14 Occupational safety and health

14.1 The occupational safety and health standards and codes adopted in the design

NFPA 101 Life Safety Code

OSHA PART 1910 Occupational Safety and Health Standards

Chinese occupational safety and health standards and codes were referred to when necessary.

14.2 The analysis of the occupational hazards and harmful factors involved in the production period

14.2.1 The fire risks analysis

The fire risk of each unit is analyzed by means of lists according to the codes, the features of the production process and the functions of related supporting facilities. For the fire risk of the process unit see Table 14.2-1, for the fire risk of the storage tank area see Table 14.2-2, for the fire risk of the utilities see Table 14.2-3, for the fire risk of the production and service facilities see Table 14.2-5, and for the properties of the main flammable and explosive materials see Table 14.2-5.

Table14.2-1 The fire risk of the process unit

No.	Unit Description	Unit capacity, kt/a	Fire risk classification
1	2# ADU	2,000	I
2	2# VDU	1,500	I
3	NHT	550	I
4	CCR	500	I
5	De-coker	700	I
6	DHF	1,300	I
7	VGO Hydrocracking Unit	900	I
8	H_2 Production Unit	25	I
9	Sulfur Recovery Unit	26	I
10	Dry Gas/LPG Treatment Unit	150	I
11	Isomerization	150	I

Table14.2-2 The fire risk of the storage tank area

No.	Tank name	Medium	Tank capacity (m^3)	Quantity (set)	Tank type	The fire risk classification	Remarks
1	Crude oil Storage Tanks	Crude oil	50000	7	External floating roof	Ⅰ B	
2	Feedstock Storage Tanks	Alcohol	2000	2	Internal floating roof	Ⅰ B	
3		Atmospheric kerosene 1#	1000	2	Internal floating roof	Ⅱ A	To kerosene hydrofining
4		Vacuum residue 1#	5000	1	Fixed roof	ⅢB	To vacuum distillation
5		Atmospheric naphtha 1#	4000	1	Internal floating roof	Ⅰ B	To naphtha hydrotreating
6		Atmospheric diesel 1#	5000	1	Vault	Ⅱ B	To diesel hydrofining
7		Atmospheric kerosene 2#	1000	2	Internal floating roof	Ⅱ A	To diesel hydrofining
8		Vacuum residue 2#	5000	3	Fixed roof	ⅢB	To vacuum distillation
9		Atmospheric naphtha 2#	4000	1	Internal floating roof	Ⅰ B	To naphtha hydrotreating
10		Atmospheric diesel 2#	5000	1	Fixed roof	Ⅱ B	To diesel hydrofining
11		VGO	5000	2	Fixed roof	Ⅱ B	To hydrocracking
12		Vacuum residue	5000	2	Fixed roof	ⅢB	To coking
13		Coker naphtha	1000	2	Internal floating roof	Ⅰ B	To diesel hydrofining
14		Coker diesel	2000	2	Fixed roof	Ⅱ B	To diesel hydrofining
15		Coker gas oil	1000	2	Fixed roof	ⅢB	To hydrocracking
16		Hydrocracking heavy naphtha	1000	2	Internal floating roof	Ⅰ B	To reforming
17		Hydrotreated light naphtha	1000	2	Internal floating roof	Ⅰ B	To isomerization
18		Hydrotreated heavy naphtha	3000	2	Internal floating roof	Ⅰ B	To reforming
19		Hydrotreated naphtha	1000	2	Internal floating roof	Ⅰ B	To naphtha hydrotreating
20		Light waste oil tank	2000	2	Internal floating roof	Ⅲ A	

No.	Tank name	Medium	Tank capacity (m^3)	Quantity (set)	Tank type	The fire risk classification	Remarks
21	Feedstock Storage Tank	Product (gasoline)	2000	2	Internal floating roof	Ⅰ B	
22		hydrocracking light naphtha	1000	6	Internal floating roof	Ⅰ B	
23		Naphtha Hydrotreating heavy naphtha	1000	2	Internal floating roof	Ⅰ B	
24		Isomate	1000	2	Internal floating roof	Ⅰ B	
25		Reformate	2000	2	Internal floating roof	Ⅰ B	
26		Aviation kerosene	2000	2	Internal floating roof	Ⅱ A	
27		Aviation kerosene	1000	3	Internal floating roof	Ⅱ A	To refining kerosene
28		Hydrocracking kerosene	1000	2	Internal floating roof	Ⅱ A	
29		Diesel product	10000	2	Vault	Ⅱ B	
30		Hydrocracking diesel	5000	3	Vault	Ⅱ B	
31		Diesel hydrogenation diesel	5000	2	Vault	Ⅱ B	
32		Fuel oil	500	2	Vault	Ⅱ A	
33		Heavy waste oil	3000	2	Vault	Ⅲ B	
34		Product (liquefied gas)	2000	2	Vault	Ⅰ A	

Table14.2-3 The fire risk of the utilities

No.	Unit name	Function	The fire risk classification
1	The Raw Water Treatment Plant (Water Supply Pump Station)	The complex-wide water treatment	Ⅴ
1	The Circulation Cooling Water Plant	Production and firefighting pump station	Ⅴ
2	The DM Water Station (including Condensate Purification Station)	Circulation cooling water treatment	Ⅴ
3	The Wastewater Treatment Plant	Circulation cooling water treatment	Ⅴ
4	The Water Supply/Drainage Pipeline System	Production and domestic wastewater treatment	Ⅳ

Table14.2-4 The fire risk of the production and service facilities

No.	Unit name	The fire risk classification
1	Mechanical, Electrical and Instrument Workshop	Ⅴ
2	Central Lab	Ⅲ
3	Environment Monitoring Station	
4	Administration Building	Ⅴ
5	Staff Living Quarters	Ⅴ
6	Chemical Warehouse	Ⅰ

Table14.2-5 The properties of the main flammable and explosive materials

Substance name	Explosion limit v%	Flash point℃	Auto-ignition temperature ℃	Explosion hazard classification		The fire risk classification
				Group	Class	
Crude oil	1.1～8.7	-6.67～32.2	350	T3	ⅡA	I B
Dry gas	1.0～1.5	<～66	650～750	T1	A	I
Liquefied gas	3～13	<～68	430～446	-	-	I A
Naphtha	1.2～6.0	36～177	480～510	T3	A	I B
Gasoline	1.1～5.9	<～20	255～530	T3	A	I B
Diesel	1.5～4.5	50～90	350～380	T3	IIA	III A
Kerosene	0.6～	<45	223～290	T3	ⅡA	ⅡA
LPG	2.25～9.65	<-70	426	T2	ⅡA	ⅠA
Residue	1.2～6.0	50～158	300～350	T3	ⅡA	Ⅲ
Hydrogen	4.0～75.6	4.1～74.2	570	T1	IIC	Ⅰ
Hydrogen sulfide	4.3～45	4.3～45.5	246	T3	IIB	Ⅰ
Ammonia	16～25	15～25	650	T1	ⅡA	Ⅱ
Sulfur dioxide	-	-	-	T1	A	-
Sulfur	-	>180	232	T12	-	Ⅱ

14.2.1.2 Dust and poison hazard

Some materials used and generated during the production process are of toxic substances, which will cause certain harm on the human body. For their harmful effects and extent see Table 14.2-6 (the main toxic substances and their properties).

Table14.2-6 The main toxic substances and their properties

Substance name	CAS Number	The classification of the hazard levels	Main hazards	Maximum allowable concentration mg/m^3	Permissible time-weighted average concentration mg/m^3	Permissible concentration for short-term exposure limit（mg/m^3）
Hydrogen sulfide	7783-06-4	II	Being of neurotoxic substances, it has strong irritations on pneogaster and eyes. That with low concentration has clear irritations, and that with high concentration has effect on central nervous system and even causes death.	10		
Ammonia	7664-41-7	IV	Mainly has the effect of corrosion and irritations on the upper respiratory tract.		20	30
Sulfur dioxide	7446-09-5	IV	Mainly cause irritations to pneogaster and eyes		5	10
Sulfur	7704-34-9	IV	Being of neurotoxic substances, it has strong irritations on skin and eyes.			
Coal dust		/	Has the irritation on the upper respiratory tract and lung.			
Ethanol	64-17-5	Ⅲ	Ingestion in large amounts affects the brain, lungs, gastrointestinal tract, eyes, and respiratory system and can cause coma, blindness, and death.			
MDEA		Low toxicant	Has the irritation on pneogaster and skin.			
Chlorine	7782-50-5	Ⅱ	Usually enter human body through breath, and has strong irritation on eyes, skin and pneogaster.	1		
Gasoline	8006-61-9	Ⅵ	Being of low anesthetic toxicants, it mainly causes central nervous system dysfunction, and that with high concentration can cause the paralysis of respiratory center; long-term exposure of the skin to gasoline can cause xerosis cutis, cornification, acute dermatitis, folliculitis and chronic eczema etc.		300	450
Diesel	68334-30-5	/	Causes aspiration pneumonia after inhaling diesel fog drop; if the skin is exposed to diesel, it can cause contact dermatitis and oily			

Substance name	CAS Number	The classification of the hazard levels	Main hazards	Maximum allowable concentration mg/m^3	Permissible time-weighted average concentration mg/m^3	Permissible concentration for short-term exposure limit（mg/m^3）
			acne. The waste gas from diesel can cause the irritations to eyes and noses, and cause dizziness and headache.			
Catalyst dust		/	Has the irritation on the upper respiratory tract and lung.	10		
Benzene	71-43-2	I	Being absorbed through the pneogaster and skin. The acute poisoning mainly damages central nervous system, and chronic poisoning mainly damages the hemopoietic system and nervous system.		6	10

The toxicants which can lead to occupational hazards and are generated during the production process of this refining project are hydrogen sulfide and chlorine. The organic sulfur contained in the crude oil is removed in the form of hydrogen sulfide gas as the oil products are de-sulfurized. Some units will use the corrosive sodium hydroxide. The local dust environment may be formed when loading new granular type catalyst and unloading the spent catalyst.

14.2.1.3 Hydrocarbons

The major hydrocarbon sources are volatile substances including crude oil, gasoline and liquefied gas etc. The hydrocarbon is of low toxicants, which mainly causes the anesthesia and irritation, and enters the human body through breath and skin contact. Gasoline has certain irritations on skin, eyes and mucosa, and has also effect on central nervous system.

14.2.1.4 Sulfide including H_2S, SO_2 etc

The major sulfide sources are these units including gas desulfuration, hydrogenation, sulfur-containing wastewater stripping and sulfur recovery etc. The hydrogen sulfide is of colorless gas with high toxicity and has rotten-egg smell. Being of strong neurotoxic substances, it has strong irritations on mucosa, and enters the human body through breath. The hydrogen sulfide with low concentration will cause irritations to eyes and pneogaster; that with moderate concentration will quickly cause respiratory paralysis; that with high concentration may cause immediate death. The maximum allowable concentration of it in the atmosphere within the workshop is 10mg/m3.

The sulfur dioxide gas is of the toxicant of moderate hazard and mainly from smoke, which can have the strong irritations on pneogaster and eyes. The maximum allowable concentration of it in the atmosphere within the workshop is 150mg/m^3.

14.2.1.5 Ammonia

The main sources are Sulfur-Containing Wastewater & Gas Units and Sulfur Recovery Unit etc. The ammonia is of strong-irritation gas with the toxicant of moderate hazard, which mainly has the irritations on pneogaster and skin; the people feel strong when the ammonia is in low concentration. The maximum allowable concentration of it in the atmosphere within the workshop is 30mg/m^3.

14.2.1.6 Chlorine

Chlorine is mainly used for the water treatment period. It is a highly irritating and greenish-yellow gas with high-toxicity hazard. It enters the human body through breath, and has strong irritation on eyes, skin and pneogaster; it has effect on mucosa under the condition of 0.2～16ppm, on eyes under the condition of 7～8ppm, on throat under the condition of 15ppm, and causes death by lung failure under the condition of 1000ppm. The maximum allowable concentration of it in the atmosphere within the workshop is 1mg/m^3.

14.2.1.7 Chemical agents

The sodium hydroxide is of the corrosive substances. The maximum allowable concentration of it in the atmosphere within the workshop is 2mg/m^3.

14.2.1.8 Dust

The dust pollution may be caused during the regular loading & unloading of solid catalyst and sulfur packaging of the unit. The maximum allowable concentration of it in the atmosphere within the workshop is 10mg/m^3.

14.2.2 Noise hazard

The equipment generating continuous noise of the project includes pumps, air coolers, heat furnaces, fans and generators etc. The intermittent noise is mainly from the flares, safety valves and steam venting. The high noise area includes these areas where pumps, heat furnaces, air coolers or compressors are equipped, and the area around the vent port etc.

14.2.3 Radioactive hazard

The radioactive level gauges employed in the Delayed Coking Unit and the Reforming Unit are radiation sources.

14.2.4 High-altitude falling

The operators may be exposed to falling during working on the high framework in the unit area.

14.2.5 High temperature hazard

There are a great number of equipments with high operating temperature in this unit. The

operators may be exposed to high temperature hazard if the misoperation happens.

14.3 Protection program

14.3.1 Fire & explosion protection

14.3.1.1 Automatic control

Safety control over the hazardous materials is one of the most effective measures for fire and explosion prevention. All the flammable materials involved in the crude oil introduction, processing, and product discharge of this project are enclosed within the various equipment or pipelines with reliable sealing measures for each connection. The DCS system is employed for the process control over processing units and the oil products storage & transportation system with limit-exceeding alarm & safety instrument system (SIS) so as to ensure the safety control in abnormal cases. Large-size compressor trains are also equipped with the safety interlock system. All the discharged flammable gases for purging the units during the depressurization or startup/shutdown will be sent to the flare system. The flammable gas concentration alarms are employed in various hazardous areas for monitoring and alarming.

14.3.1.2 Fire separation

The fire separation between the complex area and its adjoining enterprises or facilities, the general layout of the complex area and the plan layout within the various unit areas shall follow NFPA 30. The suitable safe distance between all units, between the equipments within the unit, and between the tank farms and oil tanks shall be reserved to satisfy the need of firefighting and routine production management. Ring roads are laid out within the complex with the road width & turn radius meeting requirements of fire engines' entry. All the potential fire sources shall be separately laid out and located at the upwind direction of the place where possible flammable materials leakage might occur as much as possible.

14.3.1.3 Firefighting design

For this project, only one fire will be considered at a time. The fire water demand is determined mainly based on the water consumption of the firefighting facilities arranged in various areas. The maximum water consumption will occur in the fixed water spray system of the crude storage tank on the tank farm simultaneously with consideration to the water consumption of the fixed foam extinguishing system, fire water monitors and fire hydrants, and the surplus volume of 200m^3/h. The fire water demand of this project is to be designed as 3300m^3/h, the water supply pressure at the worst spot is not less than 0.8MPa (G), and the duration of the fire is 6 hours.

The fire water is most effective in terms of the fire control in the unit area. When a fire occurs, to avoid the further spread of fire, the adjoining buildings & structures and equipment shall be cooled with water until clearing the flammable materials and putting out the fire so as to minimize the loss.

Because a large amount of flammable materials are stored in the oil product storage tanks, they are the primary objects for the firefighting design. Foam extinguishing is the most common and efficient method for oil tanks fire. The oil tanks adjacent to the fire shall be cooled with water while quelling the fire.

The main firefighting equipment of the whole complex includes:

The fire water system mainly includes fire water pump rooms, fire water reserve tanks, firefighting pumps, pressure maintenance pumps, high-pressure fire water pipelines, valves, valves pit, outdoor ground hydrants, fire water monitors and box-type hydrants, fire water supply standpipes, fire water cooling spray device for LPG storage tanks and automatic fire sprinkler system etc;

The foam extinguishing system mainly consists of an independent foam station, balanced pressure foam proportioning devices, ARFFF type foam concentrate, foam mixture pipelines & valves, foam hydrants and foam generators etc;

Inergen gas type fire suppression system mainly includes the steel cylinder groups for inergen fire extinguishing agents, fire detection system, startup control system, gas extinguishing system pipelines and gas spray heads etc;

Other firefighting facilities mainly include steam extinguishing pipelines, semi-fixed steam connections, portable, wheel dry power extinguishers and portable CO_2 extinguishers etc.

14.3.1.4 Flammable & toxic gas detection and alarm

The location where flammable gas may accumulate shall be equipped with flammable gas detection and alarm devices, and the location or around the equipment where toxic gas may be generated shall be equipped with toxic gas monitors with the signal being introduced into the main control room for alarming.

The flammable gas and toxic gas detection system (“FGDS” for short) shall be set up independent from the process control system (DCS) and the safety instrument system (SIS).

14.3.2 Protection against dust and poison hazard

14.3.2.1 Protection against hydrogen sulfide and chlorine poisoning

The H_2S-containing gas and sulfur-containing wastewater discharged from the Hydrogenation Unit are treated via gas sweetening and stripping respectively before the hydrogen sulfide finally being removed in the form of gas, all of which is translated into the harmless sulfur in the Sulfur Recovery Unit. Since the whole treatment process is conducted in an enclosed manner, the concentration of the hydrogen sulfide gas in the working environment of various units is less than 10 mg/m^3. To prevent the hydrogen sulfide gas from leakage, not only necessary sealing measures shall be taken, the hydrogen sulfide gas

detectors shall be provided within the production units generating hydrogen sulfide as well with the signals of the detectors being sent to the gas detecting system to display alarm.

In case the Sulfur Recovery Unit shuts down due to accidents, all the untreated acid gas will be routed into the flare system for incineration. The sulfur products produced in the Sulfur Recovery Unit are degassed to reduce the volatilization of hydrogen sulfide during the transportation and loading & unloading process.

When entering into the areas with the high-concentration hydrogen sulfide or chlorine, the operators shall carry the hydrogen sulfide or chlorine detectors and wear special filter-type protective clothing to facilitate operators' safe evacuation in case the leakage happens. In addition, the aerobic gas masks shall be provided in the areas with the high-concentration hydrogen sulfide and chlorine to protect workers when entering the high-concentration area for rescue and emergency controlling operation during leakage.

The operators shall wear gas masks and operate according to the safety requirements during the equipment maintenance and accidents handling.

The gas protection station is established within the complex to provide supervision over the toxic or asphyxiant workplaces and emergency rescue when poisoning occurs.

14.3.2.2 Dust hazard prevention

The dust is usually generated during the loading & unloading of the catalyst, the solid sulfur packaging and the petroleum coke transportation. Suitable methods including enclosed transportation, vacuum drawing, wet type of dust removal and workers involved wearing protective clothing etc shall be employed during the above operation so as to lower the dust hazard.

14.3.2.3 Protection against radiation hazard

The radioactive level gages employed in the Coking Unit and the radioactive level switches employed in the Continuous Catalytic Reforming Unit are of radiation sources, and the radiation meets the requirements of international standards concerned. Safety warning signs shall be set near the level gages, and the maintenance, storage and transport of the level gages shall strictly follow the regulations concerned to make the annual dose equivalent of the radiation suffered by the operators follow the specified requirements. During the maintenance of the units, the installation & dismantling of the radioisotope equipment and the opening & close of the lead tank valves shall be supervised and strictly recorded by the specially-assigned personnel, and be guarded by the radiation health & safety people on the spot. The spent sources of the radioisotope shall be disposed according to the international regulations concerned.

14.3.2.4 Others

The priority shall be given to low-toxicity chemical agents during the selection for this

design. The application and storage of the chemicals are performed in the enclosed environment to reduce the chances that workers are exposed to chemicals. The emergency showers and eye washers shall be installed at places where workers may be exposed to the acid, alkali and other corrosive chemicals to provide flushing in case of accidents.

The liquid ammonia desulfurizing agent, the catalysts for sulfur recovery and for tail gas treatment in the Sulfur Recovery Unit shall be disposed through harmless landfill, which will not cause environmental pollution.

14.3.3 High temperature and scald prevention

The insulation measures shall be taken on the high temperature pipelines and equipment, and personal protection devices shall be provided on the high temperature equipment and pipelines to which workers may be exposed apart from the arrangement of a conspicuous warning sign to alert operators to scald during operation. When the outside temperature is above or equal to 37℃, local temperature reduction and general heat prevention measures shall be taken by field operators and patrol inspectors. And at the sampling ports of high temperature medium, sampling coolers shall be installed.

14.3.4 Noise control

The measures including vibration reduction, sound insulation and noise abatement etc will be taken in this design to ensure that the noise level of operators' workplaces can meet the requirements of standards. Patrol inspectors shall wear anti-noise earmuffs when entering the high-noise area.

14.3.5 Safety colors and safety signs

For the locations and equipment which are accident-prone and may endanger life, the safety signs shall be arranged; for the locations where quick discovery and attention is essential during accidents, the safety colors shall be applied.

14.3.6 Emergency showers and eye washers

The priority shall be given to low-toxicity chemical agents during the selection for this design. The application and storage of the chemicals are performed in the enclosed environment to reduce the chances that workers are exposed to chemicals. The emergency showers and eye washers shall be installed at places where workers may be exposed to the acid, alkali and other corrosive chemicals to provide flushing in case of accidents.

14.3.7 Sanitary facilities

Based on the sanitary features of various units of this project, relevant sanitary rooms including bathrooms, cloakrooms, washrooms and washhouses are provided. One medical health center with necessary first-aid gear and ambulances is established in the complex for the first aid during emergency cases, and the occupational health archives for the first-aid

personnel of the whole complex are also established.

14.4 Organization structure and manpower allocation

14.4.1 Safety & health management

The complex-wide safety & health management (HSE) department headed by the general manager is specially established to perform standardized management on the safety and health work of the whole complex, to examine & eliminate various kinds of dangers and harmful factors, to supervise & implement the orders and regulations concerning safety and health instructed by the government or relevant authorities, to develop necessary rules and regulations, to provide training and education with regard to the safety & health management skills and knowledge to all sorts of personnel to ensure the staff's health and safety production, and to prevent the occurrence of accidents or occupational hazards and avoid any loss.

14.4.2 Safety & health inspection

The complex-wide safety & health inspection department shall be established to monitor the safety & health status and trend of the whole complex, to furnish reliable monitoring data and information for the safety & health management and prevention of the whole complex, and to regularly monitor the pollution sources, the pollutants discharge frequency, the efficiency of the purification equipment, the operating parameters of boilers and pressure vessels etc to provide grounds for the safety production management. This department can be established jointly with the environment monitoring station.

14.4.3 Fire station

There are two fire engines at the fire station established on the project site, which are experiencing problems including corrosion to engines and the foam regulation of foam trucks etc because of almost 20 years of operation. Based on the status quo of the existing fire station, corresponding fire facilities will be set up within the project area apart from the addition of three fire engines and four parking lots with one of them being equipped with a service pit. And necessary fire equipment such as personal protection gear, entry tool, and communication tools etc for fireman are furnished.

14.4.4 Medical health and occupational hazards prevention department

One medical health center with consulting room, treatment room, pharmacy, and necessary first-aid gear and ambulances is established in the complex according to the surrounding environment, normative requirements and the project need for the first aid during emergency cases. It is mainly responsible for the examination of the health conditions of those people being exposed to toxic or harmful substances of the whole complex, the participation of site emergency rescue during poisoning and other cases, and the arrangement for treatment or convalescence of occupational hazards sufferers.

14.5 Investment in labor safety and health

The targets of investment in labor safety and health of refinery mainly include combustible gas and hydrogen sulfide gas annunciators, fire alarm system, safety depressurization system, firefighting facilities and fire station, poison and dust prevention and ventilation facilities, noise control facilities, heat insulation and scald prevention measures, lightning proof and static grounding devices, and necessary safety and health protection gears. For the specific investment in safety and health, see Chapter 17 (Economic assessment).

14.6 Anticipated effects

The design, based on all kinds of harmful factors of occupational safety and health of the project, has selected advanced processes and equipment and employed automatic alarming, interlocking protection, safety depressurization, isolation, firefighting, and emergency rescue etc, which not only ensures the safety and health of operators, but provides prevention, controlling and rescue means for the envisioned accidents.