and relief methods set out in the plan be adopted in the event of an emergency, and the on-site rescue and relief measures be implemented in a timely, effective and correct manner to minimise casualties and property losses.

The specific objectives of emergency preparedness training and exercises are as follows.

1) Test the adequacy of emergency response plans and operational procedures.

2) Test the availability of emergency devices, equipment and material resources.

3) Improve the coordination of internal and external emergency services on site.

4) Identify and correct deficiencies in emergency plans.

5) Raise emergency awareness among the employees and the public.

5.4.2 Training of emergency response plans

Organisations and agencies at all levels should draw up emergency response training plans and use various teaching methods and approaches to strengthen the training of relevant personnel in rescue and rescue operations to improve their ability to deal with emergencies. The units preparing emergency plans should organise and conduct emergency plan training for managers and professional rescue personnel closely related to the implementation of emergency plans by compiling and distributing training materials, holding training courses and conducting work seminars. Governments at all levels and their relevant departments should make emergency plan training an essential part of emergency management training and bring it into the training of leading cadres, civil servants and emergency management cadres in their daily training. For the non-confidential emergency plans that require extensive public participation, organisation units should make full use of the Internet, radio, television, newspapers and other media to publicise them widely and produce easy-to-understand, easy-to-remember and functional publicity materials for free distribution to the public.

The *scope of emergency training* includes government authorities, community residents, enterprises' employees, and professional emergency rescue teams.

The main contents of emergency training include regulations, ordinances and standards, safety knowledge, emergency plans at all levels, emergency repair plans, professional knowledge of the position, emergency rescue skills, risk identification and control, basic knowledge, case analysis. Depending on the level of training personnel, the content of education should have a different emphasis.

1) Safety regulations

Education on laws and regulations is one of the cores of emergency training and an essential part of safety education. Through education, the emergency response personnel can firmly establish the concept of the legal system in their minds and clarify the principle of "follow the law and do things according to the rules".

2) Safety and health knowledge

Mainly includes the basic theory of fire and explosion and its brief preventive measures; identification of significant hazards and the essential characteristics of hazards; the concept of substantial hazards and their critical limit values; the ways of entry of chemical poisons into the human body and methods to control their spread.

3) Safety technology and repair technology

In practice, apply the knowledge learned to the emergency repair work to test safe operation and accident control skills.

4) Main contents of the emergency plan

Make the employees of manufacturing enterprises understand the primary contents and procedures of the emergency plan and understand their responsibilities and tasks in the emergency process, which is the critical link to ensure that the emergency rescue plan can be launched quickly and implemented smoothly.

The *objects of emergency training* include enterprise leaders and managers, all employees, emergency rescue personnel and the public.

1) Directors and managers of enterprises

They are responsible for the safe production of the enterprise. They formulate and revise the enterprise's accident contingency plan and organise and direct rescue work in emergencies. Therefore, their training should

focus on implementing national guidelines and policies, the strict implementation of the safe production responsibility system, and rules, regulations, and standards.

2) All employees of the enterprise

The pipeline companies have various members in their workforce, including regular employees, labourers, territorial workers and temporary workers. The quality of the employees varies, with varying levels of product knowledge and safety technology. Therefore, the training must be enhanced to improve their emergency response capabilities.

The training focus for the company employees includes: establishing their awareness of the law and having them abide by the law; the primary contents and procedures of emergency plans; the strict implementation of safe operating procedures; safety techniques related to the gas pipelines; and common sense and basic skills of self-and mutual-rescue.

All employees should understand and be familiar with the contents of the emergency plan of the pipeline where they are working through the training and know the corresponding duties and work, they are responsible for after activating the emergency plan. It will enable them to apply the learned knowledge in practice to improve their skills in safe production operations and handling and controlling accidents.

3) Emergency rescue personnel

Emergency rescue personnel are the main force of emergency rescue in pipeline accidents, so the technical training should be significantly enhanced. The emergency rescue personnel should be familiar with every step of the emergency plan and their duties to effectively stay calm in times of emergency and do their job well. The main contents of the training for emergency rescue personnel include: being familiar with all the contents of the emergency plan, the maintenance and rescue plan for various situations; mastering the use and maintenance of the apparatus and equipment used by the unit or department in the process of emergency rescue, mastering and understanding the control system of significant hazards and accidents; the rules, regulations, operating procedures and common sense of safety in production; their safety in the process of emergency rescue; the knowledge of protection, the correct use of protective equipment; information about the pipeline lines, stations, valve chambers, auxiliary facilities and the surrounding natural and social environment under the jurisdiction of the enterprise; accident case analysis.

The emergency rescue personnel need to be trained and evaluated regularly, and the focus should be laid on the effectiveness of training.

4) General public

Owing to the different social, economic and natural environmental conditions in each region, the residents' knowledge of safety and awareness of disaster prevention and avoidance varies greatly. In particular, in areas where the gas is just beginning to be used, it is necessary to strengthen safety education so that the public is aware and informed of the possible accidents and secondary disasters that may occur in a gas leak or other dangerous situation. At the same time, a specific gas alarm telephone number should be announced. A linkage mechanism should be established with the public safety and firefighting departments, such as the standard emergency number of 110 and 119, to ensure that once a dangerous situation occurs, the public can immediately call the police and know how to carry out the emergency evacuation.

5.4.3 Drilling of emergency response plans

To ensure that the departments of emergency rescue organisations can carry out emergency rescue work skilfully and effectively in the event of an accident, the emergency plan preparation government should establish an emergency exercise system and plan. In general, the different requirements for the frequency and scope of the drills should be put forward according to the level and type of the emergency rescue plan for accidents. Drills within the enterprise can be combined with production, operation and safety inspection work and arranged comprehensively.

The safe production supervision and management administration at all levels should organise regular emergency plan drills to improve the department's and region's ability to handle emergencies in safe production accidents. The production and operation units shall formulate their emergency practice plans. They will organise at least one comprehensive or particular emergency plan practice every year as per the characteristics of the accident risk of the unit and at least one on-site disposal practice every six months.

The drills check the adaptability of the emergency response teams to deal with various emergencies. They help to upgrade the degree of mutual support and coordination between the various functional departments and professionals, the emergency response capability of the emergency rescue

headquarters, and the ability to organise and direct the rescue of professional rescue teams and manage the emergency response of the people. The drills can confirm whether the emergency plan is feasible. The emergency drill is a comprehensive emergency response exercise for each team member who participates, and the exercise will improve emergency response skills and operational capabilities.

Through the exercise, the problems in the emergency plan can be discovered. A practical reference can be provided for revising the plan. Primarily through the evaluation and summary after the exercise, the problems not considered in the plan can be exposed, and ways to correct them can be found, which is an essential step in improving the quality of the emergency plan.

(1) Forms of emergency plan exercises

Emergency plan exercises should follow the actual situation through practical or desktop exercises, with a wide range of participants, strong linkage, various forms and efficiency.

The indoor (tabletop) drill is mainly conducted by the leaders of the command department and the departments of command, production, communication and other emergency rescue personnel, according to specific objectives and requirements, in the form of indoor organisation and management, and operational simulation. It rehearses the implementation of emergency rescue tasks by emergency agencies at all levels. The scale of the indoor exercise can be comprehensive according to the requirements of the task, or it can be a single project exercise or a joint exercise of several projects.

Field drills, i.e., field simulation drills, can be divided into single training, partial drills, and comprehensive drills according to their task requirements and scale. Personnel and equipment must conduct field actual or simulated operations to do the drills.

(2) Organization of emergency drills

Regardless of the exercise size, it should generally consist of two parts. Firstly, the people involved in the accident response make up the majority of the exercise personnel. Every professional, from the commander to the participants in the exercise, should be an active team member who may be directly involved in the accident response in the future. The second is the assessor, i.e., an expert or group of experts in accident response, who

assesses each exercise procedure. The assessor and the person conducting the exercise should prepare well, and a joint evaluation and summary should follow the exercise. For different exercises, the person with the primary task should take on more than one role to get practical exercise.

The organisational work mainly includes: the organiser prepares the emergency simulation exercise; the organiser selects a suitable form of simulation exercise for the type of accident to be exercised and organises the relevant personnel to prepare a detailed exercise plan; the organiser organises the study of the personnel participating in the exercise according to the exercise plan; the organiser organises the materials and equipment required for the exercise and makes appropriate arrangements for the exercise venue; the organiser invites in advance the relevant local departments and the relevant personnel from the higher departments of the industry to participate in the exercise and make suggestions.

(3) Issues to be considered in preparing the exercise programme

The contents are determined based on the purpose of the exercise. Moreover, the objectives that need to be achieved are accomplished through the exercise process, with step-by-step checks and assessments. Therefore, organically incorporating these items to be checked into the simulated accident is the first step in preparing the exercise program. The following problems need to be considered setting up a realistic and optional inspection for the simulated accident situation.

1) Detailed description of the accident. The occurrence of an accident has its potential unsafe factors, which is triggered by a specific factor under certain conditions or forms a chain effect from it, thus causing a more significant and more serious accident. The causes and processes of the accident's occurrence, development, and expansion should be briefly described so that the exercise participants can understand and execute the emergency handling tasks and corresponding protective actions for such an accident.

2) Scheduling. The schedule of the exercise should be arranged according to actual accident conditions. However, in exceptional circumstances, compression and extension of time are not excluded and can be set at a suitable time. The exercise schedule should generally be followed by prior notification to the relevant units and individuals participating in the exercise to facilitate adequate preparation. To improve the response capability of the emergency response team, we can also use a 'blind'

exercise, i.e., when the participants are unable to prepare in advance, the leaders and commanders will issue a notice of the exercise as planned.

3) Drill conditions. It is best to choose more unfavourable conditions for drills, such as at night, in meteorological conditions that can illustrate the problem, and in more severe natural environments such as high and low temperatures. However, in cases where the preparation is not sufficient, or the quality of the exercise personnel is low, to test the feasibility of the plan or improve the exercise personnel's technical level, it is also possible to choose an environment with better conditions for the exercise.

4) Safety measures. The field simulation exercises should be conducted under absolutely safe conditions, such as security cordon and isolation, traffic control, protective measures, safety and security of fire and rescue drills must be carefully and meticulously considered. The people in the area should be informed of the drill within its influence to avoid unnecessary panic and ensure they are informed of what they are required to do.

5) Evaluation of emergency drills. The organising unit of the emergency drill should organise the evaluation of the drill. The main contents of the evaluation include the implementation of the drill, the reasonableness and operability of the plan, the command and coordination and emergency linkage, the disposal of emergency personnel, the applicability of the equipment and equipment used in the drill, the opinions and suggestions for improving the plan, emergency preparedness, emergency mechanism and emergency measures. The third parties are encouraged to be entrusted with evaluating the exercise.

5.5 Other Management of Emergency Response Plans

5.5.1 Revision of emergency response plans

An emergency preparedness unit shall establish a regular evaluation system for emergency preparedness plans and analyse the content's pertinence, practicality and operability. Finally, it concludes whether the emergency plans need to be revised to achieve dynamic optimisation and scientific and standardised management.

The production and operation units shall evaluate the emergency plan every three years. The assessment of the emergency plan can be conducted by inviting relevant professional organisations or experts or personnel with

experience in emergency rescue work, and if necessary, entrusting the implementation of safety production technical service agencies.

After completing the emergency plan exercise, amendments to the emergency plan may also be proposed based on the evaluation report of the emergency plan exercise.

The emergency plan shall be revised on time if any of the following circumstances exist.

1) Changes have occurred in the relevant laws, administrative regulations, rules, standards, or applicable upper plan provisions.

2) There is a significant adjustment of the emergency command structure and its functions.

3) There is a significant change in the risk.

4) Major changes have taken place in essential emergency resources.

5) Other important information in the plan changes.

6) In the actual response to emergencies and emergency drills, it is found that problems need to be significantly adjusted.

7) Other circumstances that the emergency plan development unit considers should be revised.

When the revision of an emergency plan involves essential contents such as the organisation and command system and responsibilities, emergency disposal procedures, main disposal measures, and classification standards for emergencies, it should be organised regarding the guidelines for the preparation, approval, filing and publication of the plan as stipulated in the *Measures*. If only other contents are involved, the revision procedure can be appropriately simplified according to the situation; governments at all levels and their departments, enterprises and institutions, social groups, citizens can propose amendments to the relevant plan preparation unit.

5.5.2 Awareness and education of emergency response plans

The emergency plan preparation unit should organise emergency plan training for management personnel and professional rescue personnel closely related to the implementation of the emergency plan. For non-confidential emergency plans that require broad public participation, the preparation unit should make full use of the Internet, radio, television,

newspapers, and other media to widely publicise them and produce easy-to-understand, memorable and valuable publicity and popularisation materials for free distribution to the public.

The safe production supervision and management administration at all levels and the production and management units of all types should take a variety of forms to publicise and educate about emergency plans, popularise the knowledge of safe production accident avoidance, self-rescue and mutual rescue, and raise the safety awareness and emergency handling skills of the employees and the public.

5.5.3 Organization guarantee of emergency response plans

Governments and their relevant departments should strengthen guidance and supervision of emergency response plans for their administrative regions and industries (fields). Relevant departments of the *State Council* may, as needed, prepare guidelines for the preparation of emergency contingency plans for their respective sectors (areas).

Governments at all levels, as well as their relevant departments and units, shall designate specialised agencies and personnel to take charge of specific work in this regard and shall include in their budgets and the funds required for the planning, preparation, approval, promulgation, exercise, revision, training, propaganda and education of emergency preparedness plans.

5.6 Gas Companies' Emergency Planning

The city gas supply system is one of the city's lifeline projects. The local People's Government at or above the county level should organise the gas emergency plans. They take comprehensive measures to improve the ability of gas emergency safety. The municipal gas administration should work with relevant departments to develop the city's gas emergency plans, report to the people's government at the city level for approval and then organise the implementation. The district and county People's Governments should manage relevant departments to prepare the gas emergency plans within the administrative area and report to the upper People's Government for the record. The gas supply units should follow their gas emergency plans and the upper provisions.

5.6.1 System structure of gas enterprise of emergency response plans

The gas company's emergency plan is an emergency rescue work plan to protect the lives and environmental safety of the employees, related parties and the public, reduce property damage, and maintain the company's reputation and social image. The main content of the emergency plan should include the scope of application, event classification, emergency response organisation and responsibilities, emergency response, emergency disposal principles, emergency safety and other relevant requirements. They are applied to the gas enterprise and its affiliated units of the gas emergency rescue and disposal of gas emergencies. The gas emergency plan should specify the gas emergency source and type, emergency supply mode, emergency disposal procedures and emergency rescue measures.

The emergency plan of the gas enterprise can be divided into four categories, i.e., comprehensive plan, particular plan, on-site disposal plan and emergency disposal card.

The emergency planning system for gas companies can be developed in Table 5-1.

Table 5-1: Conception of the emergency planning system for gas enterprise

Project number	Project name	Secondary No.	Specific name of the project	Contents and requirements of the project
1	Integrated emergency response plan	1.1	Integrated emergency response plan	Including contingency plans for four types of emergencies, i.e., natural disasters, accidents and disasters, public health and social safety events.
		1.2	Comprehensive safe production Emergency Response Plan	The overall emergency work programme for production activities within the enterprise's jurisdiction
2	Special contingency plans	2.1	Unique contingency plans for natural disasters	Including contingency plans for disasters such as earthquakes, floods, landslides.
		2.2	Unique contingency plans for accidental disasters	Including emergency response plans for fire, third-party sabotage, the impact of other facility incidents.
		2.3	Unique contingency plans for the social safety category	Including counter-terrorism.
		2.4	Unique contingency plans during significant events	Including early warning at important events, special dates and contingency work programmes.
3	On-site disposal programme	3.1	Emergency Response Plan for Gas Field Station Emergencies	Emergency response plan for different gas sources, including natural gas, LNG, CNG, LPG and different sizes of station accidents.
		3.2	Emergency response plan for gas network emergencies	Emergency response plan for city gas transmission and distribution pipeline emergencies
		3.3	Emergency response plan for gas users in case of emergency	Emergency response plan for all types of crowd users, gas pipeline and facility emergencies in buildings
		3.4	Cross-regional support for emergency response programmes	Based on territoriality, formulate a plan for mutual support within the group and emergency support from external companies and specialised organisations.

4	Emergency response cards	4.1	Departmental emergency response cards	Emergency response cards are prepared by the responsibilities of the administration and the division of labour, highlighting the division of departmental emergency response responsibilities.
		4.2	Post emergency response cards	Emergency response card prepared according to the duties and responsibilities and the division of labour, with emphasis on the responsibilities
		4.3	Scenario Emergency Response Card	Emergency response cards are according to the type and scenario of gas emergency (leak, fire, explosion, overpressure gas delivery, gas outage), emphasising scientific, rapid and effective disposal.
		4.4	Emergency response card for premises	Emergency response cards are prepared according to the location of the incident (stations, outdoors, inside buildings), highlighting site characteristics and rapid response in adverse environments such as confined spaces and confined spaces.

5.6.2 Classification for gas events and corresponding responses

After the occurrence of a gas emergency, an initial classification of the event should be made based on the initial situation, and the appropriate level of emergency response should be initiated. The initial type of the event is based on the initial report and the corresponding information and is not necessarily equivalent to the final class of the event result.

(1) Classification of the incident

Gas companies can refer to the relevant national and local documents to classify gas emergencies according to factors such as the degree of harm they may cause, their controllability and the scope of the social impact.

Gas emergencies can be classified into four levels, i.e., level I, severe gas emergencies; level II, major gas emergencies; level III, general gas emergencies; and level IV, common gas emergencies.

A gas company's gas emergency classification is shown in Appendix 1.

(2) Emergency response classification

The emergency response to gas emergencies will be uniformly graded to facilitate the uniformity and standardisation of the judgment. The level of the emergency response of gas enterprises can be divided into four levels corresponding to the classification of the event, in descending order by red, orange, yellow and blue.

The first-level response: indicated in red, is an emergency that affects many users, causes a high degree of harm to society, has a severe impact on the city's gas system, has caused or may cause casualties, and requires unified organisation and coordination by government departments to mobilise all forces and resources for emergency response.

The second level response: indicated in orange, refers to the emergencies that affect a more significant number of users, cause a higher degree of harm to society, have caused or may cause injuries, and require unified organisation and coordination by gas companies to mobilise all forces and resources for emergency response.

The third level response: indicated in yellow, refers to the incidents that occur within the jurisdiction of a branch (subsidiary) company, have a particular impact on users and are harmful to society, and require the

mobilisation of internal resources of the branch (subsidiary) company to coordinate solutions.

The fourth level response: indicated in blue, refers to the incidents that occur within the jurisdiction of a primary station, have a low level of impact on users and require the mobilisation of internal station resources to coordinate a solution.

For the gas incidents occurring at particular locations or times, the response level may be raised or lowered as appropriate by the decision of the emergency command or leadership team.

For a gas company's response to the provisions of the trigger and escalation conditions, please see Appendix 2.

5.6.3 Basic emergency response processes

The basic process and main steps of the gas emergency response are shown in Figure 5-1.

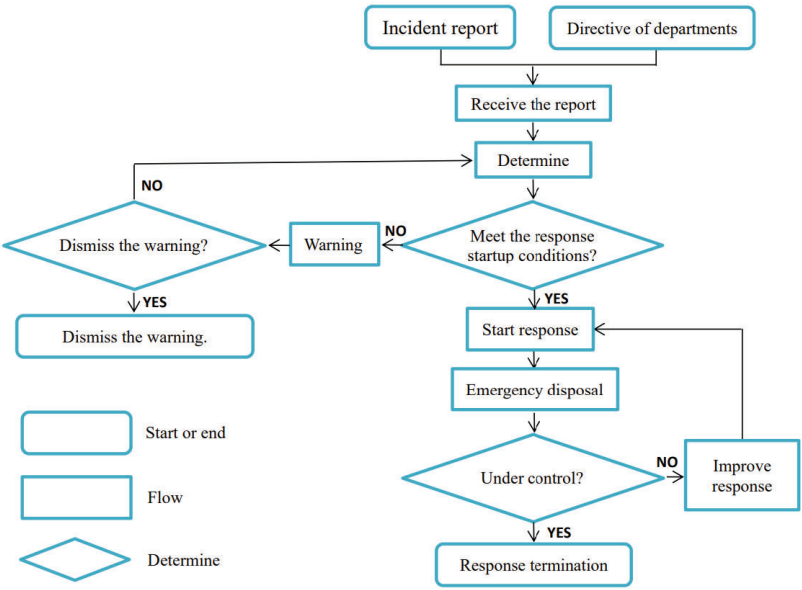

Figure 5-1 Basic gas emergency response flowchart

1) The starting point for emergency response is the "incident report" and "relevant authority directive": after an "incident" has occurred, the emergency response team will not respond if no one reports it. When an "incident report" is received, the response team should respond at the first opportunity; in some cases, when a "relevant authority order" is issued, the gas specialist must also respond regardless of whether a gas incident has occurred.

2) "Early warning" is one of the states of emergency response preparation and should be incorporated into the emergency response process. During the "early warning" process, new information should be observed and added at any time to determine whether to end the warning or enter the emergency response according to the development and the actual situation.

3) During the emergency response process, a judgement should be made at any time whether the situation is under control; when it is necessary to "extend the emergency" or "escalate the response", a new "emergency response" should be activated quickly.

4) "Emergency disposal" is an essential part of the emergency response to gas emergencies. The principles of emergency disposal include carrying out work on the premise of ensuring safety, organising emergency personnel to carry out gas concentration testing and environmental monitoring, delineating and blocking dangerous areas, controlling dangerous sources, notifying and cooperating with the local government and relevant authorities when necessary. Following the plan's requirements, safety measures should be implemented to repair and control the development of the situation and to eliminate unauthorised command and operation. The on-site response plan should specify the "emergency response" measures for different incidents.

5) The conditions for "response termination" should be determined in advance according to the actual situation; it should be clearly defined which commanders can declare "response termination" for different levels of events.

Following the relevant national and local regulations, the incident information should be reported, made public and released throughout the process from the incident to the end of the emergency response, in a factual, objective and fair manner, with detailed, timely and accurate content.

After the emergency response is over, the gas supply system and environment should be restored. The cause of the incident and the emergency response process should be analysed and summarised. The emergency rescue

capabilities and equipment should be assessed, and the documentation and information on the incident should be collated and retained.

5.6.4 Emergency on-site organisation and responsibilities

The organisation of the gas emergency scene and the division of responsibilities between the various departments significantly impact whether the emergency disposal can be carried out smoothly. Setting up a reasonable emergency organisation, dividing duties under the law and planning, cooperating and coordinating work in the emergency process can ensure a rapid, scientific and orderly response to the emergencies. The on-site emergency organisation of a gas enterprise can be set up in Figure 5-2.

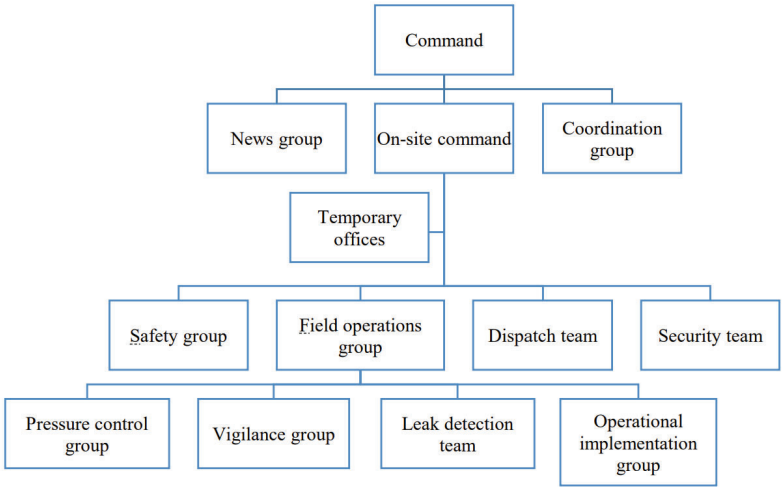

Figure 5-2 Gas companies' on-site emergency organisations

The division of responsibilities of the gas emergency on-site organisation is shown in Table 5-2.

Table 5-2: Responsibilities of the on-site gas emergency organisation

Department	Duty
Command	1) The commander-in-chief organises the discussion and validation of the on-site disposal plans and public release materials.
	2) The deputy commander-in-chief assists the commander-in-chief in his work.
	3) Command members participate in the discussion and validation of the program and materials for the work, make relevant comments, and complete the tasks assigned by the commander-in-chief and deputy commander-in-chief on an ad hoc basis.
Newsgroup	Be responsible for preparing news reports as authorised by the command and conducting news releases and media responses by the relevant regulations.
Coordination group	1) Identify and coordinate the internal and external emergency resources needed to be deployed to support the government's efforts.
	2) Continuously track the development of the incident and report to the command on time.
	3) Interfacing with on-site command agencies such as fire and government.
	4) Integrate emergency relief resources (e.g., equipment and human resources for gas replenishment, excavation, and operations).
On-site command	1) Organise and adjust the emergency rescue plan according to the situation and the development, and report to the headquarters.
	2) Organise the revision of the programme by the opinion of the command.
	3) Organise the on-site emergency rescue plan as authorised by the command.
Temporary offices	1) Dispose of on-site personnel check-in.
	2) Issuance and recovery of communication and identification equipment.
	3) Operation and application of the systems in the command.
	4) The collection, collation, reporting and preparation of relevant materials on site.
	5) Coordination of logistics.
Safety group	1) Safety management and supervision, and inspection of the site.
	2) Communicate with environmental authorities and oversee the implementation of environmental protection control measures.

	3) Monitoring of environmental restoration after an accident.
	4) Cooperate with medical personnel at the scene in case of injury or death.
	5) On-site evidence collection and retention.
Field operations group	1) Collect site information, verify the site situation, report site information to the temporary office every 10 minutes, and ensure that the transmission of information between the site and the command is accurate, timely and smooth. The information contains pipeline information, damage, the scope and number of users affected, the scope of the leak, and the leak detection results.
	2) Formulate and adjust the emergency rescue plan on site according to the situation on-site and the development of the case.
	3) Carry out on-site emergency rescue programs as authorised by the command.
	4) Organise the work of edge control, pressure control, leak detection.
	5) Directing cooperative units for on-site disposal.
Dispatch team	1) Remote technical support.
	2) Cooperate with the adjustment of working conditions.
Security team	1) Assist the field operations team in site policing and traffic diversion.
	2) Maintain the order at the scene outside the perimeter of the alert area.
Pressure control group	Adjust the pipeline pressure according to instructions.
Leak detection team	Continuous leak detection around the worksite and report immediately once there are any abnormalities.
Vigilance group	They were circling the alert range by the instructions, site policing and traffic diversion.
Operational Implementation Group (OIG)	Carry out the on-site disposal and implementation by the emergency rescue plan developed.

5.6.5 Reference catalogues of the comprehensive safe production emergency plan of gas enterprises

The gas enterprises should prepare their emergency plans according to the national, local and industry requirements and based on the actual state of the enterprise production.

CHAPTER 6

ACCIDENT PRECAUTION AND MANAGEMENT

Safe production and life are the eternal themes of the movement of human existence. Human survival depends on production, and human happiness requires safety. Since production labour, human beings have made unremitting struggles against various accidents and disasters and achieved excellent results. However, the development of science and technology and the progress of human civilisation have given new meanings to accident prevention and put forward new research topics. Today and in the future, the survival and development of humankind are more and more dependent on the support and protection of the high technology invented by itself, and the whole social system is in the critical state controlled by high human technology. If the situation gets out of control, unimaginable consequences may occur.

With the development and increasing scale of modern production, sources of danger in the production process and life increase the possibility of accidents, especially fires, explosions, and toxic substance spills, which often lead to severe consequences. Although a series of measures such as safe design, standardised operation, routine maintenance and regular inspection has been taken, absolute safety is still not achieved. Like any other thing, the occurrence and development of accidents also have specific characteristics and laws. Understanding the causes and laws of accidents and taking corresponding measures can effectively prevent accidents.

Accident precaution and the emergency response generally include four stages, i.e., precaution, preparedness, response and recovery.

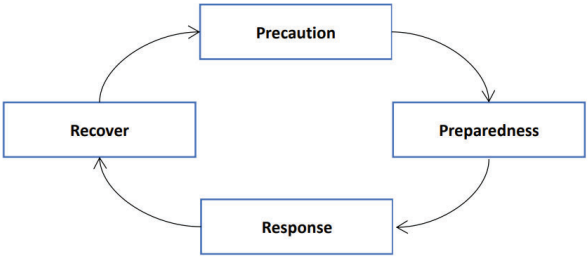

Figure 6-1 Four phases of accident prevention and emergency response

1) Precaution

Precaution aims to prevent emergencies or accidents and avoid emergency actions, e.g., the formulation of safety laws, regulations, safety planning, safety and technical standards and norms, strengthening safety management measures, and the promotion and education of safety to employees, managers and community members from the perspective of emergency management.

2) Preparedness

Preparedness, also known as preparation, is the work performed before an emergency response occurs, mainly to improve emergency response capabilities, establish the emergency response systems, and develop the emergency plans.

3) Response

Response, also known as a reaction, is the response action taken before, during and immediately after an incident. The purpose of the response is to contain the situation and minimise the consequences of life loss, damage to property and environmental damage by performing emergency services functions such as early warning, evacuation, emergency response, search and rescue and provision of shelter and medical services.

4) Recover

Recovery should begin immediately after an accident, with the primary task of restoring minimum functions and services to the production system or area affected by the accident. Efforts then continue to return the affected areas to normal conditions. Recovery efforts include accident damage assessment, debris removal, food supply, shelter and other equipment. In

contrast, long-term recovery efforts include reconstruction of production systems and plant sites, community redevelopment, and safety and disaster mitigation plans.

6.1 Accident Precaution and Safety Measures

Adhering to the policy of "safety first, precaution first, comprehensive management" in the *Safe Production Law of the People's Republic of China*, it is essential in all industries to prevent safe production accidents and promote scientific informatisation and standardisation of accident prevention work.

6.1.1 Basic principles of accident precaution

(1) The principle of possible precaution

Unlike natural disasters, accidents and disasters should be prevented before they happen. In direction, accidents and disasters can be prevented. Therefore, it is essential to consider what to do after an accident and before it happens. The focus on preventing disasters before they happen is based on the idea that accidents and disasters can be prevented. However, it is difficult to avoid all accidents and disasters in real life. Ultimately, the principle of possible prevention of accidents and disasters should be adhered to, with accident prevention as the goal of safety management.

In the investigation reports on the causes of accidents, we sometimes see it recorded that the cause of the accident was "irresistible". By "irresistible", we mean that the accident was unavoidable for the victims themselves in the specific circumstances of the time and place. However, if one takes the position of preventing the recurrence of such accidents, the cause of the accident can hardly be described as "irresistible".

In traditional safety management, accident countermeasures tend to be taken after the accident. For example, the countermeasures against fire and explosion include: conducting fire partitioning, limiting the number of hazardous materials stored, setting up a safe distance between the source of danger and the surrounding area, setting up explosion-proof walls around the explosive materials, setting up liquid-proof dikes around the storage tanks of hazardous liquids that may spill, setting up gas leak alarms, fire alarms and fire extinguishing equipment to detect and extinguish fires at an early stage, setting up evacuation facilities, first aid facilities. These are all measures to reduce the impact and damage after an accident. Even if these

post-incident countermeasures are fully effective, they cannot prevent fires and explosions before they happen.

On the other hand, it is possible to prevent fires and explosions by properly managing hazardous sources and substances.

In short, preventive measures should be paid more attention to accidental disasters than post-accidental countermeasures. Safety management should focus on the preventative measures before an accident, reflecting the safety policy of "prevention first". It is also necessary to take adequate post-accident countermeasures in an accident.

(2) The principle of incidental loss

Analysing the concept of the word disaster, it encompasses both the accident and the resulting damage. Accidents that cause injury or death to people are generally referred to as personal accidents. Those that cause damage to property and equipment are referred to as physical accidents; some accidents may also cause damage to the environment.

Personal accidents can be divided into the following categories:

1) Accidents caused by the movement of people, such as tripping, falling from a height, collision between people and objects, twisting of the human body, wrong operation in production.

2) Accidents caused by the relative movement of objects, such as the blow of objects on people, crushing by heavy objects, clamping by rotating objects, crushing by vehicles.

3) Accidents caused by contact or absorption, for example, electrocution caused by contact with live wires, high or low-temperature objects, radiation, inhalation or contact with toxic or harmful substances.

The result of these personal accidents can cause fractures, whitening, trauma, electric shock injuries, burns, frostbite, chemical injuries, poisoning, asphyxiation, radiation injuries and other diseases or injuries locally or throughout the body and even death.

For personal accidents, there are Heinrich rules, such as fall trials, and if multiple falls occur, the consequences will be 300 no injury incidents, 29 minor injuries, and one serious injury incident. It is known as the "1:29:300" rule. This ratio is the general, regular conclusion of safety scholar Heinrich's statistics on many injuries.

This rule varies somewhat with the type of accident, such as falls, electrocution and other accidents with a very high percentage of serious injuries. Thus, this law is not just a mathematical ratio because it implies the principle of probability that there is a chance between the accident and the degree of injury.

When there is no loss at all at the accident, it is called a near-accident. Even in the case of such a loss-avoiding hazardous event, the kind of loss that would occur if it were to happen again can only be determined by chance and not predicted.

It leads us to conclude that there is a relationship between accidents and losses. The magnitude or type of loss resulting from the accident's consequences is determined by chance; recurring accidents do not necessarily produce the same result in terms of loss.

(3) Principles of secondary causes

In general, the causes of accidents can be divided into two categories, i.e., direct causes and indirect causes.

Direct causes, also known as primary causes, are those closest in time to the occurrence of an accident and usually include, e.g., unsafe human behaviour, dangerous physical conditions and poor environment.

Indirect causes of accidents include technical causes, educational causes, physical causes, mental causes and management causes.

The cause of an accident may be one of the above or two or more of the above at the same time.

As long as the cause of the accident is not eliminated at the root, then similar accidents will repeat and occur many times.

Accidents are inevitably related to their causes, and accidents are accidentally associated with their losses.

(4) Principles for selecting countermeasures

Technical, educational, and management measures are recognised as the three pillars of accident prevention. By applying these three pillars, the effect of preventing accidents can be achieved. If only one of these pillars is emphasised in a one-sided manner, satisfactory results in accident prevention will not be achieved. For example, the emphasis on laws and

regulations must be accompanied by technical and educational measures to prevent accidents. Furthermore, when problems arise with accident prevention measures, the order of improvement should also be technological, educational and managerial responses in that order. Policies and regulations can only be implemented through safety education after the technical measures to prevent accidents have been effectively implemented. Otherwise, any safety regulations will only remain on paper.

1) Technical measures

Technical countermeasures are one of the most critical countermeasures in safety engineering. The potential hazards should be carefully studied and discussed when designing machinery, equipment, construction, or plants. The possibility of hazards should be predicted, and technical measures should be taken to prevent these hazards. To implement fundamental technical countermeasures, we must know all the relevant chemical substances, materials, machinery, equipment and facilities, their hazards' nature and structure, and the specific methods to control them. For this purpose, it is necessary to summarise all known information and measure the hazard properties of unknown substances of interest. To obtain additional information required for the safe design of mechanical devices, we need to conduct repeated experimental studies to collect data on technical accident prevention methods. For machinery and facilities where safety design has been implemented, inspection and maintenance techniques are applied to ensure the effectiveness of safety measures.

2) Educational measures

Safety education includes education on laws and regulations, safety awareness, safety knowledge, and safety operation skills.

As an educational countermeasure, safety education and training are equally necessary for the production sector and educational institutions and organisations of all kinds of schools. Safety education should start at an early age if possible. It will help instil good awareness and safety habits from an early age. The specific safety education and training should also be implemented in the secondary schools and higher education institutions through tests, competitions and operations, both inside and outside the classroom. As specialised educational institutions, the higher engineering schools should also provide education in safety techniques and management methods for students working in technical jobs following the specific content of their specialised business. Enterprises or professional technical

training institutions generally educate safety operation skills.

Safety education should be diversified, repeated, and reinforced many times, following the law of education and paying attention to education's scientific, systematic, and practical nature.

3) Management countermeasures

Management countermeasures are based on the national laws and regulations, various standards, safety directives and norms and operating procedures of academic groups and industries, and production and work standards within companies and factories to safely manage production and operational activities. The mandatory ones are generally called directive standards, and the advisory, non-compulsory ones are called recommended standards. Regulations must be mandatory, with principle and applicability. If the regulations are too detailed, it is difficult to include all possible circumstances, which will inevitably hinder the implementation of rules. In addition to the directive regulations, the national standards can also be specified by developing industry and local standards.

The management countermeasures generally include the review of the feasibility study, preliminary design and completion inspection of construction, the inspection of the hazard identification and safety evaluation of production and operation systems, and the management of risk control and safety objectives.

When selecting countermeasures for accident prevention, the effectiveness of countermeasures should be considered. The three types of countermeasures are usually adopted in combination. The priority is given to the technical countermeasures.

6.1.2 Technical strategies

There is a view that the essence of an accident is the accidental release or abnormal transfer of energy. According to this view, the study of the law of accident should start from the type of the energy effect of accident, and study the transfer law of mechanical energy (kinetic energy and potential energy), electrical energy, chemical energy, thermal energy, acoustic energy and radiation energy; the study of the law of energy transfer, i.e. the time and space law of energy transfer from the control technology of energy level; the essence of accident prevention is energy control, which can be achieved through the elimination of system energy, the limit value, and the control

technology of energy level; the study of the law of energy transfer, i.e. the control technology of energy level, and the study of the time and space law of energy transfer; the essence of accident prevention is energy control, which can be achieved through the elimination of system energy, the limit value, and the control technology of energy level; the study of the law of energy transfer, i.e. the control technology of energy level, and the study of the time and space law of energy transfer. The essence of accident prevention is energy control. It can be used to control the accidental release or abnormal transfer of energy through technical measures such as elimination, limiting, sparing, shielding, isolation, transfer, distance control, time control, local weakening, local strengthening and system blocking of system energy.

The technical safety countermeasures for accident prevention and control are to consider taking measures to avoid or reduce accident losses, prevent the accidental energy release from reaching people and objects, and reduce its effect on people and objects before the accident occurs. After the accident occurs, it can quickly control the situation and the scale of the accident to prevent causing secondary accidents and releasing more energy or dangerous substances.

The following technical principles are generally followed in the specific safety technical countermeasures for accidents and prevention.

1) Principle of eliminating potential hazards

Eliminating the accident hazards at their essence is the most desirable, proactive and effective accident prevention measure. Its basic approach is to replace old, unsafe systems and processes with new ones, new techniques and technologies that fundamentally eliminate the possibility of accidents. It replaces combustible materials with non-combustible materials. We replace direct heating methods of electricity and open flames with indirect heating techniques using steam or hot water. Machinery and equipment eliminate the risk factors for human subjects, and the working environment is improved. It excludes the effects of noise, dust, and toxicity on the human body and essentially realises occupational safety, health.

2) Principle of reducing the value of potential risk factors

If the danger of the system cannot be eradicated, the consequences and severity are minimised by a malfunction. This principle is applied in the design of city gas distribution pipelines by reducing the design pressure in densely populated areas, limiting gas stations' storage capacity, and

classifying LPG supply stations according to the number of cylinders stored.

3) Redundancy principle

The principle of redundancy refers to the measures such as multiple insurances and backup systems to improve the system's safety and increase the safety margin. The measures include lower power ratings in industrial production, increased wire rope strength, dual-engine set-ups in aircraft systems and additional backup devices or equipment in the system. This principle is also widely used in city gas systems. For example, the wall thickness of pipelines and storage tanks is reserved for corrosion margin, and the discharge valves on LPG storage tanks should be set up in two or more groups, etc.

4) Lockout principle

The lockout principle refers to the interlocking of machines or electrical interlocks in a system through several original devices as a condition for ensuring safety. This principle is employed in production systems to block the chain of accidents between the source of danger and the fault by using an automatic emergency shutdown. Cutting off an abnormal system operation or weakness prevents the flaw from becoming an accident. It stops the impact of the accident from expanding further. An overflow valve on the LPG vehicle tanker of the loading dock pipeline cuts off the LPG pipeline in case of abnormal flow. Gas leak alarms and low-temperature alarms are generally linked to the emergency shut-off valve of the gas pipeline, which allows the pipeline to automatically cut off the gas line when a gas leak or abnormally low temperature is detected.

5) Energy barrier principle

The safety of people and equipment can be effectively ensured by erecting barriers between people, objects and sources of danger to prevent accidental energy from acting on people and objects. For example, this principle is used in gas storage and distribution stations. A solid wall of a certain height is generally required between the production area and the living support area.

6) Distance protection principle

Generally, the harmful effects of hazardous factors diminish with the increasing distance, so keeping people as far away from the source as possible can provide some protection. This principle can be applied to noise sources, radiation sources and other hazards to reduce their harm.

In 1984, an LPG processing plant and distribution centre on the outskirts of Mexico City caused 542 deaths, 4248 injuries and 10,000 homeless people when the LPG leaked, and then the fire and explosion occurred. Post-mortem analysis revealed that the slums kept encroaching on the vacant land around the plant, and houses were built closer and closer to the plant, far from meeting the safety distance requirement, which caused such heavy casualties in the event of an accident.

The requirement that gasses stations, pipelines and equipment should be kept at a certain distance from surrounding buildings and structures also follows the principle of distance protection for safety.

7) Principle of time guarding

The principle of time protection asserts that the duration a person is exposed to a hazard or in an environment where harmful elements are present must be reduced to safe levels. For example, when workers mine radioactive minerals or carry out work in which radioactive substances are involved, the working time should be reduced; in environments with dust, poisonous gases and noise, the exposure time of the person has reduced accordingly with the increase of their hazards.

In daily production, the principle of time protection should mainly focus on occupational safety; in the fault and accident scene disposal, attention should be paid to the safety of emergency personnel. Enterprise managers must take special care to observe this principle and not arrange for their employees to work overtime in dangerous environments. Otherwise, they will be liable for the corresponding legal responsibilities.

8) Weakness Principle

The weakness principle is to artificially set up weak artificial links in the system so that in case of faults and accidents, the system's overall safety is exchanged for minimal, local losses. Examples include fuses in electrical circuits, fuse pins in boilers, blast films in gas generators, pressure relief release valves in pressure vessels. They are destroyed first before a severe change in the hazardous situation, thus releasing or blocking the energy to ensure the system's safety as a whole.

Weak links should be set up scientifically and reasonably, and the energy released should also be under control. Otherwise, it will also cause accidents and losses. At an LPG site station, after the safe discharge of the storage tank, the LPG vapour mist drifted away. It was ignited by an open flame

outside the station, which burned back into the station and eventually caused the LPG storage tank to explode. Therefore, safe dispersion should be centrally managed, discharged, and monitored at a gas site station. Otherwise, the weak link principle can ensure to a certain extent that the equipment is not damaged, but it still does not entirely prevent accidents from occurring.

9) Ruggedness principle

The robustness principle is the opposite of the weak link principle of a countermeasure, i.e., it ensures its safety by increasing the system's strength, e.g., by increasing the safety factor, increasing the structural strength.

In gas systems, the design pressure of the tanks, piping and equipment should be higher than the operating pressure, i.e., this principle is used. Applying this principle generally increases the investment in equipment. Therefore, a balance should be found between safety and the economy: under the premise of ensuring safety, the acquisition should be controlled; however, giving up safety just to save investment is more than worth the loss.

10) Principle of individual protection

The protective equipment and gear should be provided to workers by the nature and conditions of their work. It is a reactive approach to mitigating injuries or losses from accidents and disasters.

Managers must consider expenditure plans for protective gear and equipment when arranging safety investments; they must not direct employees into hazardous environments, even in emergencies, when the appropriate protective equipment cannot be provided. The practitioners should also gradually strengthen the concept of law and enhance self-protection; they can refuse to enter dangerous places when they do not have protective equipment and gear.

The city gas regulations and norms have repeatedly stressed that enterprises must be equipped with appropriate protective equipment and appliances for the operating personnel and repair teams to protect personnel safety and reduce casualties and losses.

11) Principle of the substitute operator

In conditions where it is impossible to eliminate and control the dangerous and harmful factors, replacing certain personnel operations with robots,

manipulators, automatic control devices to prevent the danger of the dangerous and harmful elements to the human body is also a vital safety tool.

In the scene of earthquakes and fires, the role of rescue robots is very significant. Production systems, remote control, and remote-control devices can generally replace the personnel in the field operations. With the development of science and technology, this principle is more and more widely used in production and life.

12) Principle of warning and forbidden information

The use of light, sound, colour or other signs to convey warnings and prohibitions is an essential safety tool. Examples include safety posters, safety signs, warning signs.

In 2010, the *Ministry of Housing and Urban-Rural Development* issued the CJJ/T153-2010 *Standard for city gas signs*, which stipulates the graphic symbols of the city gas production, transmission and distribution systems and various gas-related places. The city gas signs are divided into safety signs and unique signs. The safety signs include four symptoms, i.e., prohibition signs, warning signs, instruction signs and indication signs. The warning signs should be placed at the construction and building sites, around the gas pipeline networks and facilities, maintenance and repair work areas to protect the safety of the public and the surrounding environment while protecting the system's facilities. To serve as a warning, we should use as eye-catching signage as possible, in line with the relevant national regulations, but should not cause fear and panic.

13) Principle of evacuation and rescue

Efforts should be made to control the situation after an incident has occurred. Still, when it is judged to be beyond control, all personnel should choose to evacuate the danger zone quickly to reduce casualties and damage.

To meet the emergency needs, we should fully consider the layout of the plant, the design of the buildings and the transport facilities and the setting of production facilities to provide them shelter and rescue for personnel (including emergency rescue personnel) in the event of an accident.

i) Adopting isolation measures to protect the personnel, such as setting up refuge and shelter spaces.

ii) Enabling people to quickly evacuate the danger zone, e.g., by defining

evacuation routes and setting up safe exits and emergency conveyance devices.

iii) If the people in the danger zone cannot escape, they should, as far as possible, enable themselves to be found and rescued by rescue personnel.

In 1966, there was a leaking accident of a 1200m^3 propane ball tank in France. The ball tank exploded 90 minutes after the propane vapour mist was ignited and caught fire, killing 15 rescuers (including ten firefighters) and injuring more than 80 people. The severe lesson from this accident in terms of casualties was the failure to evacuate personnel from the accident scene on time and decisive manner when the scene got out of hand.

6.1.3 Management philosophy for accident prevention and control

It is essential to prevent and control accidents using management tools, procedures, and measures established under national laws, regulations, and various standards.

With the continuous development of China's city gas industry, gas production, storage, transportation, and use are increasing in volume and scope. How to carry out effective safety management of city gas, prevention and containment of disasters and accidents has become a significant issue. Therefore, drawing on management experience in safety management, accident prevention and control, the study of city gas accident prevention and control management methods suitable for China's national conditions can provide a basis for improving the level of city gas safety management.

To prevent and control dangers and hazards in the production, storage, transport and use of city gas, and to effectively prevent fires, explosions, poisoning accidents and occupational diseases, we should promote the following concepts in safety management.

(1) Systematisation concept

Safety management and accident prevention is a complex systematic project that must be planned, designed and operated in an integrated manner. In the horizontal aspect, safety management and technical measures should be formulated for the system composed of three interrelated elements: people, objects, and environment; in the vertical element, safety management and technical countermeasures should be comprehensively considered for production and storage transportation and utilisation.

(2) Scientific concept

According to the characteristics of the city gas, the risk identification, monitoring and surveillance are carried out scientifically by the technical methods of safety management. The specific supervision and control are implemented for significant danger sources. The enterprises are urged to carry out safety evaluations to formulate emergency plans. The importance is attached to the research and development of the safety technology applicable to the industry and increased safety investment.

(3) Institutionalisation concept

In recent years, the relevant departments are gradually formulating and improving the regulations and standards of the city gas accident prevention and control management, making corresponding provisions for accident prevention and safe working mechanism; clarifying the responsibilities, giving full play to the normative, guiding, regulating and safeguarding functions of the laws and regulations, establishing a sound management system and supervision mechanism; and reducing or eliminating the occurrence of malignant accidents through effective management and technical measures.

(4) Informatisation concept

The construction of intelligent gas and the safety management of information network platforms for city gas is progressing rapidly. It should be essential to establish the industry safety management database and dynamic statistical analysis system in the coming period. It aims to exchange the lessons learned from the safety management of the industry and enterprises with the help of government or professional information websites. It aims to release the news and developments in accident prevention and control work. It aims to supply general knowledge on preventing and controlling city gas hazards. It seeks to establish the safety management files for production enterprises and their follow-up management. It aims to supply online advisory services so that the city gas safety of information network provides professional services for enterprises and users.

(5) Regionalization concept

According to the principle of "territorial-based", regional management bodies and administrative responsibility systems should be further established at the city, district, and county levels to strengthen the links

between various departments. Especially those between production and operation units and the fire, public security and traffic management departments, to prevent and control safety accidents jointly, implement national effective and industry regulations and systems, and strengthen the safety supervision of city gas.

(6) Dynamism concept

Constantly summarise the experience and lessons of the city gas safety management to guide the prevention of accidents. Reduce accidents through strengthening management, implementing safety measures, strengthening safety inspections, risk assessment, plan review and other work, and putting forward the corrective actions to feedback problems. The safety situation and accident prevention should be managed dynamically in response to the development of the industry and the safety technology and equipment.

(7) Integration concept

Based on laws and regulations, a scientific and standardised integrated operation mechanism will be established at multiple levels, including law enforcement supervision, technical services and enterprise management, to prevent accidents jointly. It is also in line with the "comprehensive management" principle in the *Safe Production Law.*

(8) Quantitative concept

Carry out safety evaluations under the national, industry, and local safety evaluation and risk assessment standards, establish and improve the safety evaluation systems and indicator systems applicable to the industry. Based on the quantitative assessment and data statistics, provide a reference for the accident prevention and control, recommend the scientific and reasonable technical measures, and provide a basis for decision-making in supervision, management and safety investment.

(9) Internationalization concept

The overall level of accident prevention and control of China's city gas industry could be improved with the help of international cooperation, exchange and technical support. By digesting and absorbing advanced technologies and methods of accident prevention and control from abroad, we can get more indirect experience in safety management.

6.1.4 Prevention and handling of gas safety accidents

(1) Accident prevention

Gas operators should establish a sound gas safety assessment and risk management system. If found, they could take timely measures to eliminate the hidden gas safety hazards. They should develop their emergency plans for gas safety accidents, equip the emergency teams and personnel, and organise regular drills of the emergency plans.

Any unit or individual who discovers a gas safety accident or a hidden gas safety accident shall immediately inform the gas operator or report to the gas management department: the public security authorities, fire-fighting agencies and other relevant departments and units. The gas management department and other relevant departments and units shall, following their respective responsibilities, supervise and inspect gas operations and the safety conditions of gas use. Where hidden gas safety hazards are found, gas operators and gas users shall be notified to take timely measures to eliminate the hidden risks. When the failure to eliminate hidden dangers may seriously threaten public safety, the gas management departments and other relevant departments and units shall take measures under the law. The relevant units and individuals shall cooperate.

(2) Disposal of accidents

In the event of a gas-related emergency, all departmental units should respond quickly according to their respective responsibilities; the primary responsibilities of the gas supply units are pre-emptive handling, information reporting and securing supply.

The gas supply units should quickly initiate an emergency response in response to the emergency and make initial judgments based on the information, instructions and the actual situation. They take immediate measures for technical disposal and control of the case based on the gas enterprise emergency plan. Then they report to the gas industry management, production safety supervision, quality and technical supervision, public security and fire-fighting and other administrative departments following the requirements of the procedure according to the level of the incident. According to the level of the incident, the relevant government departments should follow the plan and their respective responsibilities and scope of business, work closely together to do an excellent job in the command and disposal of the gas safety emergencies. The gas supply unit must take emergency evacuation measures in a gas leak and other emergencies. The

government and traffic management departments should assist in the implementation of control. The community, the public security and fire services should cooperate with the gas supply unit to implement household rescue and emergency repair operations.

Suppose the gas supply unit cannot guarantee the regular gas supply and the public interest is seriously affected. In that case, the gas administration shall take the necessary measures to ensure a safe gas supply. Accidents in gas production and safety shall be reported and investigated by the provisions of the laws and administrative regulations on the reporting and studying of production and safety accidents. If an investigation determines that an accident is responsible, the cause should be identified, the responsibility clarified and pursued under the law.

6.2 Accident Management

Accident management is the general term for a series of work such as investigation, analysis, research, report, treatment, statistics and file management of accidents.

Accident management is an essential part of safety management, and this work is technically rigorous and strictly policy-oriented. Scientific accident management makes it possible to grasp the critical information about accidents, recognise the potential dangers and hazards, explore effective preventive measures to prevent accidents from recurring, and ultimately improve safety management.

6.2.1 Classification of accidents

(1) Classification in *Regulations on the Reporting and Investigation of Production Safety Accidents*

According to the *Regulations on the Reporting and Investigation of Production Safety Accidents,* accidents are divided into four levels, i.e., particular major, major, large, and general.

1) Particularly major accidents refer to the accidents that cause more than 30 deaths, or more than 100 serious injuries, or more than 100 million RMB of direct economic losses at one time.

2) Major accident means an accident that causes the death of more than ten but less than 30 people, or the severe injury of more than 50 but less than

100 people, or the direct economic loss of more than 50 million RMB but less than 100 million RMB at one time.

3) A significant accident means an accident that causes more than three but less than ten people, serious injury of more than ten but less than 50 people, or direct economic loss of more than 10 million RMB but less than 50 million RMB at one time.

4) A general accident is an accident that causes the death of fewer than three people, serious injury of more than three people but less than ten people, or direct economic loss of more than 3 million RMB but less than 10 million RMB at one time.

As for the accidents with destructive social impact, the grade cannot be determined. The corresponding rate of the accident can be defined in practice according to the effects and harm.

According to the degree of injury (to the injured individual), the accidents are classified as major personal injury accidents, minor injury, serious injury and death.

1) Major personal injury accident

It refers to the accidents that nearly result in serious injury, death, or multiple casualties. These include a risk incident in a non-production area and of a non-production nature, an incident that occurs due to a production or equipment accident but does not result in personal injury or death and a general breach of regulations.

2) Minor injury

Refers to the injury where the employee has been off work for more than one working day after the injury but does not reach the level of severe damage.

3) Serious injury

Injuries are classified as severe if any of the following conditions apply: physician-diagnosed disability or probable disability; injuries so severe that major surgery is required to save them; severe burns or scalds on body parts or burns covering more than one-third of the body, although not vital details; severe fractures or concussions; serious eye injuries that may cause blindness; injuries to the hand if the thumb is crushed off one section; injuries to the other four fingers; injuries to the feet in which more than three

toes are broken; injuries to local muscles in which more than three toes are broken; injuries to local muscles in which more than three toes are broken; injuries to internal organs in which there is internal bleeding or damage to the peritoneum. As for the injuries mentioned above, which are considered inflicted upon diagnosis by a doctor, the enterprise will put forward preliminary views based on the points mentioned above and submit them to the local safe production supervision and management agency for review.

4) Death

The *6th International Conference on Labour Statistics* established that each accident resulting in death or permanent total incapacity is equivalent to 7,500 workdays lost, assuming that the average age of the deceased or incapacitated person is 33 years. One has lost 25 years of working time after death or disability, and that one works 300 days per year. Thus, the number of workdays lost is 300 x 25 = 7,500 (workdays).

(2) Classification standard in GB6441-86, *the classification for casualty accidents by enterprise staff and workers*

GB6441-86, the national regulation for t*he classification for casualty accidents of enterprise staff and workers,* classifies the accidents into four categories according to the severity of the casualties: lightly injured accidents (accidents with only light injuries), seriously injured accidents (accidents with only serious injuries but no fatalities among the wounded), significant casualties (accidents with one to two deaths in a single occurrence) and especially significant casualties (accidents with three or more fatalities in a single event).

The accidents are classified into 20 categories according to the cause of injury.

1) Object blows (means falling objects, rolling stones, hammer blows, fractures, fragments, bruises, but does not include object blows caused by explosions).

2) Vehicle injuries (including hitching, crushing, hitting, subversion).

3) Machine tool injuries (including reaming, grinding, poking).

4) Lifting injuries.

5) Electrocution (including lightning).

6) Drowning.

7) Scalding.

8) Fire.

9) Stabbing (means stabbing at the site of a machine injury, such as a nail in the foot, a cut with sharp-edged objects).

10) Falling from a height (falling from a ridge to the ground and from a level surface into a crater).

11) Collapse.

12) Roofing.

13) Permeable.

14) Discharge of artillery.

15) Gunpowder explosions (accidental explosions during production, transport, storage).

16) Gas explosions (including pulverised coal explosions).

17) Explosions in forge furnaces and pressurised containers.

18) Other explosions (including chemical explosions, explosions of furnace steel).

19) Poisoning and asphyxiation.

20) Other injuries (sprains, bruises, frostbite, animal bites).

(3) Other classification methods

The *International Confederation of Labour* (ICL) recommends the classification by injurious objects where possible and lists harmful things as machinery (prime movers, power transmissions, crane processing machinery); transport (railways, ships, vehicles); explosions; hazardous, hot or corrosive substances; electrical; falls of persons; shocks and collisions; falling objects; falls; non-mechanical operations; hand tools; animals.

The Ministry of Labour of Japan defines the categories of casualties as following: falling, rolling; overturning; intense collision; collapse, the collapse of flying and falling objects; crashing through; intercepted, caught in; severed, rubbed, pierced; drowning; contact with high and low-temperature objects; contact with harmful things; electric shock; explosion; rupture; fire; road traffic accident; other traffic accident; reverse action; other; an accident that cannot be classified.

The method and level of classification of accidents depend on the purpose and scope of statistics on casualties. When higher management needs to have a comprehensive picture of losses, accident categories can be more general. A department or an enterprise often wants to be more detailed to investigate the root causes of accidents and explore corrective measures, but the more precise the classification, the more scattered the data.

6.2.2 Accident investigation

Accident investigation is an essential part of accident management, should adhere to the scientific and rigorous, under the law, realistic, pragmatic, pragmatic principles, timely and accurately investigate the accident, the cause of the accident and accident losses, to identify the nature of the accident. Through the objective, scientific and comprehensive accident investigation, the cause of the accident could be found out to distinguish the responsibilities and be targeted to explore the accident prevention measures through the analysis of accidents and the development process.

According to the specific circumstances of the accident, the accident investigation team is composed of people from the relevant people's government, the safe production supervision and management administration, the relevant departments with safe production supervision and management responsibilities, the supervisory organs, the public security organs and the trade unions. The people's procuratorate should also be invited to send people to participate. The accident investigation team may engage relevant experts to participate in the investigation. The accident investigation team members should have the knowledge and expertise required for accident investigation and have no direct interest in the accident under investigation.

The accident investigation should be started as early as possible after the accident to prevent the loss of evidence. The investigation and collection of the evidence of pre-accident conditions should be carried out one step ahead or simultaneously as the site investigation. The investigation may take various forms such as questioning, access to information, investigation and collection of evidence, and sending physical evidence for examination. Investigate and verify with the relevant medical institutions and forensic identification departments the injury areas, state and cause of death of the casualty.

The subject and content of the investigation should be determined by the location, nature of the incident site and the people involved. As listed, engaged in forming an accident hazard and witnesses and who called police are included in the investigation.

1) The activities of associated persons, the operation of equipment and facilities, and their use.

2) The production status, storage of raw materials and finished products, process and operating conditions, technical requirements and management regulations, and dispatching and commanding states.

3) Regional environmental and natural conditions, such as lightning, rain, sunshine, wind direction, temperature and humidity, earthquakes, floods, and other relevant external factors.

4) Abnormalities in production operation and the judgment and handling of situations arising from the operation of equipment use.

5) The physical and working conditions, emotional changes and changes in circumstances of the person concerned.

The production and operation units and individuals should cooperate with the investigation under the law and provide clues and relevant information about the accident. The site investigation and the investigation of the pre-accident situation should cooperate and be based on each other. In the investigation, attention should be paid to confirming personal testimony with material evidence and revealing the facts of the accident with material evidence.

(1) Accident investigation procedures

The general procedure for accident investigation is: the first thing to do is to protect the scene of the accident, and at the same time to report it to superiors and the relevant departments on time when an accident has occurred. Protect the accident scene while actively resuscitating the injured. The unit where the accident occurred and the appropriate higher-level unit in charge should promptly form and send an accident investigation team to the scene of the accident to investigate. The team in principle should include the administrative leadership of the unit, the head of the trade union, the personnel and labour department, the medical department and relevant personnel from the safety management department. Collect information about all aspects of the accident and human and material evidence at the scene, and hold seminars and analysis meetings with the people involved. Based on mastering the whole situation, we will clarify the causes, distinguish the responsibilities, propose the handling of the accident, and finally fill in the accident investigation report to summarise, file, close and report all the accident information.

The accident investigation team should be organised following the management authority to investigate and deal with the accident quickly and thoughtfully. The unit where the accident occurred should, as far as possible, maintain the accident site in its original state until the investigation team has investigated it to provide first-hand information on the cause of the accident. For major accidents, audio-visual and other information should be left at the scene before repair work is carried out to provide a basis for accident investigation.

When conducting an accident investigation, the unit where the accident occurred should actively cooperate with the investigation team to investigate the cause of the accident. It provides information on the geographical location of the accident, the time of occurrence, the production process parameters, operation records, maintenance and overhaul at the time. The parties involved in the accident and the maintenance and overhaul personnel should write a written report to provide a detailed explanation of the sources of information, confirm the situation, the situation at the scene of the incident, and emergency disposal measures.

When investigating an accident, accident investigators must adhere to the working principle of seeking truth from facts, analysing based on the actual situation at the accident site, and drawing conclusions based on physical evidence, supplemented by human evidence. The investigators must master the accident investigation techniques and know the performance of the raw materials products, production systems, process conditions, equipment structure, operating techniques and other professional knowledge. No matter how big or small, the accidents should be investigated according to the accident investigation procedures.

Generally, the accident investigation process must not be omitted or crossed. Only after the origin of the accident has been determined and the cause of the expansion be determined. Only based on identifying the cause of the accident can the analysis of the nature of the accident and responsibility be done.

The accident investigation procedure is shown in Figure 6-2.

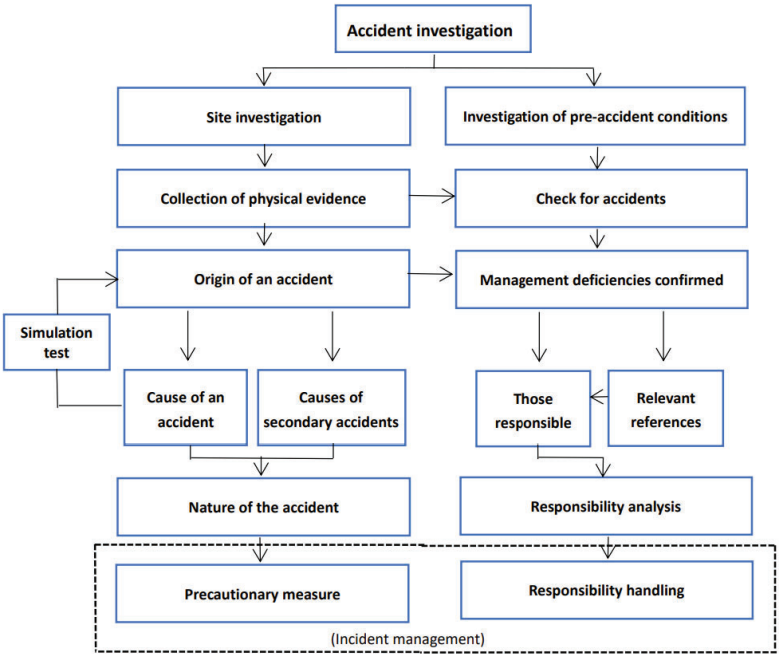

Figure 6-2 Accident investigation procedures

(2) Methods and procedures of accident scene investigation

1) The first step is to protect the accident scene. The accident scene is where the original state is maintained after the accident, including the scope involved in the accident and the places connected with accidents. The scene investigation work has practical significance only when the set is kept in its original state. The accident site cannot be abolished and destroyed, nor can it be opened until the origin and the accident's initial cause have been entirely determined and the filming, recording and evidence collection processes have been completed.

2) The purpose of the investigation of the accident scene. To find out the damage caused by the accident (including loss of materials, destruction of equipment and buildings, functional role and destruction of preventive measures, casualties); to discover or determine the material evidence of the accident origin and cause, and to determine the occurrence and development process of the accident; to collect all kinds of technical data

to provide a basis for studying new preventive measures.

3) Preparation for the survey work. The safety department should always prepare for the investigation of the accident scene. It is best to have an accident investigation box that stores the tools and instruments for photography, video equipment, lighting, surveying, and mapping. Relevant drawings, records and data are prepared. The accident investigators should receive the appropriate training in advance and be equipped with the necessary protective equipment to carry out rapid investigation work in an accident.

4) Investigation work steps. According to the actual situation at the scene, the scope of the accident site is delineated, an investigation plan is developed, and the whole set and critical parts are photographed, videoed, mapped, and recorded. Then, according to the investigation procedures, various physical evidence from the scene that can be used to prove the occurrence and development process of the accident will be identified. The origin location of the accident must first be verified. After the initial determination of the accident origin, the cause of the transformation of the accident potential into an accident at the accident origin (i.e., the first excitation) and the cause of the expansion of the accident (i.e., the second excitation) are then verified. If necessary, simulations are carried out to verify the origin and cause of the accident.

5) Survey record. To preserve the memory of the scene, we should keep proper recording and videotaping when surveying the scene.

(3) Reliability of witness materials

The conclusion of the investigation must be based on material evidence. Moreover, the conclusive opinion cannot be made only on some people's testimony or inferential judgment. However, the witness materials are still indispensable. Moreover, sometimes, one sentence can explain the key to the accident, especially when the accident has just occurred or just finished. The testimony of the relevant personnel is often authentic. Full attention should be paid to the validity of the initial questioning or interview materials.

(4) Simulation tests

The simulation test is the scientific basis for examining the accident's origin, cause, and development in investigating accidents. After determining the source and cause of the accident, physical simulations or software simulations of the actual accident can be carried out, as required, to

corroborate the accident investigation findings. In some cases where the physical evidence is sufficient, the origin and cause of the accident are apparent, and the investigators agree and can draw direct conclusions, a simulation may be dispensed.

(5) Content of the accident investigation report

The accident investigation report should include the following.

1) Overview of the accident occurrence unit

2) The circumstances of the accident and the circumstances of the rescue.

3) The human casualties and direct economic losses resulting from the accident.

4) The cause and nature of the accident.

5) Determination of responsibility for the accident and recommendations on treating those responsible for the accident.

6) Accident prevention and rectification measures.

The relevant evidentiary materials shall accompany the accident investigation report, and the accident investigation team members shall sign the accident investigation report.

6.2.3 Accident reporting

According to the *Report on safe production accident and regulations of investigation and treatment* issued by the *State Council*, the accident reports shall be timely, accurate and complete. No unit or individual shall delay, omit, lie or conceal an accident, and no unit or individual shall obstruct or interfere with the reporting of an accident.

After the accident occurs, the persons concerned at the accident scene shall immediately report it to the person in charge of the unit. After receiving the report, the person in charge of the unit shall, within one hour, report it to the safety production supervision and administration department of the people's government at or above the county level where the accident occurs and the relevant departments responsible for safety production supervision and administration.

In case of emergency, the persons concerned at the accident scene may report directly to the safe production supervision and administration of the

people's government at or above the county level where the accident occurred and the relevant departments responsible for safe production supervision and administration.

The safe production supervision and management administration and the relevant departments responsible for safe production supervision and management shall report the accidents level-by-level. Each level takes no more than two hours to report.

The supervision and administration departments of the safe production and the departments responsible for the supervision and administration of safe production shall establish a duty system and announce the duty telephone numbers to the public to receive the accident reports.

(1) Content of accident reports

The accident unit shall report the accident to the relevant authorities by the most expeditious means (telephone, fax), and the accident report shall include the following.

1) Overview of the unit where the accident occurred.

2) The time and place of the accident and the circumstances of the scene of the accident.

3) A brief account of the accident.

4) The number of casualties (including persons unaccounted for) and the preliminary estimate of direct economic loss that has resulted or may result from the incident.

5) Measures already taken.

6) Other situations that should be reported.

If the situation continues or new information emerges, the follow-up report should be made on time. The follow-up report should include more specific information about the accident, what emergency measures were taken by the parties after the accident, and the treatment of the accident scene.

The gas supply company must fill out an internal accident report where the accident occurred. The accident report should include the process of the accident, cause analysis, responsibility analysis, treatment opinions, measures. It should list the time, location, type of accident, casualties, loss of facilities and impact on gas supply; the basic situation of the risk, the

brief process of the accident, emergency disposal measures; direct economic losses; preliminary analysis or basic conclusion of the threat or cause of the accident; measures taken and the judgment of effectiveness; incident reporting unit, issuer and time of reporting.

(2) Graded release of incident reports

According to the regulations, the contents of the accident report include the course of the accident, analysis of its causes, analysis of responsibility, opinions on handling and measures. The report should describe in detail the process of the accident, investigate the evidence and analyse the causes of the accident, draw conclusions on the analysis of the accident, clarify the responsibility, and put forward opinions on handling and rectifying the accident.

However, the mere submission of accident reports to the higher authorities, following the national regulations, is far from adequate for the scientific management of accidents and is insufficient to prevent a recurrence.

1) For the industry's safety management and research institutions, the accident report should provide an essential basis for conducting a technical analysis of accidents and building a safety management database. Such accident reports should be detailed and pay special attention to the technical analysis of the accident and the provision of specific parameters and data, including the failure, the disposal and emergency response after the accident, the system repair and recovery technology, and the accident loss statistics.

Therefore, a specific research institute should be set up as soon as possible under the guidance of the industry authorities. It will carry out statistical analysis of the safety hazards and accidents in the city gas industry extensively based on the safety assessments. It establishes a safety management database to provide safety guidance and technical reference for the gas industry's management, operation, and business sectors.

2) For the safety management personnel and the general technical personnel in the gas industry, the purpose of providing accident reports is to give them indirect experience to guide them in their practical work to prevent similar accidents and improve safety management. The accident report should focus on analysing the cause of the accident, the failure, the description of the technical details of the occurrence, development and expansion of the accident and the presentation of successful emergency response techniques and methods.

3) The accident report should be provided with warning and education as the primary purpose for the general employees and the public. The public, especially the gas users, should be able to check their behaviour, regulate the use of gas, and learn how to find the hidden danger, the accident alarm and personal emergency protection through the accident report. The accidents are what we do not want to see, but at the same time, they are precious lessons that people have learned at the cost of their lives and property, and they are precious assets of humankind that must be treasured. The scientific management and in-depth analysis of the accident can deepen the understanding of the occurrence and development of the accident. It provides the basis for the safety assessment and the emergency plan for the accident. The discussion and exchange of the emergency disposal method after the accident and the study of proper management and control measures are essential to effectively preventing similar accidents.

6.2.4 Accident analysis

(1) Analysis of the nature and the responsibility

The analysis of accidents nature: After the origin and cause of accidents are investigated, the nature of the accident should be analysed. The accident nature is generally divided into three categories: political accidents, natural accidents and production liability accidents. Regardless of the nature of accidents, it is necessary to conduct a comprehensive analysis of the causes of the formation of hidden dangers and the process of the accident's development to learn lessons truly.

The analysis of accident responsibility is to divide and trace the responsibility for the causes of accidents. In the causes of accidents, there are responsibilities of operation and operator and duties of the organiser and conductor. Only when responsibilities are identified can accidents be handled correctly, lessons learned and preventive measures formulated to prevent similar accidents.

(2) Analysis of the accident cause

The cause of accidents is the excitation and technical conditions that transform the risk factor at the origin of the accident into an accident.

The technical conditions for transforming dangerous factors into accidents refer to the physical or chemical changes of the material conditions (nature, energy and susceptibility). In contrast, the excitation conditions refer to the

effect of the wrong operation and external constraints on transforming dangerous factors into accidents.

The causes of accidents (direct causes) can be divided into primary causes and secondary causes. There should be only one cause of a unit accident and no more than three causes of accidents that are difficult to determine accurately. Generally, more than one cause of an accident has been analysed may indicate that the actual cause of the accident has not been found. Further investigation and evidence should be taken and analysed in-depth to identify the most significant cause of the accident. The causes of the accident can be interpreted in each of the following ways.

1) Unsafe human behaviour

Human misjudgments, presumptions and wrong behaviours that have caused or may cause accidents are called unsafe human behaviours. Such as identification and comparison, judgment, decision-making, output errors; system errors or random errors; illness, drunkenness, drug reaction, lack of strength and other physical reasons; intuition, relying on luck, want to save energy, habit, tension, forgetfulness and other psychological (subjective attitude) reasons; lack of job skills, unskilled operation and other technical reasons; unclear requirements, training and education deficiencies and other educational reasons. All may cause unsafe human behaviour.

2) Unsafe condition of objects

The unsafe condition of the machinery, materials, production objects and production factors can directly lead to accidents. For example, the defective equipment, facilities, tools and accessories; faulty operation of equipment and facilities; untimely or substandard maintenance and repair; lack of or insufficient protection, safety and signal devices; lack of or defective personal protective equipment and appliances; inadequate monitoring and monitoring, all belong to the unsafe state of objects.

3) Adverse effects on the environment

A poor environment can induce unsafe behaviours and unsafe conditions of the objects and directly lead to the occurrence and expansion of the accidents. For instance, adverse climatic and meteorological conditions include bad weather, cold season, extreme heat, narrow workplaces, disaster or accident sites, unfavourable working conditions such as insufficient illumination, inadequate operating conditions, and lack of tools. Under adverse environmental conditions, the movement of the people and the

operation of the equipment and facilities may be out of order, and the operation action is not up to standard.

4) Management factors

The management of the production process should be to achieve the effective control of people, objects and the environment. If such control is ineffective or defective, the chain from human, material and environment to accident cannot be cut and may even lead to the accident directly. The control of the people, things, and environment includes the establishment and implementation of laws and regulations and measures; the clarity of standards and requirements; the training, induction, access, examination system and performance; the effectiveness of supervision, inspection and guidance; the understanding and control of people and things; the issuance and implementation of prohibitions and warnings; the decision-making of safety investment.

(3) Methods for identifying the causes of accidents

The three general methods of determining the causes of accidents are visual inspection, causal analysis and technical analysis.

1) Visual inspection method

The causes of accidents can generally be determined by the visual inspection method if the origin of the accident can be determined by the definition method, which applies to incidents with relatively simple circumstances.

2) Causal analysis method

The causal analysis determines the cause of an accident using the cause-effect relationship between the potential hazard and the accident. Using the causal analysis method, first of all, we need to list out as far as possible the conditions under which the risk factors at the origin of the accident are transformed into the accident, and then analyse the cause-and-effect diagram according to the cause-and-effect relationship.

The results of a causal analysis according to the direct cause of the accident, using a gas pipe leak as an example, are shown in Figure 6-3.

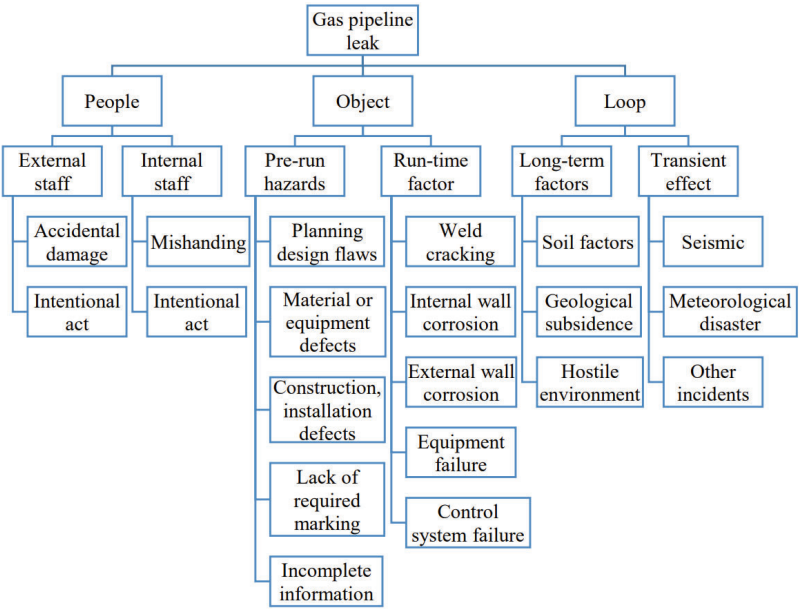

Figure 6-3 Accidental causes of gas line leaks

3) Technical analysis

If the accident cannot be visually verified and a cause-effect diagram is not available, the cause of the accident can be confirmed by technical analysis. The technical analysis method is based on the technical state of the origin of the accident. It is closely related to the product, process, operation and equipment operation data at the time of the accident. It analyses the technical conditions that transformed the risk factor into an accident, the management defects and the stimulating effect of external conditions on the origin of the accident. The cause of the accident is identified.

(4) Statistical analysis of accidents

The occurrence of accidents is random, i.e., the time and place of the accident and the severity of the consequences of the accident are coincidental. It means that the prevention of accidents is complex. However, this randomness of accidents also follows statistical laws in a certain scope. The regularity of accident occurrence can be found in the statistical data of accidents. Thus, the statistical analysis of accidents is significant to formulating correct preventive measures.

Keeping good statistical records will help the company itself and the industry as a whole to improve safety management.

From the statistical report and the data analysis of accidents, we can grasp the causes and laws of accidents and take targeted countermeasures to avoid accidents by targeting the weak links in the safety work.

Through the investigation and the statistical analysis of accidents, it is possible to reflect an enterprise's achievements and safety situation. They identify the gaps with similar enterprises, procedures or areas. Statistics are an essential indicator of how well safety is being tested.

The investigation and research of accidents and statistical analysis provide a scientific basis for formulating relevant safety regulations and standards.

Through the investigation, research and statistical analysis of the accident, most employees can receive profound safety education, learn from the lessons and improve their safety consciousness of compliance with the law. Thus, the enterprise management can raise awareness of the importance of product safety, clarify their responsibilities, and improve safety management.

Through the investigation and study of accidents and statistical analysis, the leading bodies can get a timely, accurate and comprehensive picture of the system's safety situation, identify problems and make the right decisions. This work also facilitates the inspection, supervision and management administration.

The analysis and research of accidents promote the scientific and technological progress of accident prevention and safety management and the development of society.

The statistical analysis of accidents is to run mathematical and statistical methods to process, organise and analyse a large amount of data on accidents to reveal specific inevitable laws of accidents and point out the direction for the prevention of accidents. The statistical analysis of accidents is built based on perfect investigation, registration and archiving of accidents. That is to say. It relies on the ideal and complete data of accidents. These exclusive accident data are nothing more than an objective reflection of a single, isolated, accidental event, which may not appear to be regular. However, by analysing many random occurrences, it is possible to identify inevitable patterns and general trends that can be used for accident prediction and prevention.

The statistical analysis of accidents is an important content of accident management. Doing the work well can provide timely and accurate statistics to reflect the safety situation and accident development trend of the enterprise or system and provide a basis for decision-making, guiding safety production and formulating plans for leaders at all levels.

The basic statistical analysis procedure of accidents is the statistical investigation of accident data - processing and arrangement - comprehensive analysis. The three are closely connected and are essential for people to know the essence of accidents.

The statistical investigation of accident data collects accident data by various means and systematically and comprehensively concentrates a large amount of sporadic original accident data. Accident investigation items should be set according to the purpose of accident investigation, such as the time and place of the accident, the name, gender, age, age of the victim, type of work, injury part, nature of the injury, direct cause, indirect cause, causative agent, harmful agent; kind of accident, accident economic loss, number of days off work. Items can be completed in numeric, judgemental or textual form.

The accident information is collated by correctly grouping and reviewing, and summarising accident information according to the day of statistical analysis of the accident and calculating the relevant values and grouping them according to the requirements, for example, grouping by industry, type of accident, the severity of the injury, size of economic loss, gender, age, length of service, education level, time of day. The process of auditing the summary is to check the accuracy of the information, see whether the content of the data is logical and whether the indicators are contradictory to each other, and check for errors through calculations. The comprehensive analysis of accident information is to fill in the summary and collate accident information and related data into a statistical table or labelled with a statistical chart to draw appropriate statistical analysis conclusions.

The figures obtained from the statistical survey are summarised, collated, and filled in a certain form according to specific requirements, called a statistical form, i.e., a form filled with statistical indicators, e.g., the *Comprehensive Monthly Report on Employee Casualties*. To use the table's absolute, relative and average hands, we should study various accident phenomena' patterns, development rates, and proportional relationships. There are many statistical tables, such as simple tables, grouped tables and compound tables. There are simple tables with month-by-month accident

statistics and tables of gender, unit; grouped tables with accident statistics by length of service, age and education; and composite tables that combine both.

The statistical analysis results can be kept as basic data materials and used for quantitative safety evaluation and scientific calculation. The scientific calculation methods require establishing a corresponding database system, and if this aspect of the data is not sufficiently accumulated, the evaluation methods applied will be somewhat limited.

Appendix A of the *Technical specification for the safety of operation, maintenance and rush-repair of city gas facilities* CJJ51-2016 gives the "Gas Safety Accident's Report Table", "Gas Accident Category Statistical Table" and "Gas Accident Cause Statistical Table" in three tables. They can be used as a reference for the statistics and analysis of accidents.

(5) Evaluation of the consequences of accidents

The consequences of an accident are generally considered in terms of human casualties, property damage and environmental damage. In recent years, the social influence factors have been added to the analysis of accident consequences. For municipal industries such as city gas supply, the supply interruption and the security degree of the facilities are also important factors that directly affect the results and rating of an accident. Even if there are no casualties or other losses, as long as the incident causes widespread supply interruption or damage to infrastructure, it should still be considered a major or significant accident.

See Appendix 1 for classification of the risk of hazards or possible consequences of accidents.

6.2.5 Accident communication

The exchange of accident information within a certain range is essential for preventing accidents, especially similar accidents. In some cases, "to prevent accidents, it is not necessary to have deep theories or conduct in-depth studies - it is only necessary to know about the previous accidents."

Some companies are reluctant to expose their jurisdictions to accidents for fear that their growth and image will be affected by them, which is unnecessary. First of all, with the standardisation of the safety management and employees, the public's awareness of the law increases, and if an accident does occur, there is no way to hide it. The consequences of some

mining enterprises to conceal the accident have been seen. Moreover, in terms of maintaining a corporate image, the public will have more faith in a company that dares to take responsibility rather than trying to shirk its responsibilities.

There was a real case at Jilin Petrochemical Company in November 2005, the benzene spilt in a double benzene plant. After the spill, the benzene leaked and caused water pollution in the Songhua River. The refusal of the management and technical staff of the enterprise to acknowledge the fact delayed the handling of the accident and seriously affected the enterprise's social image. Those responsible for the accident were not punished more lightly for shirking their responsibilities.

Trevor Kletz is a safety consultant of the British Royal Chemical Industry's Organic Chemistry Department and an expert in petrochemical accidents. He has been engaged in investigating and analysing accidents in the petrochemical industry for many years. He has some unique knowledge about the exchange of accident situations, inspiring us. He believes that,

1) Ethically: if it has information that could have prevented the accident, it is responsible for passing it on to the relevant person.

2) In terms of teamwork: people should communicate danger warnings to their team.

Humans should learn from animals on this point. Most herd animals will warn their companions of danger through sounds, movements when they are in danger, sometimes at the risk of their lives. Nevertheless, animals brave enough to call the police are elevated in social status because they spare their companions the danger.

3) In terms of economic reasons: many companies spend much money on security measures, and if a competitor is made aware of its actions, he will invest accordingly.

In a highly developed market economy where competition between good companies is open, fair and equitable, the capital investment of competitors can make business managers think about where their own money is going.

4) In terms of industry impact: if a serious safety incident occurs in one company in the same industry, then the whole industry will undergo a loss of public confidence.

There will never be a similar accident. The accident may lead to new legislation that will impose new requirements on the industry as a whole, not just on the entity that has already had an accident. Thus, while we subjectively do not want to be affected by accident in the same industry, new legislation will likewise bind us.

5) From the point of view of influence: nothing else has as significant an impact on anyone, be it the public or professionals, as an accident report, leaving such a lasting impression that people are alerted and check their behaviour.

Therefore, the exchange of information on accidents and emergencies, the analysis of typical cases, and the description of the mistakes and lessons learned by certain people and companies are of great importance in preventing the recurrence of tragedies.

Because of the current state of safety management in China's city gas industry, we believe that:

1) The scientific management of accidents that have occurred, cherishing and utilising accident information is the only way to discover accident patterns; establishing a corresponding database is the only way to make safety evaluations accurate and effective, and emergency plans scientific and reasonable.

2) The statistics and analysis of the accident situation will enable us to have a correct understanding of the gas system's safety, identify the weak links, and propose technical measures for accident prevention and safe production.

3) It is normal and desirable to exchange information on accidents within the industry. In particular, leaders, managers and technicians will benefit from an in-depth and detailed analysis and study of typical cases that occur around us.

4) Strengthening safety education for the general public and users can effectively reduce accidents among users. When educating town gas users about safety, attention should be paid to various forms and means and the use of mass media and publicity and education in schools and communities. In addition to spreading knowledge about the safe use of gas, information on accident cases should provide scientific and practical ways to prevent accidents.

The occurred accidents should contribute to preventing accidents in the city gas industry. We must use the resources of accidents to improve the emergency handling capacity and safety management level of the city gas industry and make the sector develops in a healthy and orderly manner.

The gas accident analysis report can refer to the format in Appendix 4.

CHAPTER 7

SAFE OPERATION AND SAFE USE

City gas facilities refer to the equipment, installations, and systems used for gas storage, transmission, distribution, and application, including gas plant stations, pipeline networks, customer gas facilities, monitoring and data collection systems installed in towns and cities.

The relevant departments shall organise the completion inspection and acceptance after the planning, design and construction of city gas facilities. It can be put into operation only after the acceptance is passed.

Enterprises of city gas pipeline management are responsible for the operation, maintenance, emergency repair and renovation of the municipal gas facilities within the gas supply range and the gas facilities outside the owner's only part of the building zoning. They are responsible for the personnel and vehicles engaged in the delivery service of bottled gas. The gas facilities of unit gas users should be managed following the agreement of the gas supply and consumption contract.

The city gas self-management unit that supplies gas to its users shall manage, operate and maintain the gas facilities under its jurisdiction.

The relevant departments of the people's government at or above the county level shall publicise and popularise the gas laws, regulations and safety knowledge and raise the people's awareness of gas safety. The gas enterprises should provide the gas users with the gas that meets the national quality standards and guide the gas users to use gas safely and save gas. They should conduct regular safety inspections on the gas facilities, following the relevant regulations. They should promptly inform and correct the hidden dangers when they find the hidden dangers.

7.1 Safe Operation and Operational Requirements for City Gas Facilities

In addition to complying with the relevant national and industry regulations, the operation, maintenance and emergency repair of city gas facilities should also follow the requirements of CJJ51-2016 *Technical specification for the safety of operation, maintenance and rush-repair of city gas facilities*. The provinces, cities, and gas business and supply units can also formulate more detailed and specific regulations. However, the requirements developed by the localities and the enterprises themselves shall not be lower than the basic requirements of the state and the industry for operation, maintenance and emergency repair work.

The operation of the city gas facilities is defined as the routine work of professionals engaged in gas supply to inspect, operate and record gas facilities by process requirements and operating procedures.

The maintenance of the city gas facilities is defined as the inspection, repair and maintenance work carried out to ensure the normal operation of gas facilities and prevent breakdowns and accidents.

The emergency work on the city gas facilities is defined as the operations to take emergency measures in the event of a leak that endangers the safety of gas facilities and causes accidents such as gas outages, poisoning, fires and explosions.

7.1.1 Basic requirements for city gas suppliers and personnel

1) City gas supply units should be equipped with full-time safety management personnel. The emergency repair personnel should be on duty 24 hours. the 24h repair telephone should be set up and announced to the public.

2) It is strictly forbidden to bring fire and non-explosion-proof wireless communication equipment into the production area in the station when entering the production area of the factory station. It is strictly prohibited to conduct operations that may generate sparks in the production area of the station without approval.

3) The lightning protection facilities in the station should be in normal operation. The grounding resistance should be tested before the year's rainy season, and the grounding resistance value should meet the design

requirements. the anti-static device shall not be tested less than two times a year.

4) The hoses used for the loading and unloading of LPG, CNG, and LNG and the anti-pull valve installed between the hose and the processing pipeline should be inspected and maintained regularly. the hose should be replaced periodically.

5) Before connecting the hoses to the transport vehicles carrying LPG, CNG and LNG, the transport vehicles must be braking. during the loading and unloading operations, the transport vehicles should be prevented from moving, and anti-skid blocks should be installed.

6) Before the personnel enter the gas surge chamber, compressor room, metering room, bottle group gasification room, valve room, valve well and inspection well, they should first check whether there is gas leakage in the place where they enter. Before entering the underground surge tank, valve well, and inspection well, the person should check the concentration of other harmful gases and oxygen and enter after confirming safety. The work should be supervised by a person and operated in shifts.

7) After the pipelines and equipment are repaired, the remaining gas in the surrounding interlayers, maintenance holes, flues, underground pipelines and buildings (structures) should be thoroughly inspected.

8) When the pressure regulating station or the pressure regulating box causes overpressure at the outlet due to the failure of pressure regulating equipment and safety shut-off facilities, the inlet and outlet valves of the pressure regulator should be closed immediately, and the overpressure pipeline should be relieved to eliminate the fault. When the pressure exceeds the design pressure of the downstream gas facilities, a comprehensive inspection of the gas facilities in the area affected by the overpressure should be carried out, and the gas supply can be restored after all hidden dangers have been eliminated.

9) At the hot work site of city gas facilities, the work area should be delimited, and guardrails and warning signs should be set up.

10) Identification marks shall be provided for essential gas facilities or important parts. The safety warning signs must be set up during the operation, maintenance and emergency repair of gas facilities.

11) When entering the gas surge chamber, compressor room, valve wells and inspection wells and other places to work, one should wear protective equipment and fasten the seat belts as needed. The work should be supervised by a person and operated in shifts. When repairing the electrical equipment, the power supply should be cut off. When carrying out maintenance and repair with air, explosion-proof tools or explosion-proof measures should be used. Sparks are strictly prohibited during the operation.

12) Permanent warning signs should be provided for communal valves installed in customers' rooms.

7.1.2 Regulations to be met for leak checks on underground gas pipes

1) For high and secondary pressure pipelines, not less than once a year.

2) For polyethene plastic pipes or medium pressure steel pipes with cathodic protection, not less than once every two years.

3) For the cast-iron pipes and medium pressure steel pipes without cathodic protection, not less than two times per year.

4) The newly ventilated pipes should be checked once within 24h and rechecked once in the first week after ventilating.

7.1.3 Requirements for inspection of underground gas pipeline

1) Leakage checks can be carried out by instrumentation or ground borehole detection, both in the direction of the pipeline and from above/below the ground structures such as valve wells, maintenance holes or trenches in the vicinity of the pipeline.

2) The cathodic protection systems installed on the gas pipelines should be tested regularly, and the records should be kept. the periodicity and content of the tests should be following the following provisions：

Testing of the sacrificial anode cathodic protection systems and the external current cathodic protection systems, not less than two times per year.

Testing of the electrical insulation devices, not less than one time per year.

The cathodic protection power supply testing, not less than six times per year and at intervals of not more than three months.

The cathodic protection of power supply output current and voltage detection not less than once a day.

The forced current cathodic protection system should test the parameters such as the soil resistivity along the pipeline, the natural corrosion potential of the pipeline, the auxiliary anode grounding resistance, the soil resistivity of the auxiliary anode burial point, the insulation performance of the insulation device, the pipeline protection potential, the pipeline protection current, the power supply output current and voltage.

The sacrificial anode cathodic protection systems should be tested for the parameters such as the anode open circuit potential, the closed-circuit anode potential, the pipe protection voltage, the pipe open circuit potential, the single anode output current, the combined anode output current, the single anode earth resistance, the combined anode earth resistance, and the soil resistivity at the burial point.

The cathodic protection failure area should be inspected in a focused manner. The faults such as the pipeline overlap with other metal structures, the insulation failure, the anode ground bed failure, the pipeline corrosion layer leakage, and the casing insulation failure should be eliminated on time.

7.1.4 Testing regulations for anti-corrosion coatings on in-service gas pipelines

1) Under normal circumstances, the high pressure and sub-pressure pipelines every three years, the medium pressure pipelines every five years and the low-pressure pipelines every eight years.

2) After ten years of operation, the inspection intervals are reduced to 2, 3 and 5 years, respectively.

3) The pipeline corrosion protection layer should be checked when the operating protection current is greater than the standard protection current for the pipelines with cathodic protection. The operational protection potential exceeds the normal protection potential range or is abnormal.

4) Evaluation of the condition of the pipe's corrosion protection layer, either by an excavation of a probe pit or by visual inspection, bonding inspection and EDM inspection at the inspection hole.

5) When damage occurs to the anti-corrosion layer of the pipeline, it must be replaced or repaired and should comply with the provisions of the relevant national standards in force. The corrosion protection layer to be replaced or repaired shall have good compatibility with the original layer. It shall not be lower than the performance of the initial corrosion protection layer.

6) Detectable tracer lines and the signal sources laid along the polyethene plastic piping should be tested.

7) After the first corrosion leak is found in a steel pipeline in operation, the pipeline should be selected to check its anti-corrosion coating and corrosion. Moreover, an operation and maintenance plan should be developed for the actual measurement. The steel pipelines buried for 20 years should be assessed to determine their continued service life. A testing cycle should be established, and inspections and leak checks should be intensified.

7.1.5 Provisions for the operation and maintenance of valves

1) Valves should be regularly inspected for gas leaks and damage. no water should accumulate or collapse in the valve wells. There should be no accumulation of objects that would prevent the operation of the valves.

2) Valves should be regularly opened and closed for operation and maintenance by the operation of the pipe network.

3) Valves that cannot be opened or closed tightly should be repaired or replaced on time.

7.1.6 Regulations to be met for operation and maintenance of pressure regulators

1) The inspection of the pressure regulator should include the operating conditions of the regulator, filters, valves, safety facilities, instruments, meters and other equipment, and there should be no leakage and other abnormalities.

2) The heating condition of the regulator room or the insulation of the regulator should be checked before the heating period in cold areas.

3) The operation and maintenance of the regulator and ancillary equipment shall be following the following provisions:

The connection points and the regulators should be inspected for operation. When gas leaks and problems with the regulator such as panting and

pressure jumping are detected, they should be dealt with promptly.

The oil and rust spots should be removed from all parts on time, without corrosion or damage.

For new use and maintenance and repair of the regulator after re-launch, it must be commissioned to meet the technical requirements before it is put into operation.

For regulators that are reactivated after a gas stoppage, the inlet and outlet pressures and related parameters should be checked.

The pressure difference between the front and rear of the filter should be checked regularly and should be discharged and cleaned in time.

The reliability checks on safety devices such as shut-off valves and water seals should be carried out regularly.

7.1.7 Provisions for the operation and maintenance of odorising devices

1) The level of odorant storage in the reservoir should be checked regularly.

2) The control system and parameters should be regular, out of the station odorant concentration should be in line with the current national standard GB 50028 *Code for design of city gas engineering* and should be regularly sampled and tested.

3) The lubricating oil level of the odour-filled pump should be following the operating regulations.

4) No leakage from odorising devices.

5) The odorising device should be regularly calibrated.

6) The odorising agent should be stored appropriately. The storage of the odorising agent should meet the requirements of the relevant regulations.

7.1.8 Regulations for the operation and maintenance of high or the secondary high-pressure equipment

1) After 12 months of operation of the high or the secondary high-pressure regulator and related equipment, it is advisable to carry out an overhaul.

2) The system must be in normal operation for not less than 24h or not more

than one month after the inspection before it can be transferred to standby status.

3) The regulators, safety valves, quick cut-off valves and other auxiliary equipment of high or secondary high-pressure regulators should be regularly checked and operated within the set values.

4) The inlet and outlet pressures and the filter differential pressures at high or the secondary high-pressure regulator stations should be checked on-site no less than once a week.

5) The electric, pneumatic and other power systems for high or secondary high-pressure equipment should be inspected once every six months. When high-pressure cylinders of nitrogen supply pneumatic systems, the inspection frequency should be increased to once a week.

6) Supervision is required when maintaining equipment at high or secondary high pressure.

7.1.9 Provisions for the operation and maintenance of high-pressure storage tanks

1) The operation and maintenance of high-pressure storage tanks shall be carried out following the requirements of the current national *Pressure Vessel Safety Technical Supervision Regulations*.

2) The operating pressure should be strictly controlled, overpressure operation is strictly forbidden, and the temperature, pressure and other parameters should be observed regularly.

3) Operation and maintenance records should be completed.

4) The valve should be tested regularly for opening and closing performance and should be repaired or replaced on time when the valve fails to open and close properly or is not closed tightly.

7.1.10 Regulations for the operation and maintenance of facilities in the cylinder set gas supply stations (including natural gas booster stations, CNG filling stations and CNG stations)

1) The station piping and valves should be regularly inspected and maintained, and the piping and valves should not be corroded.

There should be no leaks in the station pipework.

Valves and joints must not be leaking or damaged.

Regularly open and close the valve operation and maintenance, cannot open and close or close the valve is not tight, should be timely repair or replacement.

2) For the pressure regulators with heat tracing systems in bottle supply stations, the inlet and return water temperatures of the regulators at all levels should be observed when the bottles are unloaded and should not exceed the normal range.

3) The compressor and its ancillary and supporting facilities should be regularly drained. The dirt should be concentrated and not discharged at will. no debris should be piled up in the compressor skid box.

4) The operation and maintenance of dryers and desulphurisation units shall comply with the following provisions in addition to the maintenance and repair standards for the equipment.

The operation of the components in the system shall be following the set procedures.

The indicator instruments should be normal and operating parameters should be within the specified limits.

Valve switching should be flexible, and moving parts should be smooth, no strange noise, leakage.

The disposal of the desulphurising agent shall be following the requirements of environmental protection.

The dryer is regularly drained according to the operating conditions.

5) The operation and maintenance of filling and unloading equipment should comply with the regulations:

The hoses should be replaced at regular intervals according to the conditions of use.

The flow meters shall be regularly calibrated under the provisions of the relevant national standards in force.

Before filling and unloading, check the system connections to ensure that they are well sealed, that the automatic and interlocking protection devices are normal and that they are connected to the ground.

6) The in-use cylinder being filled with CNG should be kept under positive pressure. The filling pressure should not exceed the working pressure of the cylinder. it is strictly forbidden to load a vehicle without a certificate of conformity or with a fault.

7.1.11 Operational requirements for CNG unloading/loading vehicles

1) When the hose is connected and ready to open the valve of the bottle set, the operator must not face the valve. one must not face the muzzle of the filling gun when filling the gas. no persons unrelated to the operation are allowed to stay in the vicinity.

2) No filling or unloading operations shall be carried out when either:

Lightning weather.

A fire in the vicinity.

A gas leak was detected.

Pressure abnormalities.

Other unsafe factors or the accident occurred.

7.1.12 Requirements for CNG vehicle-carrying cylinder sets, trailer gas cylinder trucks, tractor-trailers and their transport

1) The gas cylinder sets, safety valves, pressure gauges, temperature gauges, all types of valves, joints, connecting pipes must be regularly tested or calibrated under regulations.

2) The transport should comply with the relevant regulations for the transport of hazardous chemicals.

3) The transport vehicles are strictly forbidden to carry other flammable or explosive substances or to travel with unrelated persons.

4) The vehicle should travel on the designated route and at the specified time and should not stop at will on the way.

5) When stopping temporarily due to a breakdown in transit, other dangerous goods, sources of ignition and heat should be avoided, and it is advisable to plug in a cool and ventilated place, and a conspicuous stop sign should be installed.

6) The transport vehicles should be parked in designated locations after refuelling, unloading or returning to the plant.

7) The gas cylinders must not be left in the open air for long periods when fully loaded. Otherwise, they must be relieved of pressure or cooled down.

8) The transport vehicles should be equipped with practical means of communication.

7.1.13 Requirements for inspection and recording of LNG gasification stations

The station equipment and process pipelines should be inspected regularly, and any problems found should be dealt with promptly and recorded.

1) When entering or leaving the tank, observe the level and pressure changes, check and record parameters such as tank level, pressure and temperature.

2) The frosting of the air-temperature gasifiers, the condensation on the external walls of storage tanks and the water and water temperature of water-bath gasifiers should be checked regularly.

3) The evaporation rate of vacuum-insulated storage tanks should be checked annually. they should be tested for vacuum once every two years.

4) Check the paint film on the outer wall of the tank. There should be no peeling, no dents on the outer wall, the tank base should be solid, and the vertical tank should be checked regularly for verticality.

5) Inspection of cryogenic pipe insulation and pipe supports, which should be in good condition.

6) Check all connections, and there should be no leaks.

7.1.14 Regulations for the operation and maintenance of LNG storage tanks and pipelines

1) The Tanks and pipelines should first be pre-cooled before being put into use and should contain no moisture or impurities when pre-cooled.

2) The filling volume of the storage tank should comply with the requirements of the filling coefficient in the national current *Pressure Vessel Safety Technical Supervision Regulations*. The storage level should be controlled within the range of 20% to 90%.

3) LNG from different sources and with various components should be

stored in separate tanks, and the rate of gasification should be closely monitored.

4) It is advisable to periodically decant storage tanks that store LNG for more extended periods and do not deliver gas to the outside.

5) The dry inert gas should be used for replacement before and after tank maintenance. Water-filled replacement methods are strictly prohibited.

7.1.15 Regulations for the operation of LNG unloading/loading trucks

1) Operators must not leave the site during unloading/loading, must wear protective gear as required, and no unprotected part of the human body should come into contact with unseparated pipelines and containers containing LNG.

2) The discharge hose should be purged with dry inert gas or LNG gas before the tank is fed. the remaining liquid in the hose should be recovered after discharge.

3) The same storage tank should not be used when unloading/loading and gasification operations are carried out simultaneously.

4) During unloading/loading, the valves should be opened and closed in strict accordance with the relevant operating procedures.

5) After unloading/loading, the dismantled cryogenic hose should be in a natural state of expansion and contraction. strong bending is strictly forbidden, and the interface should be blocked after recovery to room temperature.

6) LNG liquids are not allowed to remain in the closed section of the pipe after the unloading/loading operation.

7.1.16 Regulations for regular inspections of the gas installations

1) The commercial and industrial users and non-residential users of heating should be inspected no less than once a year.

2) The residential customers should be inspected no less than once every two years.

7.1.17 Contents of the home inspection and inspection records

1) Confirmation of the integrity of the user's facilities.

2) The pipes should not be altered or used as the grounding wires for other electrical equipment, should be free from rust, heavy hangings, the connecting hoses should be firmly installed and should not be over-long or aged, and the valves should be in good condition and effective.

3) The gas equipment should comply with the installation and use regulations.

4) No gas leaks.

5) The gas pressure in front of the gas equipment should be normal.

6) The metering instruments should be in good condition.

7.1.18 Requirements for repair and maintenance work on customer facilities

1) The leak detection by inspection fluid or instrumentation should be used during maintenance and overhaul operations on customer facilities. Any problems found should be taken promptly with adequate protective measures and dealt with by professionals.

2) Units and professionals must maintain and overhaul the gas installations and the gas-using equipment with the appropriate national qualifications.

7.1.19 Requirements for LPG filling, residue pouring and other production workshops

1) Well-ventilated production workshops for LPG filling and residue pouring.

2) The gas concentration alarms should be set and regularly calibrated as required.

3) The alarm concentration of the gas concentration alarm should be less than 20% of the lower explosion limit.

7.1.20 Requirements for the operation and maintenance of storage tanks and accessories in LPG stations

1) The operation, maintenance and servicing of storage tanks and accessories should be based on the process characteristics of the station

facilities and the current national *Pressure Vessel Safety Technical Supervision Regulations* to formulate the corresponding regulations.

2) The operator on duty at the station must carry out inspections at regular intervals and regularly and record parameters such as the level, pressure and temperature of the storage tank. The level and pressure changes should be observed when the storage tank is in and out of the liquid.

3) The LPG storage tanks must not be overfilled.

4) The corresponding cooling spray measures should be developed based on the design pressure of the tanks in use, the results of tank maintenance and the storage medium.

5) In winter in cold areas, the tank drainage pipes, valves, level gauges, liquid phase pipes and high-pressure water injection connections should be insulated against freezing. the tanks should be drained and discharged regularly according to the prescribed procedures.

6) At the bottom of the LPG storage tank, installing a rubber injection clamp or a high-pressure water injection connection is advisable. The tank area should be equipped with high-pressure water injection facilities, and the water injection pipeline should be connected to an independent fire pump. The outlet pressure of the fire pump should be greater than the maximum working pressure of the storage tank. Under normal conditions, the control valve at the water injection port is kept closed.

7) If the tank has more than two valves, the first valve near the tank should be normally open. The valves should be maintained regularly to keep them flexible.

8) Before and after the tank maintenance, the replacement can be done by vacuuming, filling with inert gas, filling with water. When using water-filled replacement methods, the ambient temperature should not be lower than 5℃.

9) The underground storage tanks should be regularly inspected for anti-corrosion coatings and corrosion, and those with electrical protection devices should be routinely tested no less than twice a year.

10) The water seal wells within the tank area should be maintained at a normal water level.

7.1.21 LPG cylinders in use shall be inspected before filling and shall not be filled in the following cases

1) The gas cylinders produced by the manufacturers who have not obtained a manufacturing licence issued by the State.

2) The gas cylinders with severe external damage, corrosion, deformation and those condemned to scrap.

3) The gas cylinders that have exceeded their testing interval.

4) The newly commissioned cylinders that have not been replaced or evacuated.

After filling, the LPG cylinders should be re-inspected on a bottle-by-bottle basis for filling weight and gas tightness. The qualified cylinders should be labelled with a conformity mark.

7.1.22 Requirements for the safe operation of gas storage and distribution stations

The central aspect of the operation and management of gas storage tanks is the prevention of gas leaks, which should be noted in the following areas:

1) Lifting position of low-pressure wet storage tank bells and whistles

The water level in the reservoir and water seal should be checked frequently to prevent gas from leaking out due to insufficient water seal height. in windy weather, the tower height should be made no higher than two and a half towers. In areas with significant temperature variations, attention should be paid to the expansion or contraction of the gas volume in the tank due to temperature differences, thus leaving a safety margin for its lifting position. It is advisable to use instrumentation devices to control or indicate its maximum and minimum operating limits.

2) Storage tank foundation

The uneven settlement of the tank foundation can lead to tilting of the tank. For the wet tanks, tilting their guide wheels, rails, and other lifting mechanisms are prone to wear and tear failure and water seal failure, resulting in serious gas leakage and fire accidents. The low-pressure dry storage tank tilted is also prone to cause liquid seal shortage and gas leakage. Therefore, the related departments must regularly observe the foundation of the uneven subsidence of the level point, find the problem in time to deal with.

Although the high-pressure fixed tank without moving parts, the uneven settlement will make the tank, support and connection accessories subject to high pressure, light deformation, heavy shear damage, resulting in gas leakage accidents. Therefore, the foundation of the high-pressure tank should also be regularly observed and set up compensators for the equipment receiver or designed to take measures to compensate for deformation.

3) Leak repair and corrosion protection

The gas storage tanks are set up in the open air, which inevitably brings about corrosion of the tank's skin due to the sun and rain. Therefore, regular maintenance, painting and breakdown protection should generally be arranged.

As the gas itself is chemically corrosive, corrosion perforations may occur in the gas storage tank. Within the scope of the relevant code provisions allowing for repair, measures are taken, and the repair site has been confirmed to be free of explosive risk before patching is carried out. A flaw detection, strength and airtightness test should be carried out for acceptance and record when the repair is complete.

4) Frost protection

In winter, especially in the cold areas, attention should be paid to the freezing of water seals and pump circulation systems for low-pressure wet tanks, and the inspections should be stepped up. Antifreeze grease should be applied to the tank walls for the dry tanks. There should be a freeze-proof drainage device for the fixed high-pressure tanks to avoid the drainage valve being frozen.

5) High-pressure storage tank safety valves

The working pressure of the safety valve of a general high-pressure storage tank is 1.05 times the design pressure. As long as gas tanks have been put into operation, the safety valve must be in working condition with the medium in tanks to be discharged in time to ensure that tanks are not damaged when there is overpressure. Therefore, the safety valve must be sealed with a seal mark to strengthen the inspection.

6) Gas storage tank of maintenance safety precautions

It is strictly forbidden for non-operating personnel to wander around the gas storage tank and for unrelated personnel to climb the tank.

It is strictly forbidden to smoke or work with an open fire on or near the gas storage tank, and operators and maintenance personnel are strictly prohibited from wearing shoes with nails to climb on the tank.

When repairing the gas tanks, it is strictly forbidden to carry metal objects in the pockets of the operating and maintenance personnel. The tools must be placed in the tool bag, and it is strictly prohibited to pass tools by hand-throwing methods to prevent any objects from falling into the water tank.

No iron should be used to strike the gas tank, only copper or other non-ferrous metal.

7) Safe operating procedures for gas storage tanks

The magnitude of the lift of the gas tank should be within the red line of the permitted regulations and should not be overloaded. In case of extra windy days, the tower height should be reduced.

The operating pressure of the gas storage tank must not exceed the pressure specified.

There should be no less than three times per shift for the gas storage tank inspection. Its content includes: paying attention to the top of the tower wall has no cracks, damage and leakage, and making a record. paying attention to the operation of the guide wheel and guide rail, such as the discovery of derailment and jamming problems to deal with on time. In winter, attention should be paid to the prevention of freezing. Winter to strengthen the inspection of steam hoses, valves, blowpipes and other facilities, such as found blocked, frozen, cracked, off, should be dealt with immediately. Measure the tank's water temperature and the ring cup in winter and ensure it does not fall below 4°C. Measure the depth of the ring cup of the gas storage tank and ensure that it does not fall below the specified requirements. Keep the roof, body, ladders, platforms, railings and the area around the gas storage tank tidy and free from debris. no water should accumulate in the water seal valve and other valve wells.

8) Maintenance of gas storage tanks and ancillary equipment

The sliding of the guide wheel and guide rails is checked once a shift.

Grease the guide wheel once a week and repair or replace it immediately if the oil compass is found to be damaged.

The grounding resistance of the gas tank is measured once a quarter in spring, summer and autumn, and its resistance must not be greater than 4Ω. The lightning protection system is serviced once a year.

Ensure that large and small gas valves are flexible in opening and closing.

The gas storage tank of steam pipes and valves are serviced once a year in autumn.

The gas storage tanks need to be maintained with regular painting.

7.1.23 Requirements for gas emergency repair sites

1) The emergency personnel should wear their duty symbols. The anti-static clothing, shoes and protective equipment should be worn before entering the work area and should not be worn or removed in the work area. A person should supervise the work site, and it is strictly forbidden to operate alone. When the emergency personnel arrive at the scene, they should determine a cordoned area and set up warning signs according to the extent of the gas leak and meteorological conditions. The traffic should be controlled in the cordoned area. Fire and smoke are strictly forbidden, and no extraneous personnel should remain at the scene. The ambient gas concentration should be monitored at all times.

2) In the event of a fire in a gas installation, methods such as cutting off the gas supply or reducing the pressure should be used to control the fire, and negative pressure should be prevented.

3) When an explosion occurs from a gas leak, the gas source and fire should be quickly controlled to prevent secondary disasters.

4) After the pipes and equipment have been repaired, a thorough inspection of the surrounding mezzanine, maintenance holes, flues, underground pipes and buildings (structures) and other sites should be carried out.

5) When the potential accident is not identified or eliminated, emergency personnel shall not evacuate the site and take safety measures until the potential problem is eliminated.

7.1.24 Requirements for gas emergency work

1) The emergency repairs to leaking gas installations should be carried out after a pressure reduction or gas shutdown.

2) When the gas concentration has not fallen below 20% of the lower

explosive limit, no firework shall be carried out at the worksite, and no non-explosion-proof electromechanical equipment, instruments, meters, be used in the cordoned area.

3) The control valves associated with the operation should be manned during emergency repairs, and the pressure in the pipeline should be monitored.

4) When the leak cannot be eliminated temporarily, or the gas source cannot be cut off during repair, the relevant department should be notified on time, and the site's safety should be well protected.

5) The excavation operations to deal with the underground leaks shall be under the following regulations:

The repair crew should determine the excavation point based on the pipe-laying data and should detect and monitor the gas concentration in the surrounding buildings. When a gas leak is found to have penetrated the surrounding building(s), evacuate the building(s) and disperse the accumulated gas on time according to the accident.

The gas or carbon monoxide concentration at the work site should be continuously monitored. When the concentration of gas in the environment exceeds 20% of the lower explosive limit, or the concentration of carbon monoxide exceeds the specified value, forced ventilation should be carried out, and the work should not be carried out until the engagement has been reduced below the permissible value.

The slope and support of the work pit should be determined according to geology and depth of excavation and should be supervised by humans.

7.1.25 Regulations to be complied with for plant and station leak repair operations

1) The regulations to be met for emergency repairs of leaking low-pressure gas storage cabinets:

It is advisable to use the gas concentration detectors or to use leak detection liquids, smell and hearing to find leaks.

The leak should be plugged using the appropriate method depending on the location and volume of the leak.

In the event of a significant leak causing a rapid fall of the gas storage cabinet, the inlet valve should be opened, and the outlet valve closed immediately to slow the fall by replenishing the gas volume.

2) In the event of a gas leak in the compressor room or hydrocarbon pump room, the gas source and power supply should be cut off immediately, and the indoor explosion-proof fan should be switched on. The gas supply should only be resumed after the fault has been cleared.

3) In the event of a gas leak from regulator stations/boxes on the ground or underground, the valve before and after the leak point should be closed immediately and the doors and windows opened or the explosion-proof fan switched on. The gas supply can only be resumed after the fault has been removed.

7.1.26 Over-pressure disposal of pressure regulators

When the pressure regulator station/box outlet is overpressured due to regulating equipment, the regulator inlet and outlet valves should be closed immediately. The overpressure pipeline should be discharged to reduce pressure and troubleshoot. When the pressure exceeds the design pressure of the downstream gas facilities, a full inspection of the gas facilities in the area affected by the overpressure should be carried out. The gas supply cannot be resumed until all potential problems have been eliminated.

7.1.27 CNG leak disposal

In the event of a significant leak from a CNG station, the station-wide emergency shut-off device should be activated immediately. All operations in the station area should be stopped, a safety cordon set up, and practical measures should be taken to control the leak point.

7.1.28 LNG leak and fire disposal

Do not use water to extinguish an LNG leak that has caught fire. When the flaming heat threatens facilities around the area of an LNG leak, insulate and cool down tanks, equipment and pipelines that are not on fire.

7.1.29 Requirements for repairing indoor gas leaks

1) Upon receipt of a report of a leak from a customer, a person should be sent to the scene immediately to carry out repairs.

2) No calls should be answered or made at the site of the repair work, and mobile phones should be switched off.

3) When the emergency personnel enter the scene of an incident, they should immediately control the gas source, eliminate the fire, cut off the power supply, ventilate and disperse any gas that has accumulated in the room.

4) The leakage points should be accurately determined. The hidden dangers should be eliminated, and open fires should not be used to investigate leaks.

5) During the operation, the leakage from other parts due to the emergency repairs should be avoided. The explosion-proof measures should be taken, and sparking is strictly prohibited.

6) After the gas supply has been repaired, a review should be conducted to confirm safe before the repair crew leaves.

7.1.30 Requirements for production operations such as gas shutdown, pressure reduction, fire start and gas venting

1) The production operations such as the gas shutdown, pressure reduction, fire and gas energisation should be directed by a person in charge of the site, and there should be a safety officer. The operators taking part in the operation should wear protective gear as required. The release point should be supervised during the operation, and appropriate safety precautions should be taken.

2) The site of a fire operation for city gas facilities should be designated as an operating area and should be equipped with guardrails and warning signs.

3) Except for emergencies, the customers should be notified at least 48 hours before any gas shutdown or pressure reduction affecting them.

7.2 Safe Use by Gas Users

With the increasing number of gas users, various types of user gas accidents have occurred occasionally, some of which have resulted in more serious personal injuries and property damage. They have had a more significant impact on public social safety. The safe use of gas is an issue for users and one of the priorities of the relevant departments and gas supply companies in their safety management. Effectively reducing accidents among gas users is of great social importance.

Gas consumes oxygen during the combustion and releases flue gases, mainly carbon dioxide and water, after combustion. when combustion is incomplete due to insufficient oxygen supply, the flue gases will contain carbon monoxide. Therefore, the supply of air and the removal of smoke are essential when using gas appliances in buildings.

7.2.1 Content of the promotion of safe gas consumption by city gas supply units

The city gas supply units should provide the customers with good publicity on safe gas consumption and require customers to comply with the following regulations:

1) Proper use of gas installations and gas appliances. the use of unqualified or end-of-life gas installations and gas appliances is strictly prohibited.

2) No unauthorised alteration of gas pipelines and unauthorised removal, modification, relocation or installation of gas installations and gas appliances.

3) No occupants, piles of debris shall be permitted in the specific rooms where gas metering meters, valves and gasifiers are installed.

4) Do not heat, drop, invert or dump LPG cylinders or remove accessories such as valves.

5) The use of open flames to check for leaks is strictly prohibited.

6) The hoses connected to the gas appliances should be replaced regularly. The use of the expired hoses is strictly prohibited, and they should be securely installed and not over-long.

7) It is strictly forbidden for the user to open or close the common valve on the gas pipe under normal circumstances.

8) When abnormalities are found in indoor gas facilities or gas appliances, gas leaks or accidental gas stoppages, the power should be cut off in a safe place, the valves should be closed immediately, the windows should be opened, and ventilation should be provided, the open fires and electrical switches should not be used, and repairs should be reported to the city gas supply unit on time, and telephone calls to the police at or near the scene of gas leaks are strictly prohibited.

9) The users should assist city gas supply units in the inspection, maintenance and repair of gas facilities.

10) The city gas supply units should inform users and recommend using technical safety equipment such as flammable gas concentration alarms and self-closing valves.

7.2.2. Safe gas consumption for residential customers

(1) Precautions for safe use of gas

Suppose a piped gas user needs to expand the scope of gas consumption, change the use of gas or install, modify or remove fixed gas facilities and gas appliances. In that case, he should consult with the gas operating enterprise and have it assigned professional and technical personnel to carry out the relevant operations.

The gas users should use gas safely and should not do the following: theft of the gas, damage to the gas facilities. use of the gas pipes as load-bearing supports or connections of electrical earth wires. unauthorised removal, installation or modification of gas metering devices and other gas facilities. implementation of decoration and renovation activities that endanger the safety of indoor gas facilities. The use of gas appliances that have accident hazards or are expressly eliminated. the use of bottled gas in premises that do not have safe conditions for use. the use of cylinders that have not been inspected, have failed inspection or are obsolete. the heating or impacting of gas cylinders or the use of gas cylinders upside down. Dumping residual gas cylinders. changing the inspection mark and paint colour of the gas cylinders without permission. obstructing the personnel of gas operating companies from inspecting, repairing and maintaining and renewing gas facilities without reason. other acts prohibited by law and regulations.

1) No flammable or explosive items should be stacked in the kitchen.

2) When using gas, someone must look after it and turn off the fire when people leave. Once people leave, the gas has the consequence of being blown out by the wind or the pot burning dry and the soup overflowing, resulting in the flame going out and the gas continuing to be discharged, causing accidents.

3) The gas pipes and equipment must not be located in rooms such as bedrooms.

4) Teach children not to play with the burner's switch to prevent danger.

5) Check the gas leak at the gas burner connection with a portable gas detector or by brushing with soapy water and tighten and repair any leaks

or bubbling. Leak testing with an open flame is strictly forbidden.

(2) Safe use of gas stoves

1) The gas hob should be placed in the kitchen or in a dedicated room, which should not be less than 2 square metres in size and should not be less than 2.2 metres in height.

2) The room where the gas hob is placed should be well ventilated.

After combustion, gas consumes oxygen and produces flue gases, mainly carbon dioxide and water. If the kitchen space is small, the oxygen supply is insufficient, and the fumes cannot be removed effectively, accidents of personal poisoning can easily occur.

3) When the gas pipes are connected to the hob with a hose, the length and quality of the hose should meet the requirements of national standards. the joints should be firmly attached, and the hose should be replaced regularly.

4) The gas hob should be placed horizontally on a hob made of non-combustible material, and the height of the hob should generally be 600 ~ 700 mm. At the same time, the stove should be placed in a place sheltered from the wind so that the wind does not blow the flame and reduce the furnace's thermal efficiency or blow out the flame, causing an accident.

5) The gas stoves are awarded eight years from the date of sale.

6) Do not repair a faulty gas stove by ourselves or by a non-professional. We should contact the sales unit, manufacturer or company and ask a professional to check and repair.

7) Flammable items should not be stacked near the gas stove.

(3) Safe use of gas-fired water heaters

1) The user should provide the formal sale channel to purchase and install the qualified gas water heaters and not dismantle, alter, relocate or repair them.

2) The gas-fired water heaters should be installed in kitchens, balconies. The room where the water heater is installed should have ventilation from the outside.

3) The use of gas-fired water heaters must ensure the supply of air and the efficient removal of fumes.

4) No flammable or explosive substances should be placed near the water heater, and no items should be placed at the smoke vent or air inlet of the water heater.

5) In the process of using the water heater, if the hot water valve is off, but the main burner cannot be extinguished, one should immediately close the gas valve and notify the gas management department or the manufacturer's maintenance centre for overhaul. The water heater must be stopped using.

6) If a gas leak is detected, the gas valve should be immediately closed, the external windows be opened, and the ignition or smoking be prohibited on site. It should be reported to the gas management unit or the manufacturer's maintenance centre to overhaul the water heater. It is strictly forbidden to disassemble the water heater or continue to use it under unsafe conditions.

7) A gas water heater has a lifespan of 6 years for manufactured gas and eight years for LPG and natural gas from the date of sale.

(4) Safe use of gas-fired wall-hung boiler

1) It is essential to ensure that the suction and exhaust of the wall-hung stove flue pipe is unobstructed.

The wall-hung stove flue pipe is a double-core tube with a 60mm/100mm diameter. The boiler works by the outer tube to draw in the fresh air and discharge the combustion exhaust gas. When renovating a closed balcony or moving the machine, the user must extend the suction and discharge ports of the smoke pipe outside and must not seal it indoors or use a single core pipe. Otherwise, the wall-hung stove is prone to sucking back the exhaust gas during combustion, resulting in insufficient oxygen supply during combustion, leading to the bursting of the wall-hung stove, failure to ignite, or frequent starting.

2) When the wall-hung stove is working, the hot water outlet pipe and smoke pipe temperature are high. It is strictly prohibited to touch.

3) Regularly check the water pressure of the boiler as well as its working condition to ensure proper operation of the wall-hung boiler.

4) Winter freeze protection. The wall-hanging stove should be set up with antifreeze features to prevent the pump, heat exchanger and water pipes from being frozen during low temperatures in winter. The wall-hung stove's electric, gas and water supply must be ensured normal when running in winter.

(5) Safe use of gas heaters

1) The room where the heater is installed must be well ventilated.

The room where the direct vent heater is installed must be set up with an air inlet and exhaust (or ventilation fan installed). The room where the heater without exhaust function is installed should have a sufficient area for air inlet (general area of inlet and exhaust is not less than 0.04 m^2).

2) No flammable or explosive substances are allowed to be placed around the heater. The heater must not be placed near the wooden siding or directly on the wooden floor.

3) It is strictly forbidden to locate gas pipes and heaters in habitable rooms such as bedrooms.

4) When installing a water heater, both the water and gas lines should be tested for sealing performance. the test should only be used after passing.

5) The gas leak and carbon monoxide alarms should be installed in rooms where heaters are installed.

6) Before each ignition, heaters should be checked for air leaks and the inlet and outlet of rooms where the heater is set.

7) When using a direct vent heater, the room should be well ventilated, and the continuous heating time should be within 1 hour.

8) When using a less automated heater, the heating process should be managed. the heater should be switched off when people are away.

9) After the healing period, the heater should be maintained, checked, and stored correctly. Before use, the water and gas lines should be tested again for tightness.

(6) Safe use of LPG cylinders

LPG cylinders are pressure vessels. For safety reasons, the products must be qualified products produced by manufacturers designated by the national labour department. The cylinders produced by manufacturers not designated by the labour department are strictly forbidden to be used. The cylinders must be regularly inspected under national regulations, and those that are not checked after the expiry date are strictly prohibited from use.

1) The pressure reducing and angle valves are connected with a counter-buckle. Fit the pressure reducing valve by first aligning it and then turning the handwheel in a counter-clockwise direction to hand without leaking air.

2) Do not use excessive force when installing the pressure reducing valve, as this will easily break the seal and cause air leakage.

3) When replacing the cylinder and removing the pressure reducing valve, pay particular attention to whether the seal is sticking in the valve. If the seal is inadvertently removed with the cylinder and replaced with a new cylinder and a pressure reducing valve installed, it will cause a leak. Once this happens, close the valve promptly and then acquire or replace the seal, not just replace the seal with gasket material.

4) It is strictly forbidden to screw, move or dismantle the pressure reducing valve indiscriminately. If damage is found, it must be repaired or replaced in time.

5) The pressure reducing valve should be kept clean, and the breathing holes should not be blocked.

6) To check whether a newly replaced pressure reducing valve is good or bad: blow from the air inlet with mouth after removing the pressure reducing valve. If it is ventilated, the pressure reducing valve is not blocked. Then blow through the outlet with the mouth, slowly blow some air, but blowhard but not, indicating that the pressure reducing valve works properly. If the valve is also ventilated with a strong blow, the rubber diaphragm inside the pressure reducing valve has been damaged. In this case, the pressure reducing valve should be sent to a service station for repair.

7) LPG cylinders should not be used upside down or lying down. The lower part of the cylinder is liquid LPG, and the upper part is gaseous

fossil fuel gas. In use, the liquid LPG is naturally vaporised and exported, and the pressure is reduced to operating pressure by a pressure reducing valve for combustion. If cylinders are used upside down and lying down, it is easy for liquid LPG to flow out of the valves, causing high-pressure gas delivery or liquid leakage. Leaking LPG can expand when it gasses and easily cause explosions and fires when exposed to open flames.

8) The cylinder and the gas hob should be at an appropriate distance from each other outside.

(7) Safety measures in case a gas leak is detected

The following measures can be taken to ensure safety in a gas leak. If the situation cannot be effectively controlled, evacuate quickly and report it for disposal by the gas supply units, firefighting and other professional agencies and personnel.

1) Close the gas inlet valves and the valves of the gas appliances in the user.

2) Open doors and windows immediately for ventilation.

3) Do not switch on and off the lights, exhaust fans and other electrical equipment to prevent explosions caused by the electrical sparks.

4) It is strictly forbidden to detect and locate leaks with open flames.

5) The uninvolved persons should be evacuated from the site.

6) Notify the gas company, the gas equipment manufacturer or supplier for inspection and repair.

BIBLIOGRAPHY

[1] Luo Yun, Xu Ming. Modern Safety Management (3rd edition). Beijing: chemical industry press, 2016.

[2] Jiang Zhen, Jiang Pei Sheng. Safety Management: A Basic Course for Safety Engineers. Beijing: Chemical Industry Press, 2004.

[3] Wu Zongzhi, Gao Jindong, Wei Lijun. Hazard evaluation methods and their applications. Beijing: Metallurgical Industry Press, 2004.

[4] By Trevor Kletz, translated by Wang Li et al. Petrochemical Enterprise Accident Case Analysis. Beijing: Sinopec Press, 2004.

[5] World Energy Council, Chinese National Committee. World Energy for the 21st Century. Beijing: Atomic Energy Press, 2001.

[6] Ma Liang, Yang Shousheng. Fire and Explosion Proofing in Petrochemical Production. Beijing: Sinopec Press, 2005.

[7] Zhao Qingxian, Shao Hui. Safety Management of Hazardous Chemicals. Beijing: Sinopec Press, 2010.

[8] Chen Haiqun, Wang Kaiquan. Hazardous Chemical Accident Management and Emergency Response Plan. Beijing: Sinopec Press, 2005.

[9] Luo Yun, Safety economics (2nd edition). Beijing: Chemical Industry Press, 2012.

[10] Beijing Dafei Safety Technology Co. Safety Knowledge for Plant Manager and Managers (Third Edition). Beijing: Sinopec Publishing House, 2006.

[11] Teng Goshio, Kato Takaaki, Koideji. Japan's Disaster Countermeasures System. Beijing: China Construction Industry Press, 2003.

[12] Ministry of Housing and Urban-Rural Development of the People's Republic of China. Gas system of operation safety evaluation standard [GB/T 50811-2012]. Beijing: China Construction Industry Press, 2012.

[13] Ministry of Housing and Urban-Rural Development of the People's Republic of China. Design Code for City gas [GB 50028-2006]. Beijing: China Construction Industry Press, 2006.

[14] Ministry of Housing and Urban-Rural Development of the People's Republic of China. Safety Technical Regulations on Operation, Maintenance and Repair of City gas Facilities [CJJ51-2016]. Beijing: China Construction Industry Press, 2016

[15] Yang Xiaoxiang. Oil and gas pipeline safety engineering. Beijing: Sinopec Press, 2005.

[16] Luo Yun, Pei Jingjing. Risk Analysis and Safety Assessment (3rd edition). Beijing: Chemical Industry Press, 2016.

[17] Luo Yun, Pei Jingjing. Risk Analysis and Safety Assessment (3rd edition). Beijing: Chemical Industry Press, 2016.

[18] General Office of the State Council. Measures for the Management of Emergency Response Plans for Emergencies. Beijing: 2013.

[19] National Safety Production Emergency Response Command Center. Safety Production Emergency Management. Beijing: Coal Industry Press, 2007.

[20] Miao Jinming. Accident and emergency rescue and disposal. Beijing: Tsinghua University Press, 2012.

APPENDIX 1

GAS EMERGENCY LEVELS AND CLASSIFICATION CONDITIONS

Gas emergency levels and classification conditions

Vent level	Level I (particularly significant emergencies)	Level II (major incidents)	Level III (general emergencies)	Level IV (standard gas emergency)
Grading conditions	1) An emergency in the gas supply system, resulting in the suspension of gas supply to more than 20,000 households (inclusive)	1) The number of gas outages for residential customers is between 10,000 (inclusive) and 20,000 (exclusive). the public canteens of higher education institutions are out of gas for more than 24 hours (inclusive) continuously.	1) The number of gas outages for residential customers is between 300 (inclusive) and 10,000 (exclusive).	1) The number of gas outages for residential customers is less than 300 (not included).
	2) Incidents in which three or more people died. 10 or more people were seriously injured. 10 or more people were killed or seriously injured (inclusive)	2) Accidents with three or fewer deaths, three or more severe injuries, or ten or fewer serious injuries.	2) Incidents in which less than three people are seriously injured	2) Causing minor injuries to persons without serious injury in an emergency incident

	3) Changes in the gas composition in the city gas supply or gas supply system that result in the inability to meet the regular use of end-user equipment	3) Large-scale overpressure operation of the pipeline network, resulting in many failures and leaks in the pipeline network or user facilities.	3) medium pressure (including) the following gas supply system, customer facilities, gas leakage, resulting in poisoning, fire, explosion, through the local company's emergency response plan for timely disposal, and the event and disposal process did not endanger the safety of users, did not cause casualties and more significant social impact.	3) Gas leakage was detected at all levels of the gas supply system but did not occur poisoning, fire, explosion, through the start of the local company's emergency response plan for timely disposal, and in the event and disposal process did not endanger the safety of users, did not cause personal injury and more significant social impact.
	4) Abnormal gas supply in the city due to problems with the upstream gas supply system, causing the city government to initiate an emergency supply plan	4) Incidents that cause gas outages at gas-fired power plants during the peak summer supply period and gas outages at major gas-fired power plants and central heating plants in the city during the heating period.	4) Causing the residential heating boilers to shut down during the heating period or large-scale scattered heating users to shut down, resulting in a significant heating incident.	4) The Group's daily production and operation autonomously discovered and disposed of, and did not endanger customers' safety, cause personal injury or have a significant social impact at the time of the incident or during the disposal process.

	5) Fires, explosions or gas leaks in natural gas city gateways and high-pressure B (or higher) class supply systems, natural gas storage and distribution stations, and compressed natural gas refuelling stations that seriously affect gas supply and endanger public safety.	5) gas supply systems of sub-high pressure (including) or above, gas fires, explosions or gas leaks that seriously affect the local gas supply and endanger public safety.	-	-
	6) Gas emergencies cause long-term disruptions to railways and highways or cause power supply, communication, water supply and heating systems to fail to function normally, affecting urban infrastructure on a large scale.	6) In the city, traffic arteries and large public buildings and other essential fire units and areas of the city, due to gas leakage resulting in fire, explosion, resulting in casualties, traffic disruption accidents.	-	-
		7) Abnormalities in the gas supply system led to overpressure operation or gas supply strain in a local area and reached the alarm level specified in the accident warning classification.	-	-

		8) Partial collapse of other municipal facilities due to secondary disasters.	-	-
		9) The event occurs at a unique or essential time and place that could have a significant impact.	-	-
		10) Incidents where the monitoring system is down and cannot be restored for a short period, resulting in the inability to monitor the operation of the gas supply system properly.	-	-
Upgrade condition	1) During major events, festivals and events at all levels of contingency can be escalated automatically or designated depending on the situation. 2) All levels of emergency response may be designated for escalation in the event of government interest and presence and high media attention. 3) In case of significant casualties and property and economic losses, the handling procedures shall be carried out under the relevant national regulations. 4) In case of emergencies other than the classification as mentioned earlier, it shall be reported level by level according to the information reporting system. at the same time, according to the principle of territorial management, the territorial company shall first dispose of them of it.			

APPENDIX 2

GAS EMERGENCY RESPONSE LEVELS AND TRIGGER CONDITIONS REFERENCE TABLE

Gas emergency response levels and trigger conditions reference table

Trigger condition	1) There is a large or extensive gas leak that has the potential for further expansion or secondary hazards and has occurred on a critical road or has caused road disruptions	1) There is a widespread gas leak, there is a possibility of further expansion or secondary disaster, and the location of the occurrence of: ①important road and cause partial road closure or traffic restrictions. ② important users and evacuation of personnel.	1) There is a local gas leak at the scene, and it occurs at one of the following locations: ① an important road but not causing a road cut or restriction. ② a non-significant road but causing a partial road cut or restriction. ③an important user but not causing evacuation. ④a non-significant user but causing a widespread evacuation of people.	1) There is a local gas leak, and occurred in one of the following locations: ① non-significant road and did not cause a road cut or traffic restrictions. ② non-significant users and did not cause evacuation of personnel.
	2) Fires and explosions have already occurred at the site and on critical roads.	2) Fire or explosion on-site, and occurred in one of the following locations: ① non-significant road. ② influential users. ③ non-	2) Fire or explosion at the site and in a non-significant user's home without significant damage.	-

		significant users and significant damage and large-scale evacuation of personnel within the household.		
	3) Fire burning at the scene and on a critical road.	3) Fire burning at the scene and on a non-significant road.	3) The site is on fire, and the fire occurs in a critical user's home.	2) Fire burning on-site and in a non-essential user's home.
	4) The air leakage from secondary or higher pressure pipelines due to construction, a landslide occurs at one of the following locations: ① an important road section that is cut off. ②an important user that causes large-scale damage evacuation.	4) The occurrence of construction, landslides, resulting in sub-high pressure and above the pipeline leakage, and occurs in one of the following locations: ① important road and cause part of the road cut-off or traffic restrictions. ② significant users and cause some evacuation of personnel.	4) The site occurred due to construction, landslides, resulting in secondary high pressure and above pipeline deformation or low-pressure pipeline leakage, and occurs in one of the following locations: ① non-significant section of the road, but caused some disconnections or restrictions. ② non-significant users but caused some personnel evacuation.	3) The site occurred due to construction, landslides, resulting in medium and low-pressure pipeline exposed or deformed, and occurs in one of the following locations: ① non-significant section of the road, not causing disconnections or restrictions. ② non-significant users, not causing personnel evacuation.
	5) Where one or more persons are killed or three or more persons are injured as a result of a gas leak or deflagration	5) Injury to one (inclusive) or more than three (inclusive) persons due to a gas leak or deflagration.	-	-

	6) The incident caused 30,000 or more residential customers to gas outages.	6) The incident caused a gas outage at a thermal power plant or a gas outage in 10,000 or more residential households.	5) The event caused a regional boiler room gas outage or a residential gas outage of 300 (inclusive) or more than 10,000 (exclusive) households.	4) The number of gas outages for residential customers is 300 (inclusive) or less.
	7) Attendance of Municipal Committee and Municipal Government Leaders	7) The presence of the head of the municipal office (or above).	6) The presence of the head of the district office (inclusive) or above.	-
		8) When there is a significant flow abnormality in the secondary high pressure and above pipeline.	7) When there is a significant flow abnormality in the medium pressure line.	5) When there is an abnormal flow in the pipe.
Upgrade condition	1) When an incident occurs during a holiday or other period that requires a special warning, the response level is increased by one response level from the original response level. 2) If the police and the commanding officer cannot accurately judge the response level at the first time, they can start the corresponding level according to the known conditions, and then judge again after the emergency repair personnel arrive and adjust the response level according to the scene environment and the development of the situation at any time. 3) When starting a certain level of response, a higher level of response should be prepared in advance to adjust the response level needs.			
Remarks	1) Critical roads are railways, rail transit, highways, main urban roads or essential areas, main ring roads, overpasses, and essential users. 2) Important users are essential institutions, foreign-related users, densely populated areas (such as hospitals, colleges and universities, kindergartens, shopping malls, sports stadiums, cultural relics and ancient buildings). 3) When the event occurs in the house, need to judge maintenance and emergency as appropriate. If the valve in front of the user's table is controllable, it should be repaired as far as possible. if it is not controllable, it should be treated as an emergency.			

APPENDIX 3

SAFETY RISK MATRIX

The safety risk level is generally divided into four groups from high to low, namely: major risk, great risk, average risk and low risk, which four colours can indicate: red, orange, yellow and blue, respectively.

1) Casualty M

Two indicators measure these: the number of deaths M1 and the number of injuries M2. The number of fatalities refers to the number of killed people (including those declared dead by legal procedures) due to accidents or emergencies caused by safety risks. The number of injuries refers to the number of people injured and treated by doctors or medical institutions due to accidents or emergencies caused by safety risks.

Table A3-1: Casualty risk matrix

Casualties M		**Number of deaths M1 (persons)**				
		0	0	1-2	3-9	≥10
Number of persons injured M2 (persons)	≥50	5	5	5	5	5
	16-49	4	4	4	4	5
	5-15	3	3	3	4	5
	3-4	2	2	3	4	5
	≤2	1	2	3	4	5

2) Economic loss E1

It refers to the costs of personal injury or death, the expenses for the after-treatment, and the value of destroyed property caused by accidents or emergencies caused by safety risks. Generally, only direct economic losses are counted.

Table A3-2: Risk matrix for economic loss E1

Economic loss E1 ($ million)				
≤199	200-999	1000-4999	5000-9999	≥10000
1	2	3	4	5

3) Social impact So

It refers to the damage caused to society by accidents or emergencies caused by safety risks, including the influence of sensitive targets in the vicinity (So1) and the degree of social concern (So2).

Table A3-3: Risk matrix for social impact So2

Social Concern So2		Duration			
		Within one day	In one week	In one month	More than one Month
Scope	International	3	4	5	5
	National	2	3	4	5
	This city	1	2	3	4
	This district	1	1	2	3

4) Assurance affects Se

It refers to impacts on the safety of supply caused by accidents or emergencies due to a safety risk, both in terms of infrastructure damage or disruption (Se1) and disruption of life support (Se2).

Table A3-4: Risk Level Matrix for Gas Interruption Impact Se1 in Infrastructure Assurance

Gas outage impact Se1a		Number of people affected (persons)			
		≤1000	1001-9999	10000-29999	≥30000
Time (hours)	≥24	2	3	4	5
	12-24	1	2	3	4
	<12	1	1	2	3

Table A3-5: Risk Level Matrix for Infrastructure Damage Se1b (Life Assurance Disruption)

Loss of infrastructure Se1b		Number of indicators (number)				
		1	2	3	4	5
Level of impact	5	**4**	4	5	5	5
	4	**3**	4	4	5	5
	3	**2**	3	4	4	5
	2	**2**	2	3	4	4
	1	**1**	2	2	3	4

APPENDIX 4

GAS ACCIDENT ANALYSIS PROPOSAL TEMPLATE AND BASIC REQUIREMENTS

1. Summary of the accident

(Should include important basic information related to the incident, which may include, but is not limited to, the following)

Time of the incident:

Response time:

Location of the incident:

Type of accident:

Casualties:

Property damage:

Social impact:

Type of accident (nature):

2. General information

(Brief description of the occurrence, development and outcome of the incident should be provided)

3. Gas public emergency response

(This may be documented on a timeline basis, beginning with receipts of reports and the issuance of task order and ending with the completion of the disposal and the achievement of incident closure conditions. Records should be as detailed as possible, including staffing, disposal techniques, tool use, and command decisions. Necessary photo and video data should be kept, including the location of the accident, damage to pipeline facilities, repair process and repair results when these are available).

4. The basic parameters of the gas facilities in question and the status of prior maintenance inspections

4.1 Basic technical parameters of pipeline facilities

(Including text and necessary graphic information)

4.2 Prior maintenance inspections

(Including maintenance of inspection records and compliance with regulations)

5. Evaluation of emergency response

5.1 Evaluation of emergency response procedures and technical measures

(Inspection and evaluation of whether the handling of incidents is under laws and regulations, the plan's requirements.)

5.2 Evaluation of personnel, suitability of tools

(Evaluation of the suitability of personnel and tools for incident management)

5.3 Experiences and lessons learned

(Summary of successes and identification of shortcomings)

5.4 Exploration of particular problems of the incident

6. Suggestions

(Suggestions and opinions on management, technology, involvement in the incident, and thoughts on preventing similar incidents in the future can be compiled.)