ICS 73.100.01
CCS D 10

Social Organization Standard

T/CAOE 40-2021

Technical guidelines for seafloor polymetallic nodules mining system

海底多金属结核采矿系统技术指南

Issue date: 2021-07-15

Issued by China Association of Oceanic Engineering

Contents

Foreword

China Association of Oceanic Engineering is in charge of this English translation. In case of any doubt about the contents of English translation, the Chinese original shall be considered authoritative.

This document is drafted in accordance with the rules given in the GB/T 1.1—2020 *Directives for standardization—Part 1: Rules for the structure and drafting of standardizing documents*.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. The issuing body of this document shall not be held responsible for identifying any or all such patent rights.

This document was proposed by Beijing Pioneer Hi-Tech Development Corporation.

This document was prepared by China Association of Oceanic Engineering.

Drafting units of this document: Beijing Pioneer Hi-Tech Development Corporation, Changsha Research Institute of Mining and Metallurgy Co., Ltd., Shanghai Jiao Tong University, Third Institute of Oceanography (Ministry of Natural Resources), National Center of Ocean Standards and Metrology, Tsinghua University, China University of Geosciences (Beijing), Xiangtan University, BGRIMM Technology Group.

The main drafters of this document are, Li Bo, Xiao Lina, Jin Xing, Xia Jianxin, Xu Lixin, Wang Xuyang, Luo Yang, Mu Changqing, Gao Yuqing, Song Shiji, Deng Xuhui, Jiang Xunxiong, Han Luwei, Du Liang, Yang Quankai, Li Huiqiang, Wang Yang, Wang Hongyi.

Technical guidelines for seafloor polymetallic nodules mining system

1 Scope

This document provides green, economy, reliability, intelligence, and safety technical principles for seafloor polymetallic nodules mining system, as well as factors to be considered, and gives the relevant technical guidelines.

This document is applicable to design, construction, operation and management of seafloor polymetallic nodules mining system and the relevant key components in the "area".

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including amendments) applies.

GB/T 5080.1, *Reliability test—Part 1: Test conditions and statistical test principles*

GB/T 31024.1, *Cooperative intelligent transportation systems—Dedicated short range communications—Part 1: General technical requirement*

GB/T 37472, *General requirements for heave compensation system of submersible mothership*

GB/T 40073, *External pressure strength test procedure for metal pressure hull of submersibles*

ISO 14000, *Environment management systems*

ISO 9001, *Quality management systems—Requirements*

ISO 31000, *Risk management—Guidelines*

API RP 1111, *Design, Construction, Operation, and Maintenance of Offshore Hydrocarbon Pipelines (Limit State Design)*

API RP 16Q, *Design, Selection, Operation, and Maintenance of Marine Drilling Riser Systems*

API RP 17B, *Recommended Practice for Flexible Pipe*

API RP 2RD, *Design of Risers for Floating Production Systems (FPSs) and Tension-Leg Platforms (TLPs)*

API Spec 17J, *Specification for Unbonded Flexible Pipe*

3 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

3.1

area

the sea-bed and ocean floor and the subsoil thereof, beyond the limits of national jurisdiction

[SOURCE: *United Nations Convention on the Law of the Sea*]

3.2

polymetallic nodules

a type of polymetallic ore existing on the seafloor in the form of nodules, generally rich in manganese, cobalt, nickel, copper and other metal compositions

NOTE Also called manganese nodules or ferromanganese nodules.

3.3

exploitation

recovery of polymetallic nodules and extract minerals from polymetallic nodules for commercial purposes, including the construction and operation of mining, processing and transportation system for the production and sale of minerals.

[SOURCE: *Decision of the Council of the International Seabed Authority relating to amendments to the Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area and related matters*, modified]

3.4

mining system

a system includes seafloor ore collecting system, underwater lifting system (e.g. hydraulic lift system and underwater shuttle lifting system), surface support platform/vessel, transport system, offshore mineral processing system, etc, to collect polymetallic nodules from seafloor and transport nodules to the sea surface, then process and transport nodules to the target port.

3.5

collecting system

an underwater system for collecting polymetallic nodules on the seafloor, including a driving mechanism and a gathering mechanism

3.6

lifting system

all equipment that used to transport polymetallic nodules from the seafloor to the ocean surface, usually refers to hydraulic lift system or underwater shuttle lifting system

3.7

hydraulic lift system

a subsystem consists of pumps and pipes for transporting polymetallic nodules from the near seafloor buffer station to the surface support platform/vessel

3.8

underwater shuttle lifting system

a subsystem with underwater shuttle transports polymetallic nodules from the seafloor to the surface support platform/vessel

3.9

surface support platform/vessel

platforms/vessels support mining, ore loading and unloading, ore storage, central control, power supply or related functions on-site for mining operation

3.10

transport system

ships and associated marine devices transport the seafloor polymetallic nodules from offshore to port

3.11

offshore mineral processing

the process of producing concentrates, intermediate concentrates, or metal products by picking, sorting, washing of ores on the seafloor or/and surface support platform/vessel

3.12

plume

a dispersion of seawater that contains dense sediment particles

[SOURCE: *Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in the Area,* International Seabed Authority Legal and Technical Commission, modified]

3.13

underwater shuttle

an underwater shuttle system that operates between the seafloor and a surface support platform/vessel and has the function of gathering and transporting seafloor polymetallic nodules

3.14

flexible pipe

flexible pipe connecting the seafloor collecting system and the buffer station

3.15

buffer station

a device with the upper end connected with the surface support platform/vessel through a riser, and the lower end connected with the seafloor collecting system through a flexible pipe, and quantitatively and continuously feeds the ore to lifting riser

4 Basic principle

Principles of Green, Economy, Reliability, Intelligence and Safety (GERIS) shall be met in

the entire production process and mining system service life.

5 Green principle

5.1 General requirements

The overall requirements of Green principle for the seafloor polymetallic nodules mining system are as follows.

— Comply with the provisions of the *United Nations Convention on the Law of the Sea*.

— It should select low environmental impact materials and techniques during the mining system life cycle.

— Advanced, reliable and environmental friendly technologies should be approved by International Seabed Authority.

— Energy saving technologies and measures should be adopted in entire production chain include seafloor collecting system, lifting system, surface support platform/vessel, transport system.

— It should meet with ISO 14000 environmental management standards.

— Technologies used to reduce influence of noise, light, magnetism, heat, mechanical disturbance and oil pollution should be selected.

— Environmentally friendly materials and coatings, such as corrosion-resistant, pollution-free, should to be considered.

— Given priority, the energy module should use clean or renewable energy with high energy density, stable output and low frequency replenishment, and should be adopted with technologies and processes to improve energy efficiency.

— It should reduce carbon dioxide emissions and promote the process of carbon neutrality.

5.2 Requirements for underwater ore collecting system

Collecting method should consider with minimum disturbance to the deep-sea sediment, the details are as follows.

— Collecting method should cause limited plume diffusion range, factors considered should include the initial velocity, duration, suspended matter content, near-bottom hydrological conditions, and sediment damage thickness.

— It should choose seafloor non-contact movement and/limited contact collecting

technologies.

— While the contact collecting technology is used, it is advisable to adopt a design that should minimize the contact area and contact pressure between the vehicle and seafloor as possible.

5.3 Lifting system requirements

The lifting system should meet with the following requirements.

— The amount of seawater lifted from the bottom to the sea surface should be reduced to minimize the environmental impact of tail water.

— It should minimize the nodules fragmentation and liquification to reduce the content of fine particles discharged into the tail water.

— Discharge of tail water should be selected with low plume impact method.

— Tail water should be discharged near seafloor, and surface discharge is prohibited.

5.4 Surface support platform/vessel requirements

The surface support platform/vessel should conform to *Articles of the Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships, 1973* and *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*.

5.5 Transport system requirements

The transport system should be zero or pollution-free discharge. There should be no tail water leakage during the transportation process. It is appropriate to achieve zero or pollution-free discharge during the polymetallic nodules temporarily stored on the surface support platform/vessel.

5.6 Offshore mineral processing system requirements

The offshore mineral processing system should meet with the following requirements.

— It is advisable to adopt environmental friendly beneficiation and smelting process, as well as comprehensive utilization technology, it should use clean energy and environmental friendly chemicals, and should use seawater as process water.

— Tailings should be treated to meet with the relevant standard before discharge, and tail water should be zero discharge at surface.

— Set up environmental monitoring points around the discharge locations.

6 Economy principle

6.1 General requirements

Taking the economics benefits and efficient utilization of seafloor polymetallic nodules resources and the protection and preservation of deep-sea environment as constraints, it should improve the mining efficiency and reduce the mining cost in the entire production chain. The details are as follows.

— Improve mining efficiency by improving the collection coverage rate and the collection efficiency of the ore collector, reducing the loss of resources and energy consumption per unit.

— Control the operation mode of the entire circulation process, simplify operation procedures, control the unit mining cost and acquire the commercial benefits.

— The design life of mining system should be complied with mining development period, and cyclic utilization should be considered in system components design to reduce costs.

6.2 Collection rate

The collection rate (C) is determined by collection coverage rate (C_f) and collector collection efficiency (C_x). The collection rate is calculated in accordance with formula (1). Collection coverage rate (C_f) and collector collection efficiency (C_x) should be optimized by mining plan.

$$C = C_x \times C_f \quad \cdots\cdots (1)$$

where

C_f is the collection coverage rate, which is the ratio of the mining coverage area (A_c) to the designated mining area (A_d), shown as formula (2).

C_x is the collection efficiency, which is the ratio of the mining amount per unit area (A_m) to the ore existing amount per unit area (Q_a), shown as formula (3).

$$C_f = \frac{A_c}{A_d} \quad \cdots\cdots (2)$$

$$C_x = \frac{A_m}{Q_a} \quad \cdots\cdots (3)$$

The collection rate of mining system should not be less than 90%. The following measures should be taken to improve the system collection rate.

— Design and optimize ore collection planning by collector position control.

— Ensure the system has accurate positioning and navigation capabilities.

— Improve the moving stability of the seafloor ore collecting devices.

— The collection trajectory should be closely connected, and the overlap coverage of collector collection surface should not exceed 10%.

6.3 Recovery rate

The recovery rate (R) is an important indicator to measure the mining technology level of mining system. It depends on the recovery of polymetallic nodules in the mining area (R_C) and the estimated reserves in the same mining area (R_S). The recovery rate is calculated as the formula (4).

$$R = \frac{R_C}{R_S} \quad (4)$$

where

R_C is the recovery of polymetallic nodules in the mining area, the unit is tonne (t).

R_S is the estimated reserves of polymetallic nodules in the same mining area, the unit is tonne (t).

The recovery rate of seafloor polymetallic nodules should be greater than 85%.

6.4 Energy consumption per unit

The following consumption reduction technologies and measures should be adopted in all mining systems.

— Increase the transport concentration of seafloor polymetallic nodules on the premise of smooth transportation.

— Design the surface support platform/vessel for continuous transport of nodules, shorten the production process, and design the transport vessels and transportation mode according to the simplest transport process.

6.5 Cost of seafloor polymetallic nodules mining system

Mining system cost should be improved by optimizing system design, prolonging the service life, and introducing intelligent management to improve economics benefits; the following measures should be used to reduce the system cost according to the system composition.

— The seafloor ore collecting system should adopt with the following measures:

- use high-efficiency ore collecting method to minimize down time;
- control the collector construction cost;

- collecting plan should be designed in accordance with the collection rate requirements to improve economics benefits.

— The underwater lifting system should adopt an energy-saving and operation efficiency mode, and should choose the economical and high-efficiency hydraulic lift system/ underwater shuttle lifting system.

— The surface support platform/vessel should be designed to transport seafloor polymetallic nodules in a continuous and large-scale way, shorten the transport process on the platform, improve the operational economy of the mining system as much as possible.

— In the design of transport system, transportation ships design and transportation plan should in accordance with the simplest transport procedure.

7 Reliability principle

7.1 General requirements

Mining system should be designed to operate under complex marine environmental conditions continuously and reliably during service life. The system should be complied with ISO 9001, and the design requirements may refer to the provisions of GB 5080.1. Details are as follows.

— The service life of the mining system should not less than 20 years.

— Mining system should be capable to survive in the 100-year environmental condition.

— The steady and reliable working time of the mining system is more than 280 days throughout the year.

— The coupling dynamics of the linkage of the seafloor ore collecting system, the underwater lifting system and surface support platform/vessel should be verified through numerical simulation and model test.

— Underwater vulnerable components should be quick-replaceable.

7.2 Seafloor ore collecting system reliability

Seafloor ore collecting system should ensure the reliability of continuously maneuvering the system along a given route, and should ensure the reliability of system operations in terrain changes, precise detection, ore collection and ore lifting. Measures should be taken as follows.

— Keep sufficient redundancy to ensure ore feeding operation smoothly, continuity and reliability, and keep spares for vulnerable components.

— Design factors of flexible pipe, such as pressure, temperature, erosion, corrosion, aging, abrasion, fatigue, geometrical constraints and mechanical strain, should be complied with the relevant design standards (such as API RP17B) or manufacturer standards, and flexible pipe reserved buoyancy should be designed to adapt to the certain concentration changes during nodule transport.

— When using collecting robot, the robot should be able to adapt to the changes of microtopography, nodule abundance and sizes, it should keep ore collection smoothly and keep high collection rate, sufficient spares should be prepared as well.

7.3 Lifting system

7.3.1 Hydraulic lift system reliability

If hydraulic lift system is adopted, the system reliability should meet with the following requirements.

— Lifting system should be designed to avoid pipeline blockage.

— For conveyor riser design, the structural strength should refer to the requirements of API RP 2RD, API RP 16Q, API Spec 17J and API RP 1111, and safety factor should be greater than 1.5 in the 100-year environment.

— Load, corrosion and abrasion should be considered in the lifting pipe design to meet the system life.

— If vortex-induced vibration appear on the lifting pipe, a vortex suppression device should be designed.

7.3.2 Underwater shuttle lifting system reliability

If underwater shuttle lifting system is adopted, the reliability of the system should meet with the following requirements.

— The construction of underwater shuttle should meet the requirements of GB/T 40073, *Rules for Classification of Diving Systems and Submersibles* and *Guide for Submersible Vehicle Inspection* by China Classification Society.

— In addition to design parameters (pressure, temperature, vibration, operation and environmental conditions, etc.), the influence of improper lifting operation and the impact of incidents should also be considered in underwater shuttle design.

7.4 Surface support platform/vessel reliability

The reliability of the surface support platform/vessel should meet with the following requirements.

— Surface support platform/vessel should be complied with classification rules, national laws of flag state and sponsoring state.

— Surface support platform/vessel should equipped with dynamic position system, the horizontal offset position of surface support platform/vessel on operation and survival conditions should meet with relevant standards.

— The service life should not less than 20 years.

— Survival conditions should meet the 100-year environmental design requirements.

— When using underwater shuttle lifting system, the navigation system on surface support platform/vessel should be complied with the underwater shuttle navigation requirements, which at least includes the vehicle control factors, such as depth/height, heading, velocity, attitude, position, capability of autonomous collision avoidance (ROV is not applicable); surface support platform/vessel design should be complied with GB/T 37472.

— When using underwater shuttle lifting system, the positioning and communication system on surface support platform/vessel should be able to receive position signals send by shuttle, to reduce the risk of shuttle lost.

— Surface support platform/vessel should be designed with mooring system and anti-collision devices for cargo ships berthing, and have ship berthing plan.

7.5 **Transport system reliability**

Transport system includes machinery and cargo ships for transporting polymetallic nodules produced from the seafloor. The reliability of the transport system should be ensured by the following measures.

— The transport machinery should be complied with industry design standards, be equipped with adequate mechanical protection and be capable to protect critical components during normal or emergency transport operations, and the service life of transport machinery should not less than 20 years.

— The service life of cargo ship should not less than 20 years.

— The transport system should be prepared with spare nodule storage facilities to ensure the continuous mining operations.

— Cargo ships should be reserved with sufficient fuel according to the offshore operation duration and the sailing distance. The endurance should be able to support no less than the expected marine operation consumption plus 7 days extra reserves.

— Cargo ship should meet the requirements for the surface support platform/vessel berthing plan, and should meet the stability requirements of loading and unloading polymetallic nodules during berthing.

7.6 Offshore mineral processing system reliability

The reliability of offshore mineral processing system should meet the following requirements.

— The service life of offshore mineral processing system should not less than 20 years.

— Use pipeline for transportation and watertight components for processing.

— The processing system is easy to maintain.

8 Intelligence principle

8.1 General requirements

The intelligence of seafloor polymetallic nodules mining system should be capable with the following functions:

— intelligent and coordinated operations in ore collection, conveying, and transportation;

— consider the use of advanced technologies such as information technology, data transmission, sensing technology, intelligent control and computation technology for mining system.

8.2 Intelligent collaborative control of seafloor polymetallic nodules mining system

The intelligent collaborative control of mining system means provide status analysis and decision support in the operation of ore collection, underwater lifting and ore transportation based on intelligent technologies. The intelligent collaboration of mining system should have the following capabilities.

— Operation and maintenance

- With advanced perception and scene reproduction capabilities, it can analyze mining system health status in real time, and provide real-time operation status evaluation.
- Based on big data technology, the future development of the operating status of the seafloor polymetallic nodules mining system can be predicted.
- It can provide mining system information of operation, maintance, and failure detection, which based on the historical data and model analysis.

— Status warning

- Based on big data technology, prediction algorithms and model analysis, it can predict the future mining operation status and on-line forecast mining system health status, and early warning can be provide.

- The early warning system should have a self-checking function, which can automatically detect and alarm (or indicate) the failures, then send visual and audible alarm signals when falilure is detected.

— Seafloor ore collecting system, underwater lifting system and transport system should collaborate, make reasonable route planning, avoid devices collision, and improve operation economics benefits.

8.3 Intelligent requirements of seafloor ore collecting system

Intelligent ore collection means apply artificial intelligence, control theory, and information processing technology to provide path planning and optimized control method for collecting system. The intelligent ore collection should have the following capabilities.

— Path generation

- It can provide the optimal collecting path planning in accordance with nodule abundance, collecting duration, energy consumption, operational capability, and complex environmental conditions such as bathymetry.

- It can intelligently and quickly optimize the path planning, based on the real-time data during collecting operations.

— Intelligent operation

- The collecting system can optimize the collector working parameters in accordance with sediment condition, nodule abundance, ore particle size and seafloor micro-topography, and it can provide online assessement results for ore collection efficiency and operation accuracy.

- It can provide perception, assessment, learning and decision-making online, and can optimize the operational control parameters, and improve the ore collection efficiency and operation accuracy.

8.4 Intelligent requirements of underwater lifting system

8.4.1 Hydraulic lift system

If hydraulic lift system is adopted, the following capabilities should be required.

— Producing status intelligent detection and control.

- It can monitor the producing status, pressure and concentration,as well as monitor pump speed and lifting efficiency. It can give intelligent diagnosis and the producing status early warning based on the online historical data learning.

- It have decision-making ability on failure detection, and have emergency response to ensure smooth flow inside the pumps and pipes.

— Lifting system perception and early warning.

- It is appropriate to monitor the underwater lifting system offset and mechanical status online.

- It should be able to distinguish and predict the status of key components, quickly response the adjustment strategies and solutions, avoid alarm missing and excessive sending.

8.4.2 Underwater shuttle lifting system

If the underwater lifting system is in the form of underwater shuttle, it should have the following capabilities.

— Underwater shuttle should able to control the heading, velocity and travelling routes intelligently, and be able to avoid possible collisions.

— Multiple underwater shuttles can work together for cooperative control.

8.5 **Intelligent requirements of surface support platform/vessel**

The intelligent requirements of surface support platform/vessel should be required for the following capabilities:

— a central intelligent control center for mining system;

— intelligently monitor the working status of collecting system, lifting system and transport system, and able to intelligently control the collecting system and underwater transport devices online;

— intelligent berthing cargo ships;

— intelligent recovery and storage of polymetallic nodules transported by underwater shuttles;

— emergency response, early warning and sending alarms functions.

8.6 Intelligent requirements of transport system

The intelligent transport system means system with intelligent technologies to provide decision optimization for the ship navigation and nodule transport. It includes intelligent ship navigation and intelligent nodule transport, which should have the following capabilities.

— Intelligent ship navigation should comply with the requirements of *Rules for Intelligent Ships* (2020) by China Classification Society and GB/T 31024.1.

— Intelligent ship navigation should be able to allow ships to navigate autonomously in different scenarios and complex environmental conditions, and should be flexible connect with the unmanned dock.

— The transport system should be able to intelligently plan ore storage paths.

— The transport system should be able to support big data storage and analysis, by means of intelligent path planning, it can unmanned manage and control the entire transport process, including nodules loading, shipping, port entering, docking, unmanned berthing, sailing to mining area. Models and algorithms of transport system can be updated as needed to improve transportation efficiency and safety.

9 Safety principle

9.1 General requirements

The safety of seafloor polymetallic nodules mining system should meet with the following requirements.

— The production and mining process should meet with the safety requirements for people, environment and machinery components.

— It should comply with international rules and standards such as ISO 31000, *International Convention for the Safety of Life at Sea*, *Articles of the Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships, 1973*, and *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*.

9.2 Safety contingency plan

The safety contingency plan shall be made in accordance with standard and guidelines of International Seabed Authority, which should meet with the following requirements.

— Be prepared in accordance with Good Industry Practice and the relevant regulations, Standards and Guidelines.

— Contingency plan should include the following details:

- processes of work in close cooperation with International Seabed Authority, coastal states, other competent international organizations, and emergency response organizations;
- the overall aims and objectives and arrangements for controlling the risk of incidents;
- complied with relevant codes, standards and protocols;
- details of emergency response equipment, safety management system and environmental management system;
- a description of all foreseeable incidents, an assessment of their likelihood and consequences and associated control measures;
- a description of the arrangements to protect persons on surface support platform/vessel, and to ensure their safe escape, evacuation and rescue;
- details of arrangements for the maintenance of control systems to monitor the Marine Environment in the event of an Incident;
- details of predictable marine environmental conditions that may affect mining system or mining operations;
- information and measures relating to the prevention of incidents which could result in Serious Harm to the Marine Environment;
- an assessment of pollution hazards and the measures to prevent or reduce such hazards;
- an assessment of mining discharges and measures to control such discharges;
- details of training programmes for personnel, and a description of the monitoring of performance under the plan;
- details of the presence of other hazards/harmful substances;
- an assessment of the likelihood of oil spills, leaks, etc., due to the normal operation of the surface support platform/vessel.

9.3 Safety of mining system and system components

The safety of mining system and system components should be considered the following requirements.

— Mining system and components shall be designed to consider on-site environment, operation conditions and loading test.

— Mining system should have safety inspection devices, which is required to ensure system safety & stability, monitor devices operation & environmental changes, identify system error & risks, and mining system should have maintenance plans & measures.

— Structure components should be equipped with mechanical protection to protect critical components in emergency operations.

— Underwater system and all electrical facilities shall be checked first to ensure it have reached the normal operating conditions, and should be equipped with underwater electrical protection and alarm devices.

— All components should be equipped with self-protection and warning alarm in a case of over-capturing.

— Underwater shuttle should be able to keep normal operation condition with one component failure.

— Energy system safety for the mining system shall be complied with relevant safety regulations.

— Lashing or sea fastening design for onboard devices should consider the moving force at the maximum roll angle of surface support platform/vessel as well as the impact of wind pressure and wave strike.

— The design of transport equipment, such as bulk carrier, should meet with the *International Maritime Solid Bulk Cargoes Code (IMSBC).*

— There is evacuation plan for the surface support platform/vessel in emergency environmental conditions.

9.4 Safe operation in the seafloor polymetallic nodules mining process

The following measures should be taken to ensure the safety of the mining operation.

— Establish safety zones around the mining area.

— Pre-assessment of safety operations shall be conducted, and corresponding operation procedures shall be carried out.

— Regular safety inspection records are required during production process.

— Ensure the accuracy and effectiveness of monitoring program can be regularly assessed by the system safety inspection agency.

— At the site of hoisting and launching large-scale mining equipment, it should prepare surface guard ship for monitoring, early warning and give operation assistant.

— A material management system and a liability system for hazardous materials safety management during the process of seafloor polymetallic nodules mining should be established.

— All operation personnel, before assuming their duties, have the necessary experience, training and qualifications and are able to conduct their duties safely, competently and in compliance with the Rules of the Authority and the terms of the exploitation contract; all personnel engaged in mining operation should understand the occupational and environmental risks which may result from their work and the manner, and should have the capability to deal with such risks.

— Personnel engaged in electrical installation, modification and maintenance of equipment, systems, tools and underwater structures related to underwater operations should be proficient in electrical operation, familiar with the dangers and the problems of underwater practice, hold certificates recognized by qualified agencies, and be familiar with relevant international safety regulations for seafloor mining operations.

9.5 Environmental safety of seafloor polymetallic nodules mining process

Environmental safety of seafloor polymetallic nodules mining process should meet with the following requirements.

— The mining system should be complied with the requirements of *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*, *Articles of the Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships, 1973* to prevent the safety impact of oil spills and leakage pollution to the marine environment caused by the surface support platform/vessel.

— Develop daily environmental safety management and contingency plan; There are measures and emergency response devices for environmental safety incidents.

— During environmental damage incidents, it shall appoint the person onsite in charge of the situation, and production devices shall be shut down and take protective measures, emergency response shall be carried out in accordance with contingency plan.

9.6 Offshore emergency evacuation of engineering personnel

Engineering personnel emergency evacuation during mining operations should meet with the following requirements.

— A separate circuitry for mining system to provide emergency alarm.

— Audio and visual alarm should be provided at surface support platform/vessel control center to monitor dangerous situations.

— General emergency alarm system shall be equipped and monitoring both at control center

and fire control station.

— There is personnel or devices at control center to ensure any alarms issued by the emergency system can be received on time by the person on duty.

— Detection system should be equipped with at least two sets of power supply, one of which shall be emergency power supply.

— The system should be regularly maintained to prevent system failure.

— The surface support platform/vessel should be prepared with emergency operating procedures in accordance with the requirements of International Seabed Authority, and applicability of escape routes should be evaluated by evacuation plan.

— There should be two separate, safe and barrier-free escape routes lead to emergency meeting place or the other evacuation points for people work on the surface support platform/vessel. The design of escape routes should be considered that at least one escape route should not be damaged when incidents happened at any location.

— It shall provide emergency assembly points, which are capable of accommodating the total number of people on the surface support platform/vessel. The emergency assembly points shall be protected and close to the location of lifeboats and rafts.

— Emergency lighting should be provided in all working and accommodation areas.

— There should be sufficient number of signs along the escape routes.

Bibliography

[1] *United Nationas Convention on the Law of the Sea*, China Ocean Press, 2013.

[2] *Law of the People's Republic of China on the Exploration and Development of Resources in Deep Seabed Areas*, Standing Committee of the National People's Congress, 2016.

[3] *Marine Environmental Protection Law of the People's Republic of China*, Standing Committee of the National People's Congress, 2017.

[4] *Rules for Intelligent Ships*, China Classification Society, 2020.

[5] *Rules for Classification of Diving Systems and Submersibles*, China Classification Society, 2018.

[6] *Guide for Submersible Vehicle Inspection*, China Classification Society, 2019.

[7] *International Convention for the Safety of Life at Sea*, International Maritime Organization, 1974.

[8] *Articles of the Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships, 1973*, International Maritime Organization, 2016.

[9] *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*, International Maritime Organization, 1996.

[10] *Regulations on Prospecting and Exploration for Resources in the International Seabed Area*, China Ocean Mineral Resources R & D Association, 2015.

[11] *Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in the Area*, International Seabed Authority, 2019.

[12] *Draft regulations on exploitation of mineral resources in the Area*, Legal and Technical Commission of International Seabed Authority, 2019.

[13] *Guide for the Application of Structural Design and Assessment of Environmental Conditions in Offshore Engineering*, China Classification Society, 2021.

[14] *Adoption of the International Maritime Solid Bulk Cargoes (IMSBC) Code*, International Maritime Organization, 2008.

[15] *Guide for Subsea mining*, American Bureau of Shipping, 2020.

[16] Vonnahme T R , Molari M , et al. *Effects of a deep-sea mining experiment on seafloor microbial communities and functions after 26 years*[J]. Science Advances, 2020, 6(18). eaaz5922

[17] Konneke, M., Bernhard, A.E., De, L., et al. *Isolation of an autotrophic ammonia-oxidizing marine archaeon*. Nature 437(7058), 2005, 543-546.

[18] *Resilience of benthic deep-sea fauna to mining activities*[J]. Marine Environmental Research, 2017, 129:76-101.

[19] Dani¨elle S.W. de Jonge, Tanja Stratmann, Lidia Lins et al. *Abyssal food-web model indicates faunal carbon flow recovery and impaired microbial loop 26 years after a sediment disturbance experiment*[J].Progress in Oceanography,2020,189,102446

[20] Tatsuhiko Hoshinoa, Hideyuki Doib, Go-Ichiro Uramotoa et al.*Global diversity of microbial communities in marine sediment*[J].PNAS, 2020.https://www.pnas.org/lookup/suppl/doi:10.1073/pnas.1919139117/-/DCSupplemental.