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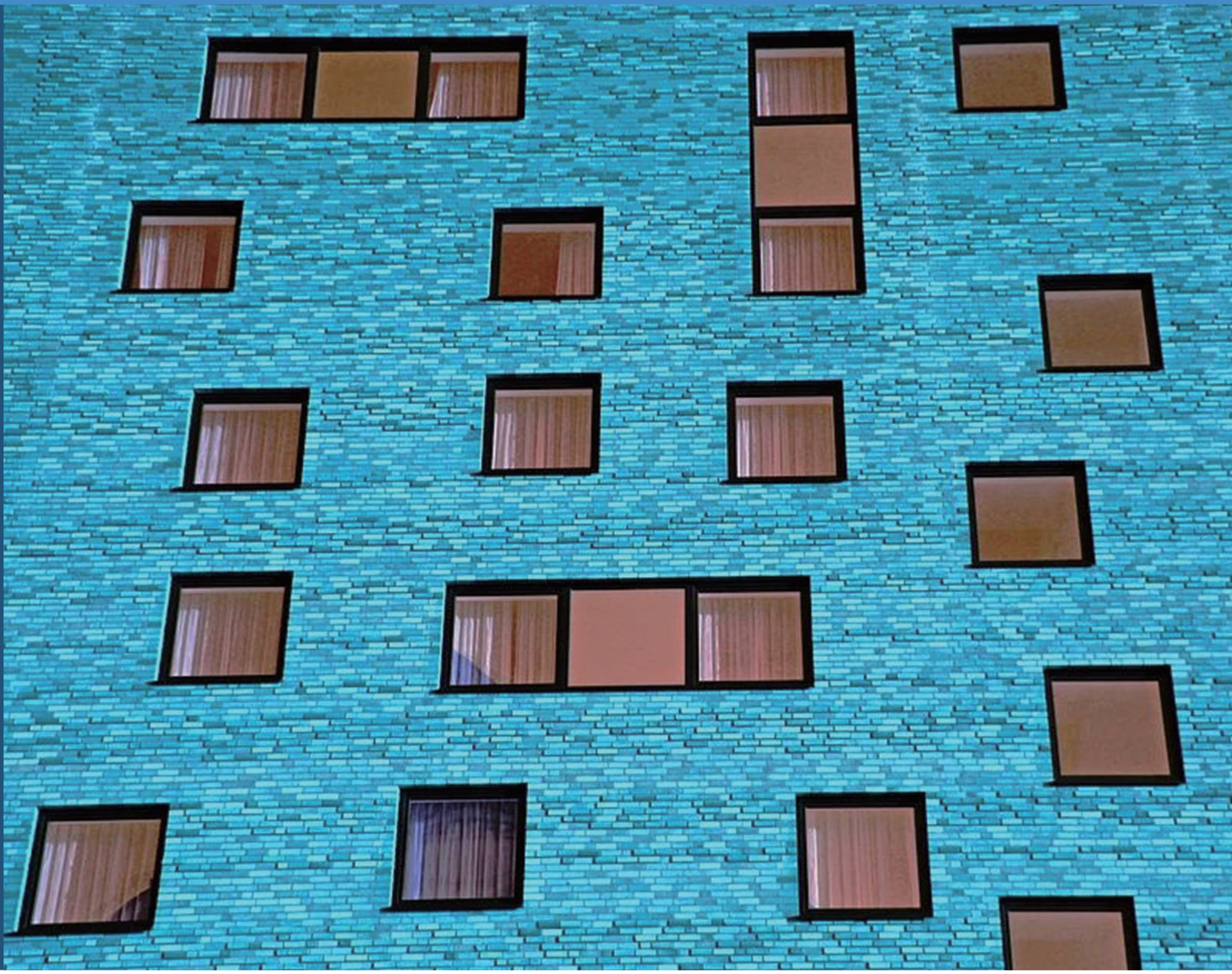
Frontiers Research of Architecture and Engineering

Volume 3 Issue 3 • October 2020 • ISSN: 2591-7595(Online) 2591-7587(Print)



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- Industrial and mining engineering building
- Municipal engineering
- Central heating and central gas supply for building
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Volume 03 Issue 03 • October 2020
ISSN 2591-7587 (Print) 2591-7595 (Online)

Frontiers Research of Architecture and Engineering

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Frontiers Research of Architecture and Engineering
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The Impact of the Agency Role-Based Model on Decision Making in Real Estate Development Projects

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ARTICLE INFO

Article history
Received: 3 September 2020
Revised: 10 September 2020
Accepted: 24 October 2020
Published Online: 30 October 2020

Keywords:
Decision-making
Development model
Berlin Brandenburg Airport
Input market
Output market

ABSTRACT

The professionalism of real estate development makes the decision-making environment of development relatively complicated. Building the decision model can help investors make reasonable decisions in real estate development. This paper analyses the construction project of Berlin Brandenburg Airport by using the agency role-based model of real estate development proposed by Adams & Tiesdell. The research found that the existing research is looking for different objective factors from real estate development cases, without analysing the influence of actors involved in the development process on the entire real estate development decision. In the process of real estate development, not only the changes in the market environment should be considered, but also the influence of different roles on decision-making in the development process. The conclusion of this paper provides a useful supplement to the real estate development model and proposes specific improvement measures.

1. Introduction

Real estate development is a commercial process that encompasses activities from renovating and re-leasing existing buildings, to purchasing undeveloped land and the sale of developed land or parcels to others[1]. Real estate development investment has its own special characteristics: the product is immovable, the investment cycle is long, the amount of capital required is large, and the market information is incomplete[2]. At the same time, the professional and entrepreneurial characteristics of real estate development cause the decision-making environment for development to be very complicated [3], leading to great risks in real estate investment projects. Therefore, the real estate industry is a high-input, capital-intensive industry [4].

Some scholars have conducted investment risk analysis on different stages and factors of real estate development, and built models with different methods to help investors make reasonable decisions in real estate development; for example, the fuzzy comprehensive evaluation method[5], the land supply system model[6], and the Monte Carlo simulation [7]. All three seek different objective factors from different real estate development cases, and do not analyse the influence of different actors involved in the development process on the whole real estate development decision. Urban development is a complex process that requires coordination of finance, materials, labour and expertise among many actors in a broad social, economic and political environment[8]. In this extended process, the relationship between people is often cultivated over many years [9].

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 DOI: https://doi.org/10.30564/frae.v3i3.2305

2. Problem Statement

This paper attempts to critically evaluate and summarise the agency role-based model of real estate development proposed by Adams & Tiesdell, and analyses how to change this model to help improve decision-making. The construction project of Berlin Brandenburg Airport was selected in this paper, and analysed according to the agency model. As the largest infrastructure built in Berlin since the beginning of the new century, Berlin Brandenburg Airport is of great significance in promoting the aviation industry in Berlin, and the wider economic development of Berlin as a whole, however, the airport has not been officially delivered yet. Such a large infrastructure development project needs to be coordinated by many actors in the political, economic, social and other environments, but frequent changes in the investor body of the project, lack of experience of the designer, and corruption of the government and regulatory agencies have resulted in disastrous performance in the project implementation process. By analysing the problems caused by the above roles and based on the adjustment of the agency role model, this paper analyses the decision-making in real estate development projects and finally draws conclusions about improving the model.

3. Theoretical Basis

The agency role-based model was proposed by Adams & Tiesdel, as shown in Figure 1. In this model, there are eighteen types of role ascribed to seven different markets, representing five different interests. The political market, land market, financial market, labour market and materials market are input markets, which provide policy support, capital, raw materials, land and labour for the whole real estate development project. Development interests form the core component of real estate development. The investment market and occupier market belong to the output market, corresponding to two actors, investors and occupiers, the two roles which act on behalf of customers' interests.

There are different roles in each market: role refers to the role of actors in the development process, such as investors and developers; actors are also referred to as the agents or agencies of particular individuals and organisations; and agency refers to the capacities of individuals and organisations to make their own free choice of strategic activities independently. Because of the constant interaction between structure and agency, the rules of the structure may potentially be changed by the agency behaviour[10], therefore, structure and agent should be considered at the same time [11]. This structure may give priority to the strategic interests of actors and change due to the strategy of pursuing interests. Those markets are connected through benefits, and although the whole model seems to be static, the interaction between roles and markets often has an unpredictable influence on development benefits in the process of resource flow[9]. At the same time, arguably, people paid too much attention to the decisions made by senior managers in the workplace, resulting in the neglect of the role caused by the change of external environment[12].

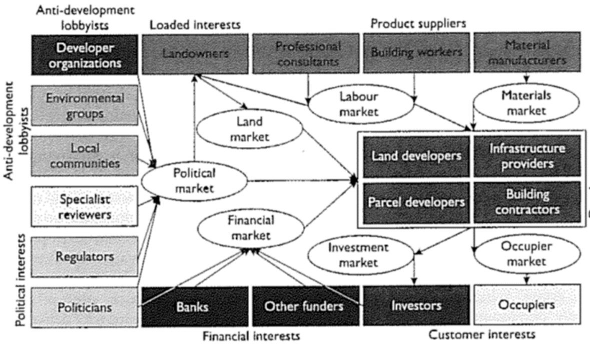

Figure 1. Agency role-based model of real estate development[9]

4. Discussion and Analysis

Berlin Brandenburg Airport is an international airport under construction near the German capital of Berlin, 18 kilometres (11 miles) south of the city centre. It was originally intended to replace Schönefeld and Tegel airports as the only commercial airports serving Berlin and Brandenburg. However, the current plan is to only replace Tegel Airport, and Schönefeld Airport, which is currently being expanded, still needs to meet the increasing passenger flow [13]. After nearly 15 years of planning, construction of the airport began in 2006. However, due to poor construction planning, cost overruns and management corruption[14], the airport opening may be delayed until 2021. Since the airport is not completed yet, the model analysis based on the agent role in this paper does not include two output markets. Next, the project is analysed in detail in terms of the five input markets, and how to adjust this model to improve decision-making is be explained.

4.1 Political Market

When evaluating the Berlin Brandenburg Airport project, some news media believed that failure of management was an important reason for the project not being completed on time. Management corruption and poor control of the project schedule led to frequent management turnover. In 2013, the airport construction company paid a €2m

DOI: https://doi.org/10.30564/frae.v3i3.2305

bribe to an airport construction supervisor in exchange for €25m in additional investment, in order to get more money for the renovation of the fire protection system after discovering potential problems. So far, in the construction of the new airport project, the airport technical director, drainage system engineer, the airport construction director and other staff have been suspected of corruption. In May 2016, an engineer working at Berlin's new airport was poisoned, and German media said the man was the whistle blower involved in a corruption scandal involving an airport construction company[15].

According to the agency role model, the corruption and poor control of the project schedule are caused by the internal decision-making departments of the government. In this project, the government is not only the policy-maker of the early planning, but also plays the role of the project regulatory agency, and needs to take into account the role of specialist reviewers. As a result, a single individual undertaking multiple-role tasks will lead to a decline in the role execution quality. Corruption is inevitable when both the regulated and the regulators belong to the government. For their part, developer organisations are reluctant to shoulder the sole responsibility for building infrastructure. Because of the high cost of infrastructure, it will greatly increase the development cost met by developer organisations. Therefore, synergistic effect is used to enable each actor in the market to control the process of each link of project construction, and share the responsibility for infrastructure construction, so as to mobilise the enthusiasm of actors in different links, reduce the risk cost of large-scale infrastructure construction, and protect the interests of developer organisations.

4.2 Labour Market

During the construction of the project, a series of issues of improper employment occurred. The fire safety systems engineer, Alfredo di Mauro, was not a qualified engineer, in fact he was an engineering draughtsman[16]. The inefficiency of construction workers has also led to delays, which are bad for the German government and good for builders. Government development has been delayed, but day-to-day expenses, including employment, are still being met. For the construction companies in developed countries faced with a shrinking construction market, delay and go-slow are undoubtedly very attractive.

According to the agency role model analysis, in the labour market, professional consultants are the key to the success of the overall project development. The lack of professional consultants' experience has led to the unplanned expansion of the airport, by adding two wings midway through construction. Due to the expansion of the airport, new modules such as fire water and fire control have to be added, and the layout of the existing pipeline system and equipment area needs to be adjusted. Macro planning, but also by the construction of half of the site existing conditions. Therefore, the adjustment of a planning scheme is almost equivalent to the redesign, and because a considerable proportion of the build has been completed, the complexity of the engineering site will inevitably lead to difficulty in the implementation of the new design part of the project. Specialist review was also introduced into the labour market to ensure the feasibility analysis of the planning scheme before the start of the project construction, so as to reduce the later construction risk. At the same time, the introduction of competition mechanism to mobilise the working enthusiasm of building workers also plays a decisive role in whether the project can be delivered on schedule.

4.3 Marterials Market

The most important cause of sustained delays is the fire and alarm system. Inspectors found flaws in wiring, programming and the implementation of highly complex systems designed by Siemens and Bosch. Due to the lack of proper oversight, in particular, many instances of poor workmanship were found by the circuit inspectors concerned. Cable pipes carried too many cables, or cables were put together in incompatible ways, such as by placing telephone lines next to high-voltage wires. In an assessment published on July 29, 2014, the Technischer Uberwachungsverein found that some lightning rods were missing and that the backup generators powering the sprinkler system were not providing enough power[17].

According to the agency role model, the role in the materials market is filled by the materials manufacturers. In the process of airport construction, a variety of raw materials were not quality-tested, resulting in failure to pass the completion inspection. As materials manufacturers are the only player in the materials market, there is no market competition pressure and no regulatory agency. Therefore, the quality of raw materials controlled by construction materials suppliers is arguably reduced in exchange for higher profits. In the materials market, the key to improving decision-making is how to play the role of a supervisory body and introduce this role in the current market.

4.4 Land Market

In 1991, after an extensive comparative study of site selection and plan, due to the shortage of land resources in Berlin, the new airport could only be located in the Brandenburg state near Berlin, which required the approv-

DOI: https://doi.org/10.30564/frae.v3i3.2305

al of the two states and the federal government for the construction plan of the new airport. The location of the new airport (BER) is shown in Figure 2. According to the agency role model, landowners represent vested interests in the land market, and the state of Brandenburg, which is the land supplier for the airport project, has a 37% stake in Flughafen Berlin Brandenburg holdings limited (BBF).

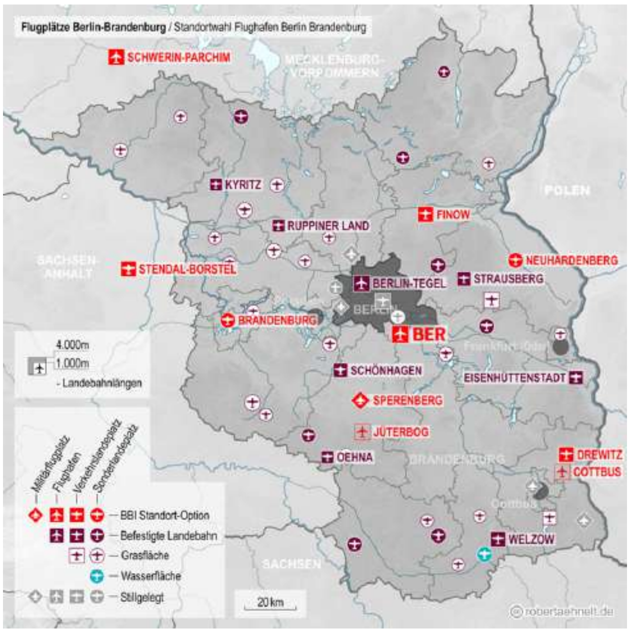

Figure 2. The map of Berlin showing all airports

Sources: https://de.wikipedia.org/wiki/Flughafen_Berlin_Brandenburg#/media/File:Standortwahl_BBI-BER.png

4.5 Financial Market

As of 2009, Berlin Brandenburg Airport had a budget of €2.83 billion. The BBF raised €2.4 billion through credit to continue financing the project [18]. In the construction process, due to the underestimate of the actual cost, construction defects and the increase in the cost of sound insulation for nearby houses, the cost of the airport increased significantly. The series of delays is expected to lead to a series of lawsuits against FBB, which could lead to massive damages for affected airlines and airport operations. At the end of 2012, total spending at Berlin Brandenburg Airport was €4.3 billion, nearly double the original cost estimate. The BBF signed a €2.4 billion loan on February 13, 2017, containing €1.1 billion financings and €1.3 billion repayments of previous bad loans. The federal government, Berlin and the state of Brandenburg guaranteed the debt. Costs will rise further as the airport will not open until 2017. It is not expected to be operational until 2020, when the total cost is €6.5 billion. At present, Wilfried von Aswegen [19]and other experts point out that the airport may not be profitable in the future.

According to the agency role model, there are four roles of the financial market: Politicians, Banks, Other funders and Investors. From their respective financial interests, they finance project development through the financial market. Essentially, they are equal and interchangeable. According to economic principles, when the supply of a commodity declines, the supply of its substitute will increase[20]. As a government-owned airport operator, Flughafen Berlin Brandenburg falls into the position of politicians in the model. This enterprise will be operated as a state-owned enterprise. If it goes bankrupt, it will be a significant event of credit default of government debt. So, at the end of 2017, the German federal government, Berlin and the state of Brandenburg chose to continue debt guarantees for the project. However, in the decade since the new airport was built, the development of the European aviation market has sent passenger turnover soaring in Berlin, while the old aviation infrastructure has struggled to cope. In 2016, the utilization rate of Schönefeld Airport had reached 130%, and at Tegel Airport has reached 160%. The existing aviation facilities are overburdened. The importance of Berlin Brandenburg Airport for the future development of Berlin's aviation industry is self-evident. Therefore, based on the model analysis, the bank and other funders and investors have no positive feedback on the decision-making in the financial market, which only belongs to the politicians' dominant position, which is a particular point of this case. At present, there are still no suitable suggestions for improvement in this part of the model.

5. Conclusion

Real estate development directly changes the urban form and provides a new perspective for us to look at urban changes. In this complex process, we should consider not only the changes in the market environment but also the influence of different roles in the development process on decision-making. Although the Berlin Brandenburg Airport development project was a failure to some extent, the lessons learned from this project can be applied to other projects.

(1) Add the role of specialist reviewer in the labour market, conduct a feasibility analysis before the preliminary planning of professional consultants is finalized, and avoid the occurrence of late modification and project delay.

(2) The role of the regulators in the political market should be promoted as another main line of project development in every market throughout the development process. Only by carrying out strict supervision in each market and at each stage, can we keep the whole project

DOI: https://doi.org/10.30564/frae.v3i3.2305

running efficiently.

(3) In view of the strong position of politicians in the financial market in the development projects of state-owned enterprises, the politicians concerned can ensure the safe supply of funds for the project development by means of supervision.

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An Overview of EGS Development and Management Suggestions

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ARTICLE INFO

Article history
Received: 3 October 2020
Revised: 10 October 2020
Accepted: 24 October 2020
Published Online: 30 October 2020

Keywords:
EGS
Energy Challenge
Hot Dry Rock

ABSTRACT

The world is facing the energy challenge to over-reliance to fossil-fuels, the development of renewable energy is inevitable. From a clean and economic view, enhanced geothermal system (EGS) provides an effective mean to utilize geothermal energy to generate. Different form the conventional hydro geothermal, the host rock of EGS is Hot Dry Rock (HDR), which buries deeper with high temperature (more than 180°C). The generation of EGS is promising. The development of EGS can be combined with the tech Power to geothermal energy. Exceed power is supposed to drive fluid working in HDR layer to obtain geothermal energy for generation. The whole article can be divided into three parts. In the first art, evaluation indexes of EGS as well as pilot EGs Projects (e.g. Fenton Hill and Basel) and exiting EGS project (e.g. Paralana and Newberry) are summarized, which points a general impression on EGS site. The dominate indexes are heat flow, geothermal gradient and thermal storage. The second part is focused on the simulation methods and working fluids selection of EGS. A detailed comparison of the main simulation software (e.g. TOUGH2 and FEHM) is carried out. With the respect of working fluid selection, the comparison between water and CO_2 is researched and CO_2 is a preferred option for EGS development for less fluid loss and less dissolution to HDR. The art of CO_2-EGS is introduced clearly in this part. The third part is about the addition consideration of EGS plant operation, it excludes auxiliary plant support and HSE management.

1. Introduction

1.1 Energy Challenge

Energy transition has been discussed worldwide over decades. The world is under the status of over- reliance on fossil-fuels in various fields. According to the BP Statistic 2019, from 1993 to 2018, global energy consumption increases year by year (Figure 1) and fossil-fuel dedicates a great share. Among them, coal occupies the first with a consumption of 14000 million tones oil equivalent. The great share of fossil-fuel is not a coincidence. Figure 2 depicts the trend of shares of global primary energy consumption by fuel and the top three are oil, coal and natural gas. All are fossil-fuels. The shares of hydroelectricity, nuclear energy and renewable energies are all below 10% [1]. As a consequence, the carbon dioxide emissions raise to 33890.8 million tones and it increases by 2% compared with 2017. Obviously, the domination and over-reliance of fossil-fuels in primary energy consumption is not a suitable way for sustainable development. Energy transition is an evolution to increase the share of renewable energy and improve the energy efficiency. In 2018, the world renewable energy consumption is 561.3 million tones oil equivalent and it increases by 14.5% compared to 2017. The renewable energy con-

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DOI: https://doi.org/10.30564/frae.v3i3.2452

sumption excludes the gross generation from renewable energy sources including wind, geothermal, solar, biomass and waste. The capacity of power generation of renewable energy is expanding in recent years, especially wind power and solar power. According to IRENA's latest data, global installed wind-generation capacity onshore and offshore has increased by a factor of almost 75 in the past two decades, jumping from 7.5 GW in 1997 to some 564 GW by 2018 [2]. Solar power also shows a promising potential for a similar capacity to the wind power. Solar power contains the power generation from solar thermal and solar photovoltaic also known as solar PV. The whole installed capacity of solar power in 2019 is around 586 GW, of which solar PV contributes 580 GW [3]. Not only is the expansion to increase the share of renewable energy in power generation, but an effective method to improve energy utilization efficiency also important for energy transition. Since there is always a time gap between power generation and power use. Normally, the power demand in winter season is high while the demand is relatively low in summer season. From a daily view, power peak often comes in the early morning and evening, while the afternoon is a time of power surplus. Energy storage provides means to store the surplus power as other forms when power is in low demand and generates when power is in high demand. It is called power to X and X refers to the storage forms. When the storage form is chemical gases (e.g. natural gas and hydrogen), it is called power to gas. When the generation energy is converted and supported by the gravity potential energy, it is called power to gravity potential energy and the corresponding storage medium is water. When the tech is combined with geothermal energy, it is called power to geothermal energy.

In this paper, power to geothermal energy is focused and discussed. Geothermal energy refers to the thermal energy that exists in the earth's internal rock, soil, fluid and magma bodies and can be developed and utilized. Depending on its characteristics, geothermal energy can be used for direct heating, geothermal heat pumps and be harnessed to generate clean electricity. The technology for electricity generation from hydrothermal reservoirs with naturally high permeability is also mature and reliable and has been operating since 1913 [4]. Geothermal power has been expanding since the 1950s. As of 2010, a total of 24 countries have geothermal power plants with a total installed capacity of approximately 11 GWe [5]. Liu [6] estimated that 46 countries would have geothermal power plants by 2015 with a total installed capacity of approximately 19 GWe. The growth of geothermal power from 2010 to 2015 is mainly due to the development of conventional geothermal power plants, especially in the Philippines, Indonesia, Iceland, New Zealand and the United States. The developments in the Philippines, Indonesia, Iceland, and New Zealand mainly focused on large-scale high-temperature geothermal fields and particularly on steam-type geothermal power generation. The installed geothermal capacity of the Philippines increased from 1904 MWe in 2010 to 2519 MWe in 2015 [7], whereas that of Indonesia increased from 1197 MWe in 2010 to 3451 MWe in 2015 [8]; these were the largest increases in the world. With the development of supercritical geothermal systems, Iceland increased its installed geothermal capacity from 575 MWe in 2010 to 1285 MWe in 2015 [9]. By using binary cycle power generation systems to enhance the efficiency of power generation, New Zealand increased its installed geothermal capacity from 762 MWe in 2010 to 1237 MWe in 2015 [10]. Meanwhile, because of the sophisticated technologies of mining evaluation and low-temperature geothermal heat extraction, the installed capacity of conventional geothermal power plants in the United States increased from 3098 MWe in 2010 to approximately 5000 MWe in 2015 [11–16]. Many of the power plants in operation today are dry steam plants or flash plants (single, double and triple) harnessing temperatures of more than 180°C. In this kind of plants, dry steam or water is the medium carrying the geothermal energy, which is called hydrothermal resources. In the hydrothermal system, high-permeability pores or fissure media provide circulation channels for fluids and geothermal energy can be directly used by mining fluids. Such resources depend on considerable amounts of heat, fluid and low permeability levels in their reservoirs, and the belief based on the current state of the art is that sites which meets all these requirements are rare on the earth. These limitations have forced the scientists to seek alternative solutions so as to minimize the problems entailed and maintain geothermal energy as a viable. Functional power source with a promising future [17].

Apart from the hydrothermal resources to generate, there is another type of geothermal energy also carrying huge geothermal energy named Hot Dry Rock (HDR) geothermal resources. Different from the host rock in hydrothermal resources, HDR is a rock with higher temperature above 180℃ but lower permeability. Normally, there is little fluid in HDR, in some specific situation, even no fluid. So that the geothermal energy in dry hot rock needs to be enhanced by artificial fracturing to form an enhanced geothermal system (EGS). The HDR resources are abundant. For instance, the total HDR geothermal energy ranging from 3 km -10 km underground in mainland China is 20.9×10^6 EJ [18]. Power to geothermal energy is a tech that allows electricity converts into water or other medium

 DOI: https://doi.org/10.30564/frae.v3i3.2452

when the power is in low demand and generates when power is in high demand. The corresponding geothermal system is EGS. Cooling water or other storage medium is injected into HDR layer through the artificial fracturing to exchange heat and then produce hot water or other hot storage medium by using the exceed electricity. When power is in peak demand, the produced hot water or other hot storage medium is going to be used to generate. In the following chapter, the development and methods of EGS are introduced further as well as the available storage and generation medium for EGS.

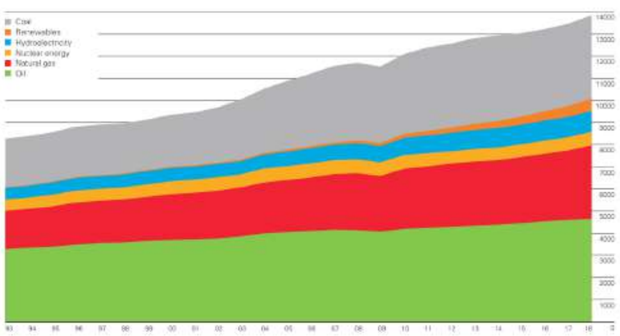

Figure 1. Primary energy consumption from 1993-2018 [1]

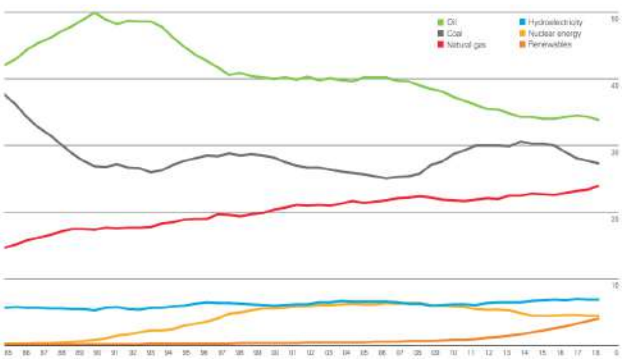

Figure 2. Share of power generation from 1985-2018 [1]

1.2 Objectives

The main object of this work is to study the status of art, technology and research of EGS systems as well as management suggestions for EGS power plant.

2. Evaluation Index of EGS

2.1 Earth Heat Flow Value

The geothermal flow value is a direct thermal parameter, which can quantitatively reflect the geothermal background of a region and is a basic parameter for evaluating the potential of geothermal resources [18]. The geothermal flow at the deep geothermal energy test site in Fenton Hill, USA is 92~247 mW·m^{-2}[19]; the geothermal flow at the deep geothermal energy test site in Pohang, South Korea is up to 80mW·m^{-2}[20]; The geothermal flow at the deep geothermal energy test site in Soultz, France is 82 mW·m^{-2}[21,22]; The geothermal flow at the deep geothermal energy test site in Milford, Utah, United States is (120±20) mW ·m^{-2}[23,24]. The relative movement between the Mesozoic and Cenozoic plates determines the distribution pattern of terrestrial heat flow in China's land and sea [25] (Figure 1), which is shown in the east (average heat flow value of 65 mW·m^{-2}) and the southwestern part (average heat flow value of 90 mW ·m^{-2}) High, the middle part (average heat flow value is 55 mW·m^{-2}) and the northwest part (average heat flow value is 50 mW·m^{-2}) compared with the global average, which are normally low heat flow values.

According to the distribution of land heat flow in the continental area and the characteristics of the ground heat flow in the existing deep geothermal energy test area, it divided the ground heat flow value into 5 levels, and the representative values of each level are: 90 mW·m-2 is good; 80 mW·m^{-2} is relative good; 70 mW·m^{-2} is moderate; 60 mW·m^{-2} is relative poor; 50 mW·m^{-2} is poor [26].

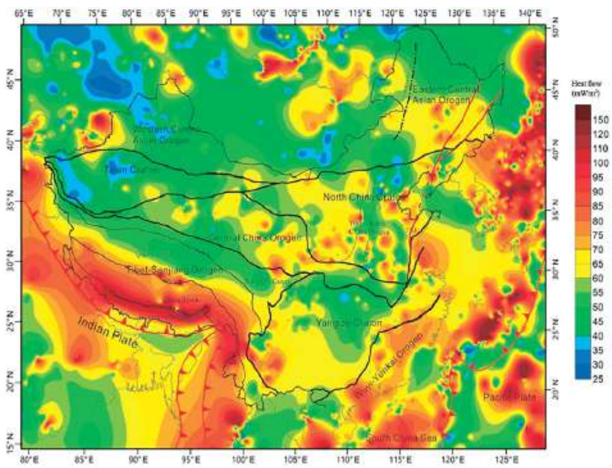

Figure 3. Map of heat flow in mainland China [25]

2.2 Geothermal Gradient

Generally, the average geothermal gradient at the target depth exceeds 30 °C·km^{-1} is regarded as a geothermal anomaly zone. In the western United States, one of the characteristics of power generation-level geothermal resources is that the geothermal gradient is higher than 50 °C·km^{-1} [27-28]. The geothermal gradient of the deep geothermal borehole target reservoir of Fenton Hill in the United States is higher than 60 °C·km^{-1}[29], the bottom hole temperature is above 200 °C, and the highest is 323 °C; Pohang deep layer in South Korea The geothermal gradient of the target reservoir for geothermal energy

  DOI: https://doi.org/10.30564/frae.v3i3.2452

drilling is 40 °C·km^{-1}, and the bottom hole temperature is 180 °C[30]; the geothermal gradient of the target reservoir for deep geothermal energy drilling in Cooper, Australia is higher than 50°C· km^{-1}, bottom hole temperature is 250 °C[31,32]; the target reservoir geothermal gradient of deep geothermal energy drilling in Soultz, France is close to 40 °C·km^{-1}, bottom hole temperature is about 200 °C[33]; The target geothermal gradient for deep geothermal energy drilling in Milford, Utah, USA is 70 °C·km^{-1}, and the bottom hole temperature reaches 200-250 °C[34].

2.3 Thermal Storage

The EGS technology for artificially constructed reservoirs is the key to the development of deep geothermal energy. The effect of artificially created reservoirs is directly related to the fluid circulation and heat exchange efficiency and determines the economic cost of geothermal development. At present, the reservoir reconstruction technology mainly includes: ① hydraulic fracturing technology, which is to inject a high-pressure water into a closed well hole to cause a large number of cracks near the hole wall, causing the original cracks in the rock body to open and expand. Medium and high pressure water injection connects the fracture zone composed of the crack system between the two wells to form an artificial reservoir; ② Chemical dissolution technology is to inject acidic fluid into the reservoir to make it chemically soluble with the soluble mineral components in the rock Reaction, thereby expanding the pore space. Whether the thermal reservoir rock is easy to be reformed is also an important factor that affects the effect of deep geothermal energy extraction. This should be fully considered during the site selection stage of deep geothermal energy projects. There are many sub-categories of these two types of technical models. As a safer option, the "flexible storage" technology with lower fracturing pressure is gradually favored.

Existing enhanced geothermal systems are dominated by mining sandstone, granite (including granodiorite, mixed granite) and metamorphic rock (including gneiss) reservoirs [35,36]. Most rock masses have high hardness, dense structure and extremely low permeability. For example, the Fenton Hill deep geothermal energy test site in New Mexico, USA, the reservoir lithology is granodiorite [37], the EGS project in Soultz, France is granite [38]. The technical difficulty of EGS is mainly to improve the permeability of hot rock mass and achieve the goal of storage. The harder the rock, the more difficult it is to create and store. The specific problems are: in the drilling process, the hard rock has serious wear on the drill bit, and frequent replacement of the drill bit reduces the construction efficiency and increases the drilling cost; in terms of thermal storage transformation, natural rocks in granite, metamorphic rock, sandstone and other rock bodies There are fewer void channels, and the effects of hydraulic fracturing and acidification dissolution are poor. In terms of hard rock, the brittleness is strong, the injection pressure is high, it is easy to induce earthquakes, affect engineering safety and system stability, and increase environmental risks [39,40]. With the continuous development of EGS technology, the engineering technology of extracting deep geothermal energy through artificial storage and storage can be extended to rock bodies that are easier to transform. Medium-thick layer carbonate rocks under high-heat background conditions can be preferred reservoirs. The advantages of this type of heat storage are mainly reflected in the following aspects: ① Carbonate rocks are sedimentary rocks, which are generally distributed in layers and have obvious bedding, which can provide advantageous channels for dissolution and hydraulic fracturing; ② Limestone, dolomite, marble and other carbonate rocks are all soluble rocks, and high-temperature background areas often have high-concentration acid gases such as CO_2 and H_2S, which can promote the occurrence of deep karst processes; ③ Carbonate rocks are Dissolution easily occurs during water injection or acidification, increasing the porosity and permeability of the rock; ④ Carbonate structure in medium-thin to medium-thick layers has dense and short fissures and even distribution, which is conducive to the formation of a relatively uniform fissure network; It is the limited pressure range of acid fracturing, which belongs to the typical "flexible storage" technology. Therefore, the carbonate rock thermal reservoir realizes artificial storage at a lower pressure, and as the fluid heat exchange continues, the circulating fluid will continue to dissolve the surrounding rock minerals, which can further enhance the permeability of the reservoir and improve production efficiency. The above characteristics make carbonate thermal storage become the key target reservoir for deep geothermal energy extraction after the mid-deep hydrothermal system.

3. Development of EGS

3.1 Introduction to EGS Sites

Enhanced Geothermal System, EGS, is an adaption to traditional thermal energy. Different from hydro geothermal energy, the geothermal energy in dry hot rock needs to be enhanced by artificial fracturing. Gallup posed the concept of EGS that EGS system should consist of extracting heat from tight rock that has not fractured naturally, where the permeability is extremely low. Baria

DOI: https://doi.org/10.30564/frae.v3i3.2452

et al. claims that EGS were not viable at first, but technological advancements in recent years have pushed the idea firmly towards commercial operation. The boost given to these techniques includes heat extraction from low-permeability geothermal systems. Stober states that as general rule permeability decreases when pressure increases. MIT predicts that once commercial operations are established, the production of energy from these geothermal resources will increase dramatically all over the world and provides a list of steps for setting up an EGS plant. A general concept of EGS plant is pictured in Figure 4. The first step for EGS is to find a suitable site to create EGS reservoir. The reservoir is supposed to be at a suitable depth to meet the drilling art like 4-5 km and the temperature at such a depth should be as high as possible. Here the reservoir refers to the numbers of areas of HDR where EGS can be applied is exponentially greater. Next, wells are drilled into the hot dry rock, which is stimulated to produce fractures stable enough for fluids to be injected and circulate through it. The fractures provide the permeable pathways. Through these fractures, cooling injected fluids are intended to exchange temperatures from heat HDR so that the high temperature and geothermal energy is obtained. Then, the hot fluid is extracted via production wells. When the hot fluid is brought up to the surface, it is sent to the power plant to generate. Furthermore, the fluid after generation can be sent back to the injection wells to be re-heated and hence a closed loop is formed. When the power using to inject fluid is from the surplus power, it is called power to geothermal energy. It consists of two parts. First, the exceed power is used to drive cooling fluid into injection wells to exchange heat from HDR with higher temperature, during this period, the electricity is converted into geothermal energy. Second, hot fluid is transported to the power plant then electricity is converted into power. The concept of power to geothermal energy is favorable for the energy transition trend, however, there are still some fields need to be focused and researched, such as drilling process, creating fractures, the velocity and temperature of fluid for a good heat exchange and ground facilities management.

Over the past four decades, due to experience in oil and gas production, the technology to generate fractures hard rock and hard rock has been developed. Technical feasibility depends on the local conditions of the demonstration site. According to the degree of difficulty, the United States divides EGS development technologies into three categories: on-site EGS, near-field EGS, and undeveloped EGS. All early development projects such as Fenton Hill, Rosemanowes, Hijori, Fjällbacka and Ogachi Basel are difficult greenfield EGS. As the hydraulic fracturing technology matures, the success rate of EGS gradually increases, such as Soultz, Habanero, Paranala, Insheim, Landau, Newberry, Desert Peak and Geysers. In addition to the development of mining technology, the early experience of EGS development also shows that EGS site selection is very important. For example, successful reservoirs are easier to develop in tensile stress environments (such as grab stone) than in compressive stress environments. In the following chapter, EGS pilot projects will be introduced.

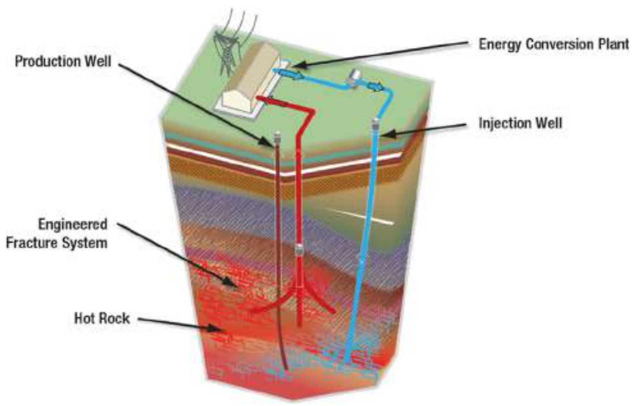

Figure 4. A concept of EGS Scheme

3.2 Pilot EGS Projects

3.2.1 Fenton Hill (1974-1995)

The first proposal of the use of geothermal energy generated at a great depth was posed at the Los Alamos Scientific Laboratory (LASL) in the USA in 1970. The concept of EGS was put forward first by the Los Alamos National Laboratory (LANL) in the USA. It was set out in a patent field in 1974 that describes the formation of an entirely natural tank designed to obtain geothermal energy. The venue for the project was around 40 km west of Los Alamos, west of the Río Grande (New Mexico). The task included creating a 4.4 km deep reservoir in granite with a temperature of 300 km and testing the 60kWe binary cycle power generation system operating at low and medium temperatures. However, due to the inability to achieve the expected capacity, the project was terminated. Although it was not possible to develop a commercial-grade EGS power plant at the Fenton Hill base, the project achieved the following important results:

(1) The project verified the technical feasibility of drilling 5 km into hard rock.

(2) The project confirmed that hydraulic fracturing technology can be used in low-permeability crystalline rock to create fractures with a total volume greater than

  DOI: https://doi.org/10.30564/frae.v3i3.2452

1 km^3 for electricity generation.

(3) If the reservoir formations are in a compressive stress environment, continuous high-pressure reinjections are required to maintain the openings of the fractures. However, high pressure pumps consume the most power at the EGS site.

(4) Because the formation stress varies with depth, high-temperature downhole detection equipment should be developed to acquire data about the formation stress, fracture orientations, downhole temperature, flow rate, and pressure.

3.2.2 Rosemanowes (1977–1991)

Camborne Mining School conducted EGS testing in Rosemanowes, Cornwall, UK, with a potential of approximately 3 GWe. The on-site development goal is to maintain a capacity of 50–100 kg/s, 5 years of use time and no reduction in temperature. However, the reservoir is mainly controlled by natural fractures, so it is almost impossible to produce artificial fractures through hydraulic fracturing. The loss of circulating fluid on site exceeds 70%. In addition, due to high hydraulic impedance and short circuit, the goal could not be reached, Rosemanowes ceased operations in 1991. Recently, using the results of Rosemanowes EGS, the UK has developed a 50MWe commercial-scale EGS power plant in Eden in the same region. region. In addition, a commercial-scale EGS is planned to be built in the small town of Redruth in Cornwall, which will be put into production in 2015 and can generate 10MWe of electricity and 550MWt of heat.

3.2.3 Hijiori (1981–1986)

The geological conditions of Hijiori EGS are similar to Fenton Hill. Both locations are volcanic geothermal fields. Hijiori EGS is conducted by the Japan New Energy and Industrial Technology Development Organization (NEDO) and is Japan's first EGS test site. A 130kWe binary cycle power plant is used to generate electricity. Although the maximum temperature in the fracture area of 1800 m depth is 250°C, even if the distance between the injection well and the production well is only about 50 m, the loss of circulating fluid still exceeds 70%. Due to various factors, including fluid loss and reservoir fouling, Hijiori EGS was unable to achieve the expected target, so the test was terminated. Important information obtained through Hijiori EGS test:

(1) Because natural fractures already exist in the two wells, even if hydraulic fracturing will enhance connectivity, a short circuit may occur during heating. Therefore, underground sealing should be used to prevent undesirable fractures.

(2) At that time, it was still difficult to predict the fracture direction or stress field. However, underground microseismic arrays should be used to monitor and/or identify the development of artificial fractures.

(3) Fenton Hill and Hijiori are located near the crater. If shallow wells are drilled in this type of EGS, high temperature fluids and lower power generation costs can be obtained.

3.2.4 Fjällbacka (1984–1989)

Fjällbacka EGS is located in western Sweden. The goal is to develop EGS as a greenhouse heat pump. The plan was implemented from 1984 to 1989. The hydraulic fracturing test used two wells with a depth of about 500 m. The horizontal distance between the two wells is about 100 m. Water was injected through the reinjection well at a temperature of 7°C, an injection pressure of 5 MPa and a flow rate of 1.8 kg/s. The hot water is then discharged from the production well at a temperature of approximately 16°C and a flow rate of approximately 0.9 kg/s. Despite the small distance between the two wells, the loss of circulating water is still about 50%, so the site is not economical.

3.2.5 Ogachi (1989–2001)

The second EGS project in Japan was carried out at the Ogachi plant near Yamabushi. The temperature at a depth of 1000 m exceeds 230°C. Under the supervision of the Central Electric Power Research Institute (CRIEPI), undeveloped EGS experiments and CO_2 isolation tests were conducted at the Ogachi EGS site. However, due to the loss of up to 75–90% of the circulating fluid in the field during the test, Ogachi EGS could not reach the level of commercial operation. The important results of Ogachi EGS are the same as those of the above EGS site. Due to the complex underground geological conditions, it is difficult to predict the direction of fractures before drilling. Downhole geophysical exploration is still needed to understand the stress distribution and fracture development in the well.

3.2.6 Basel (2005-2006)

Basel's EGS site is a project of the "Deep Geothermal Drilling Program" implemented by Geopower Basel. The goal of the project is to develop commercial-grade EGS power plants and heat pumps. The site is located in Basel and has a population of over 700,000. Basel is the third largest city in Switzerland and the hub of the European pharmaceutical and chemical industries. In 2006, a hydraulic fracturing test was carried out in the granite layer at the EGS site in Basel, with a depth of approximately 5000 m and a temperature of approximately 200°C . The test caused thousands of micro-earthquakes. Due to the rapid increase in seismic activity, the hydraulic fracturing test was stopped. However, a few hours after the injection stopped, a magnitude 3.4 earthquake occurred and damaged the local structure. As a result, the plan was terminated, and local residents were compensated for their losses. Whether the impact was caused by the EGS project is questioned. Due to the Basel EGS case, the European Commission created a geothermal engineering integrated mitigation of reservoir induced earthquakes (GEISER) to standardize the development of EGS .

3.3 Exiting EGS Projects

3.3.1 EGS projects in EU

3.3.1.1 Soultz

Soultz EGS is the world's first commercial-scale EGS power plant. The production capacity has reached 25 kg/s, and the plant currently provides continuous hydrothermal power generation. The Soultz website is led by the European Commission. From 1997 to 1998, when commercial production was realized, the management of Soultz EGS was transferred to private companies such as Shell and several French and German companies. The important results of Soultz EGS are:

(1) Soultz EGS is an artificial fracturing reservoir that has been successfully used as a commercial-scale geothermal power plant. Site characteristics (such as natural cracks and their connectivity) are the main factors for the success of this EGS.

(2) The reservoir maintenance at this location is mainly affected by scaling. In order to reduce the skin-gathering effect in the well, acid leaching treatment was performed on this part to keep the reservoir fractures.

(3) The program adds a submersible pump to increase production and reduce reinjection pressure.

(4) High temperature of underground detectors. There is an urgent need to develop high-temperature materials and system designs.

3.3.1.2 Landau and Insheim

Since most geothermal reservoirs in Germany are low-temperature reservoirs, geothermal power generation applications are concentrated on EGS, while shallow low-temperature applications are concentrated on heat pumps. The German leading EGS geothermal power plants Insheim and Landau are located in the Upper Rhinegraben region of Germany, and their lithology is almost the same as that of Soultz in France. The lithology of all artificial oil reservoirs is granite. Although the microseisms were caused by hydraulic fracturing on site, the degree of damage was still within acceptable limits. After completing about 150 geothermal projects, Germany successfully proved the commercial feasibility of greenfield EGS and related activities, such as transportation regulations. By 2020, the total capacity will reach 280 MWe.

3.3.1.3 Gro**ß** Sch**ö**nebeck

The GroßSchönebeck test site is located 50 kilometers north of Berlin, Germany. The geothermal resource potential of this field is about 10MWe. The development of GroßSchönebeckEGS is led by the German Geoscience Research Center (GFZ, GeoForschungsZentrum Potsdam). The EGS well at the site is an old natural gas exploration well drilled in 1990 and a 150°C geothermal well drilled in 2006. The maximum horizontal distance between the production layers of these two wells is about 500 m. GFZ carried out site planning and installation in 2001. In 2003, a hydraulic fracturing test was performed on the old well, and the injection well was deepened to 4309 m, and the fracture channel of the old well was added. In 2004, a long-term reinjection test was conducted, and the hydraulic conditions of the reservoir were evaluated. In 2006, 8 months of geothermal well steering drilling was performed at a depth of 4440 m. The second hydraulic fracturing test was conducted in 2007. Depending on the thermal fluid conditions that can be produced, several binary cycle power generation units (500 kWe, 350 kWe and 150 kWe) were installed at the Groß Schönebeck site.

3.3.2 EGS projects in Australia

3.3.2.1 Habanero (Cooper Basin)

Habanero EGS was developed by Geodynamics Limited (GDY) in a resource collectively known as Innamincka granite. Much of the work is at the Habanero location, where four wells ranging from 4,205 m to 4,420 m were drilled near the early oil well McLeod 1 (McL). Naturally cracked granite is saturated with water and insulated by an overlying sedimentary layer of approximately 3,650 m. The EGS reservoir in this granite is limited to the critical low-angle sub-horizontal fault zone, that is, the Habanero fault that is easy to slip off. GDY recently demonstrated the technical feasibility of EGS in Habanero after completing the Habanero pilot plant project in October 2013. This work outlines the first numerical reservoir model established for the Habanese using the TOUGH2 thermodynamic simulator.

In 2003, Habanero 1 (H01) was hydraulically stimu-

DOI: https://doi.org/10.30564/frae.v3i3.2452

lated, resulting in 28,000 seismic events within an approximately planar seismic cloud. The well was re-stimulated in 2005, adding a further 16,000 events and extending the seismic cloud. In November 2012, stimulation was conducted at Habanero 4 (H04) with the intent to expand the existing reservoir and to gain a better understanding of the geothermal system. Over 36 ML of water was injected and over 27,000 events were recorded.

The Cooper Basin is located in Adelaide in northern South Australia, close to Queensland. The goal of the project is to develop successful EGS in homogeneous granite and construct a binary cycle power generation system of approximately 100 MWe. Granite in southern Australia contains a lot of radioactive elements (such as uranium), which results in many shallow local high-temperature reservoirs. Geodynamics deepened the Habanero 1 injection well (depth 4421 m) from the original oil exploration well in 2003. The granite is under overpressure (35 MPa). Frequent drilling and industrial safety issues have delayed development. 1 The MWe EGS power plant was put into operation on site in early May 2013, followed by the 40 MWe power plant in 2015. The ultimate goal is a total of 450 MWe.

3.3.2.2 Paralana

The Paralana Geothermal Project is located about 600 km north of the city of Adelaide in South Australia in the Lake Frome Embayment east of the Mt Painter Inlier. Mesoproterozoic granitoids and gneisses of the Mt Painter Inlier can contain anomalously elevated U and Th contents resulting in high to very high heat production rates by global standards. Average heat production in the Mt Painter Inlier is 10 μWm^{-3}, which is around 4 times the rate of average granite and individual granites such as the Yerila Granite yield up to 62 μWm^{-3}. The Paralana project is exploring for viable EGS resources within the adjacent Poontana Graben where the Mt Painter basement rocks are overlain by a thick sequence of flat-lying Neoproterozoic, Cambrian and Tertiary sediments.

Petratherm (PTR) also adopted a strategy to collect mid-depth ultra-fine-line drilling to collect data about the project area before committing to drilling wells that reach reservoir depth. The preliminary results of the data well Paralana 1BDW1 are encouraging. In 2009, Paralana 2 was drilled to 4003 m and the temperature is expected to be about 180 – 200°C. The well is designed as a potential injection well, but instead of repeating the previous EGS project's strategy for hydraulic stimulation in long open-hole completions, it is better to fully casing and selectively perforate Paralana 2 to achieve multi-stage stimulation. Ok. The well is perpendicular to approximately 3400 m, below which the system deviates to 17°. During drilling between 3670 and 3864 m depth, multiple unstable regions intersect with overfilled fluid-filled fractures, indicating widespread fracturing in deeper rock masses. The shut-off pressure indicates an overpressure of ~3300 psi. Weigh the slurry to 13.2 ppg to control the flow. As a result, the well can only be cased up to 3,725 m. The calculated bottom hole temperature at this depth is 190°C. By applying heat exchangers in the heat insulation layer (HEWI) mode, hydraulic fracturing and heat exchange are performed at the interface between the sedimentary rock layer and granite. The thermal insulation layer is shallow, and most of it is composed of sedimentary rock with low mechanical strength. In this type of geothermal site, it is easy to successfully create artificial cracks, so the cost and risk are low. This technology has been successfully used in petroleum reservoir engineering. Therefore, the engineering cost is lower than that using granite as the heat exchange rock. Currently, the production flow rate at the EGS site in Paraná is about 21.6 tons/hour and the fluid temperature is about 171°C. Petratherm plans to complete the third well including drilling, hydraulic fracturing and fluid circulation in 2014, and plans to build a 3.5 MWe binary cycle power plant in 2015.

3.3.2.3 Other EGS projects in Australia

Green Rock Energy has four EGS sites in southern Australia and one EGS site in western Australia. The largest site of EGS is the Olympic Dam in southern Australia, and it is expected that a 400 MWe EGS power plant will be built by 2020. The Raya Group has three EGS sites, two of which are located in the Otway Basin and one in the Cooper Basin. Geothermal Resources has two EGS sites, and Torrens Energy EGS has two EGS sites and is currently in the verification drilling phase. KUTh Energy has two EGS sites and is currently in the exploration and drilling stage. Greenearth Energy has EGS and oil extraction at two locations, and the demonstration plant is currently in the planning stage. Hot rock has 5 EGS sites in the Otway Basin and is currently in the stage of verification well drilling.

3.3.3 EGS projects in Asia

At present, the largest EGS development project in Asia is the Pohang project in South Korea. The EGS research project started in 2010 and is expected to build a 1.5 MWe EGS power plant in 2015. The reservoir lithology is granodiorite with a depth of 5 km and a temperature of 180°C. Pohang EGS will become the first MWe-level EGS power plant in Asia.

3.3.4 EGS Projects in USA

3.3.4.1 Newberry EGS Project

The Newberry EGS site is a volcanic geothermal field

 DOI: https://doi.org/10.30564/frae.v3i3.2452

with granite reservoirs and an undeveloped oasis EGS with high development difficulties. The Newbury Reservoir is located at a depth of 3067 m and the temperature is 331°C. The development goal for 2013-2014 is to complete two production wells. The site was developed by AltaRock Energy. The development tasks are divided between the cooperation teams as follows:

(1) Oregon State University (OSU) and National Energy Technology Laboratory (NETL) are responsible for the new reservoir 4D monitoring technology;

(2) The University of Oklahoma (OkU) is responsible for establishing EGS micro-seismic (MEQ) simulation technology based on geological and in-situ stress and statistical viewpoints;

(3) The Institute of Energy and Earth Sciences (EGI) at the University of Utah (UU) is responsible for novel crack tracking and evolution technologies;

(4) Davenport Holdings is responsible for new mining technologies;

(5) WLA-Fugro is responsible for 3D velocity imaging

(6) Lawrence Livermore National Laboratory (LLNL) is responsible for selecting drilling locations. The total capital required to develop the Newberry EGS site is $43.8 million, of which $21.4 million is subsidized by the Department of Energy (DOE) grant.

The main technology of the site is the use of thermally degradable strip insulation (TZIM) for hydraulic fracturing without the need for traditional closure methods to minimize drilling time. The AltaStim™ hydraulic shear model predicts possible electric shocks and risks. In addition, the structure of the 14-stage electric high-pressure centrifugal pump allows injection at 1000 gpm at 2000 psi. Other facilities include 15 microseismic monitoring stations, 8 borehole geophones, 7 ground geophones and a powerful monitoring station. A reservoir with an area of 1.5 km×0.7 km was successfully created, with a total reserve of about 1.5 -3 km and an injection index of about 2 kg/s/MPa. Overall, excellent artificial cracks were created at the site.

3.3.4.2 Geysers EGS Project

Geyser is a traditional geothermal field, with the world's largest geothermal installed capacity, with a total of 22 geothermal power plants. Calpine owns 19 companies. Calpine is responsible for the development of the EGS site in the northwest of the field, where existing geothermal wells with insufficient capacity are being developed as near-field EGS. The 20th geothermal power plant will be a 5 MWe EGS power plant. The site used metamorphic sandstone reservoirs at a depth of 3396 m and a temperature of 280°C. At present, the P-32 water injection well that has caused artificial cracks has been completed. PS-31 production wells continuously produce high-quality hydrothermal steam. Lawrence Berkeley National Laboratory (LBNL) is a member of the Geysers EGS development team and is responsible for:

(1) Evaluation of fracturing technology;

(2) Combining InSAR surface deformation research and geomechanical simulation to conduct injection-induced earthquake research;

(3) Install at least 14 MEQ monitoring stations;

(4) Establish a tourism center as an EGS education exhibition and public communication space.

The important features of the EGS project are:

(1) After treatment, the urban sewage is pumped to the top of the hills, and then injected into the low-permeability stratum with a temperature of 400°C using a gravity head;

(2) Without using a large pressure pump, the cold fracturing method successfully produced artificial cracks around the wellbore due to thermal effects, thereby reducing vibration and energy consumption of the pump. As a result, the largest earthquake was less than M2.87;

(3) Hydrogen and oxygen isotopes are used to determine whether the produced water reacts with the geochemical reaction with the rock layer, and the results can be used to determine the flow path of reinjection;

(4) Since the development of this EGS site involves the transformation of existing oil wells, the development cost is low. Total funding is approximately $133.3 million, of which $6.2 million is subsidized by the US Department of Energy grant.

3.3.4.3 Raft EGS Project

The University of Utah is responsible for the Raft River EGS project. There is a traditional geothermal power plant of about 12MWe near the site, for which 4 production wells and 3 reinjection wells were drilled to achieve a total production flow rate of 315 kg/s. The EGS site has been planned since 2008 and already has four observation wells to measure earthquakes. The RRG-9 ST-1 well is 1,800 m deep and was completed by hydraulic fracturing in 2013. It is essentially a near-field EGS with moderate development difficulty. The reservoir lithology at the Rahe River EGS site is granite with a temperature of approximately 150°C. In the process of hydraulic fracturing, 60°C of water is injected, followed by the cold fracture method, which involves injecting 13°C of water into the reservoir to create fractures around the well. Finally, 50,400–347,000 pounds of 20/40 and 100 mesh silica sand were used to generate reservoir fractures. The characteristics of this EGS project development are:

(1) Combined with the technology developed by the

DOI: https://doi.org/10.30564/frae.v3i3.2452

US research team, such as the "cold crack hydraulic fracturing simulation" of the Idaho National Laboratory (INL), the impact events caused by the hydraulic fracturing process were simulated and predicted;

(2) LBNL conducted MEQ, downhole temperature distribution measurement, distributed temperature sensing system (DTS), inert gas monitoring and resistivity measurement;

(3) Measurements of underground telescopes are carried out by Sandia National Laboratory (SNL);

(4) Freight testing is performed by EGI.

The development goal of the Raft River EGS project is to operate a 5MWe EGS power plant, and by 2020, the continuous production flow rate of each well will be at least 20 kg/s. The funding required for this site is US$ 10.6 million, of which US$ 7.4 million is provided by the US Department of Energy grant subsidies.

3.3.4.4 Desert Peak EGS Project

ORMAT Nevada Corporation (ORMAT) has shared costs and received funding from the United States Department of Energy (DOE) to study the technical and economic feasibility of establishing an artificial underground heat exchanger in the eastern desert peak geothermal field. 130 kilometers (80 miles). The ultimate goal of the project is to develop 2-5 MW EGS power generation from an independent binary power station provided by one well or three wells. Initially focused on well DP 23-1, a hot and tight hole about 2.5 kilometers (1.5 miles) east of the hydrothermal well being produced at Desert Peak , a system for the EGS potential of the area. The evaluation was completed in May 2004. The first stage of evaluation includes:

(1) analysis of existing geological data, including new petrologic analyses of samples from well DP 23-1 and a nearby core hole (35-13 TCH);

(2) review of previously collected geophysical data;

(3) mechanical testing of cores from 35-13 TCH (none are available from well DP 23-1);

(4) obtaining and evaluating a new wellbore image log in well DP 23-1 to determine stress field orientation and evaluate the intrinsic fracture population;

(5) conducting an injection test of well DP 23-1 to determine baseline (pre-stimulation) well and reservoir characteristics;

(6) developing a conceptual model of the EGS portion of the field;

(7) numerical modeling of heat recovery to develop generation forecasts for various well configurations over a range of stimulated volumes;

(8) designing and conducting a "mini-frac" in well DP 23-1to determine the magnitude of the least principal stress;

(9) re-completing well DP 23-1 in preparation for hydraulic stimulation;

(10) preparation of a detailed plan to guide the next activities at the field (Phase II).

3.3.4.5 Bradys Hot Spring EGS Project

The Bradys Hot Spring Geothermal Field is the second field EGS site owned by Ormat, 7 km from the Desert Peak Geothermal Field. Using the existing 15-12 ST-1 geothermal wells, hydraulic fracturing was performed on the site in 2013 to establish a rhyolite geothermal reservoir with a temperature of 204°C. The purpose of the project is to increase the power generation capacity of each well to 2-3MWe, use self-supporting shear hydraulic fracturing technology, and use the site as a training base for the development and application of "EGS Toolbox" technology, which can be transferred to Other EGS projects. The development tasks of this EGS project are divided according to the cooperation team as follows:

(1) Ormat is responsible for the overall planning;

(2) GeothermEx is responsible for technical management, hydraulic fracturing facilities and simulation;

(3) The University of Nevada Reno (UNR) is responsible for the development of three-dimensional geological models and surface stress indexes;

(4) USGS is responsible for stress field analysis and construction simulation conducted with Temple University;

(5) EGI is responsible for tracer testing and geological modeling;

(6) Schlumberger's Terra Tek is responsible for the formation and Core analysis

(7) GeoMechanics International is responsible for failure analysis and planning of hydraulic fracturing;

(8) LBNL is responsible for impact monitoring and analysis;

(9) Hi-Q geophysics is responsible for data collection and ground vibration interpretation;

(10) LANL and NETL are responsible for the EGS fracture network Imaging and simulation;

(11) SNL is responsible for the measurement of underground TV viewers.

The development funding of this EGS site is approximately \$6.6 million, of which \$3.4 million is subsidized by grants from the US DOE.

4. Simulation Methods of EGS

It is important to establish a framework to discuss and determine the common characteristics of EGS reservoirs that are critical to successful operation. The general concept is a reservoir system consisting of porous media, usually with a natural fracture network, which may be intersected by high-conductivity, hydraulically induced artificial fractures. Flow mainly occurs in fractures and depends on the fracture pores, which may be a function of fluid pressure and thermal contraction in adjacent rocks. In the EGS system, the main challenges are to increase the permeability by enhancing natural cracks or forming artificial cracks, and to optimize heat recovery by injection. The heat is removed by injection fluid through the fracture system. On the premise that the behavior of the enhanced geothermal system (EGS) will be dominated by fracture flow, this article reviews the special functions required by any actual EGS numerical simulator. In addition to the basic functions of conventional geothermal simulators (that is, the ability to handle two-phase fluid flow in porous media and fracturing media, heat transfer and tracer transport), the following functions are also required: clearly indicating cracks, effective crack width Changes in stress and shear force, thermoelastic effects, the relationship between fracture pore size and electrical conductivity, and the passage of fluid flow in the fracture. The chemical reaction between water and rock and the coupling of reservoir model and wellbore model are also ideal characteristics. This article reviews the famous simulators that have been used or can be used to model EGS (TOUGH2, TETRAD, STAR, GEORCRACK, FEHM, FRACTure, GEOTH3D, and FRACSIM-3D) for the functions listed above.

About 70 projects participated in the experience of all HDR/HWR reservoirs (Rosemanowes, UK; Soultz-sous-Forêts, France; Hijiori, Japan; Fenton Hill, USA; and Ogachi-Akinomiya, Japan). Their experience and conclusions represent a large amount of accumulated knowledge related to EGS reservoirs. Based on their conclusions and our survey of geothermal developers and operators, we can list the necessary and ideal features to be included in the HDR simulator as follows:

(1) explicit representation of the fractures;

(2) fracture opening as a function of effective stress;

(3) shear deformation and associated jacking of the fractures;

(4) a relationship between fracture aperture and fracture conductivity, including the potential for turbulent flow in the fractures;

(5) “channeling,” and thermo-elastic effects;

(6) mineral deposition and dissolution;

(7) a tracer module;

(8) two-phase flow and the consequent complexities of phase change, relative permeabilities, capillary pressure effects etc.

4.1 Software Introduction

4.1.1 FRACTure

FRACTure is a finite element code for discrete fractures, used to simulate the coupling of hydraulic, thermal and mechanical behavior of fractured media. The model represents fluid flow through a permeable rock matrix and discrete fractures. The fluid flow can be modeled using Darcian and turbulence control equations. Thermoelastic and porous elastic effects are applied to porous media, and the crack opening is nonlinearly related to rock stress. Heat transfer includes conduction in rocks and transmission in fluids, and is coupled to elasticity and pyrolysis through thermal expansion and nonlinear constitutive relations. FRACTure has been used to model various geological problems, including: transportation to buildings, space heating, tracer propagation, non-layered hydraulic behavior at Soultz, and heat extraction during aquifer utilization. It has also been used to compare the simulation of HDR reservoirs using 2D and 3D single fractures and multiple fractures. It has been used to model Soultz HDR reservoirs using flow and turbulence models in major fractures. FRACTure’s methods and concepts make it suitable for analysis of various reservoir operations. Its advantage is that the physical range has been achieved through three-dimensional hydraulic, thermal and mechanical coupling. It does not include the coupling of two-phase flow or geochemistry and flow. Channels are not directly supported, but can be modeled using the material properties of different crack elements. No coupling between fracture shear displacement and aperture.

4.1.2 GEOTH3D

The GEOTH3D simulator by Yamamoto et al. use microseismic data as a guide for permeability distribution and have applied it to Hijiori, Ogachi and Fenton Hill reservoirs. GEOTH3D uses 3D finite difference approximation to solve mass and energy balance according to Darcy’s law. The model can describe the water and heat transfer in porous media. When applied to geothermal reservoirs, the available microseismic data will be used to define non-uniform porosity proportional to the microseismic intensity. Therefore, the flow rate in the reservoir area with the strongest microseismic activity during stimulation is greater. GEOTH3D is attractive for modeling non-uniform porous media using microseismic data obtained during stimulation. The model does not include discrete cracks. In general, porous media models tend to be optimistic in terms of energy production. This is because porous media models often cannot capture the sharp local temperature

DOI: https://doi.org/10.30564/frae.v3i3.2452

gradients and cooling that may occur in cracks, and cannot represent pore size changes due to stress or thermoelastic effects.

4.1.3 FRACSIM-3D

FRACSIM-3D codes (including fracture network models of fluid flow and heat transfer) have been used to model the Hijiori and Soultz reservoirs. As described by Jing, the model is an extension of the 2-D fracture simulator FRACSIM-2D. Tezuka and others have developed similar models. The model focuses on the following reservoir effects: 1) fracture shear and expansion during stimulation and circulation; 2) thermoelasticity during circulation; 3) chemical dissolution and precipitation during circulation. FRACSIM-3D can be used to analyze stimulation and reservoir testing operations, including tracer analysis and simple chemical dissolution models. In the Hijiori model, the correlation between the amount of microseism and the predicted simulation is very good. Then perform statistical flow calculation. Depending on the distribution of the fractures produced, different flow rates are obtained between the injection well and the production well. However, the average value of these holes is very consistent with the observed flow rate. The tracker calculation also obtained a good match. Then, the best-fit flow and tracer models were used to predict reservoir behavior during the 30-day test period and during long-term production and injection. Once developed, FRACSIM-3D can analyze both reservoir enhancement (well stimulation) and reservoir operation. Stimulation analysis seems to be very powerful, including shear expansion (based on a single bulk stress). The reported stimulus results show a good correlation with the observed microseismic data. However, there has been active debate about the exact meaning of micro-earthquake events, especially in Hijiori, where the best connection to the fault system occurs in areas of relative earthquake. FRACSIM-3D draws cracks to form an uneven porous media model. Inevitably, this will lead to tailing of local gradients near fractures and may lead to optimistic predictions of reservoir life. Including simple chemical dissolution and deposition are useful functions.

4.1.4 Geocrack2D

Geocrack2D is a finite-element-based simulator developed by Swenson and Hardeman that focuses on flow in fractures and has been used to model the Fenton Hill and Hijiori reservoirs. The code can solve coupled thermal, hydraulic and mechanical problems where the flow is in fractures. A Geocrack2D model consists of rock blocks with nonlinear contact and discrete fluid paths between the blocks. Heat transfer occurs by conduction in the rock blocks and transport in the fluid. A tracer model is also included that uses particle tracking with thermal decay, diffusion, and adsorption of the tracer. The user interactively defines the finite-element mesh, the material properties, boundary conditions, and solution controls. Geocrack2D's discrete-fracture approach is similar to that used in FRACTure. The fracture aperture is a function of effective stress, flow is calculated using the cubic law, thermo-elastic effects are included in the model, and tracers are calculated using a particle-tracking algorithm. The model does not include coupling of fracture aperture to shear displacement, and there is no porous-medium flow. The program is interactive, with graphical feedback to the user in all phases. At the present time the implementation is 2-D; however, a three-dimensional version is under development.

4.1.5 TOUGH2

TOUGH2 is a general-purpose numerical simulation program for multi-phase, multi-component fluid and heat flow in porous and fractured media developed at Lawrence Berkeley National Laboratory of the U.S. TOUGH2 allows simulation of 1-D, 2-D and 3-D geometry of porous or fracture media. The heat and mass transfer processes are completely coupled. The transport of tracers with adsorption and radioactive decay is illustrated. The treatment of natural gas in the regulations is extensive, including all the major gases normally found in geothermal reservoirs. For dissolved solids, including the effect of NaCl precipitation and dissolution on porosity and permeability. One of TOUGH2's more important features is the multiple interactive continuity or "MINC" method. In EGS or HDR systems, there is usually a high temperature gradient between the matrix rock and the circulating fluid. MINC can distribute the rock matrix in order, so it can simulate the pressure and temperature transients between the matrix rock and the injected fluid. TOUGH2 allows irregular grid heights, so discrete cracks can be easily handled. When using an irregular grid, care must be taken because the accuracy of the solution depends on the accuracy of the various interface parameters in the flux equation that can be represented by the average condition in the grid block. A prototype interface between TOUGH2 and Golder Associates' FracMan discrete crack generator has been developed. No consideration is given to flow channel effects and discrete fracture pore size changes due to stress or thermoelastic effects. The compressibility and expansion coefficient constants of rock are used to simulate the influence of pressure and temperature on porosity and permeability. The space discretization is made directly from the integral form of the governing equations. This method avoids any reference to a global system of coordinates and allows irregular discretization of the considered domain.

4.1.6 TETRAD

The TETRAD simulator developed by the Calgary Computer Modeling Group in Alberta, Canada is a finite-difference numerical simulator that has been widely used in the simulation of hydrothermal, oil, and natural gas reservoirs. Conservation equations are expressed in the form of traditional differential equations and then discretized. These equations are fully coupled, and the simulator can be used to simulate one-dimensional, two-dimensional, and 3-D heat and mass flow in porous or fracturing media. The fracture can be specified by using the dual porosity/permeability option. It is assumed that each matrix or crack block is in local thermodynamic equilibrium. The Warren and Root formula is used to describe the interaction between the matrix and the crack. The simulator allows selective zoning of the considered reservoir area by using the "Local Mesh Refinement" option. This function allows partitioning of various parts of the basic grid, so that the selected part of the simulation area has a higher grid block resolution. However, this local mesh refinement method is not similar to the MINC method used in TOUGH2 and cannot be used to model pressure and temperature transients within the matrix block. TETRAD contains all the functions required for reservoir research. The unresponsive tracking package is comprehensive. Discrete cracks can be simulated, but does not include pore size changes due to stress or thermoelastic effects. The flow channel effect is not considered. The documentation is very rich, and TETRAD is considered to be one of the more user-friendly simulators in the industry.

4.1.7 STAR

The STAR simulator developed by Maxwell Technologies in San Diego, California has been used for hydrothermal, oil and gas reservoir simulation (including heavy oil thermal recovery). In the discretization of the governing equation, a finite difference scheme is adopted. It is a one-dimensional, two-dimensional or 3-D simulator that contains all the functions commonly found in hydrothermal reservoir simulators, including tracer modules, NaCl deposition and dissolution, and non-condensable gases. The standard processing method for rock compaction includes using a user-specified rock compressibility factor in the simulator. Changes in pressure and temperature lead to changes in rock porosity and permeability. STAR has been used for simulation studies in hydrothermal, natural gas and heavy oil thermal recovery projects. This is a typical reservoir simulator with all the necessary functions for hydrothermal reservoir simulation studies. The "Permeable Matrix" option can be used to simulate pressure and temperature transients between fractures placed in a rectangular grid system and matrix rock. The simulator includes a comprehensive non-reaction tracking package. Did not consider the effect of fluid channel, nor the effect of stress on fracture pore size.

4.1.8 FEHM

The FEHM (Finite Element Heat and Mass Transfer) developed by Los Alamos National Laboratory has been used to simulate hydrothermal fluids, oil and gas reservoirs, nuclear waste separation, groundwater modeling, and HDR reservoirs at Fenton Hill Reservoir. It simulates non-isothermal, multiphase, and multicomponent flow in porous media. Using the controlled volume finite element method, the heat and mass transfer equations of multiphase flow in porous media and permeable media are solved. The permeability and porosity of the medium depend on pressure and temperature. The specification also specifies the mobile air and water phases and uncoupled tracers (e.g. tracer solutions that do not affect heat and mass transfer solutions). The tracer can be passive or active. FEHM can simulate 2D, 2D radial or 3D geometry. Using double porosity/double permeability models or double porosity models, FEHM can simulate the flow controlled by fractures and fault flows in many areas. The code can handle coupled heat and mass transfer effects, such as boiling, drying, and condensation, and can incorporate various adsorption mechanisms, from simple linear relationships to nonlinear isotherms. FEHM is a powerful two-phase porous media model with good traceability and multiple reaction tracers. The formula is rigorous and well documented and has undergone extensive verification. FEHM can model the motion of water and steam phases and thermal motion through convection and conduction, making it very suitable for EGS simulations. FEHM combines 3-D volume elements with 2-D flat elements to allow integration with discrete fracture network (DFN) generators. The 3-D version (official release) does not include elastic deformation, discrete fractures or pore size changes due to stress or thermoelastic effects. These are only included in the 2-D version and are not widely used. A prototype interface between FEHM and Golder Associates' FracMan discrete crack network generator has been developed. FEHM does not provide mechanical coupling, but has a tracer test modeling interface, which is helpful for model calibration.

  DOI: https://doi.org/10.30564/frae.v3i3.2452

Table 1. Comparison for different software

Capability	FRACTure	GeoTH3D	FRAC-SIM-3D	GEOC-RACK
Discrete fractures	√		√	√
Aperture function of normal stress	√		√	√
Aperture function of shear			√	
Flow rate as function of aperture	√			√
Channeling	√			√
Porous flow in matrix	√	√		√
Thermo-elastic effects	√		√	√
Tracer transport	√		√	√
Multi-Phase Flow				
3D	√	√	√	√
Irregular grid			√	
Mineral deposition/dissolution			√	
Capability	**FEHM**	**STAR**	**TEDRAD**	**TOUGH2**
Discrete fractures	√	√	√	√
Aperture function of normal stress				
Aperture function of shear				
Flow rate as function of aperture				
Channeling				
Porous flow in matrix	√	√	√	√
Thermo-elastic effects	√	√	√	√
Tracer transport	√	√	√	√
Multi-Phase Flow	√	√	√	√
3D	√	√	√	√
Irregular grid	√			√
Mineral deposition/dissolution				√

4.2 Literatures of Simulation Development

At present, numerical simulation is the main tool for studying EGS systems. Initially carried out HDR (hot dry rock) exploration, HDR volume and grade evaluation, the construction of artificial geothermal reservoirs and heat exchange and transportation research. Huang et al. Based on the data from the HDR site of the Songliao Basin in China, the heat extraction process of fractured reservoirs was numerically simulated and the main parameter changes in the next 30 years were predicted. Chen et al. The long-term operation process of EGS system under different geological conditions is predicted by the numerical model developed by us. Song et al. CO_2 was used instead of water as the working fluid in the studied EGS. Wang and Zhang introduced the fracture network simulation method in the analysis of hydraulic fracturing and studied different conceptual models of EGS fracture flow. Due to induced earthquakes, the development of many new deep geothermal technologies (such as the Enhanced Geothermal System (EGS)) has slowed. The advanced traffic signal system can timely evaluate the efficiency of the implemented stimulus strategy to make changes, which can help the successful development of EGS technology. Karvounis et al. proposes a hybrid model modeling method that combines numerical calculation with stochastic geomechanical modeling and can be used from such traffic lights. The hybrid model can help probabilistically assess the risk of induced earthquakes and the thermal energy gains that should be expected from the decided stimulus strategy.

When controlling the feasibility and feasibility of the enhanced geothermal system (EGS), the permeability structure generated by the high fluid pressure of geothermal resources is the most important parameter. Miller used a minimalist approach to modeling, and the results showed that all observations from the Basel (Switzerland) fluid injection experiment matched well with a simple model that controlled the main system. It is a large-scale change in permeability at the beginning. The excellent agreement between the observations of these and these simplest models suggests that these systems may not be as complex as envisioned, and therefore provide strategies for more complex future modeling to help constrain and utilize these systems. McClure and Horne used a discrete fracture network simulator to perform the calculation model, which couples the fluid flow to the stress caused by the fracture deformation. The modeling results show that several geological conditions must be passed to enable stimulation to occur only by inducing slippage on existing fractures, and to avoid significant opening of new or existing fractures. In Börner's paper, virtual experiments can be used to optimize geophysical monitoring systems. Secondly, the 3D geological model is processed, meshed and used for finite element simulation research. Third, it shows the transient electromagnetic simulation results of a deep-enhanced geothermal system. Fourth, when using a borehole receiver, the detectable change in the measurement signal occurs by 25%. Börner concluded that the optimal positioning of the source and receiver requires advanced simulation techniques. In Xu, a new method for modeling flow and heat transfer in a complex fracture model is proposed. Second, for larger physical scales and longer spans, there is computationally feasible modeling. Finally, the model verification of the industrial scale enhanced geothermal system reservoir is carried out.

The evolution of EGS requires a spatial and temporal permeability field. During the injection of non-isothermal fluids, thermoelastic stress and fluid pressure changes will act on partially opened or hydrothermally changed fracture groups to increase the formation permeability. The physical couplings that drive this behavior are non-linearly dependent on each other to varying degrees. To explore these interactions, we are developing a simulator that can use multiple methods to couple the main physical principles of shear stimulation, thereby allowing flexibility when using integral or interleaved numerical schemes. Numerical simulation has become a standard analysis tool for scientists and engineers to evaluate the potential and performance of EGS. Various numerical simulators developed by industry, universities, and national laboratories are currently available and have been used to understand EGS on site. White and Phillips summarized the initial combination of seven benchmark problems, described code comparison activities, provided example results of the problem, and recorded the function of currently available numerical simulation codes to indicate that they occurred during the production of geothermal resources coupling process.

Biagi et al. studied the simulation of using CO_2 as a working fluid to extract heat from geothermal reservoirs; the underground flow simulation uses a multiphase flow solver TOUGH2; developed an optimized code based on genetic algorithms for geothermal applications; and CO_2. The injection rate is optimized for constant mass and constant pressure injection. Gaucher et al. provides a comprehensive overview of existing methods suitable for geothermal environments. The overview outlines the advantages and disadvantages of different methods, points out the gaps we understand, and describes the requirements for geothermal observations. In the paper, most of the prediction methods are focused on the stimulation stage of the enhanced geothermal system that is most prone to seismic events.

4.3 Coupled Simulation Development

4.3.1 Thermal-Hydro Coupled Model

When cold water is injected into the reservoir and hot water is pumped out of the reservoir after receiving heat energy, a hot liquid flow occurs. In the thermo-hydro coupling, the influence of deformation (the evolution of porosity/permeability due to fluid pressure and chemical reaction and the decoupling of deformation) can be ignored, but the fluid characteristics (such as viscosity, density, transmission, etc.) related to temperature and pressure Thermal coefficient, etc.) can be ignored. The main control variables that determine the endothermic performance of the system are important geophysical processes, such as advection, dispersion, diffusion, delay, buoyancy, and regional surface flow. In TH coupling, a lot of research has been conducted on the operation of geothermal reservoirs and reservoir parameters. A significant number of studies have been done on operational and reservoir parameters of a geothermal reservoir in TH coupling. These studies are grouped according to the factors such as fracture spacing, reservoir heterogeneity, reservoir thermal gradient, reservoir fluid salinity, injection temperature, flow rate, injection fluid properties, areal flow and well spacing.

4.3.1.1 Fracture Spacing

Kolditz modeled the heat transfer process in fractured crystalline rocks when extracting heat from HDR reservoirs. He studied the effect of size on heat extraction and compared the results of the 2½-D model with the 3D model. In the 2½-dimensional model, only the 1-dimensional heat conduction in the rock matrix is considered. The results of the study show that after 20 years of production, the 2.5-D model overestimates the heat loss by as much as 11% compared to the 3-D model. Zeng et al. studied the heat extraction of granite reservoirs in the Yangbajing geothermal field. Based on geological data at a depth of 950-1350 m, the reservoir was modeled at a uniform temperature of 248°C (ignoring the geothermal gradient). They modeled the heat extraction process in the reservoir by considering horizontal wells (dual well system). The results showed that the reservoir maintained 3.23–3.48MW of electricity for 20 years, with an energy efficiency of approximately 17.16%-50%. Zeng et al. numerically simulated granite reservoirs by considering horizontal and vertical wells. They showed that compared to vertical wells, the horizontal well system increased water production and reduced reservoir impedance parameters. The analysis also showed that the horizontal well system was more efficient due to the presence of buoyancy and also reduced the pumping capacity. Guo et al. investigated the power generation potential of the Songliao Basin (Northeast China). Use the TOUGH2-EOS1 code to perform 3-D coupled thermal fluid simulations. The changes of internal temperature and pressure of the reservoir under different mass flow rates and their effects on energy production were studied. Yu et al. applied the TOUGH-EGS code to study the thermal recovery potential in Yilan, Taiwan.

  DOI: https://doi.org/10.30564/frae.v3i3.2452

The parameters of different well distances were studied. The proposed model shows that the closer the distance between the water injection port and the production well, the faster the temperature drops, thereby reducing the heat absorption of the reservoir. Mudunuru et al. Use a reduced-order model to predict the thermal performance of the Fenton Mountain (second stage) geothermal reservoir. They concluded that the fracture zone permeability plays a major role in heat extraction. Few studies have undertaken reservoir stimulation measures to increase the reservoir's flow conductivity. Some past studies believe that there are multiple hydraulic fracturings in low permeability geothermal reservoirs. Multiple hydraulic fracturing provides more conductive flow paths and increases the surface area between the flowing fluid and the surrounding formation. Studies of multi-fractured reservoirs have shown that as the fracture spacing decreases and the number of reservoir fractures increases, the heat rejection performance also increases. Li et al. Through numerical simulation, by considering key sensitivity parameters (such as well spacing, lateral length, reservoir permeability and series of multi-fractured reservoirs), through numerical simulation, the mass flow is optimized, and the benefits are maximized Present value. Chen et al. consider randomly distributing fractures into 3-D low permeability reservoirs. Studies have shown that in larger fractured orifices, the fluid temperature in the production well decreases faster than in smaller fractured orifices. Shaik et al. studied the effects of mass flow and working fluid heat transfer coefficients in fractured geothermal reservoirs.

4.3.1.2 Reservoir Heterogeneity

The existence of spatial heterogeneity in the reservoir may cause water channeling and reduce the volume of the reservoir participating in the flow field. Huang et al. studied the effect of heterogeneity on thermal recovery performance and reservoir life. Vogt et al. studied the transient temperature and pressure of 400 sets of fault zones in a dual wellbore system to achieve heterogeneity in production wells. Their research shows that the distribution of porosity/permeability and thermal conductivity in the fault area greatly affects the heat rejection rate of the reservoir. Crooijmans et al. studied the effect of the phase heterogeneity (net-to-gross ratio, N/G) of geothermal dual structure under different operating conditions on life and energy production. In all groups of heterogeneous reservoirs, at lower N/G ratios, the temperature of the production wells decreases more slowly than higher N/G ratios. Willems et al. shows that if the well is placed parallel to the ancient flow direction, the pumping losses will be reduced. Hadgu et al. studied the effect of fracture orientation relative to the well-plane on the thermal recovery performance of heterogeneous reservoirs. They show that the orientation of horizontal wells is more effective than the orientation of vertical wells inside the reservoir, and the temperature decreases more slowly. Kalinina et al. showed that heat extraction and temperature drop usually depend on the horizontal/vertical distribution of the permeability field and the fracture spacing. Cracks in granite and carbonate reservoirs usually exhibit a rough surface. Few researchers have numerically studied the effect of crack roughness and heterogeneity on flow field evolution and endothermic properties. Neuville et al. studied the effect of crack roughness on heat extraction. Their results indicate that the roughness of the fracture may be the cause of fluid channeling inside the reservoir and affecting heat extraction.

4.3.2 Thermo-Hydro-Chemical Coupled Model

The injection of cold water into the geothermal reservoir will enhance the water-rock reaction, which will initiate the dissolution/precipitation process, change the pore geometry of the reservoir, and thus its hydraulic and transport characteristics, such as porosity/permeability. Many studies have focused on the evolution of porosity/permeability affected by geochemistry during thermal extraction. In fact, the rate of permeability change caused by thermo-water-chemical processes depends on reservoir mineralogy and temperature, and injection conditions (e.g. mass flow rate, injection temperature). Jing et al. numerically studied the effect of initial rock temperature and permeability evolution on dry-hot granite reservoirs. In their study, a 3-D fracture network was simulated in an equivalent porous medium. The permeability is calculated based on the pore size of a single fracture. The increase in pore size is related to local temperature and fluid chemistry. They found that with the enhancement of the water-rock chemical interaction, the evolution of permeability is more significant at high reservoir temperatures. Kiryukhin et al. numerically simulated the hot water chemistry (THC) process of different geothermal reservoirs in Japan and Russia. They observed that the rate of decrease in porosity depends on the mineral composition of the reservoir, temperature, and flow conditions (mass flow, single-phase/two-phase). Rabemanana et al.Bächler and Kohl and André studied the evolution of porosity/permeability caused by the dissolution and precipitation of Soultz granite (ie calcite, dolomite, quartz, and pyrite) in the Soultz-sous-Forêts enhanced geothermal system. These results indicate that the increase in porosity/permeability near the injection well is mainly due to the dissolution of calcite. The reaction rate kinetics of other minerals (ie quartz and pyrite) are slower than calcite. In Pandey's paper, numeri-

DOI: https://doi.org/10.30564/frae.v3i3.2452

cal simulations were conducted in fractured limestone reservoirs. The results show that the evolution of the fracture transmittance is sensitive to the injection temperature and the concentration of dissolved minerals in the injection water. In both saturated and undersaturated cases, due to rapid changes in reservoir solubility and reaction rate, the transmittance of fractures is not monotonous in time. They reported that the transmissivity evolution is faster at higher injection temperature than for lower injection temperature. In fact, in a carbonate reservoir, facture heterogeneities have a minor role in flow channeling and their effects are insignificant in heat extraction. Research by Pandey et al. and Pandey and Chaudhuri show that the rapid reaction kinetics and retrograde solubility of calcite lead to very different flow patterns compared to silicate reservoirs. This indicates that the higher water-rock (especially calcite and slower dolomite) interactions in carbonates may create significant complexity in the heat extraction process. However, in granite reservoirs, injection of fresh water/unsaturated water at a lower injection temperature (>70°C) will enhance the heat extraction and dissolution of minerals, resulting in a longer flow path.

4.3.3 Thermal-Hydro-Mechanical-Chemical (THMC) Simulation Models

Geothermal reservoir simulation can increase geothermal recovery efficiency by about 10% and provide data on drilling depth and location to reduce drilling costs. At present, the EGS numerical simulation including the thermal-water-mechanical-chemical (THMC) coupling process is not yet fully mature. The five EGS sites in the United States all use THMC simulation technology suitable for the site characteristics. Currently, there are twelve EGS simulation programs funded by grants from the US Department of Energy. The total expenditure is about 10.34 million US dollars, accounting for 17-27% of the total funds, which shows the importance of numerical simulation technology. Seven laboratories and institutions funded by the US Department of Energy are involved in the development of hydraulic fracturing simulation technologies, including PNNL, LANL, LBNL, Pennsylvania State University (PSU), OkU, Colorado School of Mines (CSM) and INL. Because geothermal reservoir simulation involves formation parameters, it is difficult to accurately quantify uncertainty. For example, the assumptions and numerical limits should be set according to the local reservoir environment. It is difficult to simulate all formation environments with one software, so there are many geothermal numerical simulation software packages, and it is difficult to quantitatively evaluate their advantages and disadvantages. After Stanford University evaluated the thermal simulation software available worldwide in 1981, no new simulation software was evaluated for the next 32 years. Since geothermal development is based on local conditions, it is necessary to conduct a preliminary evaluation; therefore, it is important to choose the appropriate simulation software. PNNL compiled a database of software information and analyzed their functions to understand the advantages, disadvantages, and simulation accuracy of each numerical model.

The THMC simulation technology developed by LBNL mainly focuses on the cross-software integration of geochemical simulators, such as TOUGHREACT, ROCMECH and FLAC3D. The hydraulic fracturing simulation of Newbury EGS was performed using isotope measurements and TOUGHREACT/ROCMECH. The main body of the TOUGH EGS module was developed by CSM and is composed of resources from the LBNL TOUGH series and Computer Modeling Group Ltd. The mass and energy conservation equations of TOUGHEGS are the same as those of TOUGH series, and all use the integral finite difference method. The mechanical equilibrium equation is based on the assumption of pore thermoelectricity, and the geomechanics module and the mass transfer module are fully coupled. For geochemical coupling, TOUGHREACT convergence issues and mechanical and mass/heat transfer modules have been improved simultaneously. For the fracture module, the geochemical reaction and mass/heat transfer between the fracture and the bedrock are processed through multiple continuous processes to adapt to the in-situ discrete fracture conditions. PSU developed a model that is capable of evaluating the shock that is caused by hydraulic fracturing. The model was verified at the Soultz, the Geysers, Cooper Basin and Newberry EGS sites. A relationship between the porosity-permeability and the fractured surface was defined in the model. In conjunction with TOUGHREACT and FLAC3D, a spatial permeability evolution mode was also added to improve the asynchronous disadvantage of the continuous mode of the coupled THMC. By considering the development of stress and fractures that are caused by the contact with microscopic particles as well as their permeability, the discontinuous mode is fit onto a cellular grid for the hydraulic fracture simulations.

5. Working Fluids

Early and current attempts to develop EGS in the United States, Japan, Europe and Australia all use water as a heat transfer carrier. As a heat carrier, water has many advantages, but it also has serious defects. A disadvantageous property of water is that it becomes a strong solvent for dissolving rock ore materials at high temperatures. After

  DOI: https://doi.org/10.30564/frae.v3i3.2452

the water is injected into the hot rock fissures, it produces a strong dissolution and precipitation effect, which changes the permeability of the fissures, which makes it difficult to operate the EGS in a stable manner. Water and carbon dioxide (CO_2) are popular working fluids, mainly discussed in EGS. Compared with the idea of using carbon dioxide, water has been used as a heat transfer fluid in several EGS projects. In view of the problems in the operation of EGS with water as a heat carrier, in recent years, scholars and related research institutions at home and abroad have conducted studies on the use of supercritical carbon dioxide as a circulating fluid to strengthen the geothermal system. This method can avoid a series of problems that may be caused by the injection of aqueous solution, while achieving the resource utilization of carbon dioxide, it can also be stored in the underground medium. This is of great significance to the reduction of carbon dioxide emissions and the utilization of renewable energy, and this field is showing broad application prospects.

5.1 Compassion with Water and CO_2

Brown initially proposed a CO_2-based enhanced geothermal system (CO_2-EGS), in which supercritical CO_2 is used as a working fluid that absorbs heat. The author points out the advantages of using CO_2 as a reservoir fluid for effective thermal recovery. Many studies have reported the importance of using supercritical CO_2 in reservoirs because of its high heat absorption rate, large expandability and compressibility. CO_2 fluid temperature changes will produce a high-density ratio, resulting in significant buoyancy, which reduces buoyancy. In addition, as global temperatures rise, people strongly encourage efforts to reduce carbon dioxide emissions, and the idea of using carbon dioxide as a working fluid in geothermal heat combined with the storage and thermal recovery of carbon dioxide has attracted researchers and industry. CO_2 is a non-polar solvent, which means that it has low salt solubility, which reduces the possibility of scaling and sedimentation in the wellbore and surface equipment, so there is no obvious mineral dissolution and precipitation in the enhanced geothermal system using CO_2 problem. However, Brown also pointed out that the lower heat capacity of CO_2 is not conducive to the effective exploitation of geothermal resources, but the faster CO_2 flow rate due to the lower viscosity of CO_2 can partially offset the adverse effects of heat capacity. Table 2 compares the advantages and disadvantages of CO_2 and water that can be used as heat transfer fluids in enhanced geothermal systems.

Table 2. Comparison between CO_2 and Water

Fluid characteristics	CO_2	Water
Chemical characteristics	Non-polar solvent; weak solvent for rock minerals	Strong solvent for rock minerals
Fluid circulation characteristics in the wellbore	Greater compressibility and expansion, subject to greater buoyancy; with lower energy consumption, can maintain fluid circulation	Less compressibility; moderate swelling, less buoyancy; larger pumping equipment needed to provide energy to maintain fluid circulation
Fluid flow characteristics in the reservoir	Lower viscosity, lower density	Higher viscosity, higher density
Fluid heat transfer characteristics	Smaller specific heat capacity	Biger specific heat capacity
Fluid loss characteristics	May contribute to the geological storage of greenhouse gases (CO_2), and obtain certain economic benefits by reducing greenhouse gas emissions to offset part of the cost of thermal energy extraction	Water loss will increase engineering costs (especially in arid areas), hindering the geothermal development of reservoir

5.2 CO_2 as Working Fluid

In 2006, Pruess conducted a quantitative study on the characteristics of heat transfer and mass flow in a CO_2-enhanced geothermal system through simulation work for the first time. In addition, the simulation study also compared the differences between enhanced geothermal systems using CO_2 and water as heat transfer fluids under certain thermodynamic conditions. For the simulation of the CO_2 enhanced geothermal system, the study used a two-dimensional model. Because of the greater density difference between the hot fluid near the production well and the cold fluid near the injection well in CO_2-EGS compared to water-EGS, there will be a significant buoyancy effect. The simulation results show that under the same initial reservoir conditions (temperature 200 °C, pressure 50 MPa), the thermal recovery rate and mass flow rate of CO_2-EGS are significantly higher than that of water-EGS, which is because of the At lower temperatures (about 40 °C), the increase in water viscosity is more pronounced than CO_2, thereby enhancing the mobility of CO_2 near the injection well. Pruess also conducted a sensitivity study on the initial reservoir temperature (120, 160, 200, and 240°C, respectively). Sensitivity simulation results show that under low temperature conditions, the increase in thermal recovery rate is more obvious. This

DOI: https://doi.org/10.30564/frae.v3i3.2452

simulation result also made us realize that the method of using CO_2 to extract geothermal resources can be applied not only to high-temperature geothermal systems, but also to low-temperature geothermal systems. In addition, the simulation results of the sensitivity to the injected CO_2 temperature and the initial reservoir pressure show that the increase of the injected CO_2 temperature (from 20 ℃ to 40 ℃) gives CO_2-EGS an advantage over water-EGS in geothermal energy exploitation. Weakened, and the reduction of the initial reservoir pressure (from 50 MPa to 40 MPa) will make this advantage more obvious.

Based on the above research, Pruess studied the energy production of CO_2-EGS under different initial reservoir pressure conditions based on a two-dimensional model. The simulation results show that the initial reservoir pressure has no effect on water-EGS energy production, but has a significant effect on CO_2-EGS, and the latter's thermal recovery rate is significantly higher than the former. For CO_2-EGS, under different initial reservoir pressure conditions, the thermal recovery rate changes with time show some unique characteristics, because temperature and pressure will affect the fluid density and viscosity changes, and thus the mobility of CO_2 cause an impact. Based on the above simulation results, Pruess pointed out that in order to obtain a better geothermal production effect, it should be more feasible to set the production port of the production well at the top of the reservoir. This can prevent the cooled fluid from flowing directly into the bottom of the reservoir, thereby extending the flow path of the cooled fluid and helping to obtain more thermal energy from the reservoir. Further simulation results also confirmed the above conclusion.

In 2010, Atrens et al. used radiation instinct (the maximum work that can be done in a thermodynamic system from a given state to equilibrium with the surrounding medium) to represent the potential power generation capacity of different geothermal mining systems. However, it should be noted that in actual situations, due to the different thermodynamic characteristics of CO_2 and water in the production well, the surface power generation equipment used is also different, and the amount of power generation directly depends on the specific design of the surface equipment (such as (CO_2-EGS may use a turbine, while water-EGS may use a double-circulation system). Their simulation results show that the exothermic instinct produced by CO_2-EGS is lower than that of water-EGS. The reasons are as follows: ① CO_2 has a lower heat capacity than water, so a larger CO_2 flow rate is required to maintain an approximate thermal recovery rate; ② CO_2 in production wells has a lower density than water. The above two characteristics cause a greater pressure to drop in the production wells in CO_2-EGS. Under the influence of Joule-Thompson expansion, the temperature of the CO_2 fluid is lowered, thereby reducing the potential power generation capacity of the system. Their sensitivity to different processes and reservoir parameters showed that in high-impedance and shallow reservoirs, CO_2-EGS produces similar instincts as water-EGS. In addition, as the diameter of the wellbore increases, the potential power generation capacity of CO_2-EGS increases, but their effect on water-EGS is not obvious. The above evaluation work provides a theoretical basis for the future site selection and design of geothermal power plants related to CO_2-EGS.

It should be noted that Pruess pointed out that the traditional enhanced geothermal system will cause the presence of an aqueous phase in the geothermal reservoir, and the use of CO_2 as a heat transfer medium to continue mining the geothermal resources in the reservoir is a potential geothermal energy. Increasing production measures, and the hydraulic fracturing method used to increase cracks in dry and hot rocks will also cause a certain amount of water in the cracks. The above situation will further increase the complexity of CO_2-EGS, so a more accurate and clear understanding of the following process is required: ① The multiphase flow process between supercritical CO_2 and the aqueous phase involves the immiscible phase of CO_2 to water Displacement, the dissolution of CO_2 in the water phase, and the dissolution of the water phase in supercritical CO_2, etc., which requires obtaining the thermophysical characteristics of the mixed state of aqueous solution and CO_2 under typical pressure and temperature conditions; ② Supercritical CO_2-water- The geochemical process of rock and supercritical CO_2-rock involves the dissolution and precipitation of minerals, changes in physical characteristics of the reservoir, etc.

Spycher et al. pointed out that under the typical temperature and pressure conditions of CO_2-EGS, the phase partition behavior between the water phase and the supercritical CO_2 phase will have significant changes, so the establishment of a wide range of temperature and pressure conditions of CO2 and The phase distribution model of the mixed state of the aqueous solution is of great significance to accurately simulate the multiphase flow and the reaction solute transport process in CO_2-EGS. They improved the phase allocation model to increase the effective temperature range of the current model from the original 100 ℃ to 300 ℃ , which can basically meet the needs of simulating high-temperature geological conditions for CO_2 mining geothermal resources, and they used modified and The improved phase distribution model is the first to simulate the geothermal

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exploitation of CO_2 in the aquifer geothermal reservoir. The simulation results show that, in the initial stage of CO_2 injection, the fluid produced by the production well is a single-phase aqueous solution. With the continuous injection of CO_2, the production rate of CO_2 in the production wells began to increase, while the production rate of the aqueous solution decreased. This shows that with the continuous injection of CO_2, the relative permeability of supercritical CO_2 increases. Finally, when no aqueous solution is produced in the production well, the fluid produced is only supercritical CO_2.It should be noted that the CO_2 production rate will increase significantly at this time, because the CO_2 under single-phase conditions is absolutely The permeability is higher than the relative permeability of CO_2 under two-phase conditions; in addition, a certain amount of water will be dissolved in the supercritical CO_2 produced, and as the water in the reservoir gradually decreases, the water content in CO_2 will also gradually reduce. They also pointed out that the industrial design of CO_2-EGS previously envisaged for power generation is to directly add the generated CO_2 fluid to the turbine, so it can reduce operating costs and heat losses in heat exchangers. However, the above simulation results show that the produced CO_2 has a high content of water dissolved in it. Therefore, before adding CO_2 to the turbine, the produced fluid needs to be dried to avoid the formation of water condensation and low temperature and low-pressure conditions.

Based on the principle, feasibility and economy of CO_2-EGS, the research progress of CO_2-EGS is discussed, and the following conclusions are obtained. (1) For enhanced geothermal systems, as a potential heat transfer medium, supercritical CO_2 has greater advantages than water, such as CO_2 is a weak solvent for rocks, has greater compressibility and expansion, and Lower viscosity, etc. However, in practical applications, it is also necessary to pay attention to the shortcomings of CO_2, such as lower density and specific heat, which are not conducive to the effective exploitation of geothermal resources. (2) The use of supercritical CO_2-EGS, while mining geothermal resources, also helps to reduce greenhouse gas emissions. (3) For geothermal reservoirs that are potentially used for geothermal development, at lower initial reservoir temperature conditions, the increase in thermal recovery rate is more pronounced, and under different initial reservoir pressure conditions, supercritical The geothermal exploitation of CO_2 reservoirs may show some unique characteristics, depending on the temperature and pressure conditions that affect the mobility of CO_2. (4) For the engineering design of CO_2-EGS, the increase of the injected CO_2 temperature and the decrease of the borehole diameter are not conducive to the effective exploitation of geothermal resources.

6. Additional Support for EGS Plant

6.1 Communication

The construction of the communication system of this project is to provide a bearing network for the SCADA data, voice and video transmission of the process stations related to crude oil long-distance transportation, and at the same time set up video surveillance camera front ends and amplified broadcast telephone terminals for each process station.

At present, there are three commonly used transmission methods at home and abroad: optical fiber communication, wireless broadband communication and satellite communication.

The selection of the technical solution of the engineering system should save investment as much as possible on the premise of meeting the technical requirements, and the satellite communication method has a large investment, the capacity is relatively small compared to the optical fiber communication, and the performance-price ratio is at a disadvantage. Therefore, the satellite communication method is not suitable for this project. No further discussion will be made in this design. The optical fiber communication mode has large transmission capacity, long relay distance, stable transmission quality, and is not disturbed by external factors. The wireless broadband communication method has flexible networking, high transmission rate, and easy expansion.

According to the actual needs of this project, the communication system must not only be safe and reliable, but also save investment as much as possible. Therefore, comprehensive analysis is considering the actual situation of the project, but higher requirements for transmission quality, optical cable communications in the formal development stage can be easily incorporated directly into the new optical fiber communication transmission network. Based on the comprehensive situation, the design recommends the use of optical fiber transmission communication as the communication transmission scheme of this project.

Considering the actual situation of this project, the optical fiber transmission system considers the use of multi-service uncompressed video optical transmission equipment networking. Install light receiving equipment at the loading station and light emitting equipment at the remaining stations. The system carries SCS data, video and control signals and voice transmission services from the joint station to the loading station.

6.2 Power Supply and Distribution

6.2.1 Power Supply System

This design builds a 110kV substation near the first station of the overseas transmission to provide power for the entire project area.

6.2.2 Lightning Protection and Static Grounding

According to the requirements of "Code for Design of Lightning Protection of Buildings" (GB50057) and "Code for Design of Grounding of Industrial and Civil Power Installations" (GBJ65), all structures, stations and process pipelines shall be provided with necessary lightning protection and anti-static grounding according to the specifications , Working ground and protective ground.

Each station's transformation and distribution room is provided with a ring-shaped closed common grounding grid, the grounding resistance is less than 1Ω, and the metal shell and process equipment of all live equipment are grounded for protection.

For buildings that need protection against direct lightning strikes, Φ10 galvanized round steel is used as the lightning protection belt, and Φ10 galvanized round steel is used as the downline. The metal pipes and devices protruding from the roof are reliably connected to the roof lightning protection device.

There shall be no less than 2 connection points between grounding trunks and grounding devices for lightning protection in all buildings. The metal pipes introduced into and out of the building should be connected to the lightning protection grounding device at the entrance and exit, and the overhead metal pipes should be grounded once at a distance of about 25m from the building. The impact ground resistance is not greater than 100Ω.

The main metal objects such as equipment, framework, pipelines in the house should be connected to the lightning protection grounding device or the protective grounding device of the electrical equipment. All pipes and equipment that may be exposed to static electricity in the outdoor are connected into a continuous electrical path and grounded. The grounding resistance is not greater than 30Ω.

Bare metal brackets are placed outside the entrance of the explosion hazardous environment as anti-static facilities and there should be obvious signs, and the metal brackets should be grounded. In the production process, anti-static shoes, anti-static work clothes, anti-static gloves and other personal static protection facilities should be used; static test equipment should be provided to grasp the amount of static electricity carried by yourself before entering an explosion-proof place to take measures. The antistatic grounding resistance is not greater than 100Ω.

6.2.3 Laying Method of Distribution Lines

The power distribution adopts copper core insulated cable, the indoor part is laid underground through steel pipes, and the outdoor part is laid directly buried with armored cables. The lighting circuit adopts copper-core insulated wires through steel pipes and is dark-matched along the wall and the roof insulation layer. The lighting circuits in explosion and fire hazard locations are equipped with steel pipes. The selection of the cross-section of insulated wires and cables shall comply with the relevant regulations and be determined through calculation.

6.2.4 Electric Lighting Distribution Design

Install emergency emergency lighting in substations and power distribution rooms. Electrical lighting in explosion and fire hazard locations should meet explosion-proof requirements. The illuminance standard implements "Building Lighting Design Code" GB50034 2004. According to different lighting requirements, the light source of the lighting fixture is selected to comply with the relevant national standards and standard equipment products. Among them, the road lighting in the station is planned to use a mixed sodium and mercury light source, the light pole uses a steel column, and PVC power. Buried cable laying, photoelectric automatic control and manual control.

6.2.5 Communication

Power distribution of instrument automation system and instrument automation do not allow uninterrupted power supply. Therefore, non-interruptible power supply (UPS) is used. For UPS power supply, see the communication and automatic control section.

6.3 Building Structure

In order to improve the level of earthquake resistance, the seismic intensity of this design is 7 degrees, and the basic earthquake acceleration value is 0.1g. In general, buildings take earthquake-resistant fortification measures according to the corresponding fortification intensity. First, select a structural system that meets the requirements of seismic fortification intensity. The plane and floor layout and shape treatment of buildings should avoid and reduce the seismic weak links as much as possible. Energy absorption and dissipation structure. For class B buildings, the "Classification Standards for Seismic Fortification of Construction Projects" (GB50223-2008), and according to the "Code for Seismic Design of Buildings" (GB50011-

DOI: https://doi.org/10.30564/frae.v3i3.2452

2010), take seismic measures in accordance with the requirements to increase the seismic fortification intensity of the region by one degree. Except for the control center building, compressor room, and empty torch tower, the seismic fortification category is Category B, and the other buildings and structures are considered as Category C.

Because the project area belongs to the mid-temperate semi-humid and semi-arid continental monsoon climate. How much wind and little rain in spring, large evaporation; cool and short in summer, concentrated precipitation; rapid fall in autumn, early frost; long cold in winter, long snow area. The monthly minimum temperature is -37.8℃, and the monthly maximum temperature is 32.9 ℃. The annual sunshine hours are 2049.5 trivial, and the frost-free days are 126 days. The architectural design focuses on thermal insulation in summer and thermal insulation in winter. According to the "Code for Thermal Design of Civil Buildings" (GB50176-93), the building should not be too large from the direction, shape factor, unevenness of the flat facade, the area of the external window of the building should not be too large, double-layer windows, stucco insulation coating Consider thermal insulation of buildings.

6.4 Heating and HVAC

6.4.1 Design Principles

Strictly follow the current national standards of thermal engineering and HVAC, and the compromise documents formed by the current national standards, and design in accordance with the principles of practicality, advancedness and economy. Adopt high-efficiency, low-consumption, low-pollution equipment, implement the "safe and reliable" guiding ideology, simplify the technological process, achieve the purpose of saving investment and reducing operating costs. Fully consider environmental protection, soil and water conservation and energy conservation.

6.4.2 Heating

According to the heat load requirements for the production of process devices in each station of the block, the heating load of individual building heating in winter in the plant area, and the heat load for process heat tracing, etc., the automatic heat conduction oil furnace heating system is used for the whole plant. Heating. The scale of the heating station is 2 automatic heat conduction oil furnaces, with a single heat load of 8000kW, and the operation mode is 1 for 1 standby; according to the requirements of the heating parameters for the domestic base hot water for the operation base and the winter heating load of the building unit, etc. , It is planned to use a hot water boiler to heat the operation base. The design scale of the boiler room is 2 hot water boilers, with a single heat load of 1.4MW, and the operation mode is 1 set for 1 use.

6.4.3 Keep the Room Warm

The control room uses a heat pump type cabinet air conditioner with auxiliary electric heating to meet the requirements of cooling in summer and heating in winter. In order to meet the environmental temperature and humidity requirements of process equipment and instruments in the duty room, air conditioners and electric heating devices are installed.

6.4.4 Ventilation

The ventilation of the plant is a combination of mechanical ventilation and natural ventilation. Some production plants will emit toxic gases during production operation. In order to reduce the concentration of toxic gases to the allowable range of hygienic requirements or to eliminate indoor residual heat, forced ventilation with natural air intake and mechanical exhaust may be adopted. Axial fans or the roof fan is fully ventilated to remove harmful gases and indoor residual heat.

6.5 Automation Control

The SCADA system should be used for production and operation management in this project area. In order to ensure safe production and improve management level, this project sets up a production monitoring system (e.g. SACDA system) for the entire block. The production monitoring system (SACDA system) is divided into three layers from the logical structure:

The first layer is the production management, decision-making, dispatch and command system, which is the production monitoring system with the SCADA central control system as the core; the second layer is the monitoring system located in each station, which is the control and management of each production operation area; The third floor is a small station control system located in each intermediate station and valve room.

The central control system of SCADA system (that is, the management, scheduling, and decision-making system of the central processing plant) is located in the production dispatching command center of the loading station, with a complete and unified production database and application database, and centralized production monitoring of each station under its jurisdiction , Scheduling and management. The station control system of the SCADA system is a monitoring system set up in the station yards along the line. Responsible for the data collection and processing of the production process and the automatic control and process management of the production process; and collect and monitor the production operation to realize the centralized scheduling and management of the production operation area. At the same time, upload the production data and production information to the central control system, accept the production command and scheduling instructions of the control center, and complete the specific realization of the production plan.

6.6 Fire and Explosion Protection

6.6.1 Causes of Fire and Explosion

The subjective cause of the fire in the oil tank area is often due to the lack of attention of the personnel concerned, paralysis, inadequate system, poor management, and violation of operating rules. The objective reasons are:

(1) When the electrical equipment is short-circuited, the contacts are separated, the shell is poorly grounded, etc., the arc and spark are caused, or the heating part of the electrical equipment exceeds the maximum allowable temperature;

(2) Sparks caused by metal impact;

(3) Static electricity and lightning;

(4) Spontaneous combustion of combustibles, such as sulfur-containing oil deposits in oil tanks spontaneously ignited during removal, and accumulated oily garbage spontaneously ignited;

(5) Fire spread around the oil depot, etc.

6.6.2 Fire and Explosion Prevention Measures

The oil tank in the ground oil tank area is exposed above the ground, the target is obvious, and it is greatly affected by external factors, especially the risk of fire is large. After the accident, the oil products are easy to flow, causing damage and involving a large area. Therefore, it is necessary to enclose the fire dike around the oil tank or oil tank group. According to the requirements of GB50074-2002 "Code for Design of Petroleum Depots", the fire separation distance between oil tanks should meet the requirements of Table 8.1, the oil tanks in the group should be arranged in a row or two lines, and the distance between the slopes of the two oil tank firewalls Should be greater than 9.5m.

In addition to setting up fire dikes, it is also necessary to avoid fire and explosion by establishing a sound management system:

(1) Formulate Relevant Rules and Regulations

Establish a mass fire-fighting organization, formulate fire-fighting regulations and fire-fighting plans, divide fire-fighting areas, specify fire alarm signals, regularly organize fire-fighting education and fire-fighting exercises, and be skilled in using fire-fighting equipment.

(2) Cut off the Fire Source

① It must be strictly managed in the fire restricted area (oil storage area, receiving and sending operation area), and strictly abide by the relevant rules and regulations. No fires, such as matches and lighters, are allowed in the fire restricted area; smoking is not allowed; steam locomotives are not allowed to enter the warehouse The front chimney should be covered with a fire hood, fly out with a fire star, and close the gray door; it is forbidden to open the blower and put down the gray box baffle in the warehouse, and do not open the steam door and remove the water from the furnace; when the locomotive enters the warehouse, it There must be several isolation vehicles between the tank truck and the locomotive; the locomotive should be reversed into the warehouse; the locomotive should leave the tank truck as soon as possible after entering the tank area; the vehicle is not allowed to drive in the restricted area;

② Prevent sparks caused by metal impact, and do not wear iron spiked shoes for storage; mules and iron wheels are forbidden to enter the storehouse. Because the horseshoes and iron wheels of the horses collide with gravel or cement roads on the road, sparks are prone to occur; use metal tools and When handling oil drums, avoid collisions to avoid sparks;

③ No open flames (such as oil lamps, candles, etc.) should be used for lighting, nor should ordinary electrical equipment be used for lighting. In order to prevent electrical equipment from causing sparks due to short circuits, contact separation, etc., explosion-proof electrical equipment must be used in the restricted area;

④ In the event of thunderstorms, do not load, unload, measure and sample gasoline, kerosene and diesel fuel.

(3) Do a good job in fire prevention of dangerous operations

Open flame operations such as electric welding, gas welding, and forging in the oil depot area are the most stringent safety requirements and relatively dangerous operations. Therefore, they must be carried out in strict accordance with regulations. Before conducting an open flame operation, a fire application must be submitted. After approval, effective fire safety measures should be taken before the fire can be used. When working with fire, firefighters who are able to cope with any situation should be assigned to be on duty, and be prepared for first aid in the event of an accident.

(4) Handle combustible materials

The treatment of combustibles in the oil depot includes

  DOI: https://doi.org/10.30564/frae.v3i3.2452

the treatment of the oil itself and other combustibles that cause the oil to catch fire.

① Prevent oil vapor accumulation and oil leakage and splashing. When the oil vapor concentration exceeds the safety regulations, mechanical ventilation or natural ventilation should be used to remove the oil vapor, or measures should be taken to collect oil and gas so that it will not escape into the air as much as possible. When oil is spilled, cover with sand or shovel clean;

② Fire dike or firewall should be built on the ground oil tank;

③ In order to prevent the spontaneous combustion of sulfur-containing materials, when removing the sediments of sulfur-containing crude oil tanks, the sulfur-containing sediments should be continuously wetted with water. After the sulfur-containing sediments are taken out, they must be transported away and buried in the soil while wet. Oily gauze and rubbish should be placed in covered iron drums and removed in time. Do not stack them in a place where there is no wind to prevent spontaneous combustion;

④ Dispose of other combustibles in time. It is forbidden to store and remove combustible materials, such as wood shavings, cotton yarn, hay, garbage, etc. around oil tanks, warehouses, pump rooms, etc.

(5) Ensure that firefighting equipment is in good condition and reliable

① The oil depot should have sufficient fire extinguishing equipment. In the warehouse, pump room, barrel room, laboratory, loading and unloading station, cavern and other places, sufficient fire extinguishing equipment and firefighting pool or fire hydrant shall be arranged. And set up fire-fighting points in appropriate places, equipped with all rescue equipment, such as buckets, fire hooks, shovel, axe, etc.;

② Fire equipment should be intact and reliable. It is necessary to check and maintain at ordinary times, and it is forbidden to use it for other purposes. Fire trucks and fixed firefighting equipment should be launched regularly. Always maintain good technical status.

6.7 Fire Protection at Station

6.7.1 Fire Extinguishing Principles and Methods

The principle of fire suppression is to destroy the combustion conditions. According to the three conditions of combustion and the chain reaction that constitutes flame combustion, three basic physical methods of cooling, suffocation and isolation are often used in firefighting technology to extinguish fire and chemical interruption.

(1) Cooling method

The purpose of the cooling method is to absorb the heat released during the oxidation of combustibles. For burned substances, the temperature can be lowered to below the ignition point, while the decomposition process of combustibles is suppressed, and the speed of combustible gas generation is slowed down, causing the fire to be extinguished due to the "supply shortage" of combustible gases. For other combustibles in the vicinity of the combustibles, they can be protected from the threat of flame radiant heat and destroy the combustion temperature conditions.

(2) Asphyxiation

The suffocation method is to eliminate the combustion aid oxygen O2, so that the combustion extinguishes itself when it is isolated from fresh air. The methods of using this method to extinguish fires are:

1) Use non-combustible or incombustible materials to directly cover the surface of the combustible materials to isolate fresh air;

2) Use water vapor or refractory gas to spray on the combustion products to dilute the oxygen in the air and reduce the oxygen content in the air to less than 9%. For example, the steam in the pump room extinguishes the fire;

3) Try to seal the holes and gaps of the burning container, so that the flame will extinguish after the air in the container is exhausted. For example, after a fire in a cavern, closing a closed door is one of suffocation.

(3) Quarantine

The isolation method is to isolate the fire source from combustible materials to prevent the spread of combustion. The specific methods are:

1) Quickly remove combustibles, combustibles, and explosives near the fire;

2) Demolition of combustible buildings and fire debris adjacent to the fire site in time;

3) Cut off combustible and flammable substances into the burning zone;

4) Limit the flow and splash of burning materials;

5) Move the movable combustibles to an open place, so that the combustibles burn under human control. For example, the tank truck caught fire and quickly dragged out of the warehouse.

(4) Chemical interruption method

Chemical interruption method is also called chemical suppression method to extinguish fire. It is a new fire-extinguishing technology developed rapidly in modern times. The new combustion theory believes that combustion is a chain reaction maintained by certain active groups. Chemical fire extinguishing means spraying a chemical fire extinguishing agent into the flame. With the help of chemical fire extinguishing agents, the generation and existence of these active groups are inhibited, and the chain reaction of combustion is prevented to stop the combustion, thereby achieving the purpose of extinguishing the fire. Commonly used chemical fire extinguishing agents include dry powder fire extinguishing agent and high-efficiency halogenated fire extinguishing agent.

6.7.2 Fire Extinguishing Methods and Equipment

Foam fire extinguishing facilities and fire cooling water system should be installed in the oil tank area in the station.

(1) Fire extinguishing with foam

According to the design of fire extinguishing equipment, it is divided into fixed, semi-fixed and mobile fire extinguishing systems.

1) Fixed air foam fire extinguishing system It is a semi-automatic foam fire extinguishing device. This system means that all equipment is fixed. There is no need to connect other equipment when extinguishing the fire. When the oil tank fires, just start the water pump (prior to prime the pump before starting), open the pump outlet valve, rotate the foam proportion mixer pointer to the required foam liquid volume index, and mix The device mixes the foam liquid automatically with water in proportion and transfers it to the foam generator through pumps and pipelines. After inhaling the air, the foam is formed and sprayed into the oil tank to cover the oil surface and extinguish the fire.

The fixed air foam fire extinguishing system has the advantages of no need to lay pipelines and installation equipment during fire extinguishing; rapid start-up, fast foam output; simple operation, saving manpower; low labor intensity and so on. The basic disadvantage is that the equipment has a large investment at one time, such as the collapse or explosion of the oil tank, and when the fire fighting equipment installed on the oil tank is damaged, the entire system loses the ability to extinguish the fire. Therefore, when the fixed air foam fire extinguishing system is used, a head is often left on the foam pipe network close to the oil tank area, so that when the fire fighting equipment on the oil tank fails, the mobile fire extinguishing equipment is replaced.

The fixed air foam fire extinguishing system is mainly suitable for oil tanks where the oil tanks are relatively concentrated, the number of independent oil depots and the oil tanks with few fire fighting lines required is relatively small, and the oil depots with complex terrain.

2) Semi-fixed foam fire extinguishing system

This system is equipped with a fixed foam generator on the oil tank and some auxiliary pipelines underneath (it should be connected to the fire dike of the oil tank, about 1 m above the ground, and the end should also be installed with an interface, usually equipped with a boring cover) Outside, cover), other equipment is removable. In case of fire, drive the fire truck with foam liquid to the scene, take water from the reservoir or fire hydrant, and supply the foam mixture to the foam generator fixed on the oil tank with a temporarily installed hose.

Since the water for preparing the foam mixture comes from the cooling water pipe network, there is no need to set up a special foam pipe network, so the construction investment and maintenance cost of this system are lower than the former, but it requires a motorized fire truck and a water pump, and a certain amount Operator. It is suitable for oil depots with relatively flat terrain.

3) Mobile foam fire extinguishing system

The mobile foam fire extinguishing system is to replace the foam generator on the fixed oil tank by foam guns, foam guns or foam hook pipes, foam pipe racks and other equipment. The equipment and equipment are movable, so it is called the mobile foam fire extinguishing system. It has the advantages of good safety, flexible use, low investment, etc., but the operation is complicated and the preparation time for fire extinguishing is long. It is suitable for oil depots with many oil tanks, scattered layout and relatively flat terrain.

According to the requirements of GB50074-2000 “Code for Design of Petroleum Depots”, since the loading station uses three 3000m3 floating roof tanks, the foam fire extinguishing facility uses a fixed foam fire extinguishing system.

(2) Fire cooling system

For firefighting of oil tanks, two systems should be considered, namely fire extinguishing system and cooling system. The cooling system is set to prevent the fire tank steel plate from softening and to protect the adjacent tank; on the other hand, it is also necessary for the fire extinguishing with foam. Because of the fire in the oil tank, the flame temperature is generally 1050-1400°C, and the temperature of the oil tank wall reaches above 1000°C. When the temperature of the tank wall exceeds 600°C, the foam cannot extinguish the tank fire. After the oil tank catches fire, the tank wall should first be cooled with water. When the temperature of the oil surface drops below 147 ℃ , it is possible to cover the fire with foam. Under normal circumstances, when the foam enters the combustion liquid surface, the foam evaporates and bursts very quickly. Because the foam evaporates, the oil is cooled. When the oil surface temperature drops below 147 ℃ , the foam layer can advance on the combustion liquid surface to burn. The surface continues to decrease, and finally covers the entire combustion liquid surface to extinguish the fire. At this time, the foam continues to burst (evaporate) until the

  DOI: https://doi.org/10.30564/frae.v3i3.2452

oil temperature drops below 98 ℃, the foam evaporation is gradually reduced, and then, the oil surface temperature continues to drop until it reaches the liquid surface temperature before combustion.

According to the requirements of GB50074-2000 "Design Specification for Petroleum Depot", since the loading station uses three 3000m3 floating roof tanks, the fire-fighting cooling water system adopts a mobile cooling water system or a combined fire-fighting cooling water system with a fixed water gun and a mobile water gun.

6.8 Lightning Protection

A large number of flammable and combustible fuels are stored in the oil tank. Once a lightning strike occurs, serious fire and explosion accidents may occur. Therefore, the problem of oil tank lightning protection has attracted people's attention.

The current commonly used lightning protection devices to prevent oil tanks from direct lightning strikes include lightning rods, lightning protection lines, lightning protection nets, lightning protection belts, and lightning arresters. A complete set of lightning protection devices includes air-termination devices, down conductors and grounding devices. The above needles, wires, nets, and belts are actually just lightning receptors, and the lightning arrester is a special lightning protection device. The lightning rod is mainly used to protect open-air substation equipment and protect buildings (structures). Lightning conductors are mainly used to protect power lines. Lightning protection network and lightning protection belt are mainly used to protect buildings. Lightning arresters are mainly used to protect electrical equipment. In short, the lightning protection device can prevent direct lightning strikes or the introduction of lightning currents to the ground to ensure the safety of people and buildings (structures). There are generally two types of floating roof oil tanks: an outer floating roof oil tank and an inner floating roof oil tank. Three $3000m^3$ outer floating roof tanks are installed in this loading station. The outer floating roof oil tank is tightly sealed, and the oil product has a small area of contact with the atmosphere and direct contact with the atmosphere. The mixed gas of oil vapor and air on the floating roof is not easy to reach the explosion limit, even if a lightning strike catches fire. It also happens only when the sealing ring is not strict, and it is easy to extinguish. Lightning rods are not required. In order to prevent the induction of lightning and the static charge from the oil away to the metal floating roof, two soft copper strands with a cross-sectional area of not less than $25mm^2$ should be used to make a good electrical connection between the metal floating roof and the tank, and ground.

6.9 Anti-static

The friction between two different substances is a special form of static electricity, but it is not the only way. In addition to friction, the separation of two different substances in close contact, the pressure or heat of the substance, the electrolysis of the substance, and the induction of the substance by other charged objects may generate static electricity. When the liquid phase and the solid phase, between the liquid phase and the gas phase, between the liquid phase and another incompatible liquid phase, and between the solid phase and the gas phase, due to flow, stirring, sedimentation, filtration, scouring, spraying, The relative motion of contact and separation such as perfusion, splash, violent shaking and foaming will generate static electricity in the medium. Many petrochemical products are highly insulating substances. During the production, storage and transportation of this type of non-conductive liquid, a large amount of static charge is generated and accumulated, and spark discharge can occur when the static electricity accumulates to a certain extent. If there is also explosive gas in the discharge space, it may cause fire and explosion. Therefore, it has very important significance for the anti-static hazard in the oil depot.

The generation of static electricity control is mainly to control the process and the selection of all materials in the process; the accumulation of static electricity is mainly to try to accelerate the leakage and neutralization of static electricity so that the static electricity does not exceed the safety limit. Grounding and the addition of antistatic additives are all methods of accelerating electrostatic leakage; methods of using static elimination devices to eliminate electrostatic hazards are methods of accelerating electrostatic neutralization.

(1) Reduce the generation of static electricity

Impurities in oil products are important factors for electrostatic charging, however, it is difficult and uneconomical to achieve high precision in oil products. From the current state of technology, there are no measures that can completely prevent the generation of static electricity. Therefore, in order to prevent the damage of petroleum static electricity, the generation of electrostatic charge cannot be eliminated, and only the technical measures to reduce the generation of static electricity are available.

1) Control flow rate

It is known that the saturation value of the flowing current and charge density generated by the oil flowing in the pipeline is proportional to the square of the oil flow rate. Controlling the flow rate is an effective way to reduce the

DOI: https://doi.org/10.30564/frae.v3i3.2452

generation of static electricity. When the oil is in laminar flow, the amount of static electricity generated is only proportional to the flow rate and has nothing to do with the inner diameter of the pipeline; when the oil product is turbulent, the amount of static electricity generated is proportional to the 1.75th power of the flow rate.

The flammable and combustible liquid flowing in the pipeline, even with a higher average charge density, often does not show a higher electrostatic voltage due to the larger capacitance in the pipeline, and because there is no air in the pipeline, So it will not cause burning and explosion. In this case, although static electricity does not constitute a danger inside the pipeline, its serious harm is mainly at the outlet of the pipeline, which must be paid attention to. For example, China's oil tanker loading test shows that when the average flow rate is 2.6m/s, the measured oil surface potential is 2300V; when the average flow rate is 1.7m/s, the oil surface potential is 580V (because the tanker is on the ground) The capacitance is constant, the greater the charge, the higher the potential). Therefore, controlling the flow rate becomes an effective measure to reduce the generation of static electricity in oil products.

According to GB50074-2002 "Code for Design of Petroleum Depot", the filling flow rate of gasoline, kerosene and light diesel oil is not more than 4.5m/s. Some national regulations. When oil is injected from the top, before the oil injection pipe mouth is submerged, before the oil inlet pipe inlet at the top of the oil tank is not submerged, before the floating roof oil tank is not floated, when water or air is trapped in the product oil or flammable liquid, install The oil speed is limited to less than 1m/s.

2) Control the fueling method

This loading station adopts the method of upper oil loading, in order to reduce the impact of oil loading on the tank wall, reduce the agitation of crude oil in the tank, and reduce the accumulation of static electricity. When loading oil, the crane pipe should be extended close to the bottom of the tank truck. this is okay:

① Reduce oil splashing and foaming to avoid the generation of new charges;

② Reduce the atomization and evaporation of oil, and avoid the ignition of oil when it reaches the flash point temperature;

③ Avoid oil flow through the middle of the oil tank with the smallest capacitance, so as not to generate a large oil surface potential;

④ It can avoid the formation of high oil surface charge density due to the concentrated drop of oil column in a local range;

⑤ In the later stage of oil filling, when the oil surface potential reaches the maximum value, there is no protruding metal grounded on the upper part of the oil surface, which can avoid the increase of local electric field and prevent spark discharge.

3) There is enough leakage time when passing through the filter

The filter is a source of static electricity. The oil passing through the filter, due to the dramatic friction with the filter, greatly increases the strength of contact and separation, which may increase the voltage of the oil by 10-100 times.

In order to avoid injecting large amounts of charge into the container. In the oil pipeline connected with the filter, a certain length should be left at the outlet or flowed for a certain time, the ground charge will be leaked out, and then injected into the container. This length should be $L \geq 3Lb$ is called the relaxation length, if it is calculated as time, it is $t \geq 3\tau$, which is called the relaxation time or residence time.

When the length of the pipeline is limited and cannot meet $L \geq 3Lb$, consider designing a container so that the oil has a temporary relative residence in the container, and its residence time $t \approx 3\tau$. This container is called a moderator. General engineering only requires that the amount of charge leak to a level that does not cause danger, so it can be considered that the residence time $t \approx 2\tau$ can meet the requirements. It is generally stipulated that the oil passing through the filter must have a relaxation time of more than 30s. Therefore, the oil passing through the filter must continue to flow through the pipe length of more than 30s in the grounding pipeline before it is allowed to enter the container.

In order to avoid static electricity accidents. The reasonable arrangement of equipment pipelines has a great relationship with the control of static electricity. For example, the filter should not be close to the oil tank or the oil loading platform, and a certain length of relaxation should be left; the pipeline should be free of bends and diameter changes. Where rubber hoses must be used, conductive rubber tubes or conductive plastic tubes are preferred.

(2) Accelerate static electricity leakage and reduce static electricity accumulation

The generation of static electricity itself is not dangerous. The actual danger is the accumulation of electric charge, because this can store enough energy to generate sparks to ignite the combustible gas mixture. It is generally believed that when the resistivity of the insulator is less than $108\Omega\cdot m$, there will be no dangerous static electricity accumulation. However, the resistivity of oil products is almost greater than $108\Omega\cdot m$, and the

DOI: https://doi.org/10.30564/frae.v3i3.2452

charge in the oil products is not easy to leak, so the more static charges that are generated in the oil products are accumulated. In order to accelerate the leakage of oil charge, it can be grounded, bridged and increased the conductivity of the oil.

(3) Eliminate spark discharge

In order to eliminate spark discharge, the bottom of the tank must be cleared before filling the tank, and no floating conductors and other debris that fall into the tank, such as liquid level gauge floats, measuring cylinders, gaskets and other metal objects. Testing and sampling must be carried out in the oil measuring tube. If no special oil measuring tube is installed, such as conducting a simple sampling, dipstick, etc., these metals are also equivalent to spark initiators on the oil surface. According to relevant information, when oil tank cars are refueled, the discharge phenomenon will occur when the oil surface potential reaches about 28kV, but when there are free insulating metal objects on the oil surface, that is, there are quite a few charge collectors, as long as 1~ 2kV. There will be a discharge.

When the oil in the oil tank is finished, it must not be tested. This is because the maximum value of the oil surface potential sometimes occurs after the oil tank is stopped during the oil tank filling process. For safety, when it is necessary to directly measure the liquid level or oil temperature, the leakage time of the static charge in the tank should be avoided. Generally, it takes about 30 minutes to allow the settling charge in the oil to leak before it can be detected. The crane pipe of the tank truck is also a promoter of spark discharge. The crane pipe is well grounded to avoid the spark discharge of the crane pipe and the inner wall of the tank truck. However, the spark discharge of the crane pipe and the oil surface may still occur. Therefore, before changing to bottom filling, the crane pipe should be extended to the bottom of the tank truck to fill the oil; the oil injection pipe that extends into the oil tank should be as close as possible to the bottom to avoid the end of the oil filling (At this time, the oil potential is the highest) the oil surface and the protruding part of the crane pipe (oil injection pipe) are discharged. Therefore, when carrying out the oil filling operation, do not stand on the tank top, let alone do other operations.

7 HSE Risk Management for EGS

"HSE" is the abbreviation of Health, Safety and Environmental Management System. H is Health, S is Safety, E is Environment, and HSE management system is a common management method in the international petroleum industry.

7.1 HSE management of Injection and Production Pipeline

7.1.1 Analysis of Hazardous Factors for Pipelines

(1) pipelines are transported by surface, buried, etc. In the season of heavy precipitation, natural geological disasters such as mudslides, landslides, landslides caused by flash floods and floods caused by river floods often occur in the region. These disasters may cause damage to the pipeline.

(2) Factors such as poor pipeline anti-corrosion quality, mechanical damage to the anti-corrosion layer caused by pipeline construction, soil moisture, salt, alkali, and underground stray current will cause pipeline corrosion, and in serious cases, cause pipe perforation and cause accidents.

(3) When the pipeline is cleared during the operation period of the external pipeline, there may be too many corrosion products in the pipeline, which will cause the pig to be stuck, thereby forming an overpressure pig, which will cause the risk of pipeline and equipment holding back and rupture.

(4) Due to the incomplete purge and replacement of the device before it is shut down for maintenance, or the maintenance site is not well separated from the toxic medium, the maintenance personnel may be in a limited space during the process of disassembly, knocking, hot work, dynamic welding, etc. Poisoning or suffocation.

7.1.2 Safety protection measures of pipeline system

The safety of pipeline system engineering generally includes the safety of design, construction, operation management, external transportation, etc. There are many emergencies on pipelines and gathering and transportation facilities, such as pipeline leaks and fires. First of all, different measures should be taken according to different emergencies to ensure that the damage and impact of the emergencies on the public, environment, and property are minimized. Considering the safety during the design, construction and operation of the project, it should meet the relevant regulations in SY618-1996 "Safety Regulations for Oil and Gas Pipelines".

(1) Security measures

Reasonable use of advanced and mature design technologies and products at home and abroad; follow national safety production regulations, design documents comply with standards; strictly divide the scope of hazardous areas, and propose corresponding technical requirements, measures, supporting settings and operating points during design, and implement hazardous Provisions for grade division; fully consider the integrity and reliability of the oil pipeline safety system. Carry out hierarchical management on the safe operation of pipelines. Responsibility is assigned to people. Production management and operation personnel should have a strict job responsibility system; prepare safety management regulations and regular inspection plans; formulate and enforce safety training plans for all employees; establish engineering technology Files and records of accidents; establish a complete system of line inspection, maintenance, and transformation; formulate and strictly implement regulations on labor safety and health.

(2) Environmental protection measures

1) Influencing factors of engineering environment

The environmental impact of the project during the construction period mainly comes from the construction of station yards, construction access roads and pile yards, leveling construction belts, excavation of pipe trenches, construction machinery, vehicles, and trampling of soil, etc. Impact on land use types and agricultural production. In addition, the exhaust and noise emitted by various machinery and vehicles during construction, the amount of solid waste discarded during construction, and the wastewater generated by pipeline pressure testing will also have a certain impact on the environment. However, such impacts caused by the construction are temporary, and will disappear within a short period of time after the construction is completed (Table 3). The specific construction measures should be worked out according to the surrounding soil, vegetation, and environmental characteristics of the block, and a reasonable construction site and access road should be designed to isolate the agricultural block as much as possible, protect the vegetation, and control the waste and noise generated by the construction operation Within a reasonable range to minimize the impact on the environment.

Table 3. Environmental impact analysis of engineering construction team

Construction type	environmental impacts
Construction site and construction access road	Destruction of surface vegetation and soil structure
Pipe trench excavation	Change soil, affect vegetation growth and development
Construction transportation and photo album work	Produce multi-phase pollutants, exhaust gas, exhaust gas

2) Environmental impact during operation

The impact of various stations and pipelines on the environment during operation is relatively small, mainly air pollution and water pollution. The air pollution mainly comes from the discharge of pollutants from various stations. This kind of discharge is mainly the CO_2 produced by burning natural gas or crude oil during the operation of the equipment into the atmosphere; in the event of an accident, the crude oil in the system must be emptied for inspection and repair work ; The period of pigging operations varies from 10d to 30d, each time the crude oil is discharged from several cubic meters to tens of cubic meters; the overpressure of the system in the first station and the loading station of the outbound transportation will empty the crude oil, and the probability of this situation is small. According to relevant information, compared with the analog survey, the frequency of occurrence is 1-2 times/year, and the duration of each time is 2-5min. The water pollutants discharged from the first station and the loading station are mainly domestic sewage. In addition, there is a small amount of wastewater discharged during the pigging operations at each station.

In addition to domestic garbage, solid waste discharged from the first station and the loading station of the outbound transportation will also generate a small amount of solid waste during dust removal and pigging operations. The main components are dust, welding slag and iron oxide powder. Through the above comprehensive analysis, the corresponding pollutant control system was worked out (Table 4).

Table 4. Pollutant control measures

Type of pollutant	Treatment measures
Water pollutant	The sewage discharged from the plant, the sewage from the pipe cleaning, and the clean water from the device maintenance are collected and collected into the sewage tank and then loaded and transported to the central treatment plant for treatment; the domestic sewage treatment is discharged after reaching the standard.
Waste residue	The waste generated during the short-term pigging operation enters the sewage tank, and a small amount of domestic garbage is regularly sent to the garbage treatment plant.
Noise control	Choose throttling, blowout prevention devices and metering equipment that meet noise standards.

(3) Energy-saving measures

Crude oil can not only transport large amounts of energy, but also consume energy. Therefore, conscientiously implementing the relevant energy-saving technology policies of the state and group companies, actively adopting energy-saving technologies and equipment, using energy reasonably, striving to reduce energy consumption, doing a good job in energy conservation, and economically and rationally delivering crude oil are important goals of the project design. According to the characteristics of well site and pipeline operation, the energy consumption of this project mainly includes the following aspects: fuel gas consumption of self-provided small generator set; fuel gas consumption of heating furnace; fuel consumption of external pumps and loading pumps; production water,

  DOI: https://doi.org/10.30564/frae.v3i3.2452

Electricity; Consumption in the event of an accident in the pipe network system or policy maintenance. From the perspective of energy saving, the following measures have been formulated:

1) Set up pipeline cut-off valves to divide the pipeline into several small sections to reduce the crude oil loss of the oil pipeline;

2) Imported products such as high-efficiency energy pumps and other energy-saving equipment and pipeline shut-off valves are used.

7.2 HSE Management of Station

7.2.1 Analysis of Hazardous Factors in Stations

(1) The main accident hidden points of the station are pressure vessels such as external pumps and oil storage tanks. The low-carbon steel inner tube with a certain corrosion resistance is selected for the heating furnace in this design station. From the perspective of its working environment, there is a large range of fluid disturbances, and the change of crude oil composition affects its working life under certain conditions. At present, there is no full-scale monitoring means, so it should pay special attention in the production operation. If periodic inspection or replacement measures are not adopted, it is easy to cause corrosion, hydrogen embrittlement, explosion, fire and other major accidents.

The working conditions of the oil storage tank are also more complicated. Although internal anti-corrosion measures are adopted, they may also cause leakage or burst due to factors such as blockage, local pitting corrosion and valve failure, and cause major fire accidents. In addition, arcs and electric sparks caused by short circuit, grounding of the shell, and separation of contacts of the electrical equipment in the station may cause fire and explosion.

(2) Hidden dangers in station yards are the most prone events, mainly the hazards of crude oil leakage. Often caused by corrosion of pipes and devices and seal failure, or incomplete cleaning before maintenance.

(3) Hidden danger of emergency overpressure system. Generally, emergency shut-off valves are used to limit crude oil emissions during system process design, but when a certain emergency situation occurs in the treatment plant, only full venting measures can be taken, resulting in short-term excessive leakage, which is easy to produce pollution and cause human and animal environments. influences.

7.2.2 Security Measures for Stations and Yards

(1) Safety precautions

Strict implementation of the "Design Standards for Industrial Enterprises" (GBZ1-2002). Conscientiously implement the principle of "safety first, prevention first", and implement the current standard specifications in the design, so that the joint station, the first station of overseas transmission, and the loading station can meet the safety and health requirements, and all devices achieve long-term and stable production. The safety and health of employees in the process are not compromised. Therefore, the following protection work should be done:

1) Explosion-proof

The focus of explosion protection is on piping systems, pressure vessels and electrical installations. For the former, inspection and regular maintenance should be strengthened, and for the latter, it should be carried out in strict accordance with the "Code for Design of Electrical Devices for Explosive and Fire Hazardous Environments" (GB50058-92).

① Safe and reliable process equipment that is not easy to leak and low noise is used in the station.

② Seriously check the quality of equipment, materials and construction and installation quality, and minimize the unsafe factors; all pipes are made of seamless steel tubes that meet the standards, have good processing performance and good weldability; the welders must be qualified Certified welder; construction personnel should operate in strict accordance with relevant specifications to ensure the quality of the project.

③ The overall layout of the station is in accordance with the design specifications to ensure the safe distance of each area.

④ Lightning and anti-static measures are taken at the station, lightning protection belts are installed, and the process equipment and pipelines are grounded to avoid possible natural gas leakage and fire or explosion due to lightning strikes or static sparks.

⑤ All pressure vessels in the station comply with the design, manufacture and safety management regulations of pressure vessels.

2) Fire protection

Strictly implement the "Code for Fire Protection of Petroleum and Natural Gas Engineering Design" (GB50183-2004) and set up a water fire protection system throughout the site; the safety emergency rescue station shall be on duty 24 hours to meet the fire protection requirements.

① Process fire protection. The process design adopts safe and reliable equipment materials, strict construction quality requirements to ensure the quality of the project; formulate strict and correct fire protection measures for repairs, be equipped with corresponding firefighting facilities, and have full-time and part-time firefighting supervisors on-site supervision.

② Prevention of fire and explosion. Provide employees with safety and fire prevention education and training so that employees can grasp the correct knowledge and skills of fire prevention and fire extinguishing, set up safety fire prevention supervision posts, and implement fire prevention policies that focus on prevention and combining prevention and control.

3) Anti-noise

① Select low-noise equipment, and pay attention to control the speed of fluid entering and exiting the separator in the design of the separator. The flow rate of fluid entering and leaving the separator can also be controlled by adjusting the opening of the valve during production.

② Reduce or limit the working and staying time of staff under high-decibel noise, and conduct regular medical examinations for staff who often work in noisy environments.

(2) Environmental protection and pollution prevention

This project fully considers the requirements of environmental protection in the design, strictly in accordance with environmental protection standards, and has adopted effective treatment measures for wastewater, waste gas, waste residue, noise and other pollution sources discharged during the production process.

① Sewage treatment

According to the requirements of the State Administration of Work Safety and the State Environmental Protection Administration, all water that may cause pollution to the environment will be monitored and discharged after passing and discharged into the sewage treatment plant if it fails. The volume of the accident pool takes into account the collection of fire water, rainwater and possible leaking liquids, which can ensure the pollution of the army's water environment in the event of an accident. The project wastewater mainly comes from the production wastewater discharged intermittently by the process equipment such as tail gas treatment, the initial rainwater in the plant area, the wastewater from the engineering shutdown and maintenance of the equipment, domestic sewage, etc. Sewage treatment and drainage shall implement the first-level discharge standard of the Comprehensive Wastewater Discharge Standard (GB8978-1996).

② Waste disposal

The wastes generated in this project mainly include waste residue and waste gas. Waste residues need to be transported to the garbage disposal station for treatment. The waste gas can be burned as fuel or directly emptied.

(3) Energy-saving measures

In order to reduce the energy consumption of the station, such as the combined station, the first station of overseas transmission, and the loading station, the following energy-saving measures have been adopted:

① Select energy-efficient electrical equipment with advanced technology to increase the power factor of the power supply network and reduce the energy consumption of the power grid and electrical equipment itself.

② Adopt high-efficiency heat-insulating material, perfect heat preservation structure, reduce heat loss of equipment and pipeline.

③ Recover steam condensate as much as possible to improve the recovery rate.

7.3 Hse Management System Construction and Operation

7.3.1 HSE System Construction

Combined with the characteristics of the block, on the basis of extensive research on domestic and foreign safety management experience and lessons, combined with the understanding of previous field practice, a series of related systems have been formulated to form a complete HSE management system.

(1) Regulations on safety management of construction engineering

Strengthened the supervision and management of the safety production of the construction teams of construction projects. The safety and environmental protection department of the block construction project headquarters is fully responsible for the work safety supervision and assessment of each unit, and formulates corresponding safety and environmental protection measures for the construction unit, and strictly implements the pre-construction acceptance regulations according to the construction characteristics of the block.

(2) Work area safety and environmental protection training and education management system

Strengthen the safety and environmental protection training and education of the participants in the work area. All management and technical personnel in the work area should be considered: safety management, HSE and other qualification certificates.

(3) Notification of safety management of contractors in the work area

The project contractor is required to apply for safety construction qualification review to the safety and environmental protection department after obtaining the construction project contractor's construction qualification issued by the project management department. The project contractor must conduct HSE training and issue an HSE certificate after being evaluated by the safety and environmental protection department.

(4) Regulations on traffic safety management in con-

DOI: https://doi.org/10.30564/frae.v3i3.2452

struction area

According to the climate and road conditions of the work area, please refer to the unit insisting on carrying out traffic safety education for all personnel and regularly carrying out team safety activities. The vehicle must strictly control the speed of the vehicle according to the road signs; it must master the changes in the rainy season and the river; check the braking system after the vehicle passes the water, drive at a low speed for a distance, and wait until the braking performance is restored before driving at normal speed.

7.3.2 HSE System Implementation

In order to ensure the effective implementation and operation of the above-mentioned HSE safety system, in line with the principle of "focusing on management outside and promoting learning internally", the following work is carried out to connect and promote each other to ensure that the HSE system penetrates into all links.

(1) Implement graded safety supervision and management system

Established a unit supervision system and strengthened safety supervision and management responsibilities, and each grassroots unit of Party A and B is the grassroots execution unit of enterprise safety management as shown. The headquarters set up a safety and environmental protection department, and all participating units set up safety and environmental protection supervision agencies; each grassroots department is equipped with a full-time safety and environmental protection supervisor.

(2) Improve the grade requirements of engineering design and construction operations

The engineering design shall be carried out in strict accordance with the geological design, and the security measures for the inspection of engineering gathering and transportation shall be inspected. The Safety and Environmental Protection Department of the headquarters took the lead in organizing an expert group to carry out risk identification and risk assessment on key risk wells.

(3) Organize safety education and training for all employees

Pre-job training and education strictly follow the requirements. All staff who enter the area, no matter what position they have been engaged in or what professional training they have received, must strictly follow the principle of "training before going to work" and receive special training in safety and environmental protection projects to ensure that they have Improve the safety and environmental awareness and skills of the specific situation of the block.

7.4 Emergency Support System

In order to fully standardize emergency management work, establish and improve the emergency response mechanism of the region, quickly, orderly and efficiently organize various emergency response operations, rescue people in distress, and minimize the casualties and property caused by emergencies For loss and environmental damage, according to relevant national regulations, emergency plans for various accidents have been specially formulated.

7.4.1 Classification and Classification of Emergencies

(1) Classification of emergencies

According to the occurrence process, nature and mechanism of emergency events, through hazard identification and risk assessment, the block emergency events are divided into several aspects as shown in Table 9.3, so that different emergency treatments can be carried out for different emergency events. And the implementation of measures.

(2) Classification of emergencies

In order to effectively deal with all kinds of emergencies, according to the nature of the emergencies, the degree of harm, the scope of impact, the size of influence, casualties and property losses, it is divided into four levels from high to low: I (group company) level , II (headquarters) level, III (participation unit) level, IV (basic unit) level. The participating units shall classify the determined emergency events according to the nature, severity, controllability, impact range and other factors of the emergency event, and according to the setting of the organization.

7.4.2 Principles of Emergency Work

(1) Safety first, prevention first, all hands-on, comprehensive management, ecological protection, and pollution prevention

Emergency rescue work should follow the principle of prevention first and unremitting standing, strengthen the awareness of prevention, strive to reduce the occurrence of attempted incidents, make unremitting efforts to prevent accidents, and make all preparations for responding to emergencies to ensure the normal progress of all production.

(2) Putting people first, reducing harm, focusing on prevention, combining prevention with prevention

Effectively perform the management, supervision, coordination, and service functions of the functional departments of the headquarters and take the protection of employees' life and health as the primary task. The headquarters and all participating units should make full use of the rescue forces of the enterprise, unit and nearby society, and establish an emergency rescue system with clear responsibilities, rapid response, powerful command and effective measures. Use the required resources and take necessary measures to minimize emergencies and the resulting casualties, hazards and environmental pollution.

(3) Integrate resources and coordinate responses

Integrate the existing emergency resources within the enterprise, make full use of social emergency resources, realize the organic integration of organization, resources, and information, and form an emergency management mechanism with unified command, responsiveness, complete functions, coordinated order, and efficient operation.

(4) Rely on technology to improve quality

Strengthen scientific research and the development of emergency technology, use advanced monitoring, monitoring, early warning, prevention and emergency response technologies and equipment to give full play to the role of experts, provide scientific and technological content and command level for handling emergencies, and avoid the occurrence of times Health, derivative incidents; strengthen publicity and education to improve the overall quality of employees' self-rescue, mutual rescue, and emergency response to various emergencies.

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Study on the Oil Pipeline Design of R Oil Field

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ARTICLE INFO

Article history
Received: 4 October 2020
Revised: 11 October 2020
Accepted: 24 October 2020
Published Online: 30 October 2020

Keywords:
Pipeline development
Oil-water transportation
HDD
HSE

ABSTRACT

It's a compressive article consists of three parts, an overview of pipeline development in China, oil pipeline design for R oilfield and pipeline management suggestions. First, this article introduces the current status of pipeline construction, oil pipeline technology and gas pipeline technology in China in recent years. The current status of China's pipeline construction is divided into three stages. In terms of construction, pipeline construction is developing in the direction of intelligence and modernization. Long-distance oil pipelines require technical breakthroughs in two aspects. One is the sequential oil product delivery technology to improve the type of oil that can be delivered sequentially; the second is the viscosity reduction delivery technology for heavy oil. Gas transmission pipelines are developing in the direction of high pressure, large diameter and high steel grade. Secondly, based on all the pipeline development above, in order to meet the development of R oil field, an oil-water two-phase pipeline transportation design and a pipeline crossing river design were carried out. Under the condition of the design pressure of the pipeline of 5.5MPa, it is preferable to produce a pipeline of φ219×6.5mm, and the steel grade of the pipeline is L360. A heating station and pumping station are needed in the transportation process, and the heating station and pumping station are combined for one construction. Considering that the strata of the river crossing section are mainly gravel sand layer, clay layer and non-lithological stratum, horizontal directional drilling (HDD) is adopted for river crossing, and suggestions are made for the construction process. Finally, after the pipeline was put into production, the corresponding auxiliary production system and supporting engineering suggestions were put forward.

1. Introduction

1.1 The Art of Pipeline Construction in China

1.1.1 First Construction Phase

In the 1970s, the Northeast crude oil transportation pipeline network marked by the "August 3" pipeline project opened the prelude to the construction of China's long-distance oil pipelines. Welding and pipeline installation are mainly carried by people. In the 1990s, the oil and gas pipelines represented by the Ku-Shan line and the Donghuang double-track line were first used in China with X65 steel grades (micro alloyed controlled steel, carbon content of 0.10% to 0.14%). The pipe diameter is 610mm and the pressure is 8MPa. Construction began to apply self-protected flux cored wire semi-automatic welding on a large area, and a centralized control system was adopted throughout the line. The first generation of pipeline construction technology (steel grade

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DOI: https://doi.org/10.30564/frae.v3i3.2453

below X70, pipe diameter below 1000mm, and pressure not greater than 8MPa) was started, and a total of 2.6 pipelines were constructed. $\times 10^4$km, taking a new step in China's long-distance oil and gas pipeline construction technology to catch up with the world's advanced level [1].

1.1.2 Second Construction Phase

The West-East Gas Pipeline, which started construction in 2000, used X70 steel grade materials (multi-component micro alloy controlled rolling and controlled cold steel, carbon content 0.01% to 0.04%) for the first time, with a diameter of 1016mm and a pressure of 10MPa. Pipe end diameter expander and other technologies and equipment, make the pipe end dimensional accuracy, residual stress control and other indicators reach the international advanced level. The second West-East Gas Pipeline, which began construction in 2007, was the first large-scale use of domestic X80 steel grade materials with a diameter of 1219mm and a pressure of 12MPa. After unremitting research, China has made significant progress in the development of X80 pipeline steel pipes, successfully achieved precise control of micro alloy elements such as carbon and niobium, and achieved ultra-micro control of harmful elements sulfur and phosphorus, mastering the smelting and rolling of X80 high-strength steel Manufacturing process, formulated technical standards for high-strength pipes, developed high-strength and high-toughness X80 sheet; developed high-grade pipeline steel pipe forming process, and fully realized the localization of X80 large-diameter thick-walled steel pipes. The performance indicators of the second-line steel pipe meet the standard requirements, especially the excellent fracture toughness of the steel pipe, which can meet the crack arrest requirements of the 12MPa gas pipeline. In terms of welding process, we have successfully applied the fully automatic welding process, established automatic welding and semi-automatic welding construction systems, realized welding construction with a minimum ambient temperature of -45°C, and established requirements for the toughness index of girth welding joints for the characteristics of China's welding process. Solved the problem of pipeline welding across the seismic fault zone and winter low temperature environment. It has developed a series of supporting equipment such as beveling machine, butt joint, internal welding machine and external welding machine, which represents the most advanced technical level of pipeline welding in China at that time. China's natural gas pipeline has generally adopted large-scale combustion and electric drive compressor units. The unit power of the combustion drive compressor unit is 30MW and the total power reaches 3300MW; the unit power of the electric drive compressor unit is 18MW and the total power reaches 2400MW [2]. So far, the second generation pipeline construction technology has been formed (steel grade X70, X80, pipe diameter 1000~1219mm, pressure 10~12MPa, transmission volume 100×10^8~$300\times 10^8 m^3/a$), a total of 8.3×10^4km of pipeline construction, realized China's high-grade, large-caliber, high-pressure long-distance oil and gas pipeline construction technology has made a new leap from catching up to leading [3].

1.1.3 Third Construction Phase

Since the "Twelfth Five-Year Plan", focusing on the construction of key pipeline projects and adhering to the concept of safe and efficient operation, we have carried out key technical indicators such as steel grades X90 and X100, pipe diameters of 1219~1422mm, pressures of 12MPa, and throughput of $300\times 10^8 m^3/a$ and above. A major scientific and technological project represented by the "Key Technology Research on the Third Generation of Large-Volume Natural Gas Pipeline Project" has broken through a series of key technical difficulties restricting the construction and operation of pipeline engineering, and gradually formed the third generation pipeline construction technology. In order to realize China's large-capacity pipeline construction, technical reserves have been made [4]. As of the end of 2017, the total mileage of China's long-distance oil and gas pipelines has reached 131,400 km, of which natural gas pipelines are approximately 72,600 km, crude oil pipelines are approximately 30,900 km, and refined oil pipelines are approximately 27,900 km, accounting for 54.9%, 23.6%, and 20.5%. Major operators include PetroChina, Sinopec, CNOOC and provincial pipeline companies. Among them, the pipelines under the jurisdiction of PetroChina and Sinopec are 85,600 km and 34,000 km, respectively, and the national proportions are 64.8% and 25.9%, respectively. In recent years, China's gas pipeline technology has developed rapidly. As far as the engineering practice of high-pressure transportation and high-steel welded pipes is concerned, my country has become one of the international leaders. However, in terms of the overall technology of gas pipeline construction, especially the basic research on high-pressure transmission and the application of high-grade welded pipes, we are still in the tracking research stage, and there is still a certain gap with developed countries. In the flowing chapter, the development of pipeline transportation is introduced.

1.2 The Art of Pipeline Transportation

1.2.1 Product Oil Sequential Delivery Technology

The United States, Canada, Western Europe and other countries and regions have a variety of oil pipeline transportation technologies that are relatively mature. They have many varieties and large scales of transportation. The transportation network is relatively developed, which realizes the sequential transportation of chemical products, and the sequential transportation of crude oil and refined oil. Sequential transportation of light oil products such as gasoline, kerosene, diesel and other products such as liquefied petroleum gas, liquefied natural gas, chemical products and raw materials. The most famous is the Colonial Pipeline in the United States, which has 118 varieties to be transported, with a sequence period of only 5 days. Under normal delivery conditions, oil mixing is mainly along the way. The generation of mixed oil along the way is based on two mechanisms: convection transfer and diffusion transfer. The convective transfer process is caused by the uneven velocity field, which causes the axial extension of the mixed oil to increase continuously; the diffusion transfer includes axial diffusion and radial diffusion. Stretching has an inhibitory effect. The most basic factor leading to oil mixing in sequential transportation is diffusion transmission. For oil products operating under turbulent flow conditions, there is a laminar bottom layer and a buffer layer with a lower flow rate than the center area, so that the downstream oil product enters the front oil product in a wedge shape; at the same time, the turbulent diffusion causes the pipe section the concentration tends to be uniform. When the turbulent diffusion is weak, the radial diffusion plays a role, but due to the existence of the axial concentration gradient, there is both axial molecular diffusion and turbulent diffusion, which causes the concentration of mixed oil to increase continuously [5]. Sequential product oil transportation mixed oil cutting, and processing is a relatively complex, unified, and interactive process system, which is composed of mixed oil cutting time (cutting amount), mixed oil processing method and processing amount. The function of this system is to use the quality potential of oil products to reduce the depreciation loss of mixed oil and obtain the best economic benefits. The system contains the biggest contradiction between the processing method and the processing cost. How to deal with this contradiction is the main goal of studying the product oil sequential delivery mixed oil cutting and processing system [6].

There are only 3 to 5 types of pipeline transportation in China, and the distribution flow is relatively balanced. The pipeline system batch arrangement, optimized operation, system automatic control and water hammer protection are relatively simple. Sequential product oil transportation and mixed oil treatment is not only an important production link for long-distance sequential product oil transportation and oil storage, but also an important study to reduce pipeline transportation costs and improve the economic benefits of pipeline transportation. The key research direction should be: give full play to the advantages and potential of pipeline transportation, study more media sequential transportation technology, especially the transportation process control and optimized operation technology, oil quality control and quality inspection of complex working conditions such as multi-injection and multi-user full download Technology, mixed oil cutting and processing technology.

1.2.2 Heavy Oil Pipeline Transportation Technology

The major heavy oil producing countries in the world are mainly the United States, Canada, Venezuela and China. In recent years, foreign heavy oil mining technology has developed rapidly. In transportation technology, physical field treatment (magnetic treatment, vibration reduction) and water transportation (liquid ring), suspension, emulsification), device transportation (sliding box, film bag), aeration and viscosity reduction (saturated gas to increase the amount of transportation), mixed transportation and other processes have been carried out. The annual output of heavy oil and ultra-heavy oil in my country is kept above 1000×104t. In the international project, the ultra-heavy oil with the viscosity of 28000mPa·s at the temperature of 20°C in Sudan 5B pipeline will also be encountered. The main feature of heavy oil is high viscosity, and its transportation technology research mainly focuses on viscosity reduction and drag reduction [7]. The currently commonly used thick oil viscosity reduction conveying process can be summarized into three [8-12] based on the principle: ① chemical methods, which reduce the viscosity of the heavy oil by modifying the method; ② physical methods, will A certain proportion of water is mixed into the heavy oil, the pipeline is heated, and the low-temperature liquid ring is transported; ③ Physical and chemical methods, emulsifiers are added to the heavy oil to change the gel state of the heavy oil, thereby reducing the viscosity of the heavy oil.

(1) Thinner Blended to Reduce Viscosity

The viscosity of a typical heavy oil is too high, and heating alone often fails to meet the requirements of pipeline viscosity (otherwise the heating temperature is too high). Dilution of light oil (including natural gas condensate, crude oil distillate, waxy crude oil, etc.) has been the main method of viscosity reduction and drag reduction of heavy oil. When the source of light oil is convenient and sufficient, the dilution viscosity reduction and drag

  DOI: https://doi.org/10.30564/frae.v3i3.2453

reduction technology is the simplest and most effective. In order to solve the contradiction of light oil shortage, since the 1980s, foreign countries have vigorously carried out research on alternative thinners and other viscosity reduction and drag reduction technologies, for example, the viscosity reduction effect of MTBE (methyl tertiary butyl ether) on heavy oil has been studied [13]: The 25%-30% MTBE blended into the Canadian cold lake crude oil can reduce the viscosity to 270mPa·s at 4°C. MTBE can be recovered by simple distillation.

(2) Emulsification, Viscosity Reduction and Drag Reduction

The oil-in-water emulsion viscosity reduction and drag reduction technology was developed as an alternative technology for the dilution and viscosity reduction of heavy oils. The viscosity-reducing principles of surfactants are generally classified into three types: ① Emulsification and viscosity-reducing, that is, the W/O emulsion is reversed into O/W emulsion under the action of surfactants to reduce the viscosity: ② breaking the emulsion to reduce the viscosity, That is, the surfactant breaks the W/O emulsion to generate free water, and forms a "water jacket oil core", "suspended oil", and "water float oil" according to the amount and flow rate of free water to reduce viscosity; ③ Adsorption and viscosity reduction, yes The surfactant aqueous solution is injected into the oil well, destroying the thick oil film on the surface of the tubing or sucker rod, inverting the surface wettability to hydrophilicity, forming a continuous water film, and reducing the resistance of crude oil flow during the pumping process. These three mechanisms often exist at the same time, but when the surfactants are different and the conditions are different, the viscosity reduction mechanism that plays a leading role is also different [14]. A small amount of emulsifier is used to prepare an oil-in-water emulsion called Orimulsio n (Orimulsion Oil). Its viscosity at 50°C is 300 to 500 mPa·s (crude oil viscosity at the same temperature is 6 000 to 40 000 mPa·s), which can be stored stably. more than a year. Emulsifiers and emulsification processes are the key to this technology. Because the formation water has a high degree of mineralization, the emulsifier is required to be salt-tolerant, and non-ionic surfactants are often used. The emulsion must withstand various shear and thermal effects during storage and transportation without being destroyed. However, when applied to drag reduction in wellbore and oil field short distance gathering and transportation pipelines, the requirements for emulsion stability can be appropriately reduced.

(3) Liquid Ring Drag Reduction

A stable low-viscosity ring is formed near the pipe wall to separate the heavy oil from the pipe wall, which has a very significant drag reduction effect. The key to its technology is the stability of the liquid ring. Adding appropriate polymer in water has viscoelasticity, which is convenient for liquid ring stability. Tests show that [15] water accounts for 8% to 12% of the pipeline's transport volume (88% to 92% is crude oil), and its transport friction is about 1.5 times that of the same volume. Therefore, trying to inject a low-viscosity fluid between the heavy oil and the pipe wall will effectively reduce the lifting resistance of the heavy oil well [16]. Isaacs et al. [17] first proposed a drag reduction method for the lubrication interface of heavy oil pipelines. Prada et al [18] studied the flow characteristics of the heavy oil-water central flow in the riser and confirmed the significant drag reduction effect of the water ring. Silva et al. [19] found that the oxidation or roughness of the inner wall of the pipeline can reduce the adhesion of heavy oil on the wall of the pipeline. The injection of microbubbles between the aircraft and the liquid flow wall is considered by the shipbuilding community as one of the most effective drag reduction methods [20]. McCormick et al. [21] first used hydrogen bubbles produced by electrolysis to study the drag reduction of microbubbles on a towed rotor. Ortiz-Villafute et al. [22] found that the injection of 5v% microbubbles in the turbulent boundary layer of the square channel can significantly reduce drag. Jing et al. [23] noticed that the production of "foam oil" was several times higher than that of ordinary heavy oil and the phenomenon of microbubbles drag reduction, and proposed a new idea of water-based foam drag reduction in the flow boundary layer of heavy oil.

In summary, the direction of continued research is: continue to pay attention to the tracking and application research of high viscosity crude oil additives modified viscosity reduction transportation technology, viscosity reduction treatment transportation technology, high viscosity crude oil pipeline transportation energy saving technology to adapt to the crude oil pipeline construction market demand.

1.2.3 Gas Pipeline

(1) High Steel Grade

As early as the mid-1980s, the development of X100 pipeline steel was completed abroad, but because there was no real project demand at that time, X100 steel grade pipelines have not been vigorously developed. In recent years, TransCanada of Canada conducted research on the X100 test section in 2002, 2004, and 2006, respectively, including steel pipe manufacturing, on-site cold bending welding, and winter construction, as well as the X120 steel grade conducted in 2004,

DOI: https://doi.org/10.30564/frae.v3i3.2453

although just the study of the test section. After the successful application of X70 steel from the first West-East Gas Pipeline in China and the large-scale application of X80 steel on the second West-East Gas Pipeline, China has gradually achieved a major development from catching up to surpassing in the manufacture and use of large-caliber and high-grade pipelines. In recent years, the steel plant and the pipe plant have cooperated to complete the development of X100 pipeline steel. In 2007, the first domestic trial production of the first φ914×16mm X120 welded pipe was successfully produced [24]. However, the performance and quality of the X100 steel pipes trial-produced in my country are still unstable, and the worldwide problem of crack toughness has not been solved well. From the perspective of development, the performance of many steel pipes is closer to X90. For the research on the fracture criteria and parameters of ultra-high-strength X90 steel pipes, Europide Company has conducted a small amount of X90 development and conducted two full-scale gas blasting tests. In 2013, driven by the major scientific and technological projects of China National Petroleum Corporation, the research work of the relevant steel mills and pipe plants focused on the development of X90 steel pipes that meet the basic requirements of API [25-26], and the problem of fracture control has not been involved. Only China National Petroleum Institute of Petroleum Engineering Technology conducted a pilot study, conducted two physical gas blasting tests on X90 steel pipes in 2014, and built Asia's first pipeline fracture control test site in Shanshan, Xinjiang in 2015, with plans for 2016 Continue the X90 pipeline blasting test with a view to revising the empirical formula based on the CVN index, but because the number of physical blasting tests is too few, the project has not yet reported public research results [27].

(2) Improve Design Factor

In the 1980s, the ASME B31.8 committee recommended that natural gas pipelines use a design factor above 0.72, and a series of studies were conducted on pipeline design, reliability assessment, pipeline pressure test, and pipeline fracture control; in 1990, the 0.8 design factor was officially adopted Incorporated in ASME B31.8 [28], has been used until ASME B31.8-2007. As early as 1973, Canada changed the maximum allowable operable pressure of the pipeline in CSA Z184-1973, and the design coefficient of the first-level area was increased to 0.8, which was extended to CSA Z184-2007. The famous Union pipeline in North America, the Rocky Express Line, and the Alaska gas pipeline all use a design factor of 0.8 in the first-level region. The strength design coefficient increased from 0.72 to 0.8 is a trend. On the one hand, if the wall thickness is kept constant, the pipeline operating pressure can be increased, thereby effectively increasing the pipeline throughput and transmission efficiency; on the other hand, if the pipeline design pressure is kept unchanged, the pipeline can be effectively reduced. Wall thickness requirements, which will significantly save pipeline construction costs. In engineering applications, 0.8 design factor pipelines require high-intensity hydraulic tests to verify the pipeline's pressure-bearing capacity and system reliability.

Relative to the design factor of 0.72, the use of a design factor of 0.8 means that the operating pressure can be increased when the pipeline specifications remain unchanged, thereby increasing the pipeline throughput. On the other hand, if the design pressure of the pipeline is kept constant, the 0.8 design factor can be used to a greater extent to take advantage of the strength properties of the pipe itself, thereby reducing the requirements for the pipe wall thickness, which will significantly reduce the production cost of line pipe. Taking the West-East Gas Pipeline as an example, the design coefficient of the gas pipeline in the first-level area is 0.72. The grid is ⌀1219 mm×18.4mm. If the design factor is increased to 0.8, the wall thickness of the pipeline can be reduced to 16.6mm under the condition that the design pressure and delivery volume remain unchanged, and the demand for steel will be reduced by 9.7%. Pipes used in the first-tier area of the West-East Gas Pipeline are about 195×10^4t. If the design coefficient is increased from 0.72 to 0.8, the construction cost can be saved by about 1 billion CNY. Based on this, in the construction of the Third West-East Gas Pipeline, a design factor of 0.8 was adopted in the 300km test section [29]. 0.8 design factor Two key problems that need to be solved for high-strength pressure test of pipelines: ① Determine a reasonable pressure test pressure, so that the pipeline can increase the test pressure as much as possible within the acceptable risk range; ② adopt a reliable pressure test monitoring method, so that Once an abnormal situation occurs during the pressure test, it can be stopped immediately.

After the introduction to the art of pipelines in China, it comes to the design part of R oilfield in aspects of A-B pipes and the method for pipelines to cross the river.

2. Basis for R Oil Field Pipeline Design

2.1 Project Overview

When R oil field was put into development, the initial

DOI: https://doi.org/10.30564/frae.v3i3.2453

crude oil was transported out by car. In order to meet the needs of oilfield development and production, and reduce the cost of automobile oil pulling, the design of crude oil pipelines and train loading programs is required.

The starting point of the main oil pipeline is Joint Station A, passing the first station outside B, and the ending point is the C loading station. The crude oil of this station is shipped to users by train. There is a river 40km away from Union Station A. The proposed oil pipeline crosses the river and enters the first station of B external transmission. The length of the crossing channel is about 1000m. The riverbed is relatively flat, and the terrain on both sides of the riverbank is relatively high.

2.2 Design Basic Information

2.2.1 Basic Data

Table 1. Basic data of R oil field oil pipeline

Pipeline start point	Pipeline end point	length(km)
A United Station	B First Outbound	86.0
The first station of B	Loading station C	84.0

Table 2. production from 2016-2025

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Oil production (10^4t)	49.6	45.7	39.2	34.1	29.9	26.5	23.6	21.2	19.2	17.4
Liquid production (104^t)	86.7	83.6	77.3	72.6	68.8	65.6	63.1	61.4	59.8	58.7
Water content (%)	42.7	45.3	49.2	53.0	56.5	59.6	62.5	65.4	67.9	70.3

A dehydration station and an oily sewage advanced treatment station have been built at the first station of B foreign transportation to meet the needs of receiving watery oil from A united station.

The data of the longitudinal section of the external pipeline is shown in the table 3.

Table 3. Pipeline profile data

mileage (km)	0	20	38	50	72	86	110	136	158	170
Elevation (m)	562	560	572	541	556	584	568	525	536	578

2.2.2 Crude Oil Properties

Table 4. Crude Oil Properties

No.	Item	Test results
1	Density (20℃，kg/㎥)	856.07
	Density (50℃，kg/㎥)	835.1
2	Freezing point (℃)	30
3	Pour point (℃)	26
4	Wax precipitation point (℃)	42.7
5	Abnormal point (℃)	38
6	Colloid (%)	3.38
7	Asphaltene (%)	0.28
8	Wax content (%)	20.2
9	Salt content (mgNaCl/L)	30
10	Initial boiling point (℃)	67
11	Sulfur content (%,)	0.07
12	Closed flash point (℃)	<10
13	Saturated vapor pressure (37.8kPa)	25.2(37.8℃)
		31.5(45.0℃)
14	Viscosity	see viscosity and temperature data table 5
15	Specific heat kJ/(kg·℃)	2.24
16	Fuel calorific value (MJ/kg)	4.56

Table 5. Crude Oil Viscosity and Temperature Data Table of Union Station

Temperature (℃)	Viscosity at different shear rates (mPa·s)					
	8 1/s	13 1/s	25 1/s	40 1/s	80 1/s	100 1/s
27	150.819	111.311	78.7296	67.1498	52.8343	49.6133
30	88.2348	81.1386	65.939	55.1189	41.9696	38.7763
32	32.4525	50.9479	46.2511	40.9102	33.3782	31.2303
34	38.8484	36.31	32.819	30.4226	26.6783	25.5444
36	21.7525	21.6544	20.991	20.4856	19.3058	18.8751
38	14.4267					
40	13.7385					
42	13.5475					
45	11.9492					
50	10.4973					
55	8.1666					
60	6.8706					
65	5.5753					
70	6.2058					

2.2.3 Design Environment

(1) Soil Condition

The buried depth of the center of the pipeline is 1.6m;

the annual minimum monthly average temperature of -4°C and the highest monthly average temperature of 20°C; the thermal conductivity of the soil is 1.3W/(m·°C); the thermal conductivity of the asphalt anticorrosion layer is 0.15W/(m ·°C).

(2) Railway Support Conditions

The C loading station is flat, the station is located 8km east of the railway marshalling station.

(3) Meteorological Conditions

The project area belongs to a mid-temperate semi-humid and semi-arid continental monsoon climate. How much wind and little rain in spring, large evaporation; cool and short in summer, concentrated precipitation; rapid fall in temperature, early frost; long cold in winter, long snow area. The monthly minimum temperature is -37.8°C, and the monthly maximum temperature is 32.9°C. The annual sunshine hours are 2049.5 hours, and the frost-free days are 126 days.

3. Process Design of Oil Pipeline

3.1 Conveying Process

When the freezing point of high-wax oil products is higher than the ambient temperature, or the viscosity of the oil flow is very high at ambient temperature, the normal temperature delivery method cannot be used directly. The high viscosity of the oil flow causes the pressure drop of the pipeline to increase sharply, which is often difficult or uneconomical and unsafe in engineering. Therefore, measures such as condensation and viscosity reduction must be adopted. Heated conveying is currently the most commonly used method. When heating and conveying, increasing the conveying temperature will reduce the viscosity of the oil, reduce the friction loss, reduce the pipeline pressure, or maintain the minimum oil temperature of the pipeline above the freezing point to ensure safe transportation [30].

Use OLGA software to perform simple temperature drop calculation on the four groups of pipelines with 6in, 8in, 10in, and 12in diameters, divided into AB oil transfer section and BC oil transfer section. The following assumptions are made: ① The pipeline is transported at normal temperature without heating; ② The starting temperature of oil flow is 70°C. The calculation results are shown in Figure 1 and Figure 2.

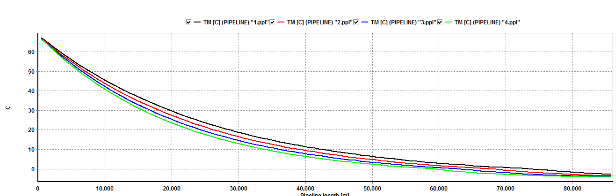


Figure 1. Temperature drop along the A-B oil transfer

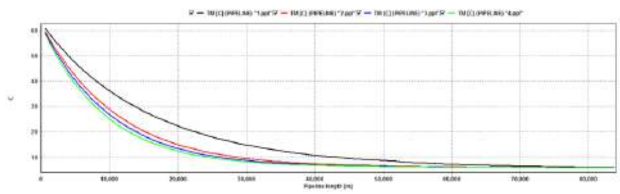


Figure 2. Temperature drop along the B-C oil transportation section

It can be seen from Figure 1 and Figure 2 that even when the starting oil temperature is 70°C, the normal temperature non-heating conveying process is adopted, and the final oil temperature is lower than the freezing point of the oil (30°C), which cannot guarantee the safe flow of oil. The heating conveying method can be used.

For waxy crude oil, the physical method of heating and transportation can effectively reduce the viscosity and improve the efficiency of pipeline transportation. Years of practice have shown that heating and transportation is effective, but it has high transportation energy consumption, high operation and management costs, and difficulty in restarting after stopping transportation. And other inherent defects. The emulsification viscosity reduction method and suspension transportation method in the chemical method require a large amount of water, which is difficult to achieve in remote or water-scarce areas and sites. The most widely used chemical method is mainly to add pour point depressant to reduce pour point and reduce viscosity. The chemical agent depressurization method is to change the shape, size and aggregation structure of wax crystals in crude oil by adding chemical treatment agents such as oil-soluble polymer polymers or some surfactants, and delay the wax crystals to form a three-dimensional space grid structure, thereby Lower temperature is required to form the network structure of crude oil, so as to lower the freezing point and improve the low-temperature fluidity of crude oil.

Comprehensive feasibility and economy, the AB section should be heated and insulated, and the BC section is planned to use the heating transfer process without pour point depressant and the delivery process with pour point depressant for program optimization and economic evaluation, and select the one that is suitable for the crude oil pipeline process design the best solution.

3.2 Design Parameters

3.2.1 Pipe Design Parameters

(1) Design Throughput

There are three definitions of liquid pipeline transportation in North America, which are design transportation,

DOI: https://doi.org/10.30564/frae.v3i3.2453

operation transportation and annual transportation. Designed output refers to the maximum output of pipeline-related equipment under ideal working conditions; operating output is the maximum output of pipelines under normal operating conditions; annual output is the shipper's hope that the pipeline will actually Completed loss. In general, the annual output is 90% of the designed output, and the operational output is 95% of the designed output.

According to relevant definitions, the maximum annual oil production in the 10-year production forecast of the area under the jurisdiction of United Joint Station A is 496,000 tons, which should be the maximum output of the pipeline under normal operating conditions, that is, the operational output. When considering the design output, 5% is taken as the design safety margin, and the design annual output should be 522,000 tons.

When calculating the amount of oil transported in the design of oil pipeline engineering, considering the factors such as pipeline maintenance and accidents, the annual working days should be calculated as 350d (4800h). The relevant design parameters are shown in Table 6.

Table 6. Design throughput

Operational output (10^4t)	Designed output of A-B section (10^4t)	esigned output of B-C section (10^4t)	Working days of pipeline (d)
49.6	91.1	52.2	350

(2) Design Pressure

There are two options for piping design pressure: conventional design and optimized design. The conventional design is based on the operating pressure in ASME/ANSI B16.5 for piping system pressure design, that is, MAOP (maximum allowable operating pressure) cannot exceed the rated stress limit of the valves and accessories used in the system, and the design pressure is based on the pressure level of the valve or accessories And design temperature. Although this method simplifies program selection, it increases investment and transportation costs. Because the pipeline is rarely carried out at the maximum working pressure, its conveying capacity is not fully utilized. Therefore, in order to rationally design the pipeline transportation capacity and reduce the pipeline transportation cost, the design pressure is planned to adopt the optimized design method [31].

The optimal design is to determine the MAOP according to the technological calculation results of the design conditions and consider a certain margin as the design pressure. GB50253-2014 also specifies that MAOP should be less than or equal to the design pressure.

(3) Optimization of Pipe Diameter

For oil pipelines with a certain design capacity, as the pipe diameter increases, the investment in steel pipe and line engineering increases, but the number of pump wars and the total investment in the pumping station decrease. With the increase in pipe diameter, the cost of oil-transmission power decreases, while depreciation, management, labor, and maintenance costs are calculated according to a certain percentage of the total investment in the design. The change trend of these costs and pipeline engineering investment vary with the pipe diameter. The trend of change is similar, so it also has a minimum. The designed output is the economic output corresponding to the selected pipe diameter, and the flow velocity in the tube at this time is the economic flow velocity.

Different pipe diameters have an economic transport range with the lowest transportation cost. The current economic flow rate of oil pipelines in my country is 1.0-2.0m/s. The corresponding economic pipe diameter is calculated by equation (1). The calculation results are shown in Table 7.

$$d=\sqrt{\frac{4Q}{\pi \upsilon}} \tag{1}$$

Where d is pipe inner diameter in m, Q is volume flow of designed output in m^3/s, v is economic flow rate in m/s.

Table 7. Pipe diameter corresponding to economic flow rate

A-B pipe diameter (mm)	A-B economic flow rate(m/s)	B-C pipe diameter (mm)	B-C economic flow rate(m/s)
201	1.5	128	1.5

According to GB-T17395 (2008) in China, six groups of similar pipe diameters were selected for preliminary optimization calculation, see Table 8.

Table 8. Pipe diameters for preliminary optimization calculation

Cases		I	II	III	IV	V	VI
Nominal diameter (mm)	A-B	180	194	203	219	232	245
Nominal diameter (mm)	B-C	127	140	159	168	180	194

(4) Steel Pipe Type Selection

Steel is divided into seamless steel pipe and seamed steel pipe according to different pipe making methods, and seamed steel pipe can be divided into straight seam pipe and spiral welded seam pipe. Due to the small diameter range of the seamless steel pipe, the complicated manufacturing process and the high price, it is rarely used on long-distance oil pipelines.

Straight seam pipe and spiral welded steel pipe have their own advantages and disadvantages. In principle, as long as the pipes that are produced and inspected according to the specifications can meet the requirements of oil and gas pipeline engineering. According to statistics from foreign sources, in high-pressure large-diameter oil and gas pipelines, the production and use of straight-seam pipes occupy a considerable advantage and dominant position. Considering the economics and safety of pipelines, in the design of China's long-distance oil and gas pipelines, spiral welded pipes are mostly used in general areas with low population density. Therefore, combined with the regional characteristics of the project, spiral welds are used for oil pipelines tube.

(5) Pipeline Longitudinal Section

Table 9. Pipeline profile data

Mileage (km)	0	20	38	50	72	86	110	136	158	170
Elevation (m)	562	560	572	541	556	584	568	525	536	578

Use OLGA software to draw the topographic relief slopes of sections A-B and B-C, see Figure 3 and Figure 4.

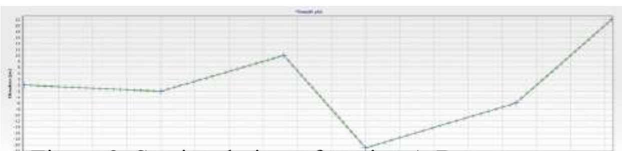


Figure 3. Sectional view of section A-B

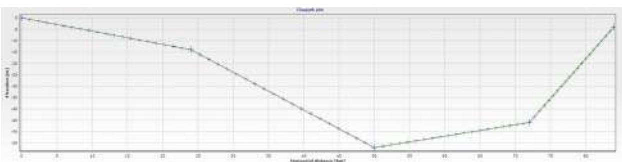


Figure 4. Sectional view of section B-C

It can be seen from Figure 3 and Figure 4 that the terrain along the pipeline has a relatively smooth terrain, but there are two points with a large drop. It is necessary to check the corresponding hydrostatic pressure to ensure the safe transportation of the pipeline.

(6) Pipeline Depth Parameters

The buried depth of the center of the pipeline is 1.6m; the annual minimum monthly average temperature of the pipeline is -4°C, the highest monthly average temperature is 20°C; the soil thermal conductivity is 1.3W/(m·°C).

(7) Pipeline Coating

The anti-corrosion layer is the main barrier for pipeline protection. The selection of anti-corrosion layer should be based on the topography and soil quality of the specific laying environment of the pipeline, combined with the use of domestic mature anti-corrosion layer. The principle of selection. At present, the commonly used anticorrosion process for the external wall of pipelines usually includes anticorrosion of petroleum asphalt, anticorrosion of three-layer PE structure and anticorrosion of polyethylene adhesive tape.

① The three-layer PE is formed by the combination of epoxy resin and extruded polyethylene coating. It combines the advantages of two-layer PE and sintered epoxy, overcomes their respective shortcomings, and makes the three-layer PE have various excellent The performance and adaptability are wider, so that the corrosion resistance of the pipeline is further improved, and the service life of the pipeline is increased, but the cost is high.

② Petroleum asphalt anti-corrosion, the main advantages are relatively simple prefabricated technology, mature construction technology, rich experience, low cost, strong construction adaptability, but large water absorption rate, poor aging resistance, not resistant to bacteria, which is a relatively backward anti-corrosion process.

③ The anti-corrosion layer of polyethylene adhesive tape is a non-heating anti-corrosion layer. It has the characteristics of convenient and flexible construction, dense anti-corrosion layer, small water absorption rate, and resistance to chemical erosion. However, it has the characteristics of poor resistance to soil stress. Peel strength should be the focus of the adhesive tape performance indicators. Generally, adhesive tape with release paper should be used, and the peel strength of the primer steel should reach 40 N/cm.

Based on the above analysis, the common grade PE with the best comprehensive performance is recommended as the anti-corrosion layer of the oil pipeline, in which the fused epoxy layer: 50 μm, the adhesive layer: 50 μm, and the polyethylene layer: 2.7 μm.

3.2.2 Physical Properties of Crude Oil

(1) Oil Density

The relative density of crude oil is approximately linear with temperature, and its temperature coefficient is related to density. The relative density of crude oil at a certain temperature T can be obtained from equations (2) and (3). The calculation results are shown in Table 10:

$$d_4 = d_4^{20} - \xi(T - 20) \tag{2}$$

$$\xi = 1.825\times10^{-3} - 1.315\times10^{-3} d_4^{20} \tag{3}$$

where d_4 is relative density of crude oil, d_4^{20} is relative density of crude oil at 20°C, ξ is temperature coefficient.

DOI: https://doi.org/10.30564/frae.v3i3.2453

Table 10. Relative density of oil at different temperatures

Temperature(℃)	relative density
10	0.863063
20	0.85607
30	0.849077
40	0.842085
50	0.835092
60	0.828099
70	0.821107

(2) Oil Viscosity

For waxy crude oil, when the temperature drops to the wax precipitation point, as the temperature further decreases, the wax crystals precipitated from the crude oil increase continuously, and the rheological properties of the crude oil also change from Newtonian fluid to non-Newtonian fluid, that is, the crude oil also has a constant temperature No longer has a unique viscosity, but an apparent viscosity related to shear rate. The temperature at which the transition from Newtonian fluid to non-Newtonian fluid is called the anomaly point. Considering that before and after the anomalous point, the fluid behaves as Newtonian fluid and non-Newtonian fluid respectively, with different viscosity-temperature characteristics. Therefore, when fitting the viscosity-temperature curve, it is divided into two parts for fitting.

In the temperature range of Newtonian fluid, below the initial boiling point, above the temperature of the wax precipitation point, and between the wax precipitation point and the abnormal point, the viscosity temperature curve can be generally fitted by equation (4).

$$lg\mu = a - bT \tag{4}$$

Where μ is oil viscosity in mPa·s, T is oil temperature in °C.

When the waxy crude oil drops to an abnormal point with temperature and turns into a non-Newtonian fluid, the waxy crude oil is generally a pseudoplastic fluid, and the relationship between shear stress and shear rate can be well described by the power law equation. For non-Newtonian fluids, based on the definition of Newtonian hydrodynamic viscosity, the shear stress can be calculated according to formula (5), and the calculation results are shown in Table 11.

$$\tau = \mu_a \cdot \dot{\gamma} \tag{5}$$

Where τ is shear stress in mPa, μa is apparent viscosity in mPa·s, $\dot{\gamma}$ is shear rate 1/s.

Table 11. Crude oil shear stress at A United Station

Tempareture (℃)	Shear stress at different shear rates (mPa)					
	8 1/s	13 1/s	25 1/s	40 1/s	80 1/s	100 1/s
27	1206.552	1447.044	1968.24	2685.992	4226.744	4961.33
30	705.8784	9031.627	1968.24	2204.756	3357.568	3877.63
32	419.62	4133.841	1156.278	1636.408	2670.256	3123.03
34	310.7872	1849.918	820.475	1617.064	2134.264	2554.44
36	174.02	786.2713	524.775	819.424	1544.464	1887.51
38	115.4136	187.5471	360.6675	577.068	1154.136	1442.67

Pseudoplastic fluids are generally solid-liquid and liquid-liquid dispersion systems and polymer solutions that do not form an overall network structure. After the wax precipitation of waxy crude oil increases to a certain degree and becomes a non-Newtonian Newtonian fluid, it is a pseudoplastic fluid. The relationship between fluid shear stress and shear rheology is called rheological equation, or rheological model. There are many rheological models that can describe pseudoplasticity, among which the most commonly used is the power law model of formula (6).

$$\tau = K\dot{\gamma}^n \tag{6}$$

Where K is the consistency factor to indicate the viscosity of the fluid in mPa·s^n, n is the flow characteristic index, indicating the degree to which the flow characteristic of the fluid deviates from Newtonian fluid in dimensionless.

According to the crude oil shear stress and formula (6) power law model formula provided in Table 9, the rheological curve when the crude oil behaves as a non-Newtonian fluid is fitted. The fitting results are shown in Figure 5.

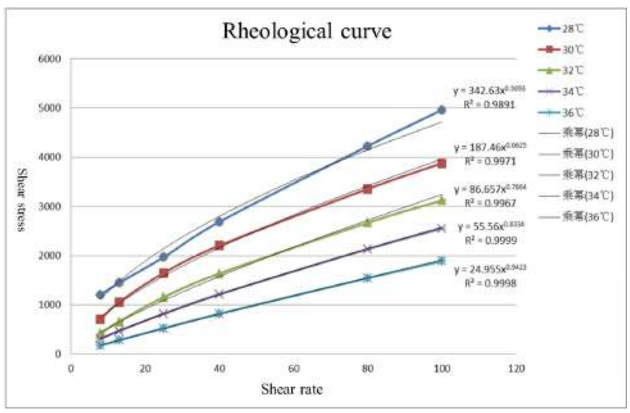


Figure 5. Rheological curve fitting

It can be seen from Figure 5 that the result of fitting the rheological curve of the waxy crude oil according to the power law fluid model is basically consistent with the actual situation. When the fluid is converted into a non-Newtonian fluid, the calculation can be performed according to the power law fluid.

(3) Crude Oil Emulsification

Section A-B is the oil-water two-phase mixed transportation section. When considering the phase state of oil and water, it is considered to be the emulsification of crude oil, and referring to Daqing crude oil (because the nature of the oil in this article is similar to Daqing crude oil), the inversion point is 65% water content. That is, when the hydraulic calculation of section A-B is performed, the water content is 65% before W/O emulsion; after the water content 65% is O/W emulsion.

The mixed viscosity of emulsified crude oil is calculated by the WOELFLIN mixed viscosity formula of OLGA software. The viscosity of crude oil with different water content is shown in Figure 6. Oil viscosity is in mPa·s.

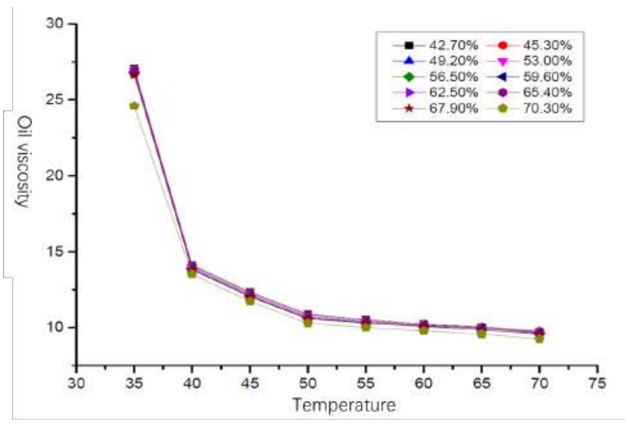


Figure 6. Viscosity of emulsified crude oil at different water contents

3.2.3 Thermal Design Parameters

(1) Outlet Oil Temperature of Heating Station

Because waxy crude oil tends to have a steep viscosity-temperature curve near the freezing point, when the temperature is higher than the freezing point by 30-40 °C, the change of viscosity with temperature is small. Because the hot waxy crude oil pipeline is usually in the turbulent smooth area, the friction resistance is proportional to the viscosity of 0.25 power, increasing the oil temperature has little effect on the friction resistance, but the heat loss is significantly increased, so the heating temperature should not be too high , And considering that the heating temperature should not exceed the thermal stress of the pipeline, the maximum exit temperature is taken as 65 °C.

(2) Oil Temperature of Heating Station

The inlet oil temperature of the heating station depends mainly on the needs of economic comparison and operational safety. For waxy crude oil with a higher freezing point, the viscosity entry temperature curve is very steep near the freezing point, so its economic inlet temperature is slightly higher than the freezing point, which can be higher than the freezing point 3-5 °C.

Under normal operating conditions, the oil temperature at the next station should be 35°C and the minimum oil temperature at the station should be 33°C.

(3) Medium Temperature T_0 around the Pipeline

For buried pipelines, T_0 takes the natural temperature of the soil at the depth of the pipeline. When designing hot oil pipelines according to "GB50253-2014 Oil Pipeline Engineering Design Code", the temperature drop, and heat load should be calculated according to the average temperature of the coldest month. And formulate the operation plan under the highest monthly average temperature and carry out the plan design in different seasons. According to the basic data of the competition, the minimum and maximum monthly average temperature of the soil is taken as the temperature T0 of the medium around the pipeline (see Table 12).

Table 12. Medium temperature T_0 around the pipeline

The lowest monthly average temperature (℃)	The highest monthly average temperature (℃)
-4	20

(4) Design of Pipeline Insulation

Since the freezing point of crude oil is 30°C and the wax precipitation point is 42.7°C, if the pipeline is not provided with an insulation layer, the temperature of the fluid in the pipe will rapidly decrease when the starting temperature is 65°C under the simulation of OLGA software. When the flow length reaches 350 meters, the temperature is reduced to 30 °C, which means that the temperature of the fluid in the tube is below the freezing point temperature. At this time, a large amount of wax crystals will be precipitated to form a network structure, which makes the crude oil have strong thixotropy and high yield stress, and the crude oil loses its fluidity, which eventually leads to "Condensation tube accident. Therefore, this scheme adopts two methods of heating transportation and heat preservation transportation to ensure the crude oil fluidity.

The thermal conductivity of the steel pipe is very strong, and its thermal conductivity is about 45-50 W/(m·°C). Commonly used thermal insulation materials are polyurethane foam, foamed diatomaceous earth, vermiculite cement, slag wool, and foam concrete rock wool pipe, glass wool tube, rubber and plastic sponge, polyethylene

DOI: https://doi.org/10.30564/frae.v3i3.2453

insulation material, composite silicate insulation material, aluminum silicate insulation material. The thermal conductivity of several commonly used insulation materials is shown in Table 13.

Table 13. Thermal conductivity of commonly used insulation materials

Material name	Polyurethane foam	Foam diatomaceous earth	Vermiculite cement	Slag wool	Foam concrete
Thermal Conductivity W/(m·℃)	0.035-0.047	0.07-0.093	0.08-0.13	0.047-0.07	0.12-0.21

This design uses polyurethane foam as the thermal insulation layer because it has the advantages of low bulk density, low thermal conductivity, low water absorption, high compressive strength, good adhesion to the steel surface and convenient construction.

After the insulation layer material is determined, the thickness of the insulation layer is an important parameter that affects the technical and economic indicators. As the thickness of the insulation layer increases, the heat transfer coefficient of the pipeline decreases, which can reduce the investment in the heating station or heat pump station, reduce energy consumption, and save operating costs, but the material cost and construction cost of the insulation layer increase. And after the insulation layer is increased to a certain degree, the improvement of the insulation effect is not obvious. The thickness of the insulation layer should be determined through technical and economic comparisons. It is proposed to choose different thicknesses of insulation layers, perform thermal and hydraulic process calculations on them, determine the pumping station, heating station and operating parameters, calculate their investment and operating costs, and then carry out technology on each program. Economic comparison to determine the best insulation thickness.

3.3 A-B Process Design

The process design mainly considers the influence of pipe diameter, thermal insulation layer, design pressure, and wall thickness (steel level) on pipeline investment and operation. The above parameters are combined and optimized. Hydraulic and thermal calculations are performed at the same time, and each set of schemes is determined based on the design output. The hydraulic scheme and the minimum output under the following schemes determine the thermal scheme under each group of schemes. The 54 groups of schemes are combined. The 54 groups of schemes are analyzed for economical and low-flow adaptability, and the best scheme is selected. According to the thermal calculation, the thickness of the heat preservation layer is 30mm, 40mm and 50mm.

3.3.1 Design Scheme under Design Throughput

(1) Plans Under 30mm Insulation

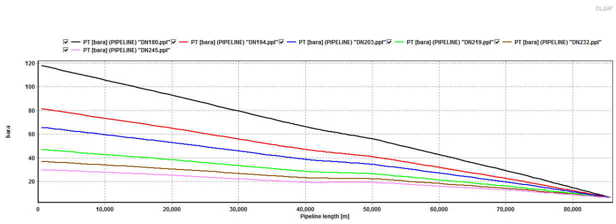


Figure 7. Starting pressure

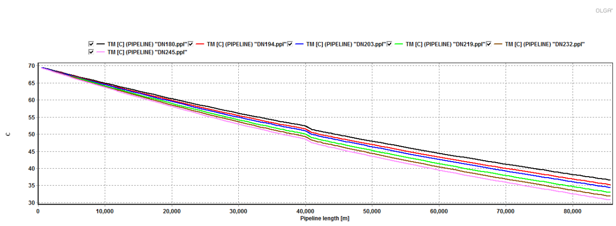


Figure 8. Temperature drop diagram

(2) Plans Under 40mm Insulation

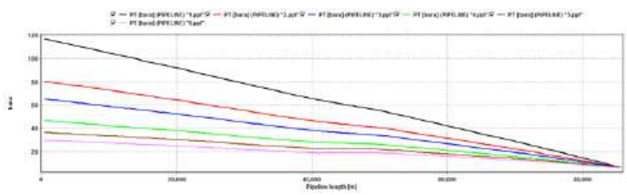


Figure 9. Starting pressure

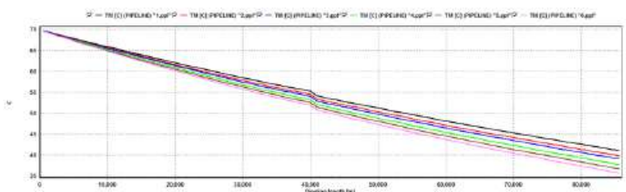


Figure 10. Temperature drop diagram

(3) Plans Under 50mm Insulation

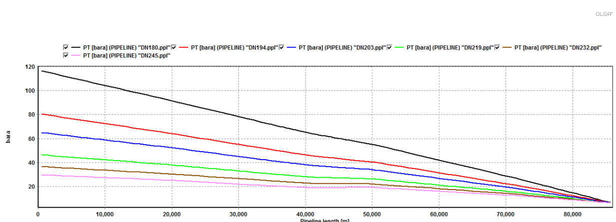


Figure 11. Starting pressure

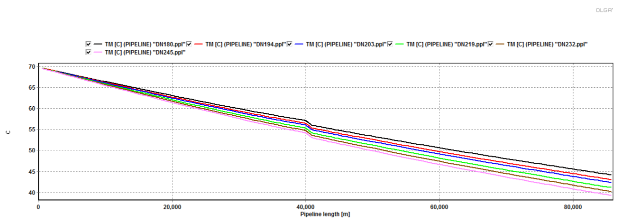


Figure 12. Temperature drop diagram

Table 14. Design scheme under design throughput

Scheme		A-B				
Pipe diameter scheme	Insulation (mm)	Outbound temperature(℃)	Incoming temperature(℃)	Starting point pressure(MPa)	Number of thermal stations	Number of pumping stations
D180	30	70	36.6	11.9	1	2
	40	70	41	11.8	1	2
	50	70	44	11.7	1	2
D194	30	70	35.2	8.2	1	2
	40	70	39.8	8.1	1	2
	50	70	43	8	1	2
D203	30	56	34.4	6.6	1	2
	40	51.8	39	6.5	1	2
	50	48	42	6.4	1	2
D219	30	59	35	4.7	2	1
	40	56	37.7	4.6	1	1
	50	53	41	4.5	1	1
D232	30	70	35	3.7	2	1
	40	70	36.7	3.67	1	1
	50	70	40	3.64	1	1
D245	30	70	35	3	2	1
	40	70	35.7	2.97	1	1
	50	70	39	2.94	1	1

3.3.2 Design Scheme at Minimum Throughput

(1) Plans Under 30mm Insulation

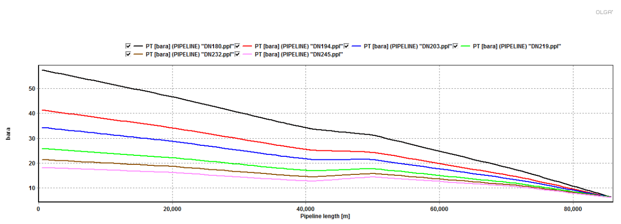


Figure 13. Starting pressure

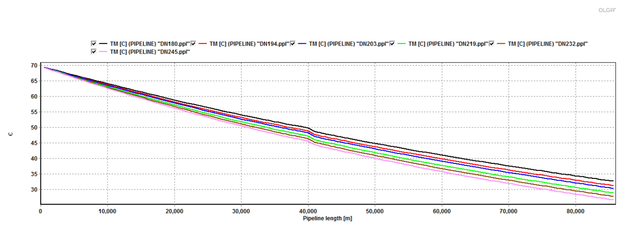


Figure 14. Temperature drop diagram

(2) Plans under 30mm Insulation

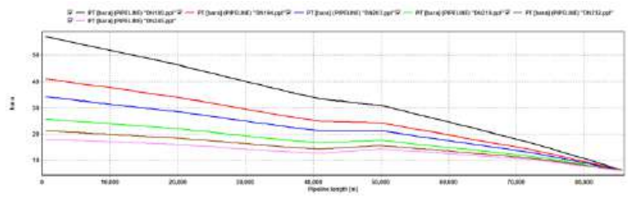


Figure 15. Starting pressure

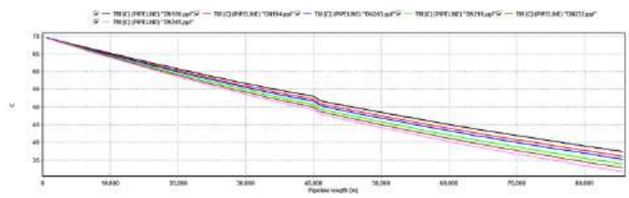


Figure 16. Temperature drop diagram

(3) Plans under 40mm Insulation

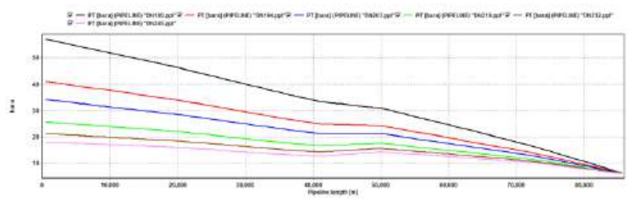


Figure 17. Starting pressure

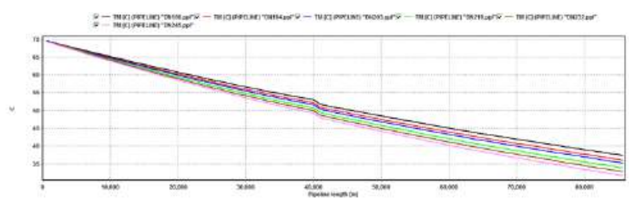


Figure 18. Temperature drop diagram

(4) Plans under 50mm Insulation

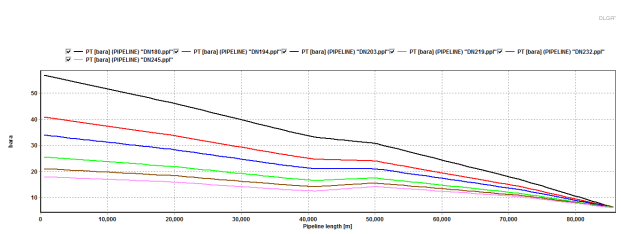


Figure 19. Starting pressure

DOI: https://doi.org/10.30564/frae.v3i3.2453

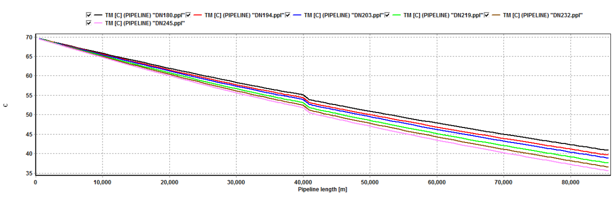


Figure 20. Temperature drop diagram

Table 15. Design scheme at minimum throughput

Scheme		A-B				
Pipe diameter scheme	Insulation (mm)	Outbound temperature(℃)	Incoming temperature(℃)	Starting point pressure(MPa)	Number of thermal stations	Number of pumping stations
D180	30	70	35	5.75	2	2
	40	70	37.4	5.72	1	2
	50	70	40.8	5.7	1	2
D194	30	70	35.2	4.12	2	2
	40	70	36.1	4.1	1	2
	50	70	39.6	4.1	1	2
D203	30	70	35	3.43	2	2
	40	70	35.3	3.4	1	2
	50	70	38.8	3.4	1	2
D219	30	59	35	2.59	2	1
	40	56	33.4	2.57	1	1
	50	53	37.5	2.56	1	1
D232	30	70	35	2.1	2	1
	40	70	35	2.1	2	1
	50	70	36.5	2.1	1	1
D245	30	70	35	1.82	2	1
	40	70	35	1.81	2	1
	50	70	35.5	1.8	1	1

3.3.3 Design Pressureand Pipe Wall Thickness

According to the hydraulic calculation results under the design throughput, a set of design pressure and three sets of steel grades are selected, and the design wall thickness is calculated by considering a certain corrosion allowance. Among them, the strength design factor of oil pipeline is 0.5. Pipe wall thickness should be calculated according to the following formula (3.7).

$$\delta = \frac{pD}{2\sigma_S F \phi t} + C \tag{7}$$

Where δ is wall thickness of steel pipe in mm, P is pipe design pressure in MPa, D is outer diameter of steel pipe in mm, F is strength design factor, σ_s is minimum yield strength of pipeline in MPa, φ is welding coefficient (0.9 for seamless pipeline and 0.8 for welded pipeline), C is additional value of corrosion allowance in mm, here taken as 3 mm, T is temperature reduction coefficient taken as 1.0.

Due to the high-water content of section A-B, considering the safe transportation of the pipeline, the corresponding internal anti-corrosion measures should be taken, and the wall thickness corrosion allowance should be 3mm.

(1) L245 steel pipeline

Table 16. Selection of design pressure and wall thickness under L245 steel grade

Cases		A-B Section			
Diameter	Insulation (mm)	Design pressure(MPa)	Number of pumping stations	Corrosion allowance (mm)	Design wall thickness (mm)
D180	30	6	2	3	8.5
	40	6	2	3	8.5
	50	6	2	3	8.5
D194	30	9.4	1	3	13.5
	40	9.3	1	3	13.5
	50	9.2	1	3	13.5
D203	30	7.4	1	3	10
	40	7.3	1	3	10
	50	7.2	1	3	10
D219	30	5.7	1	3	9
	40	5.6	1	3	9
	50	5.5	1	3	9
D232	30	4.7	1	3	8.5
	40	4.7	1	3	8.5
	50	4.6	1	3	8.5
D245	30	4	1	3	8.0
	40	4	1	3	8.0
	50	4	1	3	8.0

 DOI: https://doi.org/10.30564/frae.v3i3.2453

(2) L290 Steel Pipeline

Table 17. Selection of design pressure and wall thickness under L245 steel grade

Cases		A-B Section			
Diameter	Insulation (mm)	Diameter	Insulation (mm)	Diameter	Insulation (mm)
D180	30	6	2	3	7.5
	40	6	2	3	7.5
	50	6	2	3	7.5
D194	30	9.4	1	3	10
	40	9.3	1	3	10
	50	9.2	1	3	10
D203	30	7.4	1	3	8.5
	40	7.3	1	3	8.5
	50	7.2	1	3	8.5
D219	30	5.7	1	3	7
	40	5.6	1	3	7
	50	5.5	1	3	7
D232	30	4.7	1	3	6.5
	40	4.67	1	3	6.5
	50	4.64	1	3	6.5
D245	30	4	1	3	6
	40	4	1	3	6
	50	4	1	3	6

(3) L360 Steel Pipeline

Table 18. Selection of design pressure and wall thickness under L360 steel grade

Cases		A-B Section			
Diameter	Insulation (mm)	Diameter	Insulation (mm)	Diameter	Insulation (mm)
D180	30	6	2	3	6.5
	40	6	2	3	6.5
	50	6	2	3	6.5
D194	30	9.4	1	3	9
	40	9.3	1	3	9
	50	9.2	1	3	9
D203	30	7.4	1	3	8
	40	7.3	1	3	8
	50	7.2	1	3	8
D219	30	5.7	1	3	6.5
	40	5.6	1	3	6.5
	50	5.5	1	3	6.5
D232	30	4.7	1	3	6
	40	4.67	1	3	6
	50	4.64	1	3	6
D245	30	4	1	3	6
	40	4	1	3	6
	50	4	1	3	6

3.3.4 Economic Evaluation

The total investment of each plan should include pipeline investment, insulation layer investment, station investment, operation investment. After the economic comparison and selection of 54 sets of schemes, the "ϕ219×6.5mm" scheme was selected, the specific parameters of which are shown in Table 19 below.

Table 19. A-B pipeline design parameters

Nominal diameter	Insulation	design pressure	Wall thickness	Steel grade	thermal-pump station	Independent thermal station	Independent pumping station
D219	50	5.5	6.5	L360	1	no	no

4. Crossing River Design

4.1 Comparison of Methods for River Crossing

The crossing scheme adopted is selected to determine the most economical, reasonable and feasible technical scheme. The general principle of river crossing and crossing scheme selection is the main, crossing is the secondary. The specific principles are as follows:

(1) Due to the large investment in pipeline crossing projects, the construction is relatively complicated, and the maintenance workload is large after completion, it is preferable to use the crossing method when the pipeline passes through the river.

(2) In the selection of the crossing plan, the reasonable width of the project pipeline crossing the river, the flow rate, the flow rate, the navigable grade, the levee grade of the river bank, etc. should be determined according to the comprehensive consideration of the river shape, hydrological parameters, engineering geology, etc. Way through. For large rivers, it is advisable to exclude the underwater excavation and crossing method that has a large amount of construction work on the wa-

  DOI: https://doi.org/10.30564/frae.v3i3.2453

ter and affects navigation and try to use the non-excavating method.

(4) In the case of geological conditions that do not meet the directional drilling crossing, tunnels, shields, pipe jacking and other crossing methods or crossing methods can be considered for large and medium-sized rivers, and the optimal crossing and crossing scheme can be determined through comprehensive technical and economic comparison and selection .

(5) The crossing of small rivers mainly includes excavation, horizontal hole drilling rig (with casing) or small directional drilling. The appropriate crossing construction method can be selected according to the specific conditions of river hydrology and geology.

(3) Directional drilling crossing is an advanced trenchless pipeline crossing construction method. The construction is completely carried out on the land on both sides of the water. It has no damage to the river embankment or water embankment, does not disturb the riverbed, does not affect navigation, and has a short construction period. The advantages of safe pipeline operation and low comprehensive cost should be given priority to large and medium-sized rivers under geological conditions.

In summary, considering that the strata of the river crossing section are mainly gravel sand layer and clay layer, and no rock formation, adhering to the design concept of "safety, economy and environmental protection", the construction period is selected to be short, the environmental damage is small, and the project investment is low The horizontal directional drilling crossing (HDD) is the preferred scheme for the pipeline crossing the river.

4.2 Horizontal Directional Drilling Crossing Design

4.2.1 HDD Drillability Evaluation

(1) Cross-Site Stratigraphic Lithology

According to the comprehensive analysis of drilling results, in-situ testing and laboratory test results, the characteristics of each rock and soil layer of the site are described below from top to bottom as follows:

Within the depth range revealed by the exploration, the site stratum is divided into 6 main layers and 3 sublayers.

1) Silty clay: gray-gray-black, the cause of silt. The soil is uneven, and the layout is mixed with thin layers of silt, silt, and clay. No shaking response, slightly smooth, medium dry strength, medium toughness. Flow plastic-soft plastic. This layer is only distributed on the floodplain, with a thickness of 0.8-2.0m.

2) Medium sand: yellow, formed by impact. The particles are uniform, with a thin layer of silt and silt locally. The main mineral components are quartz, feldspar and a small amount of dark minerals. Slightly dense-medium dense, slightly wet-saturated. This layer is distributed in the west of the river channel and has a thickness of 2.0-3.0m.

3) Silt: yellow, formed by impact. The particles are uniform, with a thin layer of silt locally. The main mineral components are quartz, feldspar and a small amount of dark minerals. Slightly dense-medium dense, dry-slightly wet, only distributed on both sides.

4) Clay: yellow, the cause of siltation, the soil quality is relatively uniform, with a thin layer of plastic silty clay locally, no shaking response, slightly smooth, high dry strength and high toughness. Plastic.

5) Gravel: gray, formed by alluvial deposits. The particles are uneven, and there are thin layers of sand and coarse sand in the local area. The main mineral components are quartz, feldspar and a small amount of dark minerals. Slightly dense-medium dense, saturated.

① Medium sand: yellow, formed by impact, with uniform particles, and a thin layer of silt. The main mineral components are quartz, feldspar and a small amount of dark minerals. Medium density, saturated, this layer is only distributed in some holes.

② Silt: yellow, formed by alluvial deposits. The particles are uniform, with a thin layer of silt locally. The main mineral components are quartz, feldspar and a small amount of dark minerals. Medium density, saturated, this layer is only distributed in some holes.

6) Clay: gray-yellow-gray, the cause of siltation, the soil quality is relatively uniform, and a thin layer of plastic silty clay is locally sandwiched. No shaking response, slightly smooth, high dry strength and high toughness. Hard plastic hard. Silt: gray, alluvial origin, relatively uniform soil quality, no shaking response, shiny, low dry strength, low toughness. Medium density, wet, this layer is only distributed in part of the borehole.

It should be noted that the geological profile is a projection profile of the borehole strata on both sides of the pipeline under the pipeline location. Since the borehole is not in the pipeline location, there is a problem that the borehole elevation is higher or lower than the topographic line.

(2) Physical and Mechanical Properties of Soil across the Site

The R oil field gives the main physical and mechanical properties of each soil layer, including the natural water content of each layer, soil density, pore ratio, liquidity index, compression coefficient (MPa^{-1}), compression modulus (MPa), 5 types of indicators for standard penetration test (hit).

Natural water content: an important physical indicator reflecting the humidity of the soil. The water content of the soil layer in the natural state is called the natural water content, and its variation range is very large, which is related to the type of soil, the burial conditions and the natural geographical environment in which it is located. Generally, the value of dry coarse sand is close to zero, and saturated sand can reach 40%; the water content of hard cohesive soil is less than 30%, while that of saturated soft clay (such as silt) can reach 60% or more. Generally speaking, when the water content of the same type of soil increases, the strength decreases.

Liquidity index: It is an index to judge the soft and hard state of the soil, indicating the relative relationship between the natural water content and the limit water content. According to the Geotechnical Investigation Specification (GB50021-94), the liquidity index is shown in the table 20.

Table 20. The softness and hardness of the soil divided by liquidity index

Liquidity Index I_L	$I_L < 0$	$0 \le I_L \le 0.25$	$0.25 \le I_L < 0.75$	$0.75 \le I_L < 1$	$I_L \ge 1$
Soft and hard state	Hard	Hard plastic	Plastic	Soft plastic	Flow plastic

Porosity ratio: refers to the ratio of the volume of pores in the material to the volume of particles in the material and is an important physical property index that reflects the compactness of the material. The compactness of natural soil layers can be evaluated [7]. Generally, the soil with e<0.6 is dense low-compression soil, and the soil with e>1.0 is loose high-compression soil.

Soil compressibility coefficient a1-2: A physical quantity used to describe the compressibility of soil, defined as the slope of the secant of a pressure segment on the e-p curve obtained from the compression test. a1-2<0.1 MPa-1 belongs to low compressive soil; 0.1 MPa-1≤a1-2<0.5 MPa-1 belongs to medium compressive soil; a1-2≥0.5 MPa-1 belongs to high compressive soil [8].

The compressive modulus of soil is one of the important indicators to judge the compressibility of soil and calculate the compression deformation of foundation. The greater the compression modulus, the harder the soil [9].

Standard penetration test (hit): It is a method for determining the bearing capacity of sand or cohesive soil on site [10]. According to “Code for Design of Building Foundation Foundation” (GB50007-2011), the classification of the density of natural sand is shown in the table 21.

Table 21. Classification of the density of natural sand

Standard penetration test hammer number N	Compactness
N≤10 loose	N≤10 loose
10<N≤15 slightly dense	10<N≤15 slightly dense
15<N≤30 medium density	15<N≤30 medium density
N>30	N>30

1- Layer, silty clay layer, natural water content ω=73%, liquidity index IL=1.61, this layer is a high-water-bearing, fluid-plastic layer, which is liquified easily by vibration during the directional drilling process.

2-Layer, medium sand layer, natural water content ω = 8.9%, standard penetration test (strike) = 4.6, this layer is low water content, loose formation.

3- Layer, silt layer, natural water content ω=12%, which is water-bearing stratum.

4- Layer, clay layer, natural water content ω=36%, soil density ρ0=1.81g/cm3, porosity ratio e=1.059, liquidity index IL=0.22, soil compression coefficient a1-2=0.655MPa-1. The compressive modulus of the soil Es=3.15MPa, the layer is a hard plastic, loose and highly compressive soil layer.

5- Layer, gravel sand layer, natural water content ω=11.2%, standard penetration test (strike)=14.9, this layer is water-bearing, slightly dense soil layer.

5-1-Layer, middle sand layer, natural water content ω=17.5%, water-bearing stratum.

5-2-Layer, silt layer, natural water content ω=18.8%, water-bearing stratum.

6- Layer, clay layer, natural water content ω=35.4%, soil density ρ0=1.86g/cm3, porosity ratio e=1.004, liquidity index IL=0.24, soil compression coefficient a1-2=0.24MPa-1. The compression modulus of soil Es=9.93MPa, standard penetration test (strike)=11.2, the layer is a hard plastic, loose-slightly dense, loose medium compressive soil layer.

6-1-Layer, silty layer, natural water content ω=22.3%, soil density ρ0=1.95g/cm3, porosity ratio e=0.693, liquidity index IL=0.24, soil compression coefficient a1-2= 0.24MPa-1, soil compression modulus Es=7.20MPa, this layer is a hard plastic, medium compressive soil layer.

(3) Drillability Evaluation of Rock and Soil Layers across the Area

Engineering survey results show that: the clay 6-layer is a hard soil layer with good mechanical properties and is easy to be drilled by directional drilling; the 5-layer of gravel sand, N=14.9, is slightly dense and the mechanical properties are average, but the particles larger than 2mm are unknown about the content and cement ability between particles. The stable groundwater level across the section is higher, the elevation is (Yellow Sea Elevation System), the

  DOI: https://doi.org/10.30564/frae.v3i3.2453

elevation is 566m, and the depth is 1.2m-7.8m.

Existing problems:

① The silty clay 1-layer with high water content is fluid and plastic, which is liquified easily by vibration during the process of directional drilling;

② Due to the high groundwater level, sand in 2-layer, silt in 3-layer, gravel sand in 5- layer, and sublayers 5-1-layer and 5-2-layer are sandy formations, which are often exposed to water. Saturation is easy to dilute and dissipate. During the drilling process, the sand layer is encountered, and the stability of the shaft wall is poor. It often occurs that the cross-hole collapses and the hole cannot be formed, which causes difficulties in drilling, reaming, and dragging. It is prone to accidents such as buried drilling.

In response to the above problems, in addition to crossing below the maximum scouring line of the riverbed, the silt, silt and silty soil layer should be avoided as far as possible. The mud ratio must be strictly controlled during drilling, the mud formula must be adjusted, and the straight-line section of the access point should be set. The casing adopts effective measures such as a pre-expanding process and enhanced hole washing operations to ensure high hole formation quality and good stability of the shaft wall, to ensure that no backhauling difficulties, stuck pipes, buried pipes and other vicious accidents occur, and to ensure pipeline backhauling One-time completion success rate.

In summary, it is recommended:

① Crossing from hard clay with good self-stability;

② HDD entry and exit points avoid the 1-layer of silty clay that is liable to vibration and liquefaction, and choose embankments on both sides of the river (mainly sandy formations) capable of HDD construction;

③ The collapsible sand layer located near the unearthed point and the unearthed point, such as 2-middle-layer sand, can be solved by the construction method of setting casing during construction.

(4) Evaluation of Construction Conditions

According to the site conditions, the left bank and the right bank of the river have a certain inclination angle, which is not conducive to on-site construction. After the site is leveled and the foundation is tamped, the design of equipment such as drilling rigs can enter the site.

(5) Evaluation of Underground Obstacles

According to the survey data, there are no underground obstacles in the river crossing section that will affect the construction of the crossing pipeline.

4.2.2 HDD Crossing Curve Design

The drill ability evaluation of the HDD stratum shows that: the clay 6-layer is mainly penetrating the stratum, so the horizontal section of the crossing curve should be located at 551.65m-557.20m in the Yellow Sea elevation system; the silty clay 1-layer is liable to liquefaction due to vibration and is not suitable for selection As the point of entry and exit of the pipeline, the point of entry and exit of the crossing track is set on the banks of both sides of the river; in order to ensure the shortest distance of the pipeline passing through the bad stratum, the coordinates of the point of entry are initially selected as (9.36,573.86), and the coordinates of the point of entry are (1073.18 , 570.15). Establish a mathematical model to solve the objective function of the shortest crossing trajectory. Each design parameter is represented on the simplified drawing of the crossing curve, as shown in Figure 21.

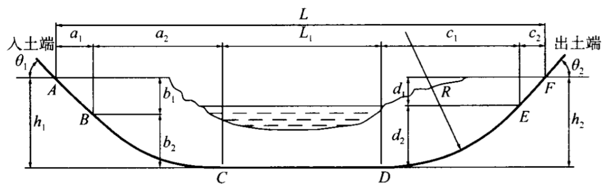
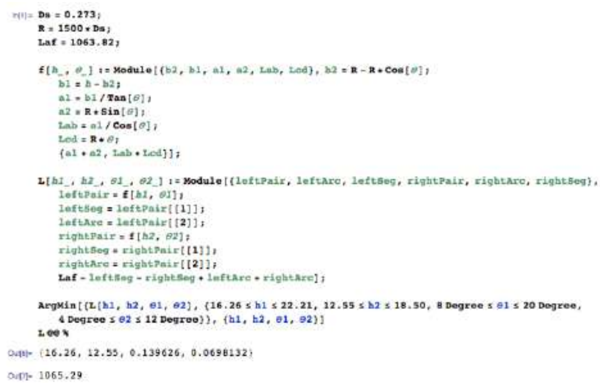


Figure 21. Simplified diagram of the crossing curve

Mathematica is used to solve the function by programming, and the calculation interface is shown in Figure 22. The detailed HDD trajectory design parameters are listed in Table 24. Figure 23 is the design drawing of the trajectory.



```
In[1]:= Ds = 0.273;
R = 1500 * Ds;
Laf = 1063.82;

f[h_, θ_] := Module[{b2, b1, a1, a2, Lab, Lcd}, b2 = R - R * Cos[θ];
  b1 = h - b2;
  a1 = b1 / Tan[θ];
  a2 = R * Sin[θ];
  Lab = a1 / Cos[θ];
  Lcd = R * θ;
  {a1 + a2, Lab + Lcd}];

L[h1_, h2_, θ1_, θ2_] := Module[{leftPair, leftArc, leftSeg, rightPair, rightArc, rightSeg},
  leftPair = f[h1, θ1];
  leftSeg = leftPair[[1]];
  leftArc = leftPair[[2]];
  rightPair = f[h2, θ2];
  rightSeg = rightPair[[1]];
  rightArc = rightPair[[2]];
  Laf - leftSeg - rightSeg + leftArc + rightArc];

ArgMin[{L[h1, h2, θ1, θ2], {16.26 ≤ h1 ≤ 22.21, 12.55 ≤ h2 ≤ 18.50, 8 Degree ≤ θ1 ≤ 20 Degree,
  4 Degree ≤ θ2 ≤ 12 Degree}}, {h1, h2, θ1, θ2}]
L @@ %
Out[6]= {16.26, 12.55, 0.139626, 0.0698132}
Out[7]= 1065.29
```

Figure 22. Program calculation interface

Table 22. Detailed design parameters of HDD river crossing

Entry point coordinates	(9.36,573.86)	Unearthed point coordinates	(1073.18,570.15)
Entry angle	8°	Unearthed corner	6°
Entry point mileage pile number	K40+30	Unearthed Mile Number	K41+148
Through the maximum depth H_{max}	14m	Curvature radius of curvature	1500D=328.5m
Horizontal length	725.72m	Total length of pipe section	1065.30m

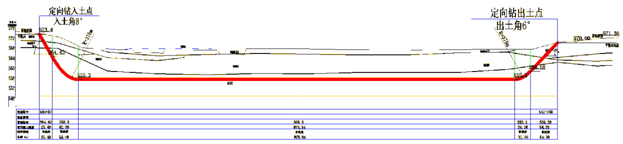


Figure 23. Crossing track design

According to the "Code for Design of Horizontal Directional Drilling Crossing of Oil and Gas Transmission Pipeline Engineering" (SYT 6968-2013), it is determined that the crossing engineering grade is medium-sized, and the strength design factor is 0.5.

Table 23

Engineering level	Crossing pipe section parameters		Strength design factor
	Crossing length (m)	Crossing pipe diameter (mm)	
Large	≥1500	Excluding pipe diameter	0.5
	Excluding Length	≥1219	
	≥1000-<1500	≥711	
Medium	1000	≥711-<1219	
	≥800-<1500	<711	
Small	<800	<711	0.6

4.2.3 Selection of HDD Equipment

(1) Type Selection of Drilling Rig

The maximum stress during horizontal directional drilling and towing is calculated according to (4.1).

$$F_t = \mu_{soil} L \left| \frac{\pi D_s^2}{4} \gamma_{mud} - \gamma \delta \pi D_s - W_p \right| + \pi D_s \mu_{mud} L \quad (4.1)$$

Where F_t is the maximum tension in KN, L is the length of the crossing pipe section in m, μ_{soil} is friction coefficient taken as 0.3, D_s is the outer diameter of steel pipe in m, γ_{mud} is the weight of the mud in kN/m^3 taken as 10.5-12.0, γ is the weight of the steel pipe in kN/m^3 taken as 78.5, δ is wall thickness of steel pipe in m, W_p is counterweight per unit length in the process of dragging back in kN/m^3, μ_{mud} is the viscosity coefficient in kN/m^2.

According to the "Code for Design of Horizontal Directional Drilling Crossing of Oil and Gas Pipeline Engineering" (SYT 6968-2013), the recommended value of the viscosity coefficient is 0.175 kN/m^2, because the effective gravity of the pipeline in the borehole does not reach the buoyancy of 2kN/m, Therefore, counterweight buoyancy control measures are not adopted. The calculated maximum pulling force of the towed pipeline is =417.37kN.

According to GB 50423-2013 "Code for Design of Oil and Gas Transportation Pipeline Crossing Engineering", the maximum pullback force of the drilling rig is selected based on 1.5-3.0 times of the calculated pulling force. Therefore, the pullback force provided by the selected drilling rig should be greater than or equal to 1252kN. It is a medium-sized drilling rig.

Because the GD1600-L horizontal directional drilling rig has the advantages of high cost performance, strong adaptability and convenient transition, this solution recommends the use of the GD1600-L horizontal directional drilling rig. The main parameters of the rig are shown in Table 224.

Table 24. Main parameters of GD1600-L horizontal directional drilling rig

Machine quality	29000kg	Dimensions (L×W×Hmm)	10300×2500×3100
Maximum pushing force	1700kN	Torque	70000N•m
Maximum push and pull speed	37m/min	Maximum swing speed	92r/min
Engine power	2*194kW	Crawler walking speed	3.0-6.0km/h
Entry angle	8-18°	Maximum grade	20°
Maximum back expansion aperture	Φ1600	Maximum construction distance	1200m

(2) Drill Tool Selection

Drilling tools mainly include drill bits, power drilling tools, drill collars, drill rods, reamers, centralizers, whipstocks and rotary joints. The key equipment: drill bit, drill pipe and reamer are selected as follows.

1) Drill bit selection

The working performance of the drill bit directly affects the drilling quality, the drilling capacity under different formation conditions, the drilling cost and efficiency, and the direction change and control method. The drill bit is divided into inclined plate drill bit (generally used for small directional drill), roller cone bit, PDC drill bit and diamond drill bit (for hard rock formation conditions). According to the preliminary geological exploration results, the stratum crossing the river does not contain hard rock formations, so the mud motor combined with hydraulic jet bit is used.

2) Selection of drill pipe

The drill pipe is the hub connecting the ground drilling equipment and the underground drilling tools. Drilling rods in complex drilling conditions are subjected to complex alternating stresses and are the weakest link in drilling tools and equipment. Therefore, the rational design of the drill string is of great significance for achieving fast and high-quality drilling.

  DOI: https://doi.org/10.30564/frae.v3i3.2453

Table 25. Working load status of drill pipe string

Axial compression and tension	It is applied by the drilling rig when drilling pilot holes, reaming holes, and towing, which is the main cause of drill pipe fatigue
Torque	Maximum torque at the entry point and minimum at the hole end Bending moment and centrifugal force
Bending moment and centrifugal force	The curved drill rod receives the bending moment under the action of axial force, and the self-rotation generates centrifugal force to aggravate the bending deformation of the drill rod string.
Longitudinal vibration, torsional vibration and pendulum vibration	Causes serious wear on the drill string

Considering the complex and changeable load of the drill pipe string in operation, the pipe material needs to have high axial strength, torsional strength and toughness, so the steel pipe with high steel grade is selected to ensure safe drilling. The arc curve of the oblique section is regarded as its projected straight line on the horizontal plane. This approximation simplifies the calculation. The error can be corrected by enlarging the calculated n value. The total length of the traversing pipe section is 1065.29m, and a total of 372.66 drill rods are required, rounded to 373 drill rods of steel grade DZ75.

3) Selection of reamer

The reamer can be divided into barrel reamer, plate cutter reamer, fly spin reamer, roller cutter reamer, etc. The main function is to cut and ream the guide hole along the curve of the guide hole. Different reamers should be selected according to different geological conditions.

According to the results of the geological survey, the strata crossing the river are mainly sand and hard clay layers, and the method of squeezing and expanding the holes is of high quality. Therefore, the use of plate reamers is more suitable for the formation conditions and is beneficial to improving the quality and expansion hole efficiency.

Table 26. Relationship between minimum reaming diameter and crossing pipe diameter

Diameter of crossing pipe section (mm)	Reaming diameter (mm)
＜ 219	Pipe diameter+100mm
219-610	1.5 times the diameter
＞ 610	Pipe diameter+300mm

Take the minimum reaming diameter of 330mm according to the table above. According to the "Code for Design of Oil and Gas Transportation Pipeline Crossing Engineering" (GB 50423-2013), pipelines with a diameter of less than 400mm can be directly expanded and withdrawn when the rig's capacity permits. Therefore, this scheme adopts a pre-reaming and dragging construction process.

4.2.4 Design of Crossing Pipeline

(1) Wall Thickness Design of Crossing Section

The wall thickness of the pipeline is designed according to the specifications of the oil pipeline and the large and medium-sized crossing projects of the "Specifications for the Design of Horizontal Directional Drilling Crossing of Oil and Gas Transportation Pipeline Engineering". The pipeline strength calculation of this project adopts the SYT 6968-2013 medium wall thickness calculation formula.

$$\delta = \frac{PD}{2\sigma_s \psi F}$$

Where D is outer diameter of steel pipe in mm, σ_s is yield strength of steel pipe in MPa, ψ is weld coefficient taken as 1.0, F is strength design factor. The grade of the crossing project is medium, so F is 0.5.

After calculation, under the pressure of 5.5MPa and 7.0MPa, the wall thickness of different steel grades is calculated as follows:

Table 27. Wall thickness calculation table for different steel grades

Steel grade	Calculated wall thickness (mm) (5.5MPa)	wall thickness (mm)	Weight (t/km)	(Ten thousand yuan/ km)	Calculated wall thickness (mm) (7.0MPa)	wall thickness (mm)	Weight (kg/ km)	price (Ten thousand yuan/ km)
L245	4.92	8.0	41.61	21.64	8.96	9.0	5800	24.23
L290	4.15	7.5	37.01	20.03	7.83	8.0	5400	22.47
L360	3.35	6.5	34.05	19.75	7.00	7.0	5200	21.22

The calculated price of L245 in the table is calculated at 5200 yuan/t; the price of L290 is 5400 yuan/t; the price of L360 is calculated at 5800 yuan/t. From the calculations in the above table, we can see that after the design pressure is increased from 5.5MPa to 7.0MPa, the corresponding increase in investment is more than 30%; at the same pressure, the steel grade is increased, the pipe cost is reduced accordingly, and the adjacent steel grades are reduced by 6%. Considering the importance of the river-crossing project and the reasons for earthquake resistance, the steel pipe of L360 grade was selected for this crossing. This can not only reduce the cost of the pipe in this project, but also improve the yield strength and tensile strength of the crossing pipeline, and the requirements for welding conditions are not very high, and the domestic supply is sufficient.

(2) Corrosion Protection and Protection of Pipelines Crossing

The three-layer structure polyethylene (3PE) anticorrosion coating with strong corrosion resistance, water vapor permeability resistance and good mechanical properties is selected for the crossing pipeline, and the selected anticorrosion layer is an enhanced level. The filler material of the pipeline should match the material of the anti-corrosion layer of the pipe body, and directional drilling should be used to traverse the special heat-shrinkable belt. The outer protective layer adopts modified epoxy glass or glass fiber reinforced material compatible with three-layer structure polyethylene as the protective layer.

After determining the traversal plan, the next step is the specific implementation process of the traversal.

4.3 Construction Technical Measures

4.3.1 Construction Preparation

(1) Before the project starts, organize technical personnel to review drawings and participate in design technical briefing; conduct safety education and on-the-job training for all employees and make technical quality briefing for all employees.

(2) Go through the procedure of handing over the piles of the project and make marks and records;

(3) Contact the owner, supervision and relevant departments to obtain information on the pipeline crossing the river, optical cables, ground and underground obstacles, and measure the pay-off.

(4) According to the requirements of pipeline construction and directional drilling for the width of the construction area, use the bulldozer or manual to clean up the debris in the occupied area. The trenches, ridges and steep slopes should be leveled, and the width of the operation area should be Meet the design requirements, meet the needs of construction equipment operation and pipeline installation.

(5) Leveling across the site: the operating site of the side-drilling rig needs to occupy 60×60m of the temporary operating site. The area unearthed is 100×30m. After the site investigation, the site of the excavation site and the crops on the access road are cleaned up, and the site is leveled and compacted with an excavator.

(6) Use an excavator to excavate the mud pool. Under normal circumstances, excavate a 15×10×2.0m mud pond at the entry point, and excavate a 15×10m×2.0m mud pit at the excavation point. At the soil entry point, two 3×2.5m×2m mud must be excavated to return to the pit. After the excavation of the mud pit is completed, a layer of geotextile is placed on the bottom and all around the mud pit to prevent mud leakage.

(7) The size of the excavation cross-section is 0.8m wide and 0.8m high, and the bottom of the ditch should be excavated longitudinally to a certain arc to ensure that the pipeline enters the hole smoothly when the pipeline is towed back.

(8) Site equipment layout

Equipment for rig work site layout includes: directional drilling rig, mud pump, mud mixing and recycling system, diesel generator set, driller's operation control room, tool accessory room, crane, mud sloping soil storage site, diesel storage tank, drill rod storage site , Drilling tool stacking site, mud surplus soil feeding site, mud sedimentation tank, mud return tank, etc.

(9) Equipment installation and commissioning

The installation of equipment into the field is smooth: rig installation → rig operation control room installation → mud system installation → mud pump installation → drill rod placement in place → other equipment in place. The centerline of the rig coincides with the centerline of the pipeline crossing; adjust the height of the rig according to the angle of entry provided by the design drawings, so that the angle between the walking track of the rig and the horizontal plane coincides with the designed angle of entry.

4.3.2 Mud Preparation

In the guide hole and hole expansion process, the loose sand layer cannot form an arch, it is difficult to maintain the shape of the channel, and it is easy to cause collapse. In the construction, high dispersion mud is used to increase the density and viscosity of the mud.

(1) The mud should be environmentally friendly mud, and it can be recycled. It is recommended to use a positive electric glue mud system, and bentonite to use high-efficiency bentonite. The basic formula of mud is recommended as: high-efficiency bentonite + positive gel + CMC + soda ash + appropriate amount of caustic soda. Lubricants can be added when pulling back, as appropriate. If slurring occurs, add a plugging agent to the mud.

(2) The directional drilling crossing of the project requires that the mud should mainly consider low fluid loss and good slag carrying performance, and the thin mud cake thickness forms a good wall protection and should also have a low friction coefficient and good Lubrication performance. According to the change of stratum conditions, the requirements for mud performance adjustment in each construction process are as follows:

① Diagonal hole section of pilot hole

In order to ensure the carrying of drill cuttings and

  DOI: https://doi.org/10.30564/frae.v3i3.2453

the cleaning of the hole, to control the water loss of the mud and prevent the collapse of the hole, it is necessary to increase the content of the wall fixing agent and the tackifier.

② Horizontal hole section of guide hole

It is necessary to increase the content of debris removal agent and lubricant in a timely manner, appropriately reduce the viscosity and cutting force, ensure the good rheological performance of the mud, make the cuttings return to the ground smoothly, enhance the lubricity of the mud, and reduce the rotation and propulsion resistance of the drilling rig.

③ Reaming section

In order to enhance the wall-building performance of the mud and prevent the hole wall from collapsing and reducing diameter, it is necessary to increase the content of the wall-fixing agent and tackifier.

④ Drag back section

In order to improve the lubricity of the mud, reduce frictional resistance, and enhance the effect of carrying chips, it is necessary to increase the content of the cleaning agent and lubricant.

(3) The mud for directional drilling crossing should be prepared with clean water. Before the start of construction, the water samples on site must be used, and the mud formula must be modified according to the specific conditions of the stratum. The calcium and magnesium ions should be avoided. Impact.

(4) The performance of the prepared mud should be determined according to the geological conditions laboratory test. It is recommended that the mud performance meet the following conditions:

Table 28. Mud performance conditions

Slurry loss	Density	Viscosity	Dynamic plastic ratio	Back slurry carrying sand	PH value
12 mL/min	1.02-1.10	25-30s	1-1.5	Above 10%	10-11

(5) The mud should be recovered and recycled, and the sand should be removed by vibrating screen. The mud content of the mud used for recycling after treatment by the mud recovery system should not be greater than 0.5%.

(6) The mud displacement in the process of hole expansion should not be less than 2.5m3/min, and the mud displacement in the process of pilot hole drilling and towing should not be less than 1.0m3/min.

(7) In order to avoid slurring, a mud pressure sensor should be installed near the drill bit to monitor the mud pressure in the cave throughout the process. If the slurry pressure is too high and the slurry is splintering or the pressure suddenly rises abnormally, the drill bit will be drawn back and washed Continue drilling after the hole.

4.3.3 Drilling pilot holes

Check whether the drill bit water hole is clogged, and after the mud is prepared, you can start the drilling rig for trial drilling. The drilling tools used in this project are: the drill pipe adopts the standard S135 internal thickened oil drill pipe, the drill bit uses the tri-cone bit and the non-magnetic drill collar; the real-time tracking of the steering system and the MGS system for tracking and positioning can be Make sure the unearthed location is accurate.

Drill pilot holes according to the design curve, and determine the angle of each drill rod according to the curvature radius of the design curve. Before starting drilling, first draw a 1:1 design curve (drawn on the computer) according to the design curve, and design the drilling angle of each drill rod according to the design entry angle, draw the drilling curve according to the design angle, and compare it with the design curve Compare, after repeated comparison, determine the final pilot hole drilling angle.

During the drilling of pilot holes, real-time tracking and measurement should be performed and records should be made. Data control points are set every other drill rod on the crossing curve. In order to increase the measurement frequency, a measurement can be performed at a certain distance in the middle of a drill rod. This controls the drilling of pilot holes. Measurement record data includes: initial azimuth, linear azimuth, initial tilt, drilling azimuth, drilling tilt, left and right offset, tool face, geomagnetic angle, total geomagnetic field, total gravity field, etc.

During the drilling of pilot holes, the steering personnel should communicate with the driller at any time to determine the angle of the tool face and the length of advancement or drilling.

During the drilling of pilot holes, the steering personnel should communicate with the driller at any time to determine the angle of the tool face and the length of advancement or drilling.

The steering personnel should draw the steering curve in time and compare it with the design curve, the design drilling inclination angle and the azimuth angle. Identify problems in time so that appropriate measures can be taken to correct them.

If it is found that the curve deviates from the design curve, the corrective plan is determined according to the deviation.

During the drilling of the pilot hole, the drilling direction must be strictly controlled to ensure that the drilling curve matches the design crossing curve.

4.3.4 Pre-Reaming Process

After the pilot hole is drilled, remove the drill bit, non-magnetic drill collar and direction control system, install a Φ330mm reamer, make sure that the reamer and mud spray hole are not blocked, and then start reaming. In order to avoid the phenomenon of hole collapse, the mud pressure, mud viscosity and mud displacement should be strictly controlled according to the formation geological conditions during the hole expansion process, and the viscosity of the hole collapse area should be appropriately increased.

Collapse generally occurs at the front end of the towing pipe section. If collapse occurs, the amount of mud pumping should be increased at this time to properly reduce the viscosity of the mud and replace the mud at the collapsed hole.

When reaming, according to the size of the hole diameter. Reaming speed should be strictly controlled during hole expansion, and the hole expansion speed should be controlled within 450mm/min.

4.3.5 Pipeline Drag Back

The towing is the last step of directional crossing, and it is also the most critical step. After checking the correctness, the towing can be carried out. Perform continuous operations during backhauling to avoid increased resistance due to shutdowns. In order to ensure the smooth towing and the anti-corrosion layer is not damaged, the following measures will be taken: before connecting the tube to the towing, to ensure the consistency of the prefabricated pipeline and the crossing axis, reduce the lateral friction of the pipeline when entering the hole, and ensure that the anti-corrosion layer is intact Holes.

The pipeline is towed back in the way of sending trenches. The transmission ditch adopts single bucket operation, and its size is 1.5m wide at the upper mouth, 0.8m wide at the lower mouth, and 0.8m deep; when the transmission ditch is dug, calculate the slope of the transmission ditch, especially the slope of this section of the transmission ditch where the pipeline enters the hole, Make sure that the distribution trench, especially the section of the pipeline that enters the hole, is smooth and smooth.

In order to reduce the friction of the pipeline during towing, ensure the pipeline to be smoothly towed and protect the pipeline anticorrosion layer, during the towing process, keep the pipeline suspended in the hole as much as possible, take floating measures to reduce the pipeline during towing Friction reduces the direct contact between the pipeline and the hole wall. As long as the pipeline is completely suspended in the hole, the drag resistance of the pipeline during dragging will be reduced to a minimum, which can ensure the smooth dragging of the pipeline.

The stress factors in the pipeline dragging process mainly include: the friction between the pipeline and the sending ditch wall, the pipeline and the hole wall; the viscosity resistance between the pipeline surface and the mud or water. The calculation formula of directional drilling crossing construction design experience, taking the middle value of the recommended multiple, the maximum pulling force of the towing pipeline is 417.37kN.

4.3.6 Pipeline Welding Inspection and Pressure Test

Welding across the pipe section uses manual downward welding or semi-automatic downward welding welding process. Welding process evaluation should be carried out before welding. For specific requirements and operations, please refer to “Method for Welding Process Evaluation of Oil and Gas Pipelines” (SY/T4052-92) and “Steel Relevant regulations of Pipe Welding and Acceptance (SY/T4103-2006).

Downward welding root welding uses high cellulose sodium type E6010 electrode, electrode diameter 4.0mm; hot welding uses high cellulose sodium type E8010 electrode, electrode diameter 3.2mm; filling welding and cover welding use iron powder low hydrogen type E8018 electrode, The electrode diameter is 3.2mm. The root welding of the semi-automatic welding E6010, the cover surface is B71T8-K6 electrode diameter 2.0mm; the performance of E6010 should meet AWS A5.1; E8010 meets the requirements of AWS A5.5, B71T8-K6 meets the requirements of AWS A5.29. Welding should be in accordance with the current national standard “Code for Construction and Acceptance of Field Equipment and Industrial Pipe Welding Engineering” (GB50236-98). Each welding port must be welded once. When the previous welding layer is not completed, it is not allowed to enter the welding of the next layer. When welding downward, the root welding should be penetrated, and the convex part in the weld bead should be polished to avoid slag inclusions.

The circumferential welding of the entire crossing section is first inspected using 100% ultrasonic flaw detection, and then 100% X-ray flaw detection is reviewed. X-ray inspection is carried out “Radiography and Quality Classification of Butt Welds of Oil and Gas Steel Pipelines” (SY4056-93). Welds above level Ⅱ are qualified. Ultrasonic flaw detection implements “Ultrasonic flaw detection and quality classification of butt welds of oil and gas steel pipelines” (SY4065-93). Welds of grade I and

DOI: https://doi.org/10.30564/frae.v3i3.2453

above are qualified.

The test pressure of the pipeline should be clean, non-corrosive water as the test medium.

Piping and pressure test of the entire crossing section pipeline, the strength test pressure is 1.5 times the design pressure is 7.2MPa, and the pressure is maintained for 4 hours; when the strength test pressure does not leak, the tightness test pressure is 6.0MPa, and the pressure is not less than 24 hours; the pressure drop during the pressure stabilization period is not more than 1% and the test pressure is qualified. After the hydrostatic test, the accumulated water in the pipe should be drained, and the drying process in the pipe should be carried out to achieve that the humidity of the air in the pipe is consistent with the humidity of the external environment. If the crossing section cannot be connected to the general line section immediately, temporary blind plates should be welded on both ends of the crossing section to prevent debris from entering the pipe.

4.4 Impact on Hydrogeology and Environment

4.4.1 Impact on Landform

Directional drilling does not destroy the landform, there is no water or underwater operation in the construction, and the pipeline is buried in the underground stable layer. Pipeline excavation construction must take measures such as precipitation and slope support, while the use of directional drilling reduces the amount of excavation works, will not cause damage to crops on both sides of the bank, reduce environmental pollution, and save a lot of investment.

4.4.2 Impact on Riverbed Structure

Directional drilling does not damage the dam and riverbed structure. There are no construction access roads and construction machinery in the entire width of the crossing river surface. There is no need for land acquisition and reinforcement of the river embankment, which reduces project investment.

Compared with other construction methods, the construction cycle of directional drilling is short, the equipment enters and exits the field quickly, and has little impact on the surrounding environment and residents' lives.

At the same time, due to the buried depth of the pipeline about 12m below the river bed, the buried stratum is deep, and the internal corrosivity of the stratum is relatively small, which plays a role in anti-corrosion and thermal insulation of the pipeline, which can extend the service life of the pipeline and reduce the annual maintenance fee and man-made damage.

Using modern construction equipment with high construction accuracy, easy to adjust the burial depth and arc to ensure the accuracy of directional drilling construction.

4.4.3 Impact on Biology

Directional drilling construction will cause the increase of suspended solids in the local area, which will have an adverse effect on the organisms. The increase of suspended solids will affect the growth of fish and slow down the reproduction rate of fish. Since the distance between the crossing section of the project and the shore is greater than 100m, the impact of suspended matter is limited.

4.4.4 Impact of the Construction Process on the Environment

The main environmental pollution generated during the construction period is dust, noise, wastewater, channel occupation and ecological loss.

(1) Air Pollutants

During the construction period, the main sources of atmospheric pollution are the tail gas and dust emitted by engineering vehicles and transportation vehicles. The tail gas emitted by vehicles during operation is unorganized emissions. The main pollutants are NO, CO and TSP. The main pollutant in the construction process is TSP, and its pollution complies with the second-level standard of the National Comprehensive Air Pollution Emission Standard (GB 3095-96).

(2) Noise

In construction operations, drilling rigs and excavators are used for construction. Due to the noise generated by construction machinery (pneumatic picks, excavators, mixers, and loaders) and vehicles, some nearby residents will be affected temporarily.

(3) Wastewater

The water pollutants during construction are mainly domestic sewage of construction personnel and engineering wastewater discharged after pressure test of pipelines. Pipeline pressure test generally uses clean water. The pollutants in the discharged water after pressure test are mainly suspended solids, which are collected and discharged into the urban sewage system.

The main pollutant of domestic sewage during construction is COD, and domestic sewage cannot be discharged anywhere. After collection, it is required to be regularly extracted by the environmental sanitation department.

(4) Solid Waste

The solid waste in construction mainly comes from waste materials (such as welding rods, anti-corrosion materials, etc.), domestic garbage and waste mud. After the construction is completed, the waste mud in the mud pool will be cleaned up and transported to the designated dump.

(5) Impact on Ecology

The impact on the ecology is mainly manifested in the destruction of the surface protective layer, the change of the soil structure, the loss of soil nutrients, and the soil erosion caused by adverse geological conditions, etc.

4.5 Fire and Safety

4.5.1 Safety and Fire Protection Measures Adopted in the Design

Under normal production conditions, fires are generally not easy to occur. Only under operational errors, violations of regulations, improper management, and other abnormal production conditions or accidents can various factors lead to fires. Therefore, in order to prevent fires or reduce the losses caused by fires, according to the policy of "prevention first, combination of prevention and elimination", the project has adopted corresponding preventive measures in design.

The design of pipeline weld requires 100% radiographic flaw detection and 100% ultrasonic re-inspection to ensure the quality of welding construction.

After detailed geological survey of the crossing river section, detailed geological survey data and detailed understanding of the conditions of the underground pipeline shall be obtained before construction drawing design.

Before construction, the construction unit shall formulate a perfect construction organization plan. After approval by the relevant departments, and before the crossing, the first step is to carry out geophysical prospecting and obtain the actual geological data of the crossing point before crossing.

4.5.2 Main Safety Measures during Construction

(1) The construction plan for crossing should be approved by the local water conservancy department before construction;

(2) The unit undertaking construction must hold the corresponding qualification level certificate and pressure pipeline installation license, and the welder and non-destructive testing personnel must have the special operation personnel qualification certificate frequently issued by the technical supervision department;

(3) Pipes and pipeline components must have quality certificates, and their quality should not be lower than the current national standards;

(4) The pressure vessels and pressure pipes in this project are manufactured by the manufacturing unit with the corresponding manufacturing license and are manufactured, inspected, tested and accepted according to the corresponding standards;

(5) Hire a qualified and experienced construction team, and at the same time hire a supervising engineer of a qualified unit to control the whole process of the installation of the device, prevent the occurrence of non-compliance with the regulations, and avoid remaining hidden dangers. And invite a qualified third-party testing team to perform non-destructive testing on all welded joints to ensure their quality;

(6) Welding operators should be trained and qualified. When welding, you must wear protective glasses with color filters, wear protective clothing, protective gloves and other supplies. Barriers should be set around the work site to prevent injury to other personnel;

(7) According to relevant national regulations, provide site workers with safety helmets, anti-static overalls and other protective equipment to prevent casualties;

(8) Cutting and welding hot work must meet the "hot work requirements" and have practical safety facilities;

(9) Strict management in accordance with the relevant provisions of the State Council Decree No. 393, "Regulations on Construction Engineering Safety Management".

4.6 Construction Risks and Countermeasures

4.6.1 Emergency Response Plan for Construction

When drilling pilot holes, when the torque increases and the drill breaks, the construction should be stopped immediately. First look for the fracture collision situation. If the fracture rule collision situation is good, remove the drill rod on the side of the working rig, put a small drill rod into the drill rod to connect the broken drill rod together, and then use a special drill the rod salvage tool salvage the broken part out of the ground, and then reorganize the construction.

4.6.2 Emergency Plan for Stuck, Held and Broken Drills in the Process of Hole Expansion

(1) The first step to be carried out when sticking and holding drills is to withdraw the reamer out of the hole: when the torque does not reach the limit of the rig, use the rig to rotate to withdraw the reamer, and then proceed to the next step; If relying on the power of one drilling rig cannot make the reamer exit the hole, we will transfer the other drilling rig to the excavation point and keep in touch with the driller on the other side after connecting the drill rod to keep the two rigs at the same speed And the steering, using the method of pushing into the soil drilling rig, pulling the drilling rig. If the above method fails to withdraw the reamer, contact the pulley block and use a com-

  DOI: https://doi.org/10.30564/frae.v3i3.2453

bination of certain pulleys and one-motion pulleys. Each pulley is worn with 8 strands of steel rope. Reinforce the ground anchor at the unearthed point. The power of this pulley block can use a hoist or an excavator to continuously increase the force until the reamer is pulled out. The combined straight drag force reaches more than 500t.

(2) In an emergency situation where the drill pipe breaks during the reaming operation, first determine whether the drill bit is at the front end or the rear end of the drill pipe break. When the drill bit is at the front end of the broken drill rod, first use the excavator to pull out the rear drill rod, and then use the drill to rotate back to slowly withdraw the drill bit, replace the broken drill rod, and re-expand the hole; when the drill bit is broken When the drill pipe is at the rear end, first use an excavator to drag the rear drill pipe. If the supporting force is large, adjust another drill to the unearthing point. After the ground anchor is strengthened, the drill is rotated and pulled back to extract the drill The tool and drill bit are used to replace the broken drill rod after drawing out the drill rod, and then re-drill the drill rod from the original hole to re-expand the hole.

4.6.3 Emergency Plan for Pipeline Jamming During Towing

(1) Once the dragging force of the pipeline gradually increases during the dragging process, the speed gradually slows down until it locks up. First, analyze the curve and mud to quickly find out the reason;

(2) If the towed pipeline is within 50m from the drilling rig, consider the method of large excavation to dig out the pipeline and then connect the head. If the distance is beyond 100m or large excavation is not possible, the pipeline should be withdrawn;

(3) Pulley sets are used for the withdrawal pipeline, and the excavator or winch is used for the power, and the force is gradually increased until the pipeline is pulled back;

(4) Because the angle of the hole formation in the backhaul pipeline section of the crossing project is gentle, the whole drill pipe curve is bound to be gentle when the pipeline is towed, and the drill pipe at the entry point is covered with thin floating soil, which is likely to cause the drill pipe to move up. , Adopt the method of adding floating weight on the overlying floating soil to prevent the drill pipe from falling and moving upwards.

4.6.4 Spilling Emergency Plan

(1) First of all, arrange special personnel to monitor the entire project for the occurrence of spattering, especially near geological prospecting holes that are prone to spattering. Once a small range of slushing is found, the cofferdam will be carried out immediately to prevent the spread of the slushing area.

(2) In the case of large-scale slurry pouring and failure to stop the leakage, dig the diversion channel to lead the mud to the mud pit or dig the mud pit on the spot, and arrange the mud truck to pump out.

(3) If it is found that there is a slurry hole along the line, due to the slurry leakage, the mud in the hole is lost and the debris in the hole cannot be discharged out of the hole. A certain amount of water glass agent can be used to block the slurry hole.

(4) Control the haulback force and haulback speed of the rig to prevent pipeline instability. When pulling back through the pipe section, the maximum pullback force of the drilling rig must be controlled. Excessive pullback force will affect the strength of the pipeline. When pulling back the pipeline, the speed should not be too fast, and the time should be greater than 12 minutes per root.

4.6.5 Treatment Plan for Collapsed Holes

(1) Improve the viscosity and shear force of the mud, increase the density properly, control the low water loss of the mud, wash or drill with a small displacement cycle, so that the annulus mud is flat laminar or plug flow, and the slump and The cuttings are carried out;

(2) When the collapsed hole is serious and the size of the collapsed block is large, under the premise of maintaining the annulus laminar flow state, the drill bit eyehole can be increased, and the high pump pressure and appropriate displacement can be used to flush the collapsed large rock fragments. Take out the ground and can be equipped with a certain amount of high-shear, high-viscosity mud to clean the hole bottom and drill cuttings during flushing.

5 Auxiliary Production System and Supporting Engineering

5.1 Communication

The construction of the communication system of this project is to provide a bearing network for the SCADA data, voice and video transmission of the process stations related to crude oil long-distance transportation, and at the same time set up video surveillance camera front ends and amplified broadcast telephone terminals for each process station.

At present, there are three commonly used transmission methods at home and abroad: optical fiber communication, wireless broadband communication and satellite communication.

The selection of the technical solution of the engineering system should save investment as much as possible on the premise of meeting the technical requirements, and the satellite communication method has a large investment, the capacity is relatively small compared to the optical fiber communication, and the performance-price ratio is at a disadvantage. Therefore, the satellite communication method is not suitable for this project. No further discussion will be made in this design. The optical fiber communication mode has large transmission capacity, long relay distance, stable transmission quality, and is not disturbed by external factors. The wireless broadband communication method has flexible networking, high transmission rate, and easy expansion.

According to the actual needs of this project, the communication system must not only be safe and reliable, but also save investment as much as possible. Therefore, comprehensive analysis is considering the actual situation of the project, but higher requirements for transmission quality, optical cable communications in the formal development stage can be easily incorporated directly into the new optical fiber communication transmission network. Based on the comprehensive situation, the design recommends the use of optical fiber transmission communication as the communication transmission scheme of this project.

Considering the actual situation of this project, the optical fiber transmission system considers the use of multi-service uncompressed video optical transmission equipment networking. Install light receiving equipment at the loading station and light emitting equipment at the remaining stations. The system carries SCS data, video and control signals and voice transmission services from the joint station to the loading station.

5.2 Power Supply and Distribution

(1) Power Supply System

This design builds a 110kV substation near the first station of the overseas transmission to provide power for the entire project area.

(2) Lightning Protection and Static Grounding

According to the requirements of “Code for Design of Lightning Protection of Buildings” (GB50057) and “Code for Design of Grounding of Industrial and Civil Power Installations” (GBJ65), all structures, stations and process pipelines shall be provided with necessary lightning protection and anti-static grounding according to the specifications , Working ground and protective ground.

Each station’s transformation and distribution room is provided with a ring-shaped closed common grounding grid, the grounding resistance is less than 1Ω, and the metal shell and process equipment of all live equipment are grounded for protection.

For buildings that need protection against direct lightning strikes, Φ10 galvanized round steel is used as the lightning protection belt, and Φ10 galvanized round steel is used as the downline. The metal pipes and devices protruding from the roof are reliably connected to the roof lightning protection device.

There shall be no less than 2 connection points between grounding trunks and grounding devices for lightning protection in all buildings. The metal pipes introduced into and out of the building should be connected to the lightning protection grounding device at the entrance and exit, and the overhead metal pipes should be grounded once at a distance of about 25m from the building. The impact ground resistance is not greater than 100Ω.

The main metal objects such as equipment, framework, pipelines in the house should be connected to the lightning protection grounding device or the protective grounding device of the electrical equipment. All pipes and equipment that may be exposed to static electricity in the outdoor are connected into a continuous electrical path and grounded. The grounding resistance is not greater than 30Ω.

Bare metal brackets are placed outside the entrance of the explosion hazardous environment as anti-static facilities and there should be obvious signs, and the metal brackets should be grounded. In the production process, anti-static shoes, anti-static work clothes, anti-static gloves and other personal static protection facilities should be used; static test equipment should be provided to grasp the amount of static electricity carried by yourself before entering an explosion-proof place to take measures. The antistatic grounding resistance is not greater than 100Ω.

(3) Laying Method of Distribution Lines

The power distribution adopts copper core insulated cable, the indoor part is laid underground through steel pipes, and the outdoor part is laid directly buried with armored cables. The lighting circuit adopts copper-core insulated wires through steel pipes and is dark-matched along the wall and the roof insulation layer. The lighting circuits in explosion and fire hazard locations are equipped with steel pipes. The selection of the cross-section of insulated wires and cables shall comply with the relevant regulations and be determined through calculation.

(4) Electric Lighting Distribution Design

Install emergency emergency lighting in substations and power distribution rooms. Electrical lighting in explosion and fire hazard locations should meet explosion-proof requirements. The illuminance standard imple-

DOI: https://doi.org/10.30564/frae.v3i3.2453

ments "Building Lighting Design Code" GB50034 2004. According to different lighting requirements, the light source of the lighting fixture is selected to comply with the relevant national standards and standard equipment products. Among them, the road lighting in the station is planned to use a mixed sodium and mercury light source, the light pole uses a steel column, and PVC power. Buried cable laying, photoelectric automatic control and manual control.

(5) Communication

The power distribution of instrument automation system and instrument automation do not allow uninterrupted power supply. Therefore, non-interruptible power supply (UPS) is used. For UPS power supply, see the communication and automatic control section.

5.3 Building Structure

In order to improve the level of earthquake resistance, the seismic intensity of this design is 7 degrees, and the basic earthquake acceleration value is 0.1g. In general, buildings take earthquake-resistant fortification measures according to the corresponding fortification intensity. First, select a structural system that meets the requirements of seismic fortification intensity. The plane and floor layout and shape treatment of buildings should avoid and reduce the seismic weak links as much as possible. Energy absorption and dissipation structure. For class B buildings, the "Classification Standards for Seismic Fortification of Construction Projects" (GB50223-2008), and according to the "Code for Seismic Design of Buildings" (GB50011-2010), take seismic measures in accordance with the requirements to increase the seismic fortification intensity of the region by one degree. Except for the control center building, compressor room, and empty torch tower, the seismic fortification category is Category B, and the other buildings and structures are considered as Category C.

Because the project area belongs to the mid-temperate semi-humid and semi-arid continental monsoon climate. How much wind and little rain in spring, large evaporation; cool and short in summer, concentrated precipitation; rapid fall in autumn, early frost; long cold in winter, long snow area. The monthly minimum temperature is -37.8°C, and the monthly maximum temperature is 32.9°C. The annual sunshine hours are 2049.5 trivial, and the frost-free days are 126 days. The architectural design focuses on thermal insulation in summer and thermal insulation in winter. According to the "Code for Thermal Design of Civil Buildings" (GB50176-93), the building should not be too large from the direction, shape factor, unevenness of the flat facade, the area of the external window of the building should not be too large, double-layer windows, stucco insulation coating Consider thermal insulation of buildings.

5.4 Heating and HVAC

(1) Design Principles

Strictly follow the current national standards of thermal engineering and HVAC, and the compromise documents formed by the current national standards, and design in accordance with the principles of practicality, advancedness and economy. Adopt high-efficiency, low-consumption, low-pollution equipment, implement the "safe and reliable" guiding ideology, simplify the technological process, achieve the purpose of saving investment and reducing operating costs. Fully consider environmental protection, soil and water conservation and energy conservation.

(2) Heating

According to the heat load requirements for the production of process devices in each station of the block, the heating load of individual building heating in winter in the plant area, and the heat load for process heat tracing, etc., the automatic heat conduction oil furnace heating system is used for the whole plant. Heating. The scale of the heating station is 2 automatic heat conduction oil furnaces, with a single heat load of 8000kW, and the operation mode is 1 for 1 standby; according to the requirements of the heating parameters for the domestic base hot water for the operation base and the winter heating load of the building unit, etc. , It is planned to use a hot water boiler to heat the operation base. The design scale of the boiler room is 2 hot water boilers, with a single heat load of 1.4MW, and the operation mode is 1 set for 1 use.

(3) Keep the Room Warm

The control room uses a heat pump type cabinet air conditioner with auxiliary electric heating to meet the requirements of cooling in summer and heating in winter. In order to meet the environmental temperature and humidity requirements of process equipment and instruments in the duty room, air conditioners and electric heating devices are installed.

(4) Ventilation

The ventilation of the plant is a combination of mechanical ventilation and natural ventilation. Some production plants will emit toxic gases during production operation. In order to reduce the concentration of toxic gases to the allowable range of hygienic requirements or to eliminate indoor residual heat, forced ventilation with natural air intake and mechanical exhaust may be adopted. Axial fans or the roof fan is fully ventilated to remove harmful gases and indoor residual heat.

5.5 Automation Control

The SCADA system should be used for production and operation management in this project area. In order to ensure safe production and improve management level, this project sets up a production monitoring system (e.g. SACDA system) for the entire block. The production monitoring system (SACDA system) is divided into three layers from the logical structure:

The first layer is the production management, decision-making, dispatch and command system, which is the production monitoring system with the SCADA central control system as the core; the second layer is the monitoring system located in each station, which is the control and management of each production operation area; The third floor is a small station control system located in each intermediate station and valve room.

The central control system of SCADA system (that is, the management, scheduling, and decision-making system of the central processing plant) is located in the production dispatching command center of the loading station, with a complete and unified production database and application database, and centralized production monitoring of each station under its jurisdiction , Scheduling and management. The station control system of the SCADA system is a monitoring system set up in the station yards along the line. Responsible for the data collection and processing of the production process and the automatic control and process management of the production process; and collect and monitor the production operation to realize the centralized scheduling and management of the production operation area. At the same time, upload the production data and production information to the central control system, accept the production command and scheduling instructions of the control center, and complete the specific realization of the production plan.

5.6 Fire and Explosion Protection

5.6.1 Causes of Fire and Explosion

The subjective cause of the fire in the oil tank area is often due to the lack of attention of the personnel concerned, paralysis, inadequate system, poor management, and violation of operating rules. The objective reasons are:

① When the electrical equipment is short-circuited, the contacts are separated, the shell is poorly grounded, etc., the arc and spark are caused, or the heating part of the electrical equipment exceeds the maximum allowable temperature;

② Sparks caused by metal impact;

③ Static electricity and lightning;

④ Spontaneous combustion of combustibles, such as sulfur-containing oil deposits in oil tanks spontaneously ignited during removal, and accumulated oily garbage spontaneously ignited;

⑤ Fire spread around the oil depot, etc.

5.6.2 Fire and Explosion Prevention Measures

The oil tank in the ground oil tank area is exposed above the ground, the target is obvious, and it is greatly affected by external factors, especially the risk of fire is large. After the accident, the oil products are easy to flow, causing damage and involving a large area. Therefore, it is necessary to enclose the fire dike around the oil tank or oil tank group. According to the requirements of GB50074-2002 “Code for Design of Petroleum Depots”, the fire separation distance between oil tanks should meet the requirements, the oil tanks in the group should be arranged in a row or two lines, and the distance between the slopes of the two oil tank firewalls Should be greater than 9.5m.

In addition to setting up fire dikes, it is also necessary to avoid fire and explosion by establishing a sound management system:

(1) Formulate Relevant Rules and Regulations

Establish a mass fire-fighting organization, formulate fire-fighting regulations and fire-fighting plans, divide fire-fighting areas, specify fire alarm signals, regularly organize fire-fighting education and fire-fighting exercises, and be skilled in using fire-fighting equipment.

(2) Cut off the Fire Source

① It must be strictly managed in the fire restricted area (oil storage area, receiving and sending operation area), and strictly abide by the relevant rules and regulations. No fires, such as matches and lighters, are allowed in the fire restricted area; smoking is not allowed; steam locomotives are not allowed to enter the warehouse The front chimney should be covered with a fire hood, fly out with a fire star, and close the gray door; it is forbidden to open the blower and put down the gray box baffle in the warehouse, and do not open the steam door and remove the water from the furnace; when the locomotive enters the warehouse, it There must be several isolation vehicles between the tank truck and the locomotive; the locomotive should be reversed into the warehouse; the locomotive should leave the tank truck as soon as possible after entering the tank area; the vehicle is not allowed to drive in the restricted area;

② Prevent sparks caused by metal impact, and do not wear iron spiked shoes for storage; mules and iron wheels are forbidden to enter the storehouse. Because the horseshoes and iron wheels of the horses collide with gravel or cement roads on the road, sparks are prone to occur; use

DOI: https://doi.org/10.30564/frae.v3i3.2453

metal tools and When handling oil drums, avoid collisions to avoid sparks;

③ No open flames (such as oil lamps, candles, etc.) should be used for lighting, nor should ordinary electrical equipment be used for lighting. In order to prevent electrical equipment from causing sparks due to short circuits, contact separation, etc., explosion-proof electrical equipment must be used in the restricted area;

④ In the event of thunderstorms, do not load, unload, measure and sample gasoline, kerosene and diesel fuel.

(3) Do a Good Job in Fire Prevention of Dangerous Operations

Open flame operations such as electric welding, gas welding, and forging in the oil depot area are the most stringent safety requirements and relatively dangerous operations. Therefore, they must be carried out in strict accordance with regulations. Before conducting an open flame operation, a fire application must be submitted. After approval, effective fire safety measures should be taken before the fire can be used. When working with fire, firefighters who are able to cope with any situation should be assigned to be on duty, and be prepared for first aid in the event of an accident.

(4) Handle Combustible Materials

The treatment of combustibles in the oil depot includes the treatment of the oil itself and other combustibles that cause the oil to catch fire.

① Prevent oil vapor accumulation and oil leakage and splashing. When the oil vapor concentration exceeds the safety regulations, mechanical ventilation or natural ventilation should be used to remove the oil vapor, or measures should be taken to collect oil and gas so that it will not escape into the air as much as possible. When oil is spilled, cover with sand or shovel clean;

② Fire dike or firewall should be built on the ground oil tank;

③ In order to prevent the spontaneous combustion of sulfur-containing materials, when removing the sediments of sulfur-containing crude oil tanks, the sulfur-containing sediments should be continuously wetted with water. After the sulfur-containing sediments are taken out, they must be transported away and buried in the soil while wet. Oily gauze and rubbish should be placed in covered iron drums and removed in time. Do not stack them in a place where there is no wind to prevent spontaneous combustion;

④ Dispose of other combustibles in time. It is forbidden to store and remove combustible materials, such as wood shavings, cotton yarn, hay, garbage, etc. around oil tanks, warehouses, pump rooms, etc.

(5) Ensure that Firefighting Equipment Is in Good Condition and Reliable

① The oil depot should have sufficient fire extinguishing equipment. In the warehouse, pump room, barrel room, laboratory, loading and unloading station, cavern and other places, sufficient fire extinguishing equipment and firefighting pool or fire hydrant shall be arranged. And set up fire-fighting points in appropriate places, equipped with all rescue equipment, such as buckets, fire hooks, shovel, axe, etc.;

② Fire equipment should be intact and reliable. It is necessary to check and maintain at ordinary times, and it is forbidden to use it for other purposes. Fire trucks and fixed firefighting equipment should be launched regularly. Always maintain good technical status.

5.7 Fire Protection at Station

5.7.1 Fire Extinguishing Principles and Methods

The principle of fire suppression is to destroy the combustion conditions. According to the three conditions of combustion and the chain reaction that constitutes flame combustion, three basic physical methods of cooling, suffocation and isolation are often used in firefighting technology to extinguish fire and chemical interruption.

(1) Cooling Method

The purpose of the cooling method is to absorb the heat released during the oxidation of combustibles. For burned substances, the temperature can be lowered to below the ignition point, while the decomposition process of combustibles is suppressed, and the speed of combustible gas generation is slowed down, causing the fire to be extinguished due to the “supply shortage” of combustible gases. For other combustibles in the vicinity of the combustibles, they can be protected from the threat of flame radiant heat and destroy the combustion temperature conditions.

(2) Asphyxiation

The suffocation method is to eliminate the combustion aid oxygen O2, so that the combustion extinguishes itself when it is isolated from fresh air. The methods of using this method to extinguish fires are:

1) Use non-combustible or incombustible materials to directly cover the surface of the combustible materials to isolate fresh air;

2) Use water vapor or refractory gas to spray on the combustion products to dilute the oxygen in the air and reduce the oxygen content in the air to less than 9%. For example, the steam in the pump room extinguishes the fire;

3) Try to seal the holes and gaps of the burning container, so that the flame will extinguish after the air in the container is exhausted. For example, after a fire in a cavern, closing a closed door is one of suffocation.

(3) Quarantine

The isolation method is to isolate the fire source from combustible materials to prevent the spread of combustion. The specific methods are:

1) Quickly remove combustibles, combustibles, and explosives near the fire;

2) Demolition of combustible buildings and fire debris adjacent to the fire site in time;

3) Cut off combustible and flammable substances into the burning zone;

4) Limit the flow and splash of burning materials;

5) Move the movable combustibles to an open place, so that the combustibles burn under human control. For example, the tank truck caught fire and quickly dragged out of the warehouse.

(4) Chemical Interruption Method

Chemical interruption method is also called chemical suppression method to extinguish fire. It is a new fire-extinguishing technology developed rapidly in modern times. The new combustion theory believes that combustion is a chain reaction maintained by certain active groups. Chemical fire extinguishing means spraying a chemical fire extinguishing agent into the flame. With the help of chemical fire extinguishing agents, the generation and existence of these active groups are inhibited, and the chain reaction of combustion is prevented to stop the combustion, thereby achieving the purpose of extinguishing the fire. Commonly used chemical fire extinguishing agents include dry powder fire extinguishing agent and high-efficiency halogenated fire extinguishing agent.

5.7.2 Fire Extinguishing Methods and Equipment

Foam fire extinguishing facilities and fire cooling water system should be installed in the oil tank area in the station.

(1) Fire Extinguishing with Foam

According to the design of fire extinguishing equipment, it is divided into fixed, semi-fixed and mobile fire extinguishing systems.

1) Fixed air foam fire extinguishing system it is a semi-automatic foam fire extinguishing device. This system means that all equipment is fixed. There is no need to connect other equipment when extinguishing the fire. When the oil tank fires, just start the water pump (prior to prime the pump before starting), open the pump outlet valve, rotate the foam proportion mixer pointer to the required foam liquid volume index, and mix The device mixes the foam liquid automatically with water in proportion and transfers it to the foam generator through pumps and pipelines. After inhaling the air, the foam is formed and sprayed into the oil tank to cover the oil surface and extinguish the fire.

The fixed air foam fire extinguishing system has the advantages of no need to lay pipelines and installation equipment during fire extinguishing; rapid start-up, fast foam output; simple operation, saving manpower; low labor intensity and so on. The basic disadvantage is that the equipment has a large investment at one time, such as the collapse or explosion of the oil tank, and when the fire fighting equipment installed on the oil tank is damaged, the entire system loses the ability to extinguish the fire. Therefore, when the fixed air foam fire extinguishing system is used, a head is often left on the foam pipe network close to the oil tank area, so that when the fire fighting equipment on the oil tank fails, the mobile fire extinguishing equipment is replaced.

The fixed air foam fire extinguishing system is mainly suitable for oil tanks where the oil tanks are relatively concentrated, the number of independent oil depots and the oil tanks with few fire fighting lines required is relatively small, and the oil depots with complex terrain.

2) Semi-fixed foam fire extinguishing system

This system is equipped with a fixed foam generator on the oil tank and some auxiliary pipelines underneath (it should be connected to the fire dike of the oil tank, about 1 m above the ground, and the end should also be installed with an interface, usually equipped with a boring cover) Outside, cover), other equipment is removable. In case of fire, drive the fire truck with foam liquid to the scene, take water from the reservoir or fire hydrant, and supply the foam mixture to the foam generator fixed on the oil tank with a temporarily installed hose.

Since the water for preparing the foam mixture comes from the cooling water pipe network, there is no need to set up a special foam pipe network, so the construction investment and maintenance cost of this system are lower than the former, but it requires a motorized fire truck and a water pump, and a certain amount Operator. It is suitable for oil depots with relatively flat terrain.

3) Mobile foam fire extinguishing system

The mobile foam fire extinguishing system is to replace the foam generator on the fixed oil tank by foam guns, foam guns or foam hook pipes, foam pipe racks and other equipment. The equipment and equipment are movable, so it is called the mobile foam fire extinguishing system. It has the advantages of good safety, flexible use, low investment, etc., but the operation is complicated and the preparation time for fire extinguishing is long. It is suitable for oil depots with many oil tanks, scattered layout and relatively flat terrain.

According to the requirements of GB50074-2000 “Code for Design of Petroleum Depots”, since the loading sta-

DOI: https://doi.org/10.30564/frae.v3i3.2453

tion uses three 3000m3 floating roof tanks, the foam fire extinguishing facility uses a fixed foam fire extinguishing system.

(2) Fire Cooling System

For firefighting of oil tanks, two systems should be considered, namely fire extinguishing system and cooling system. The cooling system is set to prevent the fire tank steel plate from softening and to protect the adjacent tank; on the other hand, it is also necessary for the fire extinguishing with foam. Because of the fire in the oil tank, the flame temperature is generally 1050-1400°C, and the temperature of the oil tank wall reaches above 1000°C. When the temperature of the tank wall exceeds 600°C, the foam cannot extinguish the tank fire. After the oil tank catches fire, the tank wall should first be cooled with water. When the temperature of the oil surface drops below 147°C, it is possible to cover the fire with foam. Under normal circumstances, when the foam enters the combustion liquid surface, the foam evaporates and bursts very quickly. Because the foam evaporates, the oil is cooled. When the oil surface temperature drops below 147°C, the foam layer can advance on the combustion liquid surface to burn. The surface continues to decrease, and finally covers the entire combustion liquid surface to extinguish the fire. At this time, the foam continues to burst (evaporate) until the oil temperature drops below 98°C, the foam evaporation is gradually reduced, and then, the oil surface temperature continues to drop until it reaches the liquid surface temperature before combustion.

According to the requirements of GB50074-2000 “Design Specification for Petroleum Depot”, since the loading station uses three 3000m^3 floating roof tanks, the fire-fighting cooling water system adopts a mobile cooling water system or a combined fire-fighting cooling water system with a fixed water gun and a mobile water gun.

5.7.3 Fire water supply

The oil tank area of this loading station belongs to a class 4 oil depot, and an independent fire water supply system shall be provided. Normally, the fire water supply system should be kept filled with water, but since the lowest monthly temperature in the project area is -37.8 degrees Celsius, it will not be filled with water in winter.

The fire-fighting water pipeline is laid in a branch shape. The scope of supply of fire cooling water for oil tanks shall meet the following requirements: The fixed oil tank above the ground on fire and the adjacent aboveground oil tanks within 1.5D (D is the diameter of the oil tank on fire) from the tank wall should be cooled. When there are more than 3 adjacent oil tanks on the ground, the cooling water volume shall be calculated according to the larger 3 adjacent oil tanks.

The fired floating roof and inner floating roof oil tanks should be cooled, and the adjacent oil tanks may not be cooled. When the fired floating roof oil tank and inner floating roof oil tank are made of shallow plates or floating tanks made of fusible materials, the adjacent oil tank should also be cooled. Adjacent oil tanks within the range of the distance between the fired floating roof oil tank and the inner floating roof oil tank wall are less than 0.4D (D is the diameter of the larger oil tank between the ignition oil tank and the adjacent oil tank). The parts with greater heat influence should be cooled.

The fire-covered earth-covered oil tank and its adjacent earth-covered oil tank may not be cooled, but the amount of protective water used when extinguishing the fire (referring to the amount of water for personal shielding and cooling the ground and oil tank attachments, etc.) should be considered.

When the oil tank adopts the fixed fire-fighting cooling method, the installation of cooling water pipes shall meet the following requirements:

① When there is no diversion facility for the wind resistance ring or the reinforcement ring of the oil tank, a cooling water spray pipe shall be provided below it.

② Membrane spray nozzles should be installed on the cooling water spray ring, the spacing between the spray nozzles should not be greater than 2m, and the outlet pressure of the nozzle should not be less than 0.1MPa.

③ The lower end of the intake riser for the cooling water of the oil tank is to be provided with a cleaning port. The lower end of the cleaning port should be higher than the top surface of the tank foundation, and the height difference should not be less than 0.3m.

④ Control valves and anti-aircraft valves should be installed on the cooling and fire water pipelines. The control valve should be located outside the fire dike, and the vent valve should be located outside the fire dike. When the fire-fighting cooling water uses ground water as the water source, the fire-fighting cooling water pipeline is provided with a filter.

5.8 Lightning Protection

A large number of flammable and combustible fuels are stored in the oil tank. Once a lightning strike occurs, serious fire and explosion accidents may occur. Therefore, the problem of oil tank lightning protection has attracted people’s attention.

The current commonly used lightning protection devices to prevent oil tanks from direct lightning strikes include lightning rods, lightning protection lines, lightning protection nets, lightning protection belts, and lightning arresters. A complete set of lightning protection devices includes air-termination devices, down conductors and grounding devices. The above needles, wires, nets, and belts are actually just lightning receptors, and the lightning arrester is a special lightning protection device. The lightning rod is mainly used to protect open-air substation equipment and protect buildings (structures). Lightning conductors are mainly used to protect power lines. Lightning protection network and lightning protection belt are mainly used to protect buildings. Lightning arresters are mainly used to protect electrical equipment. In short, the lightning protection device can prevent direct lightning strikes or the introduction of lightning currents to the ground to ensure the safety of people and buildings (structures). There are generally two types of floating roof oil tanks: an outer floating roof oil tank and an inner floating roof oil tank. Three $3000m^3$ outer floating roof tanks are installed in this loading station. The outer floating roof oil tank is tightly sealed, and the oil product has a small area of contact with the atmosphere and direct contact with the atmosphere. The mixed gas of oil vapor and air on the floating roof is not easy to reach the explosion limit, even if a lightning strike catches fire. It also happens only when the sealing ring is not strict, and it is easy to extinguish. Lightning rods are not required. In order to prevent the induction of lightning and the static charge from the oil away to the metal floating roof, two soft copper strands with a cross-sectional area of not less than $25mm^2$ should be used to make a good electrical connection between the metal floating roof and the tank, and ground.

5.9 Anti-static

The generation of static electricity control is mainly to control the process and the selection of all materials in the process; the accumulation of static electricity is mainly to try to accelerate the leakage and neutralization of static electricity so that the static electricity does not exceed the safety limit. Grounding and the addition of antistatic additives are all methods of accelerating electrostatic leakage; methods of using static elimination devices to eliminate electrostatic hazards are methods of accelerating electrostatic neutralization.

(1) Reduce the Generation of Static Electricity

Impurities in oil products are important factors for electrostatic charging, however, it is difficult and uneconomical to achieve high precision in oil products. From the current state of technology, there are no measures that can completely prevent the generation of static electricity. Therefore, in order to prevent the damage of petroleum static electricity, the generation of electrostatic charge cannot be eliminated, and only the technical measures to reduce the generation of static electricity are available.

1) Control flow rate

It is known that the saturation value of the flowing current and charge density generated by the oil flowing in the pipeline is proportional to the square of the oil flow rate. Controlling the flow rate is an effective way to reduce the generation of static electricity. When the oil is in laminar flow, the amount of static electricity generated is only proportional to the flow rate and has nothing to do with the inner diameter of the pipeline; when the oil product is turbulent, the amount of static electricity generated is proportional to the 1.75th power of the flow rate.

The flammable and combustible liquid flowing in the pipeline, even with a higher average charge density, often does not show a higher electrostatic voltage due to the larger capacitance in the pipeline, and because there is no air in the pipeline, So it will not cause burning and explosion. In this case, although static electricity does not constitute a danger inside the pipeline, its serious harm is mainly at the outlet of the pipeline, which must be paid attention to. For example, China's oil tanker loading test shows that when the average flow rate is 2.6m/s, the measured oil surface potential is 2300V; when the average flow rate is 1.7m/s, the oil surface potential is 580V (because the tanker is on the ground) The capacitance is constant, the greater the charge, the higher the potential). Therefore, controlling the flow rate becomes an effective measure to reduce the generation of static electricity in oil products.

According to GB50074-2002 "Code for Design of Petroleum Depot", the filling flow rate of gasoline, kerosene and light diesel oil is not more than 4.5m/s. Some national regulations. When oil is injected from the top, before the oil injection pipe mouth is submerged, before the oil inlet pipe inlet at the top of the oil tank is not submerged, before the floating roof oil tank is not floated, when water or air is trapped in the product oil or flammable liquid, install The oil speed is limited to less than 1m/s.

2) Control the fueling method

This loading station adopts the method of upper oil loading, in order to reduce the impact of oil loading on the tank wall, reduce the agitation of crude oil in the tank, and reduce the accumulation of static electricity. When loading oil, the crane pipe should be extended close to the bottom of the tank truck. This is okay:

① Reduce oil splashing and foaming to avoid the generation of new charges;

② Reduce the atomization and evaporation of oil, and avoid the ignition of oil when it reaches the flash point temperature;

③ Avoid oil flow through the middle of the oil tank

DOI: https://doi.org/10.30564/frae.v3i3.2453

with the smallest capacitance, so as not to generate a large oil surface potential;

④ It can avoid the formation of high oil surface charge density due to the concentrated drop of oil column in a local range;

⑤ In the later stage of oil filling, when the oil surface potential reaches the maximum value, there is no protruding metal grounded on the upper part of the oil surface, which can avoid the increase of local electric field and prevent spark discharge.

3) There is enough leakage time when passing through the filter

The filter is a source of static electricity. The oil passing through the filter, due to the dramatic friction with the filter, greatly increases the strength of contact and separation, which may increase the voltage of the oil by 10-100 times.

In order to avoid injecting large amounts of charge into the container. In the oil pipeline connected with the filter, a certain length should be left at the outlet or flowed for a certain time, the ground charge will be leaked out, and then injected into the container. This length should be L≥3Lb is called the relaxation length, if it is calculated as time, it is t≥3τ, which is called the relaxation time or residence time.

When the length of the pipeline is limited and cannot meet L≥3Lb, consider designing a container so that the oil has a temporary relative residence in the container, and its residence time t≈3τ. This container is called a moderator. General engineering only requires that the amount of charge leak to a level that does not cause danger, so it can be considered that the residence time t≈2τ can meet the requirements. It is generally stipulated that the oil passing through the filter must have a relaxation time of more than 30s. Therefore, the oil passing through the filter must continue to flow through the pipe length of more than 30s in the grounding pipeline before it is allowed to enter the container.

In order to avoid static electricity accidents. The reasonable arrangement of equipment pipelines has a great relationship with the control of static electricity. For example, the filter should not be close to the oil tank or the oil loading platform, and a certain length of relaxation should be left; the pipeline should be free of bends and diameter changes. Where rubber hoses must be used, conductive rubber tubes or conductive plastic tubes are preferred.

(2) Accelerate Static Electricity Leakage and Reduce Static Electricity Accumulation

The generation of static electricity itself is not dangerous. The actual danger is the accumulation of electric charge, because this can store enough energy to generate sparks to ignite the combustible gas mixture. It is generally believed that when the resistivity of the insulator is less than 108Ω·m, there will be no dangerous static electricity accumulation. However, the resistivity of oil products is almost greater than 108Ω·m, and the charge in the oil products is not easy to leak, so the more static charges that are generated in the oil products are accumulated. In order to accelerate the leakage of oil charge, it can be grounded, bridged and increased the conductivity of the oil.

(3) Eliminate Spark Discharge

In order to eliminate spark discharge, the bottom of the tank must be cleared before filling the tank, and no floating conductors and other debris that fall into the tank, such as liquid level gauge floats, measuring cylinders, gaskets and other metal objects. Testing and sampling must be carried out in the oil measuring tube. If no special oil measuring tube is installed, such as conducting a simple sampling, dipstick, etc., these metals are also equivalent to spark initiators on the oil surface. According to relevant information, when oil tank cars are refueled, the discharge phenomenon will occur when the oil surface potential reaches about 28kV, but when there are free insulating metal objects on the oil surface, that is, there are quite a few charge collectors, as long as 1~ 2kV. There will be a discharge.

When the oil in the oil tank is finished, it must not be tested. This is because the maximum value of the oil surface potential sometimes occurs after the oil tank is stopped during the oil tank filling process. For safety, when it is necessary to directly measure the liquid level or oil temperature, the leakage time of the static charge in the tank should be avoided. Generally, it takes about 30 minutes to allow the settling charge in the oil to leak before it can be detected. The crane pipe of the tank truck is also a promoter of spark discharge. The crane pipe is well grounded to avoid the spark discharge of the crane pipe and the inner wall of the tank truck. However, the spark discharge of the crane pipe and the oil surface may still occur. Therefore, before changing to bottom filling, the crane pipe should be extended to the bottom of the tank truck to fill the oil; the oil injection pipe that extends into the oil tank should be as close as possible to the bottom to avoid the end of the oil filling (At this time, the oil potential is the highest) the oil surface and the protruding part of the crane pipe (oil injection pipe) are discharged. Therefore, when carrying out the oil filling operation, do not stand on the tank top, let alone do other operations.

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 DOI: https://doi.org/10.30564/frae.v3i3.2453

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Experimental Study on Dispersion of Unconfined Aquifer in a Site of Jilin City

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ARTICLE INFO

Article history
Received: 7 October 2020
Revised: 14 October 2020
Accepted: 24 October 2020
Published Online: 30 October 2020

Keywords:
Dispersion test
Dispersion parameters
Standard curve comparison method
Unconfined aquifer

ABSTRACT

Dispersion parameter is an important parameter for the establishment of groundwater solute transport model. The dispersion test uses sodium chloride as a tracer, which was conducted in a site in Jilin City. The standard curve comparison method was used to solve the dispersion parameters of the aquifer under the natural flow field. The test results show that under the natural flow field, the longitudinal dispersion of unconfined aquifer in Jilin City is 0.400m,and the transverse dispersion is 1.933×10^{-5}~6.557×10^{-3}m; while the longitudinal dispersion coefficient is 0.246m^2/d, the transverse dispersion coefficient is 1.191×10^{-5}~$4.039\times10^{-3}m^2$/d. The above results can provide an important parameter basis for the establishment of groundwater solute transport model, the accurate prediction of temporal and spatial variation of pollutant concentration in groundwater and the formulation of groundwater pollution prevention and control scheme.

1. Introduction

When establishing a model of solute transport in groundwater to study the migration law of pollutants in groundwater, the accurate determination of dispersion parameters is one of the key links to ensure the reliability of the model, which directly affects the accuracy and accuracy of the model prediction results [1]. The current effective method for determining dispersion parameters is to conduct dispersion tests. Dispersion test is divided into indoor test and field test. Because of the scale effect of dispersion parameters [2],in order to ensure the reliability of dispersion parameters, most scholars at home and abroad conduct field dispersion tests. For field dispersion tests, most of the domestic scholars focus on two-dimensional dispersion and radial hydrodynamic dispersion in one-dimensional flow field.

The two-dimensional dispersion test of one-dimensional flow field is generally carried out under natural flow field. This method can obtain more accurate dispersion parameters. For example, Wu Yaoguo and others carried out a two-dimensional dispersion test of one-dimensional flow field in Benxi City, and the dispersion parameters of unconfined aquifer in the test site were determined by linear

Fund project: National Joint Foundation for Natural Science Focus (Project No.: U 19A20107).
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  DOI: https://doi.org/10.30564/frae.v3i3.2572

graphic method[3]; Jiang Xuemin, Shao Jingli, et al .conducted a 2D dispersion test of one-dimensional flow field in a mining area in Inner Mongolia, and solved dispersion parameters by correlation coefficient polar method[4]. A two-dimensional dispersion test of one-dimensional flow field was carried out in Kashi area by using different analytical methods to solve the dispersion parameters[5].

Radial hydrodynamic dispersion test is carried out under the artificial flow field formed by pumping or water injection. For such issues, Yu Hong, Yuan Wei, Li Shiyu, Mei Jie[6-9]and others conducted dispersion tests in different regions. Zhang Yinmei[10] showed through indoor reserch that the dispersion parameter increases with the increase of hydraulic gradient, and the radial hydrodynamic dispersion test artificially increases the velocity and hydraulic gradient of groundwater. In addition, the dispersion solution method commonly used in radial hydrodynamic dispersion test can not obtain the transverse dispersion parameters of water-bearing medium.

Based on this, in order to obtain the dispersion parameters of unconfined aquifer at a site in Jilin City, this paper selects a test site in Jilin City to carry out two-dimensional dispersion test of one-dimensional flow field under natural flow field, and use the standard curve comparison method to solve the field dispersion parameters.

2. Overview of the Study Area

The dispersion test site is located in Longtan District, Jilin City, and located in Songhua River secondary terrace. The groundwater type in the study area is loose rock pore phreatic water, which mainly occurs in the Quaternary Holocene gravel layer. The average buried depth of bottom plate of unconfined aquifer is 13m. The groundwater level varies greatly within a year, with the high water period of 4~7 m and the dry water period of 3~4 m. Groundwater flows are generally north-south, and the hydraulic gradient is about 2/1000. Based on site drilling data, the stratigraphic lithology of the study area from top to bottom is backfill (0~1.5 m), silty clay (1.5~4 m), fine sand (4~7 m), gravel (7~13m), fully weathered granite (below 13m). Based on the results of pumping tests conducted in the study area, the average permeability coefficient K of the aquifer in the study area is 77 m/d.This provides parameter basis for the establishment of groundwater solute transport model and the formulation of restoration plans in this area.

3. Test Methods

3.1 Tracer Selection

Ideal tracers used in field dispersion tests should be less toxic, less easily adsorbed by solid particles in aquifers, more sensitive and less expensive[11]. At present, the main tracers used at home and abroad can be divided into four categories: ionic compounds, artificial radioisotopes, organic dyes and fluoride[12]. Considering that artificial radioisotope is known as radioactive hazard and that organic dyes are easily adsorbed by solid particles in the aquifer, in this experiment, sodium chloride (NaCl), which is less toxic, cheap and easy to monitor, is selected as tracer for field dispersion tests.

3.2 Placement of Test Wells

In general, monitoring wells in field dispersion tests are arranged along both sides of the main groundwater line[13]. In this test, the test wells respectively arranged along the main groundwater line in a circular arc with a radius of 2m, 4m and 6 m from the tracer injection well. The test wells include 1 tracer injection well ,3 rows (12) tracer monitoring wells, all of which are complete wells, with well edpth of 13m; design dispersion angles of 10° and 20°, respectively, as shown in Figure 1.

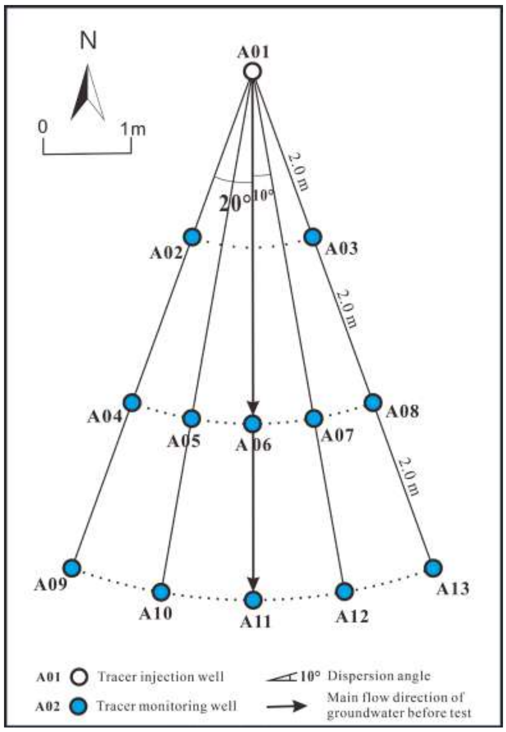

Figure 1. Plan of well for dispersion test

4. Test Process

4.1 Trial Preparation

(1) Monitoring of the initial groundwater level and monitoring of the water level before each sampling after the start of the test to correct the groundwater mainstream.

(2) The background concentration of chloride ions in each test well is measured, and the average background

value of groundwater chloride ions in this test area is 29.24 mg/L.

(3) Each monitoring well is equipped with a water level meter, a sampler and a test data monitoring record sheet.

(4) A solution of silver nitrate with known concentrations to be used for titration to test chloride concentration in groundwater.

(5) Preparation of tracer solution. The dispersion test added 60 kg of iodine-free edible salt to a plastic container containing 450 L of pure water and stirred to accelerate dissolution until the excess salt at the bottom was no longer dissolved. The concentration of chloride ion in tracer solution was 129.42 g/L.

4.2 Tracer Delivery

When the test begins, the tracer solution is injected into the well (A01), and the tracer time is used as the starting time of the dispersion test. Do not make the injection well water level too high (generally above the initial water level within 50 cm) to avoid the formation of groundwater mound, which has a significant impact on the water movement of the test site.

4.3 Data Monitoring

After the tracer solution is injected into the well (A01) of the test area, the sampling in the monitoring well of the test area is started immediately, and the buried depth of the groundwater level is determined before each sampling. At the beginning of the experiment, samples were taken every 1 hour and the groundwater level was measured. After sampling, the Cl^- in water samples were determined by silver nitrate titration concentration when the concentration of Cl^- was greater than the background value, the sampling time was encrypted for 30 minutes, when the Cl^- Concentration restored to the background value of Cl^- concentration in groundwater,returned to sampling every 1 hour and the monitoring stopped when Cl^- concentration in groundwater is basically stable as the background valu. Through continuous sampling and chloride ion concentration measurement, the Cl^- concentration curve of each tracer monitoring well can be obtained with time.

5. Calculation of Dispersion Parameters and Results Analysis

5.1 Calculation Method of Dispersion Parameters

There are two methods for calculating dispersion parameters in field dispersion test: analytical method and numerical method. The dispersion parameters of this experiment are calculated by the standard curve comparison method in the analytical method.

5.1.1 Calculation Method of Dispersion

The groundwater field in the test site is composed of loose rock type pore phreatic water. Because the hydraulic gradient of the ground water is small (about 2/1000;), the groundwater flow field in the test area is generalized into one-dimensional groundwater flow field with horizontal infinite extension and equal thickness. The tracer migration in groundwater conforms to the two-dimensional hydrodynamic dispersion equation of diving, and its mathematical model such as formula (1)[14] as shown:

$$\begin{cases} \dfrac{\partial C}{\partial t} = D_L \dfrac{\partial^2 C}{\partial x^2} + D_T \dfrac{\partial^2 C}{\partial y^2} - V \dfrac{\partial C}{\partial x}; \\ C(x, y, 0) = C_0, x, y \neq 0; \\ C(\pm\infty, y, t) = C_0, \\ C(x, \pm\infty, t) = C_0; t \geq 0; \\ \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} n_e (C - C_0)\ dxdy = M; \end{cases} \quad (1)$$

In the formula: C is the concentration of tracer in groundwater(g/L); C_0 is the tracer background concentrationin the groundwater in the test area(g/L); x and y are the longitudinal and transverse migration distances of the tracer(m) ;D_L and D_T are vertical and horizontal dispersion coefficients(m^2/d); V is the actual average flow rate of groundwater(m/d); n_e is the effective porosity; M is the amount of tracer injection per unit thickness of aquifer(kg/m); T is time (d).

Analytical solution of mathematical model (formula (1)) for two-dimensional dispersion instantaneous injection of tracer in one-dimensional flow field[15]To:

$$C（x, y, t）= \frac{M/n}{4\pi t (D_L D_T)^{-1/2}} \exp\left[-\frac{(x - Vt)^2}{4D_L t} - \frac{y^2}{4D_T t} \right] \quad (2)$$

If we ignore molecular diffusion to $D_L = \alpha_L V$, $D_T = \alpha_T V$ replaced by the above formula:

$$C（x, y, t）= \frac{M/n}{4\pi V t (\alpha_L \alpha_T)^{-1/2}} \exp\left[-\frac{(x - Vt)^2}{4\alpha_L V t} - \frac{y^2}{4\alpha_T V t} \right] \quad (3)$$

In the formula: α_L, α_T are longitudinal and transverse dispersion (m).

In a dimensionless form:

$$C_R(a, t_R) = k t_R^{-1} \exp\left(-\frac{a^2 + t_R^2}{4t_R} \right) \quad (4)$$

  DOI: https://doi.org/10.30564/frae.v3i3.2572

Among them:

$$c_R = \frac{c - c_0}{c_{max} - c_0} \tag{5}$$

$$a = (x_R^2 + y_R^2)^{1/2} \tag{6}$$

$$x_R = x / \alpha_L \tag{7}$$

$$y_R = y / (\alpha_L \alpha_T)^{1/2} \tag{8}$$

$$t_R = Vt / \alpha_L \tag{9}$$

$$k = t_{R\max} \exp\left(\frac{a^2 + t_{R\max}}{4t_{R\max}}\right) \tag{10}$$

$$t_{R\max} = (a^2 + 4)^{1/2} - 2 \tag{11}$$

According to formula (4), when the value of a is constant, the relationship curve of c_R~t_R can be obtained. After assigning a series of values to 'a', a series of relationship curve clusters of c_R~t_R can be obtained, and the c_R~t_R measuring plate curve (figure 2).

A series of relational curve clusters to obtain c_R~t_RMeasuring plate curve (Figure 2).

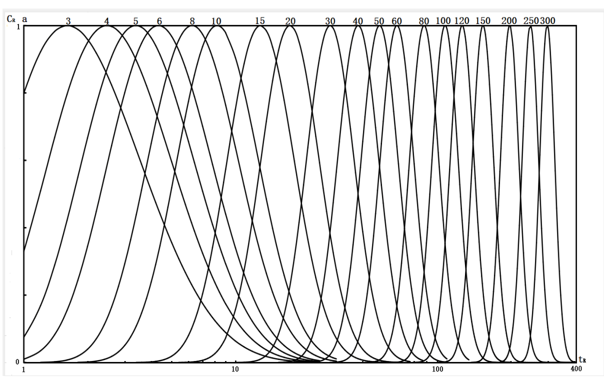

Figure 2. c_R~t_R Standard gauge plate

Finally, the formula of dispersion degree can be obtained by the transformation of formula (6),(7),(8) and (9):

$$\acute{a}_L = x_i / a_i \tag{12}$$

$$\acute{a}_T = \frac{y_i^2}{\acute{a}_L (a_i^2 - x_i^2 / \acute{a}_L^2)} \tag{13}$$

Among them: x_i and y_i are the vertical and horizontal coordinates of the i well (m); a_i is the a value of matching the observation curve of i well with the curve of measuring plate.

Convert the measured concentration values of each monitoring well into dimensionless concentration C_R. Then, the measured chloride concentration curve obtained from the groundwater mainstream upward monitoring well (y=0) is matched with the measuring plate curve (the vertical and horizontal coordinate scale of the two is the same), and the corresponding a value is obtained. According to formula (12), the longitudinal dispersion α_L is calculated.The measured curve obtained from the monitoring well (y≠0) deviating from the mainstream of groundwater is matched with the measuring plate curve (the vertical and horizontal coordinate scale of the two is the same), and the corresponding a value is obtained, and then calculate the transverse dispersion α_T according to the α_T value and formula (13).

5.1.2 Calculation Method of Dispersion Coefficient

The longitudinal dispersion α_L and the lateral dispersion α_T of the phreatic aquifer calculated from equations (12) and (13) are substituted into the following equations:

$$D_L = \alpha_L V \tag{14}$$

$$D_T = \alpha_T V \tag{15}$$

The longitudinal dispersion coefficient D_L and the lateral dispersion coefficient D_T of the site diving aquifer can be obtained.

V in formula (14) and formula (15) is the actual average velocity of groundwater, which can be calculated according to Darcy's law. The formula is as follows:

$$V = KI / n_e \tag{16}$$

In the formula: K is the permeability coefficient (m/d); I is the hydraulic gradient; n_e is the effective porosity.

5.2 Calculation of Dispersion Parameters for Unconfined Aquifer

According to the groundwater flow field diagram (Fig .3) drawn from the groundwater level in the test period, the actual groundwater mainstream direction is A01-A07-A12 direction. Therefore, the vertical dispersion of the diving aquifer in the site is calculated according to the method in 5.1.1, and the other monitoring wells are used to calculate the transverse dispersion of the groundwater aquifer.

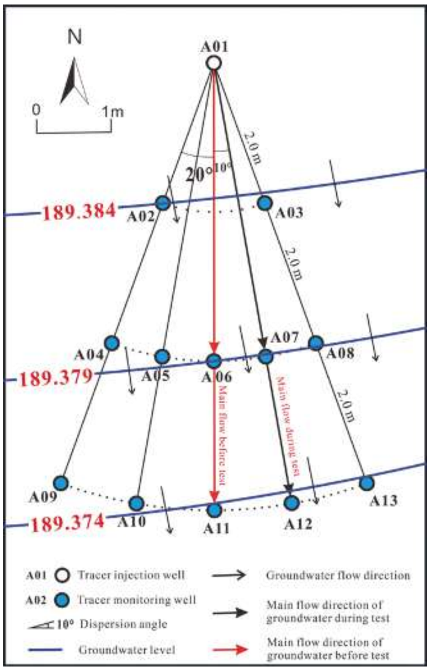

Figure 3. Field flow pattern of the site during the test

A04, A05, A06, A08, A09, A13 measured chlorine ion concentration diachronic curve of the monitoring well is fitted to the standard plate, and the fitting result diagram is shown in figure 4.

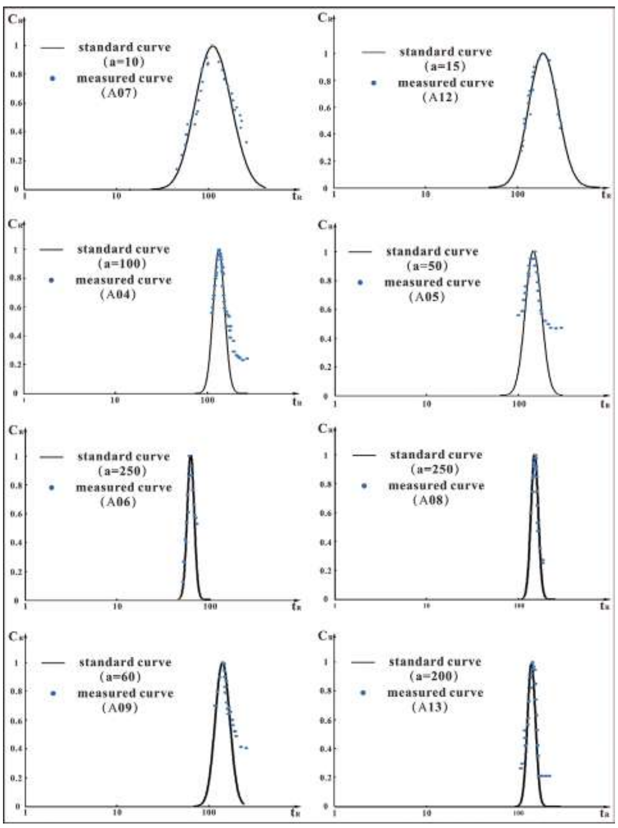

Figure 4. Matching diagram of measured concentration curve and plate curve of each monitoring well

5.3 Results and Analysis

5.3.1 Calculation of Dispersion

The a values and vertical and horizontal coordinates (x_i,y_i) of each monitoring well were substituted into equations (12) and (13) by fitting the measured chloride ion concentration of each monitoring well in 5.2 and the plate curve, and the dispersion results of the site unconfined aquifer were calculated respectively, as shown in Table 1.

Table 1. Summary of calculated results of aquifer dispersion

Well No	A07	A12	A04	A05	A06	A08	A09	A13
Longitudinal dispersion(α_L/m)	0.400	0.400	\	\	\	\	\	\
Transverse dispersion (α_T/m)	\	\	1.008×10^{-3}	1.940×10^{-3}	1.933×10^{-5}	1.933×10^{-5}	6.557×10^{-3}	6.822×10^{-5}

Table 1 shows that the longitudinal dispersion of unconfined aquifer in Jilin site is 0.400 m, the transverse dispersion is 1.933×10^{-5}~6.557×10^{-3}m. The lateral dispersion obtained from the monitoring well (A04, A05, A09) on the west side of the A01-A07-A12 is generally greater than that obtained from the monitoring well (A08, A13) on the east side, which is inferred to be caused by the heterogeneity of the diving aquifer in the site.

5.3.2 Calculation of Dispersion Coefficient

According to formula (14) and formula (15), we can calculate the dispersion coefficient D_L and D_T of unconfined aquifer.

The permeability coefficient (K) of unconfined aquifer in this dispersion test site is 77 m/d, the hydraulic gradient (I)is 2/1000; according to the hydrogeological manual, the effective porosity n_e of sand gravel unconfined aquifer has an empirical value of 0.25; substituting K, I and n_e into equation (16), the actual average velocity V of groundwater in the unconfined aquifer is 0.616 m/d.

Substituting the actual average velocity V of groundwater in the phreatic aquifer of the site into equations (14) and (15),the longitudinal dispersion coefficient D_L and the lateral dispersion coefficient D_T of the site can be calculated respectively.The results are shown in Table 2.

Table 2. Summary of calculations of the dispersion coefficient of the unconfined aquifer

Well No	A07	A12	A04	A05	A06	A08	A09	A13
Longitudinal dispersion coefficient (D_L/m· d^{-1})	0.246	0.246	\	\	\	\	\	\
Transverse dispersion coefficient (D_T/m·d^{-1})	\	\	6.209×10^{-4}	1.195×10^{-3}	1.191×10^{-5}	1.191×10^{-5}	4.039×10^{-3}	4.202×10^{-5}

DOI: https://doi.org/10.30564/frae.v3i3.2572

According to Table 2, the longitudinal dispersion coefficient of diving aquifer in Jilin site is 0.246 m^2/d, and ransverse dispersion coefficient is 1.191×10^{-5} ~$4.039\times10^{-3}m^2/d$.

5.3.3 Scale Effect of Dispersion

By comparing the dispersion of monitoring wells with 4 m, 6m distance tracer injection wells, the effect of scale effect on dispersion is discussed.

Table 3. Comparison of Dispersion Size at Different Migration Distance

Dispersion angle	Monitoring well distance from tracer injection well (m)	α_T of transverse dispersion (m)
30°	4	1.008×10^{-3}
	6	6.557×10^{-3}
10°	4	1.933×10^{-5}
	6	6.822×10^{-5}

Table 3 shows that, when the dispersion angle is 10°, the transverse dispersion of the sand-gravel aquifer in the study area calculated by the monitoring well at 6m distance from the injection well is 3.5 times larger than that calculated by the tracer concentration in the monitoring well at 4m distance from the injection well;when the dispersion angle is 30°, this value is expanded to 6.6 times. The results show that the transverse dispersion of sand and gravel aquifer increases with the increase of tracer migration distance, and the larger the dispersion angle, the greater the transverse dispersion. The studies of Domenico(1984) and Gelhar (1992) also have come to a similar conclusion: in the same aquifer, the dispersion increases with the increase of solute migration distance[16-17].

6. Conclusion

(1) The dispersion parameters of the unconfined aquifer at the site were obtained by field dispersion tests :the longitudinal dispersion is 0.400 m,and the transverse dispersion is 1.933×10^{-5}~6.557×10^{-3}m; the longitudinal dispersion coefficient is 0.300 m^2/d, and the transverse dispersion coefficient is 1.450×10^{-5} ~$4.918\times10^{-3}m^2/d$.

(2) This field dispersion test confirms the existence of diffusion parameter scale effects in field tests. In the same aquifer, the transverse dispersion increases with the increase of tracer migration distance, and the larger the dispersion angle, the greater the dispersion.

(3) The method of using standard curve comparison method to solve dispersion parameters of unconfined aquifer is simple and quick, the result of calculation is more accurate and the applicability is wide, but there are some subjective errors when the measured curve and standard curve fit in the calculation process.

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  DOI: https://doi.org/10.30564/frae.v3i3.2572

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Application of RCO Treatment on Automobile Coating Drying Waste Gas

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ARTICLE INFO

Article history
Received: 8 October 2020
Revised: 15 October 2020
Accepted: 24 October 2020
Published Online: 30 October 2020

Keywords:
RCO
Automobile coating drying
Application

ABSTRACT

With the increasingly serious environmental problems, China has adopted more and more strict industrial production emission policies. Haze pollutes the weather and limits the production of polluting enterprises have seriously affected the normal production process of the factory. The pollutants discharged in automobile manufacturing process are increasing, and the environmental pollution caused by automobile coating needs to be solved urgently. Because a large amount of solvent-based paint is used in the production process, the pollution caused by volatile organic compounds is difficult to avoid. RCO is a new technology in the field of automobile coating waste gas treatment. Application of RCO in automobile coating waste gas treatment is studied.

1. Introduction

In the automobile industry, the most seriously affected is the automobile painting workshop. In order to deal with the environmental problems of exhaust gas pollution and reduce the unit cost of products in order to save energy consumption, Ensure the normal production of enterprises and improve the level of economic profit margin.

2. Automotive Industry Overview

China's pollution of the automobile industry has been from only paying attention to development to equal emphasis on development and environment, and to three stages of development that must be environmentally friendly. The production of substandard automobile production has been shut down and restricted, which seriously restricts the normal development of automobile industry. On the one hand, the exhaust gas pollution is serious, on the other hand, the energy consumption is amazing, which has become the key point of energy saving and emission reduction in automobile industry[1]. The main components of automobile painting exhaust gas are benzene volatiles and other organic compounds. At present, the emission reduction of automobile painting exhaust gas is mainly realized by updating spraying materials, improving spraying technology and improving spraying equipment to realize the green environmental protection of automobile painting process. Over the past decade, with the increasing severity of environmental problems, China has introduced a number of emission standards for automotive spray paint. For example, in Shanghai, enterprises with non-methane total hydrocarbon emission concentrations of more than 30 mg/m3 and volatile organic compounds per unit coating area of more than 35 g/m2 are not allowed to put into production, thus promoting the improvement and re-planning of the treatment system for automotive paint gas, while the treatment of volatile organic compounds depends on the consumption of electricity and natural gas, and the energy saving pressure is enormous.

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 DOI: https://doi.org/10.30564/frae.v3i3.2659

3. Automobile Painting Exhaust Gas Treatment System

Due to the production characteristics of large amount and low concentration of automobile painting exhaust gas, the original treatment method of automobile painting exhaust gas is to discharge directly into the atmosphere, and then limit the chimney height and emission rate. Now it is necessary to limit the density index of toxic and harmful exhaust gas. According to the latest automobile painting exhaust gas treatment requirements, automobile painting exhaust gas treatment system came into being. The final purpose of automobile painting exhaust gas treatment system is to meet certain emission concentration standards and meet the requirements of production laws and regulations and industry standards[2]. According to the composition and treatment principle, the automobile painting exhaust gas treatment system mainly includes three parts: the filtration system, the concentration system and the combustion system. The function of the second part is to treat the characteristics of low density and large displacement of automobile painting exhaust gas. In order to improve the treatment effect and reduce the treatment cost, the exhaust gas of automobile painting is concentrated by the concentration system, and the maximum reduction volume is 1/25 of the original volume. After burning automobile painting exhaust gas, the highly polluting volatile toxic and harmful substances are decomposed and purified to meet the emission standard and then cooled down[3].

4. RCO Equipment Working Principle

4.1 Start-up Phase

When you press the start button, the system automatically enters the clear program. Power valves EV06 and EV08 open immediately EV04EV05, EV02. Closure of EV03 and EV07, The fan F1 and F2 start at a frequency controlled by the frequency converter 40 Hz. RCO total purge time of the equipment is 12 minutes. During work, EV01, EV04, EV02, EV03 switch valve automatically switches between two sets of beds every 3 minutes, And according to the PLC procedures alternately blowing. EV05 will automatically turn off after 30 seconds of each sync, And the backblow line will be cleared at the same time[4].

After pre-blowing, the equipment will be in a “ignition temperature rise” state. At this point, EV01, EV02, EV03, EV04, EV05 automatically switches and executes at fixed intervals and in sequence. Burners automatically detect whether the high and low pressures of LPG are within the set values of 2.5 to 5.0 mbar. If normal, it will automatically ignite and run at full power (fire). At this point, the fan F1 and F2 operate at full power. As the valve switches, the temperature of catalyst bed and heat storage bed increased alternately. As the temperature of the catalyst chamber rises to 330°C, Exhaust valve EV07 open, a new air valve EV08 closed, the exhaust gas is gradually introduced into the catalyst bed, the catalyst burner began to ignite. If due to equipment failure or inadequate detection conditions resulting in “ignition failure “, the device will automatically enter the “half blow sweep” program, for 12 minutes, then re-ignite the burner to start normal operation.

4.2 Normal Working Phase

As the temperature of the catalyst bottom chamber rises to 330°C, The device enters a “catalyst activation” state, Exhaust valve EV07 open, a new air valve EV08 closed, And EV01, EV02, EV03, EV04, EV05 at constant time intervals and in order. It will switch and use automatically. From the bottom A the regenerator bed, fully exchange heat with the regenerator, and then into the catalyst bed A. the temperature is higher than the ignition temperature and starts to rise. The catalytic reaction passes through the combustion chamber, Access to catalyst bed B, for catalytic reactions And then into B. regenerative bed The heat exchange with the circulating bed B stores the heat carried by the catalyst bed day and the oxidized exhaust gas in the circulating bed B[5].

Bed inversion interval is set according to the concentration of organic matter in exhaust gas and the heat generated after decomposition, and written into the PLC program. The inverted bed spacing should not only save combustion fuel, but also consider the ability to adjust the temperature of the regenerated bed according to the actual working conditions. Usually set to 2-5 minutes, the device is set to flip the bed every 3 minutes.

When the interval reaches 3 minutes, the switch valve automatically opens the intake valve B (EV02), closes the intake valve A (EV01), closes the exhaust valve B (EV04), and then opens the exhaust valve A (EV03). which flows from the bottom of the B of the organic waste gas regenerator bed, fully exchanges heat with the regenerator, and then enters the catalyst bed B. and the catalytic reaction begins at a temperature higher than the ignition temperature. Through the combustion chamber, it enters the catalyst bed for the catalytic reaction A, and then enters A. regeneration bed which heat exchange with the heat storage bed A and store the heat carried by the oxidized exhaust gas in the catalyst bed A and the heat storage bed A. Under normal working conditions, the two groups of beds alternately treat exhaust gas.

DOI: https://doi.org/10.30564/frae.v3i3.2659

4.3 Completion Status

When you press and operate the stop button, the equipment will be in the "air supply stop" state. At this point, Exhaust valve EV07 closed, a new air valve EV08 open. Fan is controlled by PLC program, and enter the low frequency running state. Automatically, the program detects whether the temperature of the two sets of regenerators is below 200°C. If the temperature is higher than this temperature, please repeat purge and cooling. The temperature enters the shutdown procedure. Follow the PLC security closure procedure, Will automatically shut down the burner, Close blower F2, EV01, through pneumatic valve EV02, EV03, EV01, of EV04 and EV05 closed pneumatic valves EV02, EV03, EV04 and EV05, The device will return to its initial state[6].

4.4 Other Working Conditions

If the catalyst bed and combustion chamber temperature is below 330°C, the burner will automatically ignite and operate at low power. The new air valve EV08 will automatically open and automatically dilute the VOC gas concentration to reduce the system temperature if the temperature of the catalyst bed is higher than 400°C, if the catalyst bed temperature is too high for the recommended protection temperature 480°C of the catalyst support product, the exhaust valve will be closed based on EV08 opening EV07, and the signal will be sent to the drying chamber control system to open the exhaust valve. It opens and the exhaust gas is discharged directly to the RCO equipment. Rapid cooling in the operating temperature range.

5. Energy Saving and Emission Reduction Technology for automobile Spraying

All kinds of optimization measures and improvement measures are needed to reduce the pollution and energy consumption in the process of automobile atomization, especially through the transformation of energy saving and emission reduction in the process of automobile atomization. Technological advances are gradually passing through highly polluting, high-energy processes, such as the use of phosphorus-free detergents to reduce environmental impacts, and the use of non-carbon fluorinated refrigerant to reduce ozone layer damage. By using phosphorus treatment processes (such as zirconia conversion membranes) to simplify and optimize phosphorylation processes, chromium-free passivation processes or direct passivation processes are used to reduce the consumption and pollution of passion energy. By optimizing the process, appropriate integration can be made to reduce energy consumption and pollution[7]. For example, by optimizing the process, spraying the intermediate coating immediately after the sealing PVC and combining the two drying processes can not only save equipment investment, but also reduce energy consumption and reduce exhaust emissions at the same time. After electrophoresis, the pollutants in the wastewater are usually purified. By concentrating the wastewater and sending it back to the ultrafiltration tank, the pure water can be reduced and the sewage discharge can be reduced. After conversion, spray paint to reduce investment. Consumption and sewage treatment costs will be recovered immediately. With the continuous development of automobile industry, the price and status of automobile will gradually decline. In the process of automobile spraying, the original top layer, middle layer and bottom layer spraying can completely cancel the intermediate spraying process after optimizing and improving the quality of electrophoretic structure process. The original two-layer function is achieved by improving the material on the electrophoretic film. In the replacement of highly toxic materials with harmless or less destructive materials (for example, the replacement of highly irritating and hazardous materials), energy saving is achieved while improving the process, and an increase in emission reduction of aromatic solvent coatings can be considered. At present, European standards require the automotive spraying industry to use water-soluble rather than solvent-based, China must also start to promote the work. It is necessary to start the research and development of related processes and materials as soon as possible, while reducing emissions, such as coating curing techniques, may be difficult to save energy.

Compared with traditional solvent-based coatings, the successful development of energy-saving powder coatings can reduce pollutant emissions, but the curing process requires higher energy structure, and the appearance is based on solvent, it is not as uniform as the coating and needs further improvement. The focus of improving the current automotive spray energy and emission reduction process is to optimize, merge or cancel some optional processes in the automotive spray process. Some processes are optimized by improving and adjusting the energy saving and environmental protection of materials. In the future, much progress needs to be made in simplifying and reducing automotive sprays. Promote simple spraying vehicles, reduce unnecessary style and gloss requirements, simple, economical and environmentally friendly, and reduce vehicle life in general due to low pollution and low energy consumption of existing vehicle spraying processes. Form a new energy-saving fashion[8].

6. Conclusion

With the continuous updating of technology, especially the development of new materials, the content of toxic and harmful substances in the exhaust gas of automobile painting will be continuously reduced, and the related treatment technology will be continuously improved under the stimulation of environmental protection policy.

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DOI: https://doi.org/10.30564/frae.v3i3.2659

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Research on Seismic Design of High-Rise Buildings Based on Framed-Shear Structural System

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ARTICLE INFO

Article history
Received: 9 October 2020
Revised: 16 October 2020
Accepted: 24 October 2020
Published Online: 30 October 2020

Keywords:
Frame shear wall structure
Displacement-based seismic design
Shear deformation

ABSTRACT

Under the rapidly advancing economic trends, people's requirements for the functionality and architectural artistry of high-rise structures are constantly increasing, and in order to meet such modern requirements, it is necessary to diversify the functions of high-rise buildings and complicate the building form. At present, the main structural systems of high-rise buildings are: frame structure, shear wall structure, frame shear structure, and tube structure. Different structural systems determine the size of the load-bearing capacity, lateral stiffness, and seismic performance, as well as the amount of material used and the cost. This project is mainly concerned with the seismic design of frame shear structural systems, which are widely used today.

1. Introduction

As the rapid development of domestic social economic in recent years, all kinds of buildings, especially the height of the public building has gradually developed higher, at the same time of building structure space free flexibility requirement also has become higher. It is necessary to consider adopting a structural system that can not only meet the seismic requirements but also adapt to the functional requirements.

Currently, the main structural systems commonly used in high-rise buildings are frame structures, shear wall structures, frame shear wall structures, and tubular structures. Frame structures are less rigid and are used in high-rise buildings with large component cross-sections, which affect their use and are not economical. Although shear wall structures are more rigid, the spacing between the shear walls cannot be too large, resulting in limited room space and making them less suitable for office buildings that require large spaces. The frame shear wall structure is a combination of frame structure and shear wall structure, which draws on the strengths of each, providing both a large space for the building layout and good resistance to lateral forces. In a frame shear wall structure, the seismic wall is the first line of defense against earthquakes due to its lateral stiffness, and the frame is the second line of defense against earthquakes.

Seismic damage investigations have shown that, under seismic action, frame shear structures are less susceptible to earthquake damage than other structure types. Under horizontal seismic action, two elements, the shear frame and the curved shear wall, work together through the connection of floor slabs that are infinitely stiff in plane at each level. To meet consistent deformation within the same floor, the frame in this structure differs from the frame in a pure frame structure, and the shear walls in a framed shear structure differ from the shear walls in a shear wall structure. When working together, the shear wall units are much more rigid than the frame, and the shear walls carry most

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of the horizontal external loads. Whereas at the bottom of the structure, the shear walls deform less and the frame deforms more, the shear walls constrain the deformation of the frame, which reduces the deformation of the frame. In the upper part of the structure, the lateral deformation of the shear wall increases and the deformation of the frame decreases, while the frame bears part of the shear force.

It can be seen that framed shear wall structures are superior to pure frame structures or pure shear wall structures in terms of both stiffness and load-bearing capacity. The structure combines the two advantages of good ductility of the frame and high seismic performance of the shear wall. By proper arrangement of the shear wall, the structure not only has the advantages of flexible space arrangement of the frame structure, but also has the characteristics of strong wind and seismic resistance of the shear wall structure. Therefore, frame shear wall structures are widely used in the design of high-rise buildings, both in seismic and non-seismic areas.

In this paper, the seismic design of the Rizhao Highway Engineering Design and Supervision Information Complex is taken as an example, and the seismic design points of the frame shear structure are briefly discussed.

2. Project Overview

Rizhao Highway Engineering Design and Supervision Information Complex Building is located in Yantai North Road, Rizhao City. The first underground floor is a garage and equipment room; the height above ground is 62.01m, and the total construction area is 23369.80m^2.

3. Structural Design Solutions

3.1 Floor Plan

Due to the high functional requirements of this office building, a frame and shear wall structure is used. The shear walls and frames of the main building (15 floors) of this project have a seismic rating of Grade II. The basement ~ second floor is the reinforced part at the bottom, the third floor and above is the non-reinforced part, and the end sub-story is a frame structure, separated from the main building by a seam, with a seismic rating of grade III.

Structural shear wall layout, in order to try not to affect the use of building function, the wall as far as possible arranged in the plane around the perimeter, the type of shear wall is appropriate for the L-shaped, T-shaped. The wall arrangement follows the principle of regularity and symmetry, and the lateral stiffness of the two main axis directions should not differ too much from each other. Elevator and stairwells are arranged with shear walls to form a "safe island" in the event of an earthquake, which is conducive to its evacuation function and reduces the adverse effects of stair stiffness on the structure. Based on the above principles, the office building is arranged with shear walls, and the standard floor plan of the main building is as follows:

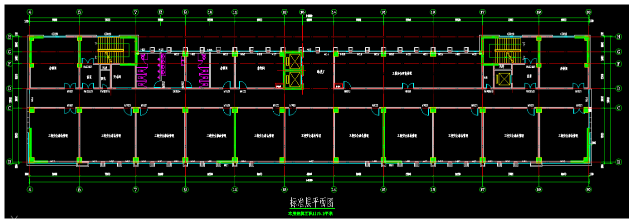

Figure 1. Standard floor plan

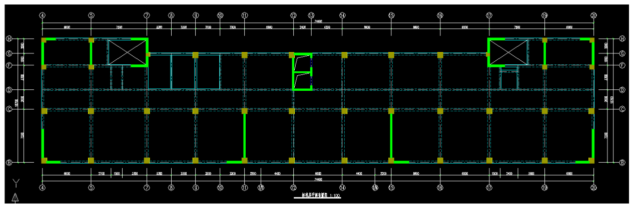

Figure 2. Structural Floor Plan

3.2 Calculation Parameters and Analysis

3.2.1 Structural Rigid Center of Mass

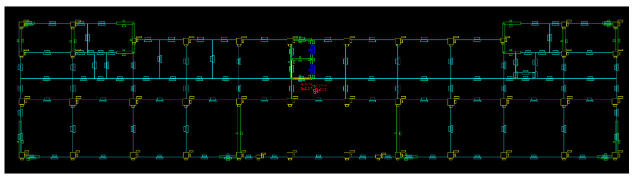

Figure 3. Structural rigid center of mass

The figure shows that the rigid centers of the standard floors of the main building structure basically coincide.

3.2.2 Cycle Parameters

Table 1. Cycle parameters

Cycle, Seismicity, and Root Type Output Files (VSS solver)				
Consider the root motion period (seconds), X, Y direction translation coefficient, torsion coefficient when torsional coupling is considered				
Root Type	Cycle	Corner	Translation coefficient (X+Y)	Torsion coefficient
1	2.0440	178.29	1.00 (1.00+0.00)	0.00
2	1.6633	88.66	1.00 (0.00+1.00)	0.00
3	1.5617	113.23	0.00 (0.00+0.00)	1.00
4	0.6228	179.82	1.00 (1.00+0.00)	0.00
5	0.4073	90.09	0.97 (0.00+0.97)	0.03
6	0.3969	89.94	0.03 (0.00+0.03)	0.97
7	0.3133	0.26	1.00 (1.00+0.00)	0.00
8	0.1939	0.31	1.00 (1.00+0.00)	0.00
9	0.1762	90.38	0.93 (0.00+0.93)	0.07
10	0.1718	89.32	0.07 (0.00+0.07)	0.93
11	0.1355	0.52	1.00 (1.00+0.00)	0.00
12	0.1044	90.81	0.95 (0.00+0.95)	0.05
13	0.1015	177.61	0.83 (0.82+0.01)	0.17
14	0.1000	16.86	0.21 (0.18+0.03)	0.79
15	0.0853	91.41	0.02 (0.00+0.02)	0.98
The direction of the greatest earthquake action = -0.671 (degrees)				

Notes: The cycle ratio is Tt/T1 = 0.764, which meets the requirements.

DOI: https://doi.org/10.30564/frae.v3i3.2670

Table 2. 1.2.3 Structural displacement parameters (from which two conditions were selected).

===condition 1==== Maximum floor displacement under the action of earthquake in X direction

Floor	Tower	Jmax JmaxD	Max-(X) Max-Dx	Ave-(X) Ave-Dx	Ratio-(X) Ratio-Dx	h Max-Dx/h	DxR/Dx	Ratio_Ax
17	1	5834	36.38	36.05	1.01	3900.	25.9%	1.00
		5834	1.43	1.36	1.06	1/2721.		
16	1	5540	35.19	34.87	1.01	3600.	12.2%	0.97
		5540	1.59	1.58	1.01	1/2261.		
15	1	5360	33.85	33.53	1.01	3600	11.0%	1.04
		5360	1.80	1.77	1.01	1/2002.		
14	1	5078	32.30	32.01	1.01	3600.	9.4%	1.07
		5085	1.99	1.97	1.01	1/1810.		
13	1	4804	30.58	30.31	1.01	3600.	7.6%	1.01
		4698	2.17	2.15	1.01	1/1658.		
12	1	4529	28.66	28.40	1.01	3600.	6.2%	0.98
		4422	2.34	2.32	1.01	1/1541.		
11	1	4253	26.54	26.31	1.01	3600.	2.7%	0.96
		4146	2.48	2.46	1.01	1/1451.		
10	1	3978	24.26	24.05	1.01	3600.	4.4%	0.91
		3978	2.56	2.53	1.01	1/1405.		
9	1	3704	21.85	21.66	1.01	3600.	3.8%	0.90
		3598	2.66	2.64	1.01	1/1352.		
8	1	3429	19.30	19.13	1.01	3600.	3.3%	0.90
		3322	2.77	2.74	1.01	1/1302.		
7	1	3153	16.61	16.47	1.01	3600.	2.3%	0.90
		3153	2.86	2.83	1.01	1/1258.		
6	1	2772	13.81	13.69	1.01	3600.	1.7%	0.88
		2878	2.94	2.90	1.01	1/1225.		
5	1	2498	10.91	10.82	1.01	4800.	10.5%	0.87
		2498	3.96	3.93	1.01	1/1213.		
4	1	2183	6.98	6.91	1.01	3900.	17.7%	0.76
		2290	2.89	2.86	1.01	1/1348.		
3	1	1901	4.10	4.05	1.01	3900.	36.8%	0.64
		1901	2.38	2.35	1.02	1/1636		
2	1	1676	2.13	1.90	1.12	4200.	86.8%	0.49
		1676	2.04	1.79	1.14	1/2064.		
1	1	1175	0.12	0.06	1.00	5100	99.9%	0.02
		1175	0.12	0.06	1.00	1/9999.		

Maximum displacement angle between layers in X direction 1/1213.（5th floor bottom 1 tower）
The ratio of the maximum displacement in the X direction to the average layer displacement 1.12（2nd floor bottom 1 tower）
The ratio of the maximum interlayer displacement in the X direction to the average interlayer displacement 1/14（2nd floor bottom 1 tower）

===condition 4==== Maximum floor displacement under the action of earthquake in Y direction

Floor	Tower	Jmax JmaxD	Max-(X) Max-Dx	Ave-(X) Ave-Dx	Ratio-(X) Ratio-Dx	h Max-Dx/h	DxR/Dx	Ratio_Ax
17	1	6098	32.28	31.50	1.02	3900.	3.6%	1.00
		5968	2.29	2.17	1.06	1/701.		
16	1	5691	29.72	29.18	1.02	3600.	2.5%	0.80
		5691	2.11	2.07	1.02	1/1707.		
15	1	5388	27.69	27.18	1.02	3600	2.2%	0.87
		5388	2.16	2.12	1.02	1/1666.		
14	1	5104	25.61	25.14	1.02	3600.	1.7%	0.88
		5104	2.21	2.17	1.02	1/1630.		
13	1	4830	23.49	23.06	1.02	3600.	0.9%	0.87
		4830	2.24	2.20	1.02	1/1604.		
12	1	4555	21.33	20.94	1.02	3600.	0.3%	0.86
		4555	2.26	2.22	1.02	1/1589.		
11	1	4279	19.14	18.79	1.02	3600.	1.3%	0.85
		4278	2.27	2.23	1.02	1/1585.		
10	1	4004	16.94	16.63	1.02	3600.	1.4%	0.83
		4004	2.24	2.20	1.02	1/1607.		
9	1	3730	14.75	14.48	1.02	3600.	2.5%	0.82
		3730	2.21	2.17	1.02	1/1630.		
8	1	3455	12.59	12.35	1.02	3600.	3.7%	0.80
		3455	2.15	2.12	1.02	1/1671.		
7	1	3179	10.46	10.27	1.02	3600.	5.4%	0.79
		3179	2.07	2.04	1.02	1/1736.		
6	1	2904	8.41	8.25	1.02	3600.	9.0%	0.76
		2904	1.96	1.93	1.02	1/1835.		
5	1	2630	6.46	6.34	1.02	4800.	15.1%	0.72
		2630	2.38	2.34	1.02	1/2017.		
4	1	2297	4.10	4.01	1.02	3900.	20.0%	0.65
		2316	1.64	1.62	1.01	1/2379.		
3	1	2021	2.47	2.40	1.03	3900.	32.6%	0.62
		2021	1.32	1.29	1.02	1/2957		
2	1	1676	1.28	1.16	1.10	4200.	86.3%	0.52
		1676	1.13	0.99	1.14	1/3721.		
1	1	1474	0.21	0.11	1.00	5100	93.9%	0.07
		1474	0.21	0.11	1.00	1/9999.		

Maximum displacement angle between layers in Y direction 1/1585.（11th floor bottom 1 tower）
The ratio of the maximum displacement in the Y direction to the average layer displacement 1.10（2nd floor bottom 1 tower）
The ratio of the maximum interlayer displacement in the Y direction to the average interlayer displacement 1.14（2nd floor bottom 1 tower）

Notes: Two conditions were selected, both of which met the requirements.

4. Summary of Seismic Analysis of the Structure

By properly arranging the shear walls, the effective arrangement of the shear walls can improve the seismic performance of the structure without affecting the functional use of the building. From the results of the calculations, the following conclusions can be drawn:

(1) The rigid center of the standard floor of the main structure of this project basically overlaps, which will greatly improve the seismic capacity of the structure compared to the irregular structural form.

(2) The maximum displacement angle between floors under X-direction seismic action is at the 5th floor, and the maximum displacement angle between floors under Y-direction seismic action is at the 11th floor, which shows that the horizontal displacement of a frame-shear wall structure under horizontal force is controlled by the displacement angle between floors. The maximum interstory displacement generally occurs between 0.3H and 0.8H of the building.

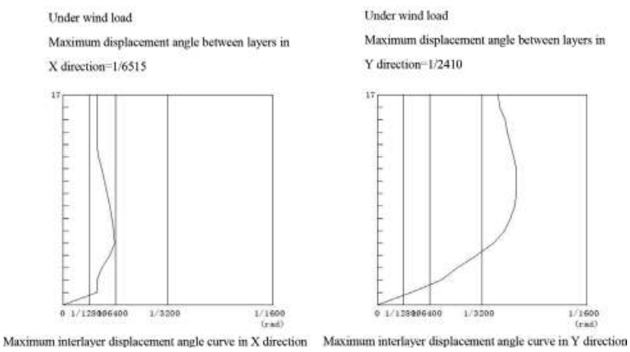

Figure 4. Maximum interlayer displacement curve

(3) The displacement of each layer is connected into a lateral displacement curve in the shape of S, without convexity and folding point. This shows that the number and location of the shear wall settings are reasonable, and also reflects the importance of shear wall seismic performance. However, how to determine the optimal stiffness of the shear wall and how to reduce the cost of the project while ensuring the seismic resistance and functionality of the structure is still a key issue to be addressed in the future design.

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DOI: https://doi.org/10.30564/frae.v3i3.2670

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Price: S$30.00