RESEARCH ARTICLE

Analysis of the Current Situation and Reform of Aviation Fuel Supply System

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Abstract: Airplanes are high-security modes of transportation with low failure rates. Recent airplane accidents have drawn global attention because even minor component failures can lead to serious disasters. This is primarily due to the extremely complex internal structure of airplanes, where every system and even the smallest component is equally vital. It is challenging to ensure thorough safety for every tiny component of an airplane. Consequently, various aviation accidents have occurred since the inception of airplanes. This article firstly introduces the fuel system of airplanes, then analyzes the classification and manifestations of fuel system failures, and finally selects three relatively typical fuel system failure cases for targeted analysis.

In the first part, the basic overview of airplane fuel provides a brief summary of the purpose of establishing the fuel system by introducing its functions and characteristics.

The second part introduces the fuel system and its subsystems of the ARJ21 aircraft. It also discusses the sources and hazards of airplane failures by combining the classification and characteristics of aircraft faults.

The third part is the analysis section, which analyzes two maintenance cases of airplane fuel system failures through systematic working principle analysis. It employs fault tree analysis to identify the causes of failures in maintenance cases.

The fourth part is a systematic analysis of the civil aviation electrical system based on knowledge method, including two aspects: the construction of the systematic model based on civil aviation aircraft experts and the expression and organization based on knowledge. The research is mainly carried out from three aspects: data dictionary table, rule base and case base.

The fifth part is based on fault tree method to carry out systematic analysis of civil aviation electrical system, firstly analyzes the fault tree research method, and then analyzes the system fault tree and its reliability case study.

Finally, the paper summarizes the methods used in this paper, points out the advantages and disadvantages, and predicts the future development trend.

Keywords: airplane fuel system; maintenance; fault analysis; energy conservation and emission reduction; evaluation index system; oil injection development project

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1 Introduction

1.1 Research Background

Airplanes possess extremely complex operational systems, coupled with the possibility of failures during flights due to human errors, manufacturing defects, material issues, and environmental factors. Moreover, fatigue driving or the aging and wear of equipment facilities can also lead to failures. The losses caused by airplane failures are immeasurable, emphasizing the importance of fault diagnosis to maintain the normal and safe operation of aircraft. Modern airplanes utilize innovative technologies spanning various disciplines, resulting in rich structural hierarchies. When conducting fault diagnosis operations, it involves multiple domains and entails prolonged diagnosis time and exceptionally high difficulty levels. Typically, it requires the collaboration of several highly skilled engineers to achieve precise diagnostic results. Furthermore, due to the continuous development of domestic civil aviation, major airlines are expanding their fleet sizes. Consequently, the volume of aircraft maintenance is increasing. Some aircraft in the fleets of domestic airlines are aging, leading to heavier maintenance tasks. However, the number of maintenance personnel has not increased accordingly. These factors can impact the operational status of aircraft.

Aircraft system failures exhibit stochastic characteristics and may occur during flight or during maintenance and crew preparation. It is difficult to promptly identify components in abnormal states or directly pinpoint the causes of failures when observing external signs of aircraft. Thus, it becomes challenging to determine whether adjustments, repairs, or replacements are necessary. Some aircraft failures only occur during flight, making it challenging to conduct ground inspections upon landing. Currently, most fault diagnoses of aircraft at external sites are conducted manually. Maintenance personnel first need to collect information about the faults and external manifestations, analyze them in conjunction with fault manuals, and then follow fault isolation procedures to identify faulty components step by step. The fault manuals cover multiple components, each capable of causing failures, and detail the sequence of component replacement. While these methods can address most aircraft faults, the maintenance process is extremely complex and time-consuming. Especially during short stopovers, once a fault is discovered, maintenance work must be initiated within a very short time. Failure to complete maintenance during the short stopover period can lead to flight delays and economic losses for airlines.

As explained above, the volume of aircraft maintenance is continuously increasing, but airlines are not consistently introducing excellent maintenance personnel. Coupled with short fault diagnosis times, the inability to improve fault diagnosis efficiency hinders the development of domestic civil aviation. These contradictions significantly restrict the development of domestic civil aviation. By scientifically and effectively researching and developing fault diagnosis methods and technologies for large aircraft, a more comprehensive understanding of equipment operation can be achieved. This can help identify latent faults, prevent sudden accidents, and make aircraft more reliable. On the other hand, it also increases profits for enterprises, promotes technological progress in civil aviation, and fosters continuous development.

This article mainly studies the problems encountered in aircraft fault diagnosis, with a focus on the fuel system of the ARJ-21 aircraft. It deeply analyzes and studies the fault diagnosis process to assist maintenance personnel in civil aviation to better diagnose and repair faults, accurately locate faults, and resolve them as quickly as possible, thereby maximizing the economic benefits of airlines.

1.2 Background of China's aviation industry

The aviation industry in China has experienced remarkable growth and transformation over the past few decades, emerging as one of the world's largest and most dynamic markets. With a rapidly expanding fleet of aircraft and increasing demand for air travel, the efficient and reliable supply of aviation fuel has become essential for sustaining this growth trajectory.

China's aviation industry has undergone unprecedented expansion, driven by factors such as rapid urbanization, rising disposable incomes, and government initiatives to promote air travel. As a result, the country has witnessed a surge in both domestic and international air traffic, with major airports experiencing a significant increase in passenger volumes and aircraft movements.

The importance of a well-functioning aviation fuel supply system cannot be overstated in the context of China's aviation sector. Aviation fuel serves as the lifeblood of the industry, powering commercial aircraft and enabling them to transport passengers and cargo safely and efficiently. Any disruption or inefficiency in the supply chain can have far-reaching implications, including flight delays, operational disruptions, and increased costs for airlines and consumers.

Given the critical role of aviation fuel in sustaining the growth and competitiveness of China's aviation industry, there is a need for a comprehensive analysis of the current state of the aviation fuel supply system. This paper aims to provide such an analysis, with a focus on identifying key challenges, evaluating existing practices, and proposing reforms to enhance the efficiency, reliability, and sustainability of the system.

The purpose of this paper is twofold: firstly, to examine the current status of China's aviation fuel supply system, including its organizational structure, regulatory framework, and key stakeholders; and secondly, to explore potential areas for reform and improvement. By assessing the strengths and weaknesses of the existing system and drawing insights from international best practices, this paper seeks to offer actionable recommendations for policymakers, industry stakeholders, and other relevant actors.

In terms of scope, this paper will cover various aspects of the aviation fuel supply chain, including production, distribution, storage, pricing, and regulation. It will also consider broader issues such as energy security, environmental sustainability, and the adoption of alternative fuels. While the primary focus will be on the civil aviation sector, insights from the military aviation sector may also be included where relevant.

Overall, this paper aims to contribute to a deeper understanding of the challenges and opportunities facing China's aviation fuel supply system and to provide practical recommendations for driving positive change in this critical area of the aviation industry.

In China, the Laojunmiao oil field began water injection development in 1955, marking the beginning of China's petroleum water injection development. In the late 1950s, Karamay Oilfield began to conduct internal cutting water injection, and in the early 1960s, Daqing Oilfield also determined the policy of early water injection to maintain formation pressure, which greatly promoted the development of China's oil injection development theory and practice. According to statistics, the average comprehensive water content of various oil fields in China has exceeded 85%, of which the water content exceeds 80%. Oil fields that have entered the late stage of high water content and ultra-high water content have recoverable reserves accounting for over 70% of the country. At the same time, the impact of China Petroleum's water injection development projects on the water environment has also attracted widespread attention.

In terms of the impact of oil injection development projects on surface water environment, Jia Bing analyzed the emission characteristics of pollutants from oil injection development projects, combined with the pollution status of surface water, and used a fuzzy comprehensive evaluation method to comprehensively evaluate the quality of surface water environment. Kang Yuan et al. sampled surface water from the upper reaches of the Luo River in northern Shaanxi, tested for hexavalent chloride, sulfate, chemical oxygen demand, volatile phenols, petroleum, etc., and conducted a water environment assessment using the single factor pollution index method. They found that the main causes of water environment pollution in the project area were mining wastewater, landing crude oil and oil sludge, drilling oil pollution, etc. At the same time, they found that the pollution levels of the river were different during the dry and semi dry periods.

In terms of the impact of oil injection development projects on groundwater environment, Li Yang used the Nemero index method, fuzzy comprehensive evaluation method, principal component analysis method, and fully arranged polygon comprehensive index method to evaluate the shallow groundwater quality of oil injection development projects. Zheng Zikuan analyzed the impact of oil injection development projects on groundwater resources and proposed water environment protection measures based on Dong Zhiyuan's current water environment situation. Cao Tongmin et al. pointed out that the oil injection development project in the Loess Plateau of Longdong poses a direct threat to the drinking water sources of local residents, such as the leakage of drilling mud, causing serious pollution of underground diving; And accidents where oil wells cut off underground runoff, leading to the drying up of motor wells. Ma Ying et al. introduced the damage to the water environment caused by oil injection development projects, and believed that crude oil leakage and the reinjection of produced water were the main reasons for groundwater pollution in the injection development project area.

In terms of the comprehensive impact of oil injection development projects on the water environment, Yu et al. analyzed the pollution characteristics of wastewater in China's mining industry, including the petroleum industry, and proposed relevant measures for wastewater control. Cui Tengke et al. investigated the impact of the oil injection development project in Changqing Oilfield on the water environment of Qingyang City and found that the development of Changqing Oilfield has exacerbated the scarcity of water resources in Qingyang City, caused pollution of surface rivers and shallow groundwater, and had an impact on key drinking water source protection areas. Lu Zaoquan also investigated the current situation of regional water environment pollution caused by the oil water injection development project in Qingyang City in his research, pointing out that the oil water injection development has caused serious pollution to the surface and groundwater environment in Qingyang City, resulting in the decline of groundwater level, the deterioration of water quality, and the direct pollution of surface rivers by the drainage outside Shantou. Zhao Dongfeng et al. conducted quantitative analysis on the diffusion, volatilization, dissolution, decomposition, emulsification, oxidation, biodegradation, sedimentation, adsorption and absorption, distribution and enrichment of petroleum pollutants in the aquatic environment, and obtained the migration and transformation process of petroleum pollutants in rivers, wetlands, and nearshore waters.

(1) Climate change has become a major issue of global environmental security

In recent years, climate change has caused frequent global extreme climate events, causing a series of major disasters and seriously threatening the space for human survival and development. However, the carbon dioxide emissions from burning fossil fuels are the main cause of climate change. In order to promote sustainable development of human society, the world has begun to advocate energy conservation and emission reduction, reducing carbon dioxide emissions to protect the global environment. The international community requires all countries to transform their high carbon emission survival and development methods in order to reduce carbon dioxide emissions.

(2) Under global emission reduction pressure, China cannot stay out of it

China has a large population and a relatively fragile ecological environment, with frequent natural disasters in recent years. China is in the process of industrialization and urbanization, characterized by intensive resource extraction and rapid consumption. Economic growth has a great demand for the heavy chemical industry, and coal is the main energy source in China. This situation has led to high greenhouse gas emissions in China. In 2007, China surpassed the United States as the world's largest emitter of carbon dioxide. In 2010, China surpassed the United States as the largest energy consumer. Since the signing of the Kyoto Protocol, the issue of climate change has risen to the international political level. With the gradual entry of carbon taxes and carbon trading into the international market, climate issues are no longer simple environmental issues, directly related to a country's political and economic lifeline. However, China has always been in a passive position on climate issues. Although it has not been subject to mandatory emission reduction requirements from developed countries, the top emitter has led some developed countries to take advantage of this opportunity to exaggerate

China's Environmental Threat Theory and China's Security Theory. Nowadays, the concept of "the lowest per capita emissions" is becoming increasingly unconvincing, and it is necessary to accelerate the transformation of an extensive economic development model and implement energy conservation and emission reduction.

(3) The contradiction between China's energy consumption structure and economic development cannot be ignored

In 2010, the global energy consumption composition was 33.6% for crude oil, 23.8% for natural gas, 29.6% for coal, 5.2% for nuclear energy, 6.6% for hydropower, and 1.3% for renewable energy; The composition of China's energy consumption is: crude oil 17.6%, natural gas 4.0%, coal 70.5%, nuclear energy 0.7%, hydropower 6.7%, and renewable energy 0.5%. My coal consumption is the most severe and high, while the proportion of other energy sources is lower than the world average. This is because in terms of energy structure, China's choices are extremely limited, and improving economic competitiveness and promoting economic growth require cheap energy as support. The government's regulation of energy prices is a good example. The resource reserves and price advantages of coal make it the top choice for energy in China, but it also emits the most carbon dioxide, with a unit of electricity generating 1.3 times more carbon dioxide than oil. The energy that emits the most pollutants is consumed the most in China. The contradiction between the limited energy structure and resources, as well as the sustainability of economic growth, is becoming increasingly acute. On the one hand, with the rapid development of the economy, we hope to undertake the industrial transfer from developed countries. The rapid development of the heavy chemical industry requires the support of a large amount of fossil fuels; On the other hand, industries based on fossil fuels inevitably bring high energy consumption, high pollution, and high emissions. In addition to meeting the phased characteristics of our own economic development, China's future economic development will also be constrained by climate change and greenhouse gas emissions reduction. Therefore, developing a low-carbon economy and implementing energy conservation and emission reduction is a necessary path for China's sustainable development.

If China's coal consumption is reduced by one percentage point and replaced by hydropower or nuclear energy, the total greenhouse gas emissions in China will be reduced by 1.14%. Replacing coal with low carbon fossil fuels such as natural gas or oil will reduce carbon emissions by 0.46% and 0.28% for each percentage point reduction in coal consumption.

(4) Unreasonable industrial structure

At present, from the perspective of China's tertiary industrial structure, economic growth is overly dependent on the secondary industry, and the development of the low energy tertiary industry is severely lagging behind and has a low proportion. Taking 2004 as an example, the proportion of added value of the tertiary industry in China's GDP is 40.6%, while the average proportion of OECD countries during the same period was 72.5%, the United States reached 76.5%, and India, which is close to China's development level, also reached 52.3%. The industrial structure of our country is unreasonable and needs to be gradually adjusted, vigorously developing the tertiary industry, and suppressing the unrestrained development of energy intensive industries. However, adjusting the industrial structure is constrained by many factors. Firstly, the industrial structure is adapted to a certain stage of economic and social development. China must fully industrialize before the tertiary industry, represented by the service industry, can lead the national economy.

1. 2.1 Problems in the research

With the expansion of the number and scale of oil injection development projects, significant progress has been made in oil injection development technology, and oil injection development has become a research focus today. However, with the increasing attention paid to the water environment, more and more scholars and organizations are paying attention to and studying the impact of oil injection development projects on the water environment. Scholars at home and abroad, such as Zheng Zikuan [16], Cao Tongmin [17], Ma Ying [18], and Cui Tengke [20], have qualitatively analyzed the impact of oil injection development projects on the water environment. They point out that oil injection development projects emit a large amount of pollutants in multiple processes and links such as surface construction, drilling, cementing, water injection and oil recovery, and gathering and transportation. These pollutants change the physical properties of surface and underground water bodies through direct and indirect effects Chemical and biological characteristics affect the quality of the water environment, and based on this, policies and suggestions for water environment protection have been proposed, as well as corresponding technologies and measures for water environment governance. The qualitative analysis of the impact of the Shiyan water injection development project on the water environment provides a research foundation for evaluating the impact of oil water injection development projects on the water environment, clarifies the research content and focus, and also points out the direction for proposing and formulating corresponding water environment protection policies and laws and regulations. However, these qualitative analyses cannot clarify the extent of the impact of oil water injection development projects on the water environment A series of issues such as whether governance measures need to be taken.

Domestic and foreign scholars have established water environment quality evaluation index systems in different regions. Through data collection and organization, the changes in pollutant content in the water environment of oil injection development projects were analyzed, and the process of pollutants affecting the water environment was analyzed. The water environment quality level was evaluated using fuzzy evaluation methods, artificial neural network methods, and other methods. These quantitative analysis and research results have solved the problem of uncertain impact degree in the water environment impact assessment of oil injection development projects, and made significant progress. However, these water environment assessments only reflect changes in water environment quality, and the impact of oil injection development projects on the water environment not only includes quality aspects, but also quantity aspects. These water environment quality assessments cannot fully reflect changes in the water environment. In addition, these water environment quality evaluations are based on static water environment quality monitoring data and cannot reflect the dynamic changes in the water environment.

In addition, there are still the following issues in the evaluation of the impact of oil injection development on the water environment:

(1) Insufficient depth of research

Deep research has been conducted on the sources and processes of the impact of oil injection development on the water environment, and the seriousness of the water pollution problem caused by oil injection development has been recognized. However, the quantitative research on the impact of oil injection development on the water environment is insufficient, only focusing on the quantitative evaluation of the project's impact on the quality of the water environment, without analyzing the impact on water volume and socio-economic factors, There is also no research on the impact of oil injection development projects on the water environment from the perspective of project management.

(2) Time limitations

Previous studies on the impact of oil injection development projects on the water environment were mostly short-term, even at a certain point in time, and continuous long-term studies were not common. The dynamic characteristics of the mountain water environment and the long-term sustainability of oil injection development projects cannot provide a reliable basis for the identification and treatment of water environment problems caused by oil injection development projects, It is even more difficult to study the development and changes in the impact of the Shishan water injection development project on the water environment. In future research, attention should be paid to time scale research, focusing on the dynamic characteristics of the water environment and the timeliness of pollutant emissions from oil injection development projects, and conducting long-term continuous monitoring research on oil injection development projects.

(3) Theory and practice are disconnected

The United States and Canada have conducted long-term research on the impact of oil injection development projects on the water environment, and have entered the cumulative impact assessment stage from the mountain environmental impact assessment stage. The cumulative environmental impact assessment is explicitly stipulated in laws and regulations. However, there are also significant issues in the cumulative assessment of the impact of oil injection development projects on the water environment in the United States and Canada. The complexity of mountain assessment and its involvement in multiple disciplinary fields lag behind theoretical research in practice. Even in theoretical research, there are no universally recognized principles, frameworks, or mature methods. The concept of cumulative impact assessment has been proposed in the guidelines for environmental impact assessment in China, but it is not mandatory to conduct cumulative impact assessment.

Moreover, China has conducted years of research on the impact of oil injection development projects on the water environment, but the pollution caused by oil injection development projects has not significantly improved. This indicates that there is a disconnect between theory and practice in the study of the impact of oil injection development projects on the water environment, and theoretical research has not been valued and applied in practice. Therefore, in the future, when conducting research on the impact of oil injection development projects on the water environment, While conducting theoretical exploration, more emphasis should be placed on the practical testing and application of theory. Accelerate policy and technical research that can effectively address the monitoring and governance of the impact of oil injection development projects on the water environment, and concretize and standardize the evaluation indicators of the impact of oil injection development projects on the water environment, providing theoretical guidance and technical support for the coordinated development of resources and environment. Connect theory with practice, practice under the guidance of theory, and improve theory in the development of practice.

1.2.2 Ways for Energy Conservation and Emission Reduction in Various Countries

From the practice and current research of energy conservation and emission reduction in various countries, the main ways to achieve energy conservation and emission reduction are as follows:

(1) Adjusting industrial structure

Industrial structure refers to the composition of various industries in a country, as well as the connections and proportional relationships between them. Industrial structure adjustment is an important topic for economic development in various countries today. Developed countries have completed industrialization and urbanization, driving economic transformation through accelerated industrial structure upgrading. The proportion of high-energy consuming raw material industries and manufacturing industries in the economy of developed countries has significantly decreased. Low emission industries such as finance, services, and information have rapidly developed, and greenhouse gas emissions per unit of GDP have shown a downward trend. At the same time, the internal structure of the secondary industry in developed countries is also undergoing significant changes. By improving environmental standards and other measures, the development of low-end manufacturing and high energy consuming industries such as metallurgy and chemical industry has stagnated or even shrunk. Developed countries will

Transfer high energy consuming industries to developing countries. For example, in the UK, from 1990 to 2007, the proportion of the secondary industry to GDP

The proportion has decreased from 35% to 23%, and the tertiary industry has increased from 63% to 76%. The upgrading and optimization of industrial structure is an important aspect for developed countries to achieve greenhouse gas emissions reduction. However, in the process of urbanization and industrialization, the phased characteristics of the rising proportion of high-energy consuming manufacturing in the national economy are still difficult to change. However, developing countries still need to incorporate the adjustment of industrial structure into their long-term national planning as an important way to control greenhouse gas emissions and achieve sustainable development.

(2) Strengthen energy conservation and improve energy efficiency

Energy efficiency refers to the efficiency of various processes such as energy development, processing, conversion, and utilization. On the basis of relatively high energy efficiency levels, developed countries are further strengthening energy conservation and improving energy efficiency, suppressing the growth of energy demand, and issuing various policy measures. The European Union has proposed to increase energy efficiency by 20% by 2020, and has issued the "Green Paper on Energy Policy" and the "Action Plan for Improving Energy Efficiency", clarifying 75 specific measures to improve energy efficiency in ten key areas including construction, transportation, and manufacturing. It is estimated that through the above measures, the EU can reduce energy consumption by 400 million tons of standard oil and reduce carbon dioxide emissions by approximately 800 million tons. In the energy consumption of developed countries, industrial energy consumption is mostly less than 30%, while building and transportation energy consumption each account for 30-40%. Therefore, building and transportation have become key areas for energy conservation and improving energy efficiency, and the results are significant. According to statistics from the International Energy Agency, the per capita energy consumption for building heating in developed countries decreased by 19% from 1990 to 2006, while the energy consumption of large household appliances such as refrigerators and washing machines decreased by 24%. The average fuel consumption per 100 kilometers of new cars decreased by 15%. Starting from 2009, EU member states have fully implemented new building energy consumption standards and vigorously promoted ultra low energy new buildings without active heating, which is expected to reduce the total terminal energy consumption of the EU by 11%. Japan has been implementing the "Leader Plan" since the beginning of this century, encouraging energy-saving and improving energy efficiency of energy consuming equipment such as appliances and cars. In 2005, the energy efficiency of R-type lighting increased by 36% compared to 1997 levels, and the fuel economy of passenger cars increased by 23%. In 2009, the United States established new fuel economy standards for automobiles, requiring all cars and light trucks manufactured and sold in the United States to reduce fuel consumption per 100 kilometers by 8% compared to current levels.

(3) Optimize energy structure

What is needed for socio-economic development is energy, not carbon. The amount of carbon contained in different forms of energy or per unit heat value varies greatly. Optimizing the energy structure mainly involves replacing high carbon energy with low-carbon and non carbon energy to achieve greenhouse gas emissions reduction. For example, natural gas replaces coal. Carbon dioxide emissions from the combustion of natural gas with the same calorific value in traditional fossil fuels

The quantity is approximately 25% lower than oil and 40% lower than coal. According to data from the International Energy Agency, developed prisoners from 1990 to 2008

In the overall energy structure of the family, the proportion of oil is relatively stable, while nuclear and renewable energy have slightly increased. The proportion of natural gas in primary energy consumption has increased from 20% to 25%, while the proportion of coal has decreased from 24% to 21%. For example, the UK's use of natural gas as a substitute for coal has achieved significant results. In 1990, the proportion of natural gas in primary energy was 22%, increased to 40% in 2008, and the proportion of coal decreased from 31% to 17%. This alone led to a 7% reduction in carbon dioxide emissions in the UK in 2008 compared to 1990.

(4) Maintaining and increasing forest carbon sinks

Forest carbon sequestration is a carbon dioxide reduction measure proposed in the context of climate change, with the core of increasing the carbon absorption capacity of terrestrial ecosystems. Maintain and increase carbon sinks and absorb carbon dioxide through afforestation and strengthening forest management. It is estimated that about 20% of the carbon dioxide gases that cause global climate change are caused by deforestation. For example, although the United States is a major country in forest products, it attaches great importance to the social and ecological benefits of forests. The federal government adopts the "cost sharing subsidy program" to increase funding subsidies to encourage states and private individuals to cultivate non timber forests. The Clean Energy and Security Act of the United States allows for the use of 1 billion tons of domestic carbon emission offset credits, primarily through increased carbon sequestration through domestic forest management. Japan has a very complete forestry legal and regulatory system, with a forest coverage rate of up to 67%. India encourages tree planting and afforestation, with the forest coverage rate increasing from 19.5% in 1990 to 23% in 2006. It plans to gradually increase the forest coverage rate to 30% through agricultural and natural forest protection. In recent years, China has implemented policy measures and key projects such as afforestation, natural forest resource protection, returning farmland to forests and grasslands, and basic construction of farmland. As a result, the forest coverage rate reached 20% in 2010.

(5) Emphasize the research and development of carbon capture and storage technology (CCS)

Carbon Capture and Storage (CCS) technology refers to the relevant technical system that collects and permanently stores carbon dioxide generated in energy consumption or industrial processes. In special cases, carbon capture and storage can also be directly carried out from the air. This technology is still in the research and development stage, and if a technological breakthrough is achieved, it can significantly reduce costs and energy consumption. CCS technology has great potential for emission reduction in future large-scale commercial applications. According to the International Energy Agency's analysis, to achieve the long-term goal of global emissions reduction, 10% of the required emissions reduction by 2030 will be achieved through carbon capture and storage technology. Developed countries such as Europe and America are actively conducting research and development on carbon capture and storage technologies in order to compete for the dominant position in key low-carbon technologies in the future. Especially in the United States, which has a high proportion of coal-fired power generation, a large amount of research has been conducted on the mechanism, potential, and economic evaluation of this technology. According to Advanced Resources International Corporation of the United States, the global capacity of depleted oil and gas to store carbon dioxide can reach 923 billion tons, which is equivalent to the highest emissions of fossil fuel fired power plants in the world in 125 years. Moreover, the United States has attempted to pass legislation that requires the application of carbon capture and storage technology in new coal-fired power plants built after 2020. In addition, Norwegian National Petroleum Corporation captures and injects 120 tons of carbon dioxide into the salt marshes below the gas field every year; British Petroleum Corporation (BP) has established the world's largest integrated hydrogen power generation and carbon dioxide storage project in Scotland. The project injects and stores approximately 130 tons of carbon dioxide annually into the Miller oilfield, producing approximately 548 tons of oil and extending the oil lifespan by 15-20 years.

1.3 Current status of international aviation fuel

As of the last update, the status of international aviation fuel remains influenced by several factors, including global economic conditions, geopolitical events, technological advancements, and environmental concerns. Here are some key points regarding the current status of international aviation fuel:

1. Global Demand: The demand for aviation fuel continues to be influenced by trends in air travel, which in turn are affected by factors such as economic growth, travel restrictions, and public health concerns (e.g., the COVID-19 pandemic). While air travel has shown signs of recovery from the pandemic-related downturn, uncertainties persist, particularly regarding the emergence of new variants and their potential impact on travel demand.

2. Price Volatility: The price of aviation fuel remains subject to fluctuations driven by factors such as crude oil prices, supply and demand dynamics, geopolitical tensions, and currency exchange rates. Airlines often employ hedging strategies to mitigate the financial risks associated with fuel price volatility.

3. Regulatory Environment: Regulatory bodies continue to play a crucial role in overseeing the quality, safety, and environmental impact of aviation fuel. Efforts to reduce greenhouse gas emissions from aviation may lead to stricter regulations and incentives for the adoption of sustainable aviation fuels (SAF) in the future.

4. Technological Developments: Ongoing research and development efforts aim to improve the efficiency of aircraft engines and reduce their fuel consumption. Advancements in engine design, aerodynamics, alternative fuels, and propulsion technologies contribute to enhancing fuel efficiency and reducing emissions.

5. Sustainable Aviation Fuels (SAF): There is growing interest in the development and adoption of SAF as a means to reduce the environmental footprint of aviation. SAF, which can be produced from renewable sources such as biofuels, synthetic fuels, and hydrogen, offer potential benefits in terms of reducing greenhouse gas emissions and dependence on fossil fuels.

6. Market Outlook: Despite short-term disruptions caused by events like the COVID-19 pandemic, the long-term outlook for international aviation fuel remains tied to the growth of the global aviation industry. Factors such as population growth, urbanization, rising middle-class incomes, and increasing international trade are expected to drive demand for air travel and, consequently, aviation fuel.

While the current status of international aviation fuel reflects ongoing challenges and uncertainties, there are also opportunities for innovation and collaboration to address environmental concerns and ensure the sustainability of the aviation industry in the years to come.

Regarding the literature available from domestic and international sources, research on aircraft electrical system fault diagnosis mainly encompasses traditional analytical methods and modern research approaches.

In traditional analysis of aircraft electrical system fault diagnosis, various interfering factors affect the system during operation. These factors include external elements such as unidentified flying objects, atmospheric pressure, temperature, and adverse weather conditions, as well as internal factors such as load performance, product quality, grid voltage, and installation environment, especially in adverse environmental and ultra-technical flight conditions. These are common reasons for aircraft system failures. When parameters characterizing the intricate and complex electrical systems within the aircraft fail, the system gradually loses its functionality, rendering the aircraft unable to operate properly. Implementing effective detection methods and information research theories in a timely manner to identify signal information under abnormal conditions and eliminate potential hazards is crucial for ensuring aircraft safety during flight and avoiding unnecessary maintenance, thereby improving operational efficiency. Specifically, traditional aircraft electrical system fault diagnosis methods include:

1. Human sensory diagnosis method: Generally, when the aircraft's electrical system experiences faults, some obvious situations arise, such as smoke, mechanical facility condition changes, abnormal heating, and sparks. Diagnosis of these faults typically does not require other sophisticated instruments; rather, they can be identified through human sensory perception methods such as visual, auditory, tactile, and olfactory senses of industry experts and scholars, pinpointing the specific areas of aircraft faults.

2. Utilizing testing experimental equipment measurement method: Specifically, major detection methods include energized thermometers, ultrasonic testing, new leakage current meter tests, insulation tests, grounding tests, and X-ray testing. Currently, aircraft electrical system fault diagnosis methods include offline diagnosis and online diagnosis. Once the aircraft fault is identified, offline diagnosis methods are preferred, but they can lead to adverse effects and economic losses. Online diagnosis can be conducted simultaneously, enabling the early detection of safety fault risks.

Compared to the above two methods, the sensory diagnosis method generally requires no investment but is generally limited to situations with minor degrees of faults and relatively obvious faults. When exceeding a certain limit, this method becomes less scientific. While testing experimental equipment measurement methods come with various testing facilities, dealing with a specific monitoring system involves complexities such as investment and system complexity, making the operation not straightforward. Therefore, another key point in diagnosing aircraft electrical system faults lies in inferring faults from data such as voltage and current. Thus, relying on sophisticated instruments, offline diagnosis, rich professional knowledge, etc., which are complex conditions and not suitable for situations with minimal equipment and requiring online detection, leads to obvious resource waste. Hence, there is a growing need for comprehensive diagnostic methods with fewer detection facilities, rapid diagnosis, and scientifically effective measures.

3. Comprehensive diagnostic method: In traditional detection methods for diagnosing electrical system faults, there exist issues such as simplified functionality, low intelligence level, and inefficiency. In the rapidly evolving scientific and technological environment, the construction of mechanical facilities becomes increasingly sophisticated. Therefore, purely relying on single diagnostic methods makes it difficult to accurately infer the faults in the electrical system. Misreports and omissions are not uncommon. It is necessary to combine traditional detection methods, absorb the essence of each method, and comprehensively apply them to improve the accuracy of fault detection. Utilizing computer equipment for monitoring and control can intelligently diagnose faults under the influence of

hardware and software, simultaneously collecting data such as generator rotation speed, output voltage and current, and excitation current, transmitting them to the main control computer through serial bus channels. Subsequent steps involve calculations, processing, data fusion, etc., providing important information for the next steps of fault localization and diagnosis.

Modern aircraft electrical system fault diagnosis methods differ significantly from traditional methods. Particularly, research on fault diagnosis methods for linear systems is becoming increasingly refined. The field of fault diagnosis for linear systems based on analytical redundancy has received significant attention from experts and scholars, yielding abundant theoretical achievements. However, there is an obvious deficiency in practical application methods that need strengthening. Moreover, fault diagnosis methods for nonlinear systems are gaining momentum, especially with the rapid development of signal processing, pattern recognition, control theory, and artificial intelligence. These developments provide indispensable theoretical content for studying fault diagnosis methods for nonlinear systems in depth. Most fault diagnosis methods for analyzing aircraft electrical system faults using analytical model theory primarily manifest in the field of linear systems. Therefore, the significance of analyzing fault diagnosis methods for nonlinear systems, especially in diagnosing faults arising from robustness, is paramount.

Signal processing fault diagnosis methods have been around for a while, but their specific application in diagnosing faults in nonlinear systems is not mainstream. In signal processing methods, wavelet transform technology is a focal point. Analyzing fault diagnosis methods for electrical systems using knowledge-based approaches does not require systematic quantitative mathematical models, making them suitable for complex practical applications like aircraft. Meanwhile, qualitative modeling methods are gradually entering the research scope of experts and scholars. Additionally, artificial intelligence technology is rapidly advancing, with the theory of expert systems and neural networks increasingly being used for diagnosing faults in electrical system equipment, becoming more frequent.

Fault diagnosis theory has been increasingly perfected under the premise of given system objects for predictive technology. Specifically, two points include determining the intrinsic structure and parameters of the system and using methods such as equivalent spatial methods, maximum likelihood methods, sequence probability methods, generalized likelihood methods, state observers, and filtering methods for inference and prediction of faults, with a focus on nonlinear systems. Since the construction and parameters of system objects are either blank or partially blank, knowledge-based reasoning methods and artificial neural network methods are more prevalent. Residual analysis and fault diagnosis based on pattern recognition are also considered. After identifying faults in the electrical system, the next step involves localizing the faults, which is a key difference between diagnosis and detection techniques. Current fault localization techniques primarily utilize knowledge theory, control theory, etc., to identify or vaguely identify corresponding patterns. Furthermore, another important difference between fault diagnosis methods for electrical systems and conventional intelligent testing systems and fault detection equipment is their ability to determine the mechanism of electrical system faults and evaluate them. Presently, expert systems based on knowledge theory remain predominant. Key theories for determining fault locations include artificial neural network technology, control theory, and fuzzy pattern recognition technology.

Overall, both domestically and internationally, knowledge reasoning methods remain the most commonly used in researching fault diagnosis of electrical systems, especially with the in-depth depiction of internal structures, parameters, and characteristics of electrical systems using artificial neural network methods, providing more scientific and rational explanations for uncertain and nonlinear objects. In the realm of neural network methods, wavelet transform theory and observer technology are representative.

1.4 Importance of aviation fuel supply system

The aviation fuel supply system plays a crucial role in ensuring the safe, reliable, and efficient operation of the aviation industry. Its importance stems from several key factors:

1. Safety: Safety is paramount in aviation, and the fuel supply system is designed to meet stringent safety standards. The system includes measures to prevent fuel contamination, such as filtration and quality control protocols, to ensure that only clean and pure fuel reaches aircraft engines. Any compromise in the integrity of the fuel supply system could pose significant safety risks to aircraft operations.

2. Reliability: A reliable fuel supply system is essential for maintaining the continuity of flight operations. Airports and airlines depend on a steady and uninterrupted supply of fuel to support their operations. Disruptions or shortages in the fuel supply chain can lead to flight delays, cancellations, and logistical challenges, impacting both passengers and airlines.

3. Efficiency: Efficiency in the fuel supply system is critical for optimizing operational costs and minimizing environmental impact. Efficient fuel logistics, storage, and distribution processes help airlines manage their fuel consumption effectively, reduce fuel wastage, and lower operating expenses. Additionally, advancements in fuel technology and infrastructure contribute to improving fuel efficiency and reducing emissions.

4. Regulatory Compliance: The aviation fuel supply system must adhere to regulatory requirements and standards set by aviation authorities and industry organizations. These regulations govern various aspects of fuel quality, storage, handling, and transportation to ensure compliance with safety, environmental, and operational standards. Non-compliance with these regulations can result in penalties, fines, and disruptions to flight operations.

5. Global Connectivity: The aviation fuel supply system facilitates global connectivity by supporting air travel across different regions and countries. It encompasses an extensive network of refineries, storage facilities, pipelines, tankers, and fueling stations to supply fuel to airports worldwide. This global infrastructure enables airlines to operate international routes and connect passengers and cargo to destinations around the globe.

6. Emergency Preparedness: The fuel supply system must be equipped to handle emergencies and contingencies effectively. Contingency plans and emergency response procedures are in place to address situations such as fuel shortages, natural disasters, infrastructure failures, and other unforeseen events that could disrupt fuel supply operations. Ensuring resilience and preparedness in the fuel supply system is essential for maintaining the continuity of air transportation during challenging circumstances.

In summary, the importance of the aviation fuel supply system lies in its role in ensuring safety, reliability, efficiency, regulatory compliance, global connectivity, and emergency preparedness in the aviation industry. A well-functioning fuel supply system is essential for supporting the growth and sustainability of air transportation worldwide.

1.5 Research Significance

During the operation of an aircraft, the aircraft fuel system directly affects the performance of the aircraft itself. With the continuous development of science and technology, increasingly complex aircraft fuel systems will be formed. Therefore, to ensure the safe operation of aircraft, stricter standards and regulations need to be established. In order to maintain the stable operation of the fuel system, current fault detection technologies must be optimized, and diagnostic levels improved.

To maintain the normal operation of aircraft, multiple systems are usually installed inside the aircraft, and the fuel system is one of them. Its main function is to reserve all the fuel required for the aircraft's flight, and under various flight conditions and working environments that meet requirements, ensure that the fuel is transported stably to the APU and engines and provide warning or instruction information to the pilots, thereby ensuring the normal operation of the aircraft. It includes critical systems such as fuel tanks, fuel pumps, transfer valves, fuel level sensors, ejector pumps, temperature sensors, etc., on the aircraft. Whether the aircraft can ensure sufficient safety is directly related to the safety and reliability of its fuel system. Therefore, research on aircraft fault detection and diagnostic technologies is a prerequisite for the development of aircraft fuel systems, and a safe and reliable fuel system is crucial in the design and operation of aircraft.

With the rapid development of civil aviation in China and the sharp fluctuations in aviation fuel prices, attention has been drawn not only from airlines and aviation fuel companies but also from the government regulatory body, the Civil Aviation Administration of China (CAAC), as well as ordinary consumers. This paper investigates the question of how to perceive the reform of China's aviation fuel system and how to further promote the depth of reform.

By introducing the supply models of aviation fuel in foreign countries, it is evident that even in mature market economies abroad, the supply of aviation fuel still requires government leadership, and monopolies still exist. However, this is not a reason to refrain from reform. How should China reform its aviation fuel supply system? Reform must be tailored to China's specific circumstances. To this end, this paper reviews the history of civil aviation development and aviation fuel supply policies. The aviation fuel supply system is gradually transitioning from a planned economy to a market-oriented approach. However, given China's current energy scarcity, aviation fuel supply cannot rely entirely on the market.

How can China seize the opportunity of accession to the World Trade Organization (WTO) and global aviation liberalization to promote the reform of the aviation fuel supply system? This paper suggests positioning aviation fuel companies, managing the relationships between aviation fuel companies, airlines, and petrochemical companies, diversifying the investment entities in aviation fuel, and strengthening government efforts in market access and safety supervision, without getting involved in specific operational matters. To cope with the volatility of aviation fuel prices, strengthening aviation fuel reserves and adopting a combined approach involving both the government and enterprises is recommended. Aviation fuel companies should also enhance their own capabilities, actively engage in the international economy, and mitigate risks.

Overall, the reform of China's aviation fuel supply system requires a comprehensive and strategic approach that takes into account both domestic circumstances and global opportunities.

1.6 Overview of China's Aviation Fuel Supply System

China's aviation fuel supply system is a vital component of its rapidly growing aviation industry, which has been expanding at a remarkable rate over the past few decades.

The aviation fuel supply market in China is dominated by state-owned enterprises (SOEs) and government-controlled entities. These include China National Aviation Fuel Group Corporation (CNAF), Sinopec, and PetroChina. CNAF, as the leading player, controls a significant portion of the market share and is responsible for the production, storage, transportation, and distribution of aviation fuel. Other entities like Sinopec and PetroChina, which are major oil and gas companies, also have substantial involvement in aviation fuel production and distribution.

The supply chain for aviation fuel in China typically involves several stages, including refining, storage, transportation, and distribution. Refineries operated by companies like Sinopec and PetroChina produce aviation fuel, which is then transported to storage facilities across the country. CNAF operates a network of storage facilities and pipelines to store and transport aviation fuel to airports throughout China. At airports, fuel is delivered to aircraft either through dedicated fuel trucks or via underground pipelines connected directly to the aircraft.

China National Aviation Fuel Group Corporation (CNAF): A state-owned enterprise responsible for managing the aviation fuel supply chain, including refining, storage, and distribution. Sinopec and PetroChina: Major state-owned oil and gas companies with significant involvement in aviation fuel production and distribution. Civil Aviation Administration of China (CAAC): The government agency responsible for regulating civil aviation activities in China, including overseeing aviation fuel quality and safety standards.

The aviation fuel supply system in China is subject to strict regulations and standards set by government authorities, particularly the CAAC. Regulatory oversight ensures compliance with safety, quality, and environmental standards to maintain the reliability and integrity of the aviation fuel supply chain. Pricing of aviation fuel is also regulated by the government, with adjustments made periodically based on factors such as international oil prices and exchange rates.

China's aviation fuel supply system is characterized by a combination of state control, regulatory oversight, and involvement of major state-owned enterprises. The system is designed to support the growth and sustainability of China's rapidly expanding aviation industry while ensuring safety, reliability, and compliance with international standards.

1.7 Research Methods and Technical Route

This article uses the idea of Analytic Hierarchy Process to obtain an indicator system for the impact of oil water injection development projects on water environment quality, quantity, and socio-economic development. An evaluation model is established to conduct a static evaluation of the quality and quantity impact on water environment. On the basis of static evaluation, the impact of oil injection development projects on water environment was evaluated through comparative analysis, and the dynamic impact of oil injection development projects on water environment quality and quantity was evaluated using linear weighting method. Finally, a comprehensive evaluation index system for the impact of oil injection development projects on the water environment was constructed, and a dynamic comprehensive evaluation model for water environment impact was established using a linear weighting method.

Since the 1970s, countries such as the United States and Japan have taken the lead in making energy conservation and emission reduction one of the strategic points for energy development. Major countries have taken various measures to control energy consumption and reduce the impact of the energy crisis on their own economies. The energy supply and demand situation varies greatly among countries around the world, so the focus of energy conservation and emission reduction work varies among them. Ernst Worrell introduced the energy-saving and emission reduction policies and experiences of developed countries, emphasizing the role of the government in market economy conditions [6]. Japan is a country with extremely scarce resources and has always been committed to building an "energy-saving society". Chinese scholar Sun Wanju analyzed the achievements of R Ben's energy strategy from the aspects of energy consumption per unit output value and structural energy conservation. Japan has been formulating correct and effective energy strategies since the 1970s and has successfully implemented them, solving environmental and energy security issues for Japan and breaking free from the constraints of traditional energy policies that rely on oil, building a sustainable economic and social foundation has laid the foundation and made Japan a country with diversified energy sources. Geller Howard et al. provided a detailed introduction to the relevant policies formulated by developing countries such as Brazil and India to encourage energy efficiency improvement and the development of renewable energy.

Based on the research of these scholars on energy strategies and energy-saving and emission reduction policies in various countries, some experiences have been drawn, which can be summarized as follows:

1. Develop laws and regulations related to energy conservation and emission reduction, and manage energy conservation and emission reduction in accordance with the law. Within the existing legal framework, countries around the world have formulated corresponding regulations, rules, and policies in all aspects of energy resources, development, production, and use, and continuously revise and improve them during the use process.

2. Develop relevant tax policies, including incentive and restrictive policies. Incentive policy measures include: promoting energy conservation among enterprises and consumers through different types of taxation, encouraging the development and utilization of renewable energy, and optimizing the energy consumption structure; Promote and popularize high-efficiency products through policies such as energy-saving and emission reduction cash rebate subsidies, tax exemptions, preferential loans, and mortgage loans. Restrictive policies include establishing new taxes on products that consume non renewable energy, such as environmental pollution tax, carbon tax, resource tax, energy consumption tax, etc.

3. Continuously increasing public budget support for energy efficiency management. The focus includes the formulation of laws and regulations, public publicity, information services, education and training, research projects, etc. At the same time, guide enterprises to develop, introduce, and demonstrate key, common, and forward-looking energy-saving and emission reduction technologies, and guide the promotion and application of energy-saving and emission reduction technologies.

4. Develop energy efficiency standards and labeling systems. Many foreign countries usually set a minimum energy efficiency value as a mandatory standard, and products that do not meet the standard are prohibited from entering the market. The current energy efficiency standards mainly target end-use energy products, such as automobiles, household appliances, buildings, etc.

5. Develop energy-saving and emission reduction promotion policies, strengthen consulting services and information dissemination, and enhance public awareness of energy-saving and emission reduction through regular targeted publicity, education, and training. There are many non-profit energy conservation and emission reduction information dissemination and consulting service organizations abroad, generally funded by the government.

6. Conduct extensive international carbon emissions trading activities. After the entry into force of the Kyoto Protocol, developed countries have actively engaged in multinational or regional international cooperation to achieve their emission reduction commitments while tapping into domestic energy conservation and emission reduction potential. Currently, international economic cooperation on carbon dioxide emissions trade is very active, with COM (Clean Development Mechanism) projects being the majority, and most of the projects are industrial energy conservation and emission reduction projects.

Chinese scholars have conducted research on energy development based on the current situation and practical significance of energy conservation and emission reduction in China. On the basis of in-depth analysis of the implementation status and existing problems of China's energy efficiency standards and labeling system, Jin Minghong and others drew on external experience and combined with China's actual situation, proposed countermeasures to improve China's energy efficiency standards or performance standards and labeling system. Famous Chinese energy economist Lin Boqiang pointed out that facing the current macro situation, China's energy strategy must be adjusted. On the one hand, the traditional mode of meeting energy demand only from the energy supply side must be changed, and management should be combined with the energy demand side. By comparing and selecting energy supply investment and energy-saving investment, the cost of meeting energy demand must be minimized; On the other hand, incorporating carbon dioxide emissions into the constraints of meeting energy demand

and formulating energy structure strategic planning based on these constraints is not appropriate. Jia Jingquan and others introduced the experience of foreign energy-saving and emission reduction policies, analyzed the various problems in China's energy-saving policies, and proposed suggestions for formulating and improving energy-saving and emission reduction policies. From the experience of developed countries, it can be seen that there must be systematic and strong policy support for energy conservation and emission reduction in the field of market failure.

2 Overview of Aircraft Fuel System

The aircraft control system consists of several subsystems, with the fuel system occupying a crucial position within the aircraft's control system, also known as the external fuel system. The engine's fuel system is internal to the aircraft control system, together forming the aviation fuel system.

In the original aircraft fuel system, the structure was relatively simple, consisting of several important fuel tanks and pipelines. Fuel was transported mainly by gravity, a method commonly used in light aircraft with piston engines. When designing the position of fuel tanks on the aircraft, they needed to be located higher than the engines. During flight, as the aircraft required fuel, it primarily entered the engine carburetor via gravity. However, various accidents could easily occur during this process, such as fuel supply interruption when the aircraft was inverted. Modern civil aircraft, including military fighter jets or supersonic aircraft, require fuel pumps to maintain fuel supply. For smooth fuel delivery from the tanks to the engines, a boost pump is necessary. Modern fuel systems often incorporate "redundancy design" to maintain system safety. In other words, core components or passages such as fuel pumps, fuel lines, or hydraulic pumps are duplicated within the system, with a minimum of two sets. This redundancy ensures that if one component fails, the backup component can be activated to maintain the aircraft's normal operation.

The aircraft fuel system serves many functions, categorized into three types: firstly, storing the fuel needed for aircraft operation to ensure a continuous supply of fuel to the engines at the preset flow rate and pressure, regardless of external environmental changes; secondly, controlling the aircraft's center of gravity to keep the aircraft within a safe range; and thirdly, conducting heat management. In the aircraft's cooling system, fuel cools the engine lubrication system while preheating itself to improve combustion efficiency.

Fuel tanks, which store fuel, are a component of the fuel system. During refueling, fuel is primarily transferred from external sources to the fuel tanks. The cockpit's fuel indicator page provides a clear display of the remaining fuel, measured in weight units (pounds or kilograms). The fuel pressure gauge indicates the fuel pressure supplied to each engine (pounds per square inch), and warnings are issued when fuel levels are low. The fuel flow meter indicates the fuel supply rate per unit time (pounds per hour), and the fuel consumption meter calculates fuel consumption (pounds or kilograms). Additionally, there are fuel pump switches to operate various fuel pumps. From a principle perspective, in multi-engine aircraft, each engine has separate fuel supply devices and indicators.

In the early stages of development, oil relies on the natural energy of the oil layer to overcome the seepage resistance in the oil layer and flow to the bottom of the well before being lifted to the ground. As the production time increases, the reservoir pressure continues to decrease. If the formation energy is not replenished in a timely manner, at a certain period, the formation will not have enough energy to lift the oil to the surface, leading to the shutdown of the oil well. In China, the vast majority of oil fields lack natural energy, and even if they can rely on natural energy for extraction, there are still many problems: limited natural energy, difficult to control, and short action time; In addition, the utilization of natural energy is unstable, with fast initial and slow later stages, low oil recovery speed, and low recovery efficiency, which cannot achieve stable production;

Furthermore, it is difficult to adjust and control oil fields that utilize natural energy for extraction.

In order to maintain or restore reservoir pressure and achieve high and stable production in the oilfield, oil development methods such as water injection and gas injection are needed. Oil injection development is currently the main method of oilfield development both domestically and internationally. Considering the specific sedimentary environment and development stage, over 90% of China's oil fields require or are undergoing injection development. The reason for choosing water injection development is because the oilfield has available water resources and good stability; In addition, water injection is rough and easy, and the equipment is relatively simple; Furthermore, water has a higher sweep ability in oil reservoirs, and it is effective in oil displacement. Water injection can maintain formation pressure, displace oil in pores, and improve oil recovery rate.

Oil injection development has many advantages:

(1) Being able to maintain high production water injection can maintain the energy needs of the formation, and can maintain high pressure differential production, resulting in high production;

(2) High efficiency: Water is relatively easy to enter the formation, and its viscosity is small, making it easy to flow in the formation. High pressure water injection can drive the oil in the reservoir towards the bottom of the production well;

(3) High recovery rate is an effective displacement medium for oil with low to medium density, and water can improve recovery rate. The recovery rate of dissolved gas drive in sandstone oil fields is 15%~31%, while water pressure drive can reach 36%~60%; The average recovery rate of dissolved gas drive in carbonate oil fields is 18%, while the recovery rate of water pressure drive can reach over 44%.

(4) It is easy to control and adjust the process of water injection into the formation. The timing and method of water injection can be adjusted according to different stages of oilfield development;

(5) Good economic effect, easy access to water, simple injection process, low investment and operating costs, and high efficiency can be achieved at low cost;

However, there are also some shortcomings in oil water injection development, mainly due to the low water recovery rate of oil fields developed by water injection. The water recovery rate during artificial water injection development is usually 5% to 8% of geological reserves, or even lower. The thicker the crude oil, the more severe the heterogeneity of the oil layer, and the thinner the well network, the lower the anhydrous recovery rate. The greater the water injection required to achieve the same recovery level, and the higher the percentage of oil production in the high water cut period to the total production. In addition, oil injection development causes early water breakthrough in the reservoir and increases production costs.

The oil water injection development project is widely distributed in Daqing Oilfield, Zhongyuan Oilfield, Dagang Oilfield, Shengli Oilfield, Changqing Oilfield, Liaohe Oilfield, and other fields. Taking the newly developed Daizhikui Oilfield by PetroChina Longdong Oilfield Company in 2001 as an example, this oilfield is a low permeability oilfield that is developed using water injection methods. By the end of 2008, a total of 4026 oil and water wells were drilled in the oilfield, including 3023 oil production wells and 993 water injection wells. However, as of now, major oil companies such as PetroChina and Sinopec, as well as authoritative departments in China, have not yet released authoritative statistics and survey data on China's oil injection development areas. There is no comprehensive information on the area of oil injection development areas, the number of producing and producing wells, the number of abandoned wells, and the number of water injection wells.

Petroleum water injection development projects are a type of project, more precisely a type of construction engineering project, so the definitions of projects and construction engineering projects are also applicable to petroleum water injection development projects.

A project is a one-time task undertaken to achieve a specific goal under certain constraints such as time, cost, and environment. Construction projects refer to the construction projects of various buildings and engineering facilities that provide material and technological foundations for human life and production, including oil and gas engineering projects. The definition of oil and gas development and construction projects in the "Technical Guidelines for Environmental Impact Assessment - Land Petroleum and Gas Development and Construction Projects" includes construction projects related to oil and gas exploration, development, surface industrial infrastructure construction, and related gathering, storage, transportation, roads, and oil and gas processing processes. The oil injection development project provides petroleum energy for human production and life, and is a type of oil and gas engineering project.

According to the definition of projects and construction engineering projects, it is believed that oil water injection development projects refer to projects that occur in a certain geological area, within a certain period of time, under certain resource and environmental constraints, and use relevant technologies and methods of water injection to extract, produce, and collect petroleum.

2.1 Functions of the Fuel System

The functions of the fuel system are as follows:

1) Storing the fuel needed for aircraft operation.

2) Continuously supplying fuel to the engines and APU in accordance with specified pressure and flow rates during all flight phases, including various changes in flight attitudes and working conditions, such as sudden changes in speed and altitude, and intense attitude changes.

3) Allowing any fuel tank to supply fuel to any engine. This process is accomplished through the fuel delivery system. During fuel delivery to the engines, fuel can be delivered directly or indirectly through cross-feed pipelines. In addition to pressure fueling, fuel can also be delivered by gravity. To connect various tanks, fuel from external tanks can be transferred to internal tanks via transfer valves, allowing fuel distribution through various pipelines. Meanwhile, the fuel tank ventilation system ensures proper ventilation to maintain safe and stable tank structures. To control all checkpoints effectively, relief valves and cross-feed or switch controls are employed. It's worth noting that all fuel pounds, transfer valves, and indicators are closely connected to the cockpit, where a control panel displays specific data, allowing the pilot to monitor the entire fuel system in real time during flight.

4) Besides serving as fuel, fuel can also be used as a lubricant and coolant. Fuel dissipates heat for hydraulic oil through a heat exchanger, while also warming up for improved combustion efficiency. It provides lubrication for components such as valves and pumps.

2.2 Characteristics of the Fuel System

Currently, many aircraft fuel systems have the following characteristics:

1) Large fuel capacity: Structural tanks are used to provide more space for fuel storage. Sealed spaces inside the wings are designed for corrosion prevention and space expansion, increasing the reserve fuel capacity. (The structural fuel tank of the ARJ-21 aircraft is shown in Figure 1).

2) Safe fuel supply: Modern aircraft are equipped with transfer fuel systems. When the system enters the fuel supply state, all fuel tanks in the system can supply fuel to the engines. Each tank is equipped with at least two boost pumps to ensure the safety of the fuel supply process. If both boost pumps in the same tank fail to function, the tank can still supply fuel to the engines by gravity.

3) Internal pumps are equipped with quick-disconnect self-sealing mechanisms, eliminating the need to drain fuel

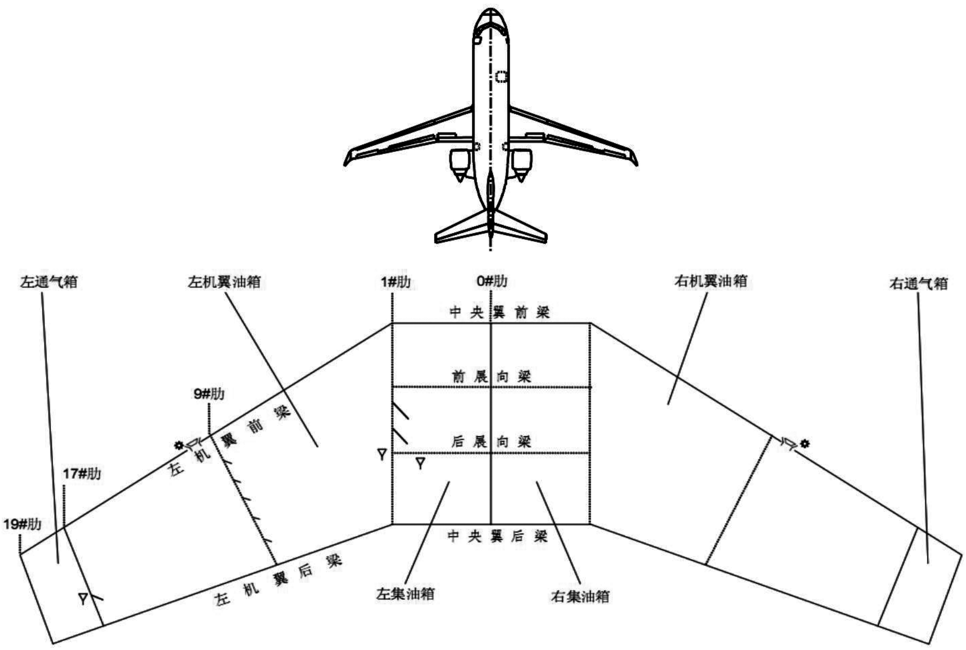

Figure 1 Aircraft Structure Fuel Tank

when dismantling pumps, thereby preventing accidental equipment loss and extending their lifespan.

4) More visual fuel control panels: When designing various components of modern aircraft, visual representation is a core requirement. The fuel control panel is no exception. Through this panel, the interconnection between different systems and the flow direction of different fuel lines can be intuitively presented, making control and operation convenient.

5) Avoiding dead fuel zones: An ejector pump is installed in the aircraft fuel tank, which utilizes the power flow from the fuel booster pump. As a result, fuel located at the lower part of the tank is preferentially introduced into the fuel supply pipeline.

6) Employing pressure refueling: Aircraft use refueling stations to complete the refueling process, allowing fuel to be delivered to any fuel tank. Pressure refueling speeds up the refueling process.

7) Using vented fuel tanks: Regardless of the aircraft's flight attitude, vented fuel tank systems can ensure ventilation to prevent excessive pressure differences between the inside and outside of the tank, ensuring the safety and stability of the tank structure.

8) Emergency fuel discharge system: Installing an emergency fuel discharge system on the aircraft allows for the rapid release of fuel in case of sudden emergencies. This reduces the aircraft's weight in the shortest time possible, keeping the aircraft within its maximum allowable landing weight range and ensuring the safety of the landing.

2.3 Components of the Fuel System

The aircraft fuel system is a crucial component of the aircraft power system, primarily responsible for storing, transporting, and supplying fuel to the engines to meet the power demands during flight. Below is a comprehensive overview of the components and functions of the aircraft fuel system:

1. Fuel Tanks:

- Fuel tanks are containers used to store fuel, typically installed within the wings and fuselage of the aircraft.

- Aircraft are typically equipped with multiple fuel tanks to provide sufficient fuel storage capacity.

- The interior of fuel tanks is equipped with fuel measuring devices to monitor fuel quantity and level.

2. Fuel Transfer System:

- The fuel transfer system consists of pipelines, pumps, and valves, among other components, used to transfer fuel from the fuel tanks to the engine fuel supply system.

- The fuel transfer system typically includes primary and auxiliary fuel transfer systems to ensure the aircraft receives fuel supply under various conditions.

3. Fuel Feed System:

- The fuel feed system supplies the transferred fuel to the engines to generate power.

- It includes components such as fuel filters, fuel pumps, regulators, and fuel lines.

4. Fuel Management System:

- The fuel management system monitors and manages fuel usage to maintain appropriate fuel levels during flight.

- Components include fuel flow indicators, fuel quantity gauges, fuel level indicators, and warning systems.

5. Fuel Jettison System:

- Some large commercial and military aircraft are equipped with fuel jettison systems used to reduce aircraft weight during emergencies, such as emergency landings or encountering abnormal conditions during flight.

6. Fuel Tank Inerting System:

- To prevent fuel explosions, some modern aircraft are equipped with fuel tank inerting systems that reduce oxygen content by injecting inert gas (such as nitrogen) into the fuel tanks, preventing the formation of flammable mixtures with fuel vapors.

The composition and function of the aircraft fuel system enable safe and reliable long-duration flights, maintaining appropriate fuel supply levels throughout different flight phases.

2.4 Forms of the Fuel System

The aircraft fuel system is primarily divided into two forms: gravity-fed and pump-fed. The gravity-fed fuel system is relatively simple. Generally, light aircraft with piston engines prefer this system. The main advantage of this system is that the fuel tanks are positioned higher, sometimes even above the engine. Additionally, fuel primarily flows to the engine carburetor via gravity. Many jet aircraft fuel systems require fueling through pumps, where fuel from the tanks is pressurized by a power-driven boost pump into the engine-driven fuel pump. To ensure aircraft maintain a safer and more reliable operational state, engineers have developed the concept of "redundancy design" and applied it to most modern fuel systems. The main feature of this system is the placement of core components or passages such as hydraulic pumps, fuel lines, or fuel pumps within the system. This configuration must include at least two sets of components. If one component fails, the backup component comes into play.

2.5 Objectives of the Fuel System

1) Fuel Storage: Storing the fuel necessary for aircraft operation.

2) Continuous Fuel Supply: Ensuring a continuous supply of fuel to the power plant during any phase of flight, including various changes in flight attitudes and working conditions such as sudden changes in speed, altitude, or intense attitude changes, while strictly adhering to specified pressure and flow rates.

3) Flexible Fuel Distribution: Allowing any fuel tank to supply fuel to any engine. This process is facilitated through the fuel transfer system. Fuel is transported from the tanks to the engines, either directly or indirectly through cross-feed pipelines. In addition to pressure fueling, gravity-fed fueling

is also utilized. To interconnect various tanks, fuel from external tanks can be transferred to internal tanks via transfer valves, allowing fuel distribution through various pipelines. Meanwhile, the fuel tank ventilation system ensures proper ventilation to maintain safe and stable tank structures. To control all checkpoints effectively, relief valves and cross-feed or switch controls are employed. It's worth noting that all fuel pounds, transfer valves, and indicators are closely connected to the cockpit, where a control panel displays specific data, allowing the pilot to monitor the entire fuel system in real time during flight.

4) Multi-purpose Functionality: Fuel serves not only as a source of energy but also as a lubricant and coolant. Through a heat exchanger, fuel dissipates heat for hydraulic oil cooling, while also warming up to enhance combustion efficiency. It provides lubrication for components such as valves and pumps.

2.6 Theoretical Basis of Oil Water Injection Development

Oil and water are two immiscible liquids. Water is injected into the reservoir, enters the pores, and displaces the crude oil where it flows, but water cannot wash all the crude oil where it passes. The leading edge of oil and water moves towards the direction of oil production over time, meaning that the two-phase flow zone continues to expand and the pure oil zone continues to shrink. When water is seen at the oil production end, only the two-phase flow zone remains in the oil layer. Under water flooding conditions, the water saturation at each point in the oil layer continuously increases over time. At the same time, the saturation at different points within the oil layer also varies. As the leading edge advances, the water resistance inside the oil layer constantly changes, so the production and pressure also change, so the water drive oil process is unstable.

The oil layer is a highly dispersed system, and the rock of the oil layer is a complex space composed of mineral particles with extremely different geometric shapes and sizes, and the composition of mineral particles is also extremely different. These factors determine that the micro geometric structure and surface properties of the pore medium are extremely uneven, and the heterogeneity of the oil layer properties increases the complexity of water flooding.

From a macro perspective, the area of the reservoir that can be contacted by injected water also affects the process of water flooding, which is related to factors such as the properties of the injected fluid, the properties of the driven fluid, the geological characteristics of the reservoir rocks, and the layout of injection wells and production wells. The geological characteristics such as rock composition and pore structure, as objective existence, cannot be changed, and the water injection time, water injection method, and water injection speed can be adjusted to affect the water flooding process.

(1) Water injection time

In terms of water injection time, from the perspective of development trends, there are more advocates for early injection than late injection, and two factors are mainly considered in the specific boundary of water injection: pressure factor, reservoir permeability, and geometric shape. For different types of oil fields, water injection at different stages of oilfield development has different impacts on the development process, and its development effects also vary greatly. From the perspective of water injection time, it can be roughly divided into three types.

Early water injection refers to injecting water in a timely manner before the formation pressure drops to saturation pressure, so that the formation pressure remains above saturation pressure or near the reservoir pressure. This water injection method can always maintain the formation pressure above the saturation pressure, allowing the oil well to have a higher production capacity, which is conducive to long-term self injection production, and has a large margin for adjusting the production pressure difference, which is beneficial for maintaining a higher oil recovery rate and achieving long-term stable production.

Medium term water injection refers to the initial stage of production that relies on natural energy extraction. After the local formation pressure drops to a low saturation pressure, water injection is carried out before the gas oil ratio reaches its maximum value. Its characteristic is to transform the two-phase flow of oil and gas in the oil reservoir into a three-phase flow of oil, gas, and water. With the recovery of water injection pressure, there can be two situations: firstly, under stable formation pressure conditions, a water drive mixed gas drive mode is formed; The second method is to dissolve the released free gas back into the crude oil through water injection. Under high formation pressure and saturation pressure conditions, the bottom hole flow is reduced to saturation pressure. Although the oil recovery index is low, the production pressure difference of the oil well is significantly increased, which may also result in higher oil production and a longer stable production period.

Late stage water injection is actually a secondary oil recovery method, which refers to water injection after dissolved gas drive. In the early stages of development, relying on natural energy extraction, without energy supply, the formation pressure will gradually decrease below saturation pressure, and dissolved gas will precipitate from the oil. The reservoir driving method will be changed to dissolved gas drive. When continuing this mining method is no longer economical or unable to maintain a certain oil recovery rate, artificial water injection development is carried out to improve the oil recovery rate of the reservoir.

(2) Water injection method

The water injection method refers to the location of the water injection well in the reservoir and the arrangement relationship between the water injection well and the production well. Choosing different water injection methods for different oilfield geological conditions, especially the properties and structural conditions of oil layers, is the main geological factor in determining the water injection method. At present, there are four main types of water injection methods used in domestic and foreign oil fields: edge water injection, cutting water injection, area water injection, and point water injection.

Edge water injection refers to a type of well arrangement in which water injection wells are distributed near the oil-water boundary according to certain rules for water injection. Edge water injection requires the drainage of injection wells and production wells to be parallel to the oil bearing edge, in order to facilitate uniform advancement of the oil and water edge and achieve high recovery efficiency. According to the relative position of the water injection well at the oil-water interface, edge water injection can be further divided into: outer edge water injection

The water injection method of arranging the water injection well in the pure water area on the outer edge of the oil-water boundary The water injection method of arranging the water injection well on the oil-water transition zone through edge water injection Edge water injection is a water injection method that directly arranges water injection wells within the inner edge of the reservoir.

Cutting water injection refers to the use of water injection wells to cut a reservoir into several blocks, treating each block as an independent development unit, and conducting development and adjustment in different zones. The methods of cutting and water injection can be divided into horizontal cutting, vertical cutting, circular cutting, zone cutting, etc. Cutting the water injection well network requires determining factors such as cutting distance, number of production well rows, rejection, and well spacing to achieve cutting the water injection line formed on the water injection well row. In order to leverage the advantages of cutting water injection, it is necessary to better select a reasonable cutting width, determine the optimal cutting well row position, supplemented by point shaped water injection, and enhance the cutting water injection system to increase the pressure difference between the water injection line and the bottom of the production well (or oil production area).

Area water injection refers to a method of arranging water injection wells and production wells evenly across the entire development area according to a certain geometric shape and density. This water injection method essentially divides the oil layer into many smaller injection production units (also known as injection production well groups). A water injection well controls one of them to simultaneously affect several oil wells, and each oil well is simultaneously affected by the water injection well in several directions. According to the different locations and well network shapes of oil wells and water injection wells, area water injection can be divided into four point area water injection, five point area water injection, seven point area water injection, nine point area water injection, inverse seven point area water injection, inverse nine point area water injection, linear row water injection, and staggered row water injection.

After determining the water injection method based on the nature of the reservoir, it is necessary to consider the deployment of the well network and determine the density of the well network. The main purpose of water injection for thousand cutting is to determine the density of the well pattern, reasonable cutting distance, and rejection; The main purpose of an area water injection well network is to select a reasonable well density and determine a reasonable injection production well ratio. The development stage of an oil field varies, and the density of its well network also changes. Factors that affect the density of the well network include the physical properties and heterogeneity of the formation; Crude oil viscosity; Mining and water injection methods; Burial depth of oil layers; Other geological factors, such as the fractures and direction of the oil layer, the fracture pressure of the oil layer, bedding, and the required oil production, all have an impact.

The reasonable density and deployment of production wells have a significant impact on the initiative and flexibility of the entire oil development process. The more wells drilled and the denser the well network in an oil development project, the higher the degree of control of the well network over the oil layer, which is more conducive to achieving high and stable production and improving oil recovery. An increase in well spacing density will lead to varying degrees of increase in oil recovery, and the smaller the flow coefficient, the greater the impact of well spacing density. This is because the smaller the water injection well spacing, the better the continuity of each small layer, and the higher the water flooding coefficient, the higher the oil recovery rate. However, after the density of the well network increases to a certain extent, when the well network is encrypted, there will be no significant increase in the control of the oil layer, and there will be inter well interference, resulting in a decrease in single well production, poor economic results, and a significant increase in oil and water well management and repair work.

(3) Water injection pressure

Before the reservoir is opened, there exists a primitive pressure field, where the fluid inside the reservoir is in a state of equilibrium and no flow occurs. With the drilling of oil wells into the reservoir for oil production and water injection, the static pressure balance inside the reservoir is disrupted. A new pressure field is established from the bottom of each injection well to the bottom of each production well, which we call the "pressure system" of the reservoir. A reasonable pressure system is a reasonable coordination of the matching relationship between the bottom hole pressure, formation pressure, and production well flow pressure of water injection wells, in order to achieve the goal of rational utilization of energy, economically and effectively exerting the production capacity of oil reservoirs, and improving oil recovery.

In the actual production process, the pressure system inside the oil reservoir is in a complex dynamic change process. From the perspective of the entire process of oilfield development, mountain water flooding oil itself is an unstable seepage process, so it is always in a cycle of changes where the old balance is constantly broken and the new balance is constantly established. In this process of change, there is a complex relationship between the bottom hole pressure of the injection well, the formation pressure, and the flow pressure of the production well that affects and depends on each other.

The level of water injection pressure is first measured by the water injection intensity required to achieve the oilfield. Water injection intensity refers to the daily water injection rate per unit thickness of an oil layer, which to some extent reflects the possible range of oil recovery rate for a certain well network. In theory, increasing water injection intensity has certain significance in improving oil displacement efficiency. However, due to the heterogeneity of the Shanqian oil layer and various contradictions, there is even a certain range of water injection intensity. So in the process of oilfield development, to maintain the water injection intensity within a reasonable range, it is necessary to select a reasonable water injection pressure to ensure the rationality of the water injection intensity.

2.7 Petroleum Water Injection Development Engineering Technology

(1) Periodic water injection

Cyclic water injection is a water injection method that began to be implemented in the late 1950s and early 1960s in the former Soviet Union and the United States. From the 1970s to the 1980s, the former Soviet Union had already used this water injection method as the main method to improve the development effect of some water injection oil fields, and it was implemented on a large scale, mainly in about 80 layers of 22 oil fields in the West Siberia, Gubishev, and Boothu oil regions. In the 1980s, China began to carry out cyclic water injection experiments in Fuyu, Putaohua, Karamay and other oilfields, and achieved certain results.

Cyclic water injection is a water injection method that improves crude oil recovery. Its mechanism of action is not completely the same as ordinary water flooding. It mainly utilizes the different transmission rates of pressure waves in different media with different filtration characteristics. By periodically increasing and reducing the water injection rate, unstable pressure fields are generated inside the oil reservoir and corresponding unstable liquid infiltration flow is generated between small layers with different permeability.

During the half cycle of boosting pressure, the injection pressure increases. On the one hand, some of the injected water directly enters the low permeability and high permeability zones, displacing the remaining oil that cannot be driven away during conventional water injection, and improving the absorption profile; On the other hand, as the injection volume of Shanqian increases, some of the water flowing in the large pores overcomes the capillary force to obtain more interfaces along the high and low permeability sections and enter the low permeability section, causing some of the oil in the low permeability section to be displaced; Furthermore, the increase in water injection pressure results in more elastic energy being obtained in low-permeability intervals, so the larger the water volume, the stronger the various activities of the fluid in the reservoir during the half cycle of pressure rise. When entering the half cycle of pressure reduction, the pressure conduction velocity in the high and low permeability sections is different. The pressure in the high permeability section decreases quickly, while the pressure in the low permeability section decreases slowly. This forms a reverse pressure gradient between the high and low permeability sections, and at the same time, the capillary force and elastic force of the mountain lead to the slow flow of some water and oil in the low permeability section towards the perforated channel of the high permeability section at the interface of the two sections, And under the action of production pressure difference, it flows along with the subsequent displacement water flow towards the production well. Therefore, the smaller the water volume, the faster the energy decrease in the high permeability section, which is more advantageous for the early utilization of its reserve energy in the low permeability section. In the high permeability section, the fluid in the low permeability section enters the high permeability section along the interface between the high and low permeability sections under the action of elastic energy and capillary force, and the earlier the timing, the more fluid there is.

(2) Subdivision water injection technology

Subdivision water injection technology is to try to place oil layers with similar properties into a single interval for water injection. Its function is to reduce interlayer interference between oil layers with different properties, improve the utilization degree of various oil layers, unleash the potential of all oil layers, and control the increase in water content and decrease in oil production. It is one of the effective measures to improve the water injection development effect during the high water content period, especially in the later stage of high water content.

Subdivision water injection is an effective measure to reduce interference between small layers within the development layer system. By adjusting the water outlet of the well, the high permeability layer that interferes with other small layers can be blocked out and appropriately restricted; At the same time, water injection can be strengthened in small layers with low permeability and low water content to reduce interlayer interference. However, the high permeability layer is not only the source of interference with other layers, but also the main oil producing layer before it is completely flooded. Practical experience has shown that, Unable to take action The approach of "negative balance" limits the water injection intensity of high permeability layers to the same level as that of low permeability layers. Otherwise, excessively strict water injection restrictions on high permeability layers will inevitably lead to a significant reduction in production of surrounding oil wells. Therefore, the correct approach should be to appropriately limit the water injection intensity of the high permeability main reservoir while fully tapping into its production potential, and at the same time, take various injection and production increase measures such as unblocking and fracturing to maximize production as much as possible The water injection intensity and production rate of low permeability layers can only achieve the effect of reducing interlayer interference while maintaining stable and even increasing oil well production.

Subdivisional water injection is also an important means of regulating the advancement of injected water on the plane. When an oil well is connected to multiple water injection wells and the water content of the oil well increases, it is necessary to strengthen water injection in the non main direction based on the analysis of the water production layer and water inflow direction, and appropriately control the water injection in the main direction. If necessary, the water injection in that direction can even be stopped. When a water injection well and multiple oil wells are in circulation, it is necessary to comprehensively consider the water injection requirements of each oil well direction within the well group, weigh the priorities, and focus on the water injection requirements in the most favorable direction. [24]

(3) Horizontal well water injection development technology

Horizontal well water injection technology was proposed in the 1990s and is an emerging technology. With the development of low-permeability reservoirs, Shanqian low-permeability oil fields have the characteristics of high water injection pressure, insufficient formation pressure, weak water absorption capacity, and insufficient natural capacity. Moreover, with the prolongation of water injection time during the production process, water injection becomes increasingly difficult, and in the end, water cannot be injected. In this situation, although the recovery rate can be improved by increasing the density of the well network, the cost of the Shanqian high-density well network is relatively high, and for the Qianlow permeability oilfield, its production capacity is low, and the economic benefits are not very optimistic. However, the cost of injecting water through horizontal wells is relatively low, making it possible to develop low permeability thin layers.

Compared to vertical wells, horizontal well water injection has many advantages, and the biggest success of horizontal well water injection technology is the control of thermal fractures. Because it can generate different types of cracks. Different types of cracks can generate different relatively small interferences through the rock pressure field, which can relatively reduce the closure of cracks; Horizontal water injection wells have relatively long horizontal intervals in thin oil layers, which can indirectly expand the injection area and effectively maintain formation pressure; Injecting water into Shanqian horizontal wells can generate abundant thermal fractures and relatively long horizontal sections in oil layers, which can be driven by water front approximately equilinear and have good stability.

Horizontal well water injection technology can maximize the development effect of low permeability oil fields. It has unique advantages. Currently, with the continuous development and maturity of horizontal well water injection technology, it has quickly formed a remarkable technology in the field of oil and gas field development. It is widely used in the development of low permeability reservoirs, thin layer reservoirs, fractured reservoirs, and depleted oil fields [25]. Some petroleum experts have proposed two modes through indoor experiments: vertical well injection horizontal well production and horizontal well injection horizontal well production.

2.8 Pollution caused by oil injection development projects

The environmental pollution caused by oil injection development projects has been long-standing. During the construction, extraction, and storage and transportation of oil injection projects, formation damage, reinjection of water, and landing of crude oil can all affect the environment, resulting in loss of environmental and resource value. According to statistics from the US Environmental Protection Agency, in the past decade, the cost of cleaning up soil and aquifer pollution caused by oil spills alone has reached 160 billion US dollars, and the cost of pollution control has reached as high as 750 billion US dollars [26]. Moreover, the prevention and control of oil pollution has always been a challenge internationally. In order to coordinate the contradiction between oil injection development and the environment, in-depth research and exploration have been conducted abroad for a long time,

Many scholars have analyzed the impact of the entire process of construction, extraction, gathering and transportation, storage and transportation during the construction and operation periods of oil water injection development projects on the water environment, soil environment, grassland environment, atmospheric environment, etc. They believe that oil water injection development projects have a significant impact on the ecological environment.

(1) Pollution caused by oil injection development projects

The main sources of pollutants in oil injection development projects are wastewater, exhaust gas, and waste discharged during the construction and development of oil injection projects. These pollutants enter the ecosystem through different channels, causing ecological pollution and damage. The construction and operation process of oil water injection development projects includes surface construction, drilling, oil production, and gathering and transportation.

During the ground construction process, the construction of stations, roads, and pipelines will generate dust and solid waste, damaging soil and vegetation. During the drilling process, land will be occupied, vegetation will be destroyed, and pollutants such as wastewater, waste liquid, rock debris, oily mud, and solid waste will be discharged. Wastewater, waste, activation fluid, etc. are discharged during the logging process. During underground operations, landing crude oil, flushing water, oily wastewater, acidizing fluid, fracturing fluid, etc. will be generated. Produced wastewater, landing crude oil, oil sludge, fuel waste gas, and process waste gas during the oil extraction process. After oil is extracted from underground, it first enters various oil depots for storage through the gathering and transportation system. A certain amount of wastewater and solid waste will also be generated during the collection and storage process to pollute the environment near the irrigation area.

In addition, sudden accidents during the construction and operation of the project can also lead to crude oil leakage, sewage discharge, etc. When oil wells enter a decline period, water and oil leakage accidents will also occur in the water injection pipeline network and oil transmission pipeline, polluting the environment.

(2) Pollution characteristics of oil injection development projects

Multiple pollution links and strong mobility: Petroleum water injection development projects have multiple types of construction, large differences in processes, complex processes, and multiple pollution links. Moreover, Shanqian implements small team mobile operations, which has strong mobility of pollution sources, increasing the difficulty of environmental management and pollution control work.

Scattered pollution sources and irregular discharge: The distribution of oil and water wells in the project development zone is very scattered, forming highly dispersed point pollution. The discharge of pollutants has no fixed discharge outlet, is discontinuous in time, and the discharge amount is uncertain, with characteristics of randomness, temporary, and suddenness.

There are many types of pollutants and complex components: various construction types such as drilling, oil testing, oil production, well repair, fracturing, acidification, gathering and transportation, storage, etc. may form pollution. There are many types of pollutants, and the components are complex, with great harm.

Large pollution range and wide coverage: Oil development operations have scattered pollution sources and a wide range of pollution discharge. It is likely that some pollution sources are located in environmentally sensitive areas such as nature reserves, aquaculture areas, and farmland, and involve multiple units. Management is difficult, and once large-scale pollution occurs, the consequences will be serious.

Long pollution incubation period and difficult recovery: During the process of water injection and oil extraction, petroleum water injection development projects discharge a large amount of pollutants into water bodies, soil, and air. Some pollutants have a long incubation period and form indirect impacts through the biological chain. Once pollutants enter the ecological environment such as water and soil, it is difficult to control and costly.

3 Aircraft Fuel System Introduction

3.1 Aircraft Fuel System

The aircraft control system consists of several subsystems, with the fuel system occupying a crucial position within the aircraft's control system, also known as the external fuel system. Designers incorporate the fuel system, which can act on the engines, into the aircraft control system by connecting these subsystem devices together, forming the aviation fuel system.

The ARJ-21 aircraft employs a combination of pressure refueling, fuel measurement equipment, and draining equipment to form the fuel system. The primary purpose of the main fuel tank is to supply stored fuel to the APU and engines, while the vented tanks at the wingtips provide overflow space for the main tank and meet its ventilation requirements. Vent float valves are installed on the inner side of the vented tanks, allowing fuel present in the vented tanks to be returned to the main tank via these valves, but fuel from the main tank cannot enter the vented tanks. Manual refueling of the main tank can be accomplished using refueling ports on the wings. Multiple maintenance access covers are installed on the lower surface of the wings as dedicated maintenance access points for repairing components. A discharge valve is installed at the bottom of each fuel tank for convenient removal of impurities and accumulated water [10].

3.2 Subsystems of Aircraft Fuel System

In the design process of traditional aircraft fuel systems, the system mainly consists of primary tanks and pipelines. In modern aircraft design, different subsystems are interconnected [11]. Generally, the ARJ21 aircraft fuel system includes the following subsystems: fuel storage system; pressure refueling system; fuel pumping system; engine fuel supply; APU fuel supply; fuel indication system.

1. Fuel Storage System

Oil tanks are divided into two compartments inside each wing, located aft of the fuselage (central wing box section).

2. Pressure Refueling System

During refueling of various tanks, it is mainly achieved through the pressure refueling system, which also allows cross-feeding between different tanks. Fuel is pumped through the refueling port on the right wing and smoothly delivered to the tanks via two refueling valves. A refueling valve is installed on each main fuel tank. Both control switches and fuel quantity processors can control the refueling valves. To enhance the efficiency of pressure refueling and concentrate refueling at one point, fuel contamination is avoided, and automatic control of the refueling quantity can be achieved [12].

3. Engine Fuel Supply System

During flight, the engine fuel supply system primarily relies on supplying fuel to the engines. This system can simultaneously supply fuel from one wing tank to two engines or supply fuel from two tanks to a single engine. Fuel supply is automatically halted in case of engine fire. The fuel control panel and engine start handle are mainly used throughout the operation process.

4. APU Fuel Supply System

The APU fuel supply system typically provides fuel required for APU operation and can also be used for assisting APU startup fueling. It can cut off fuel flow to the APU in case of an APU fire. When fueling the APU, the APU fuel supply system defaults to drawing fuel from the right main wing tank. Fuel is supplied to the APU by the right wing fuel pump. If the right fuel pump is shut down and the cross-feed valve and left wing fuel pump are open, fuel from the left tank will be drawn by the APU. The APU fuel cutoff valve controls the fuel flow to the APU, which is controlled by APU master switch, APU emergency shutdown switch, APU fire handle, and APU FADEC power. When a signal is received, the APU fuel shutoff valve needs to be opened promptly. During fueling of APU components, any leaked fuel from the APU fuel supply pipe is discharged from the aircraft.

5. Fuel Pumping System

The equipment that extracts fuel from inside the aircraft is the fuel pumping system. It pumps fuel to the refueling port, allowing suction pumping for each tank, and gravity draining for the two tanks. When pressure pumping is required for the left tank, the cross-feed valve needs to be opened. Cross-feeding between different tanks is possible on the ground.

6. Fuel Quantity Indication System

The system that calculates the fuel quantity in each fuel tank is the fuel indication system, consisting of the following components: dual-processor fuel quantity computer, two sets of fuel quantity measurement sensor arrays, and two sets of cables.

The specific fuel quantity is displayed in the cockpit and refueling panel. The fuel quantity indication system shuts off when the preset fuel quantity is reached during ground refueling. When the fuel in the tank is ample, the system prevents further fuel input. The fuel quantity indication system can also check for troubleshooting and isolation issues.

7. Fuel Temperature Indication System

The temperature sensors of the fuel temperature indication system are located inside the left collector tank, detecting and displaying the fuel temperature inside the tank.

When there is an abnormal temperature in the tank, it is indicated on the simplified page and EICAS page fault information [13].

3.3 Aircraft Fuel System Fault Classification and Manifestations

3.3.1 Sources of Faults

During the aircraft manufacturing, installation, and maintenance processes, various complex factors can lead to faults, mainly due to the following reasons:

(1) Design Issues: Designing modern large passenger aircraft is a highly complex task, often prone to errors. For example, COMAC periodically releases FTAR to correct defects and issues in control software.

(2) Manufacturing Issues: During the aircraft manufacturing process, each component may have defects due to material or manufacturing errors.

(3) Operating Environment: During each flight of a large aircraft, it undergoes complex and significant changes from ground to high altitude, affecting every component. Prolonged exposure to vibration, high temperatures, humidity, radiation, etc., can lead to component failures.

(4) Human Factors: Pilot and maintenance personnel errors contribute significantly to accidents. According to relevant investigation data, nearly seventy percent of accidents between the 1960s and 1990s were caused by human error.

(5) Accidental Events: Various aircraft accidents are documented in many publications, often influenced by the development of modern industrial society. However, as industrial manufacturing standards improve, manufacturing-related faults decrease, while human and environmental factors increasingly affect aircraft faults [14].

3.3.2 Fault Classification

Under normal circumstances, aircraft experience two types of faults: hard faults and soft faults. The former can be identified in a relatively short time and involve sudden damage or failure of certain aircraft components. Soft faults typically accumulate gradually, involving changes in control system parameters, circuit bias, etc.

During aircraft maintenance, classification is necessary and is typically based on factors such as the degree of functional impact, occurrence rate, severity, fault causes, and timing [15].

(1) Based on the degree of impact on system functionality, faults can be classified as complete or partial. Complete faults refer to equipment unable to perform primary functions, with all operations stopped; partial faults refer to some functions within the equipment being unusable, meaning certain system functions cannot be initiated.

(2) Based on fault occurrence frequency, they can be categorized as sudden, rapid, or slow. Sudden faults occur without any warning signs and are challenging to prevent; rapid faults result from accelerated wear and can be prevented with timely inspections; slow faults accumulate gradually and can be effectively prevented with regular inspections.

(3) Based on the severity of the fault across various levels, there are two categories: catastrophic faults and non-catastrophic faults. Catastrophic faults cause significant loss of manpower and resources; non-catastrophic faults include usability and economic faults, where the equipment cannot maintain normal performance or achieve expected economic benefits.

(4) Fault types can be differentiated based on the cause, including inherent, human-induced, and overstress faults. Inherent faults arise from component issues; overstress faults occur when external stresses exceed component design limits; human-induced faults are abnormalities caused during manufacturing, installation, or maintenance processes [16].

(5) Depending on the equipment usage stage, faults can be classified as early, occasional, or wear-out faults. Early faults occur during debugging and running-in periods; occasional faults occur before the equipment reaches its service life limit and have low failure rates, following an exponential distribution; wear-out faults occur as

components age and degrade, increasing the failure rate, following a normal distribution [17].

3.3.3 Characteristics of Faults

When diagnosing aircraft faults, understanding their characteristics is essential for targeted troubleshooting. Several fault characteristics include:

(1) Generally, aircraft components fail randomly, leading to varying failure rates. Natural and human factors contribute to most aircraft faults, resulting in a highly stochastic failure rate for most aviation components.

(2) Aircraft overall fault rates follow a "bathtub curve." Initially, as all components enter service, their performance parameters are unstable, leading to varied failure rates. Over time, with prolonged flight time and increased flight frequency, component performance stabilizes, reducing the probability of aircraft failures. Aircraft electronic equipment's reliability faults are common and exhibit significant randomness. As aircraft reach certain service life milestones, more components undergo wear, corrosion, fatigue, etc., due to environmental factors, increasing the overall failure rate.

(3) Fault mechanisms are complex. Modern large passenger aircraft incorporate multiple new technologies, resulting in complex electromechanical equipment. Each system operates differently, contributing to the complexity of fault mechanisms.

(4) Concurrent fault occurrence is probable. Aircraft systems exhibit complex fault phenomena due to their intricate structure. Any primary fault can trigger various abnormal conditions due to multiple underlying factors, making concurrent faults a common occurrence [18].

Each sub project and link of the oil injection development project releases a large amount of pollutants into the water environment, which affect the quality and quantity of the water environment through direct, indirect, synergistic, and cumulative effects. The impact of oil water injection development projects on the development of oil resources and the water environment will ultimately have an impact on the human economy and society, affecting the sustainable development of the human economy and society.

The primary purpose of planning, construction, and operation management of oil development projects by oil development enterprises is to develop oil resources in the most economical and scientific way according to the national strategic needs and energy needs for economic development. The process of water injection development is bound to have an impact on the water environment, or even damage it. The deterioration of water environment quality leads to a decrease in the number of available water resources that meet water environment quality standards, which increases the operating cost of oil injection development projects and subsequently affects the efficiency and social responsibility of enterprises. Oil injection development projects will also compete with other human life and production for limited water resources. Water is the source of life and the most important resource for human survival and development. The impact and destruction of oil injection development projects on the water environment have a profound impact on the development of human society.

Entering the 21st century, China is increasingly emphasizing the sustainable and harmonious development of its economy, society, resources, and environment. It is also paying more and more attention to environmental protection in the process of resource development, especially water environment protection. Therefore, the country has promulgated the "Water and Soil Conservation Law of the People's Republic of China", and various provinces have successively introduced the "Water and Soil Conservation Regulations" on this basis. This also forces oil development enterprises to pay more attention to water environment protection during the construction and management of oil injection development projects.

Whether it is the subjective protection of water environment by oil development enterprises or the objective requirements of national and social water environment protection, it is required that oil development enterprises continue to pay attention to changes in the water environment during the construction and operation management of oil injection development projects, evaluate the impact of oil injection development projects on the water environment, take reasonable measures to reduce the impact of projects on the water environment, and take timely and scientific measures to protect the water environment, Avoiding the old path of pollution before treatment has also increased the social responsibility awareness of oil development enterprises.

Therefore, scientific evaluation of the impact of oil injection development projects on the water environment has become a top priority in current scientific research. This article proposes an evaluation method for the impact of oil injection development projects on the quality and quantity of water environment, and based on this generation, evaluates the comprehensive impact of oil injection development projects on the water environment. It is hoped to provide reference for oil development enterprises to evaluate the impact of oil injection development projects on the water environment.

3.4 Principles for constructing indicator system

The establishment of an indicator system for evaluating the impact of oil injection development projects on water environment quality should follow certain principles, including:

Systemic principle: The indicator system must be able to reflect various aspects of the impact of oil injection development projects on water environment quality;

Dynamic principle: The indicator system should reflect the dynamic behavior and development trend of the impact of oil injection development projects on water environment quality;

The principle of scientificity: the physical meaning of indicators is clear, measurement methods are standardized, and statistical calculation methods are standardized;

The principle of operability should take into account the quantification of indicators, the difficulty and reliability of data collection, and make the best use of existing statistical data and normative standards related to economic development and environmental conditions;

Regional principle: The indicator system should reflect the characteristics and stages of the relationship between the construction and operation of petroleum water injection development projects in the geographical area and the water environment.

3.5 Establishment of indicator system

There are many pollution links and sources in oil water injection development, and corresponding regulations have been made both domestically and internationally for the environmental impact assessment of oil water injection development. China's "Technical Guidelines for Environmental Impact Assessment" (hereinafter referred to as the guidelines) recommend the use of water quality evaluation parameters for oil development projects in surface water environments, including pH value, COD, five day biochemical oxygen demand (BODs into dissolved oxygen (DO), suspended solids, sulfides, water temperature, volatile phenols, hazardous substances, petroleum, benzene, polycyclic aromatic hydrocarbons, and stipulate that appropriate selection can be made based on project characteristics, water area types, and evaluation levels. Additionally, it is stipulated that the number of pollutant types? 3. Or the number of water quality parameters that only contain two types of pollutants but require prediction of their concentration? 10; The number of pollutant types=2, and the number of water quality parameters for predicting concentration is less than 10. The "Guidelines" also provide detailed provisions for the selection of water quality evaluation parameters such as the complexity of project sewage quality and the size of water bodies. The

Guidelines also have similar provisions in the groundwater environment, but do not provide detailed evaluation parameters for groundwater quality. In the "Guidelines" for onshore oil and gas development and construction projects, it is stipulated that groundwater monitoring factors include pH value, total hardness, total dissolved solids, COD, high salt index, petroleum, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, volatile phenols, and appropriate supplementation of iron ions, chloride ions, sulfur ions, etc. based on the characteristics of the oil reservoir.

The impact indicators of petroleum annotation development projects on water environment are very complex. Among the selected indicators, indicators with similar properties are classified into one category. On the basis of previous research and guidelines, following the principle of constructing an indicator system, establish an evaluation indicator system for the impact of oil injection development projects on water environment quality. This indicator system divides the impact of oil injection development projects on water environment quality into surface water environment quality and groundwater environment quality. In surface water environment quality, it includes petroleum, suspended solids, water body indicators (COD, BODs, pH, DO, water temperature, etc.), volatile powder, salt alkali (sulfides, sulfides, native chemicals, chemicals, etc.), benzene, polycyclic aromatic light Metal (lead, cobalt, pickaxe, iron, etc.) and bacterial (SRB, TGB); In the environmental quality of groundwater, it includes petroleum, dissolved total solids, water indicators (pH value, total hardness, COD, etc.), volatile powder, ammonia nitrogen, saline alkali (high acid salts, sulfates, nitrites, etc.), benzene, polycyclic aromatic light, ionic (sulfur ions, sulfur ions, iron ions, strong ions, etc.), and bacterial (SRB, TGB).

The legal risks of environmental pollution borne by petroleum enterprises include both administrative and civil legal risks, as well as criminal legal risks faced by the increasingly stringent national legal environment. At the same time, the author analyzes the causes of these risks from a practical perspective, and how to avoid risks. Under existing risk management models, further improvement and improvement are needed, Establishing a more targeted environmental pollution risk management mechanism to enable petroleum enterprises to embark on the path of "green operation" requires further efforts, not only in the construction of peripheral mechanisms, but also in the establishment of a new production and operation concept by all levels of petroleum enterprises.

The establishment of modern enterprise systems is a process of balancing and choosing between opportunities and risks. Opportunities can bring profits and development prospects to enterprises, but risks always accompany them. Therefore, enterprises must incorporate risks into a manageable and controllable range in order to ensure their sustainable development. Enterprise legal risk management is one of the core contents of modern enterprise management system. Although it has only been developed for more than a decade in China, its crucial role in enterprise operation has attracted sufficient attention. Legal risks have various manifestations, and according to statistics, there are over 2000 types of legal risks faced by enterprises, covering various fields from company preparation, establishment, to bankruptcy liquidation.

In recent years, with the gradual infiltration of high-quality foreign enterprises, it has had a huge impact on China's extensive management of enterprises. Especially with the increasingly strict environmental protection laws, enterprises are facing increasing environmental pollution risks. If scientific environmental pollution legal risk management is not implemented, for enterprises, when risks arise, it will not only damage their reputation and finances, but also lead to a dismal outcome of being eliminated from the market. Legal risk is one of the important incentives for enterprises to fall into operational difficulties. Oil companies are a typical industry with high environmental pollution risks, as evidenced by recent events such as the Gulf of Mexico oil spill From the perspective of environmental pollution infringement incidents caused by improper operation and production of oil companies such as the "Bohai

Bay Oil Spill Accident", a series of unresolved problems such as huge compensation and litigation have brought immeasurable losses to oil companies, and have also caused great pressure on subsequent operations. China's oil industry is a monopoly operated by thousands of countries. With the development of network technology and the expansion of information disclosure, many previously unknown pollution incidents have surfaced Large oil companies are facing strict public opinion supervision, whether it is pollution incidents that have occurred or potential pollution risks, forcing them to face a severe situation. Therefore, strengthening the legal risk management of environmental pollution in oil companies is an important component of risk avoidance for oil companies and an important way for them to maintain sustainable development. Starting from the urgent need for environmental protection and corporate social responsibility to achieve sustainable development in China, this article explores the legal risks of environmental pollution in petroleum enterprises and corresponding risk management mechanisms.

At present, the internationally representative energy consumption evaluation indicator systems mainly include: the UK energy industry indicator system; IAEA (International Atomic Energy Agency) Sustainable Development Energy Indicator System; EU (European Union) Energy Efficiency Indicator System; WEC (World Energy Council) energy efficiency, etc.

The UK energy industry indicator system is designed in a top-down hierarchical manner, divided into three levels: the first level is the main indicators, including reliability, competitiveness, fuel poverty, and low-carbon indicators, which correspond to the four major energy development goals proposed in the 2003 UK government's energy white paper; The second layer is the supporting indicators, which are used to specify the four main indicators mentioned above; The third layer is the background indicators, divided into 12 items, and each item has a thousand indicators to refine and supplement the supporting indicators of the previous layer.

The framework of the EU energy efficiency indicator system is designed for classification, including six macro level energy efficiency indicators to evaluate the energy efficiency of a country or industry. These six types of indicators are: energy intensity, unit energy consumption, energy efficiency index, adjustment index, diffusion index, and target index.

The WEC energy efficiency indicator system is designed as a single layer, which includes 23 indicators. According to the nature of indicators, they are divided into two categories - economic indicators that measure energy efficiency at the entire economy or industry level; The other type is technical and economic indicators, which are used to measure the energy efficiency of individual industries and end use energy systems.

The IA EA Sustainable Development Energy Indicator System is also a single-layer design, with the main idea of identifying the main issues and parameters related to sustainable energy development; Determine the internal causal relationship between various important parameters related to energy and develop a set of indicators to measure the changes in parameters related to the energy sector. IAE A has finally identified 41 indicators.

3.6 Establishment of Environmental Pollution Legal Risk Management System

With the continuous deepening of the market economy, modern enterprise systems have gradually been improved and developed in various industries. The risk factors faced by enterprises in the process of operation and development are becoming increasingly complex, including not only commercial risks but also legal risks. To achieve long-term and stable development, enterprises must effectively control the occurrence of these two types of risks. Business risk refers to the risk caused by the actions of counterparties in the business process of an enterprise. Compared to commercial risks, legal risks are more controllable, and the legal compliance department can minimize the potential legal risks faced by enterprises in the business process by developing comprehensive risk control mechanisms. There are various forms of legal risk in enterprises, including default risk, violation risk, and infringement risk. In the production and operation process, if improperly handled, the occurrence of legal risk will not only lead to huge economic losses for the enterprise, but also the administrative and even criminal responsibilities that the enterprise should bear, and ultimately may lead to the brink of bankruptcy. Therefore, legal risk is one of the important incentives for enterprises to fall into operational difficulties. Oil companies are a typical high-risk industry for environmental pollution. In recent years, environmental pollution infringement incidents caused by improper operation and production of oil companies such as the "Gulf of Mexico crude oil spill" and the "Bohai Gulf oil spill accident", as well as a series of unresolved problems such as huge compensation and litigation, have brought immeasurable losses to oil companies and put great pressure on subsequent operations.

Since the reform and opening up, China's social and economic development has always been at a stage of rapid development. Through decades of efforts, the total economic output has now ranked second in the world, reaching an unprecedented height. While achieving brilliant achievements, looking back on the past, the shocking scenes have always lingered in the minds of the Chinese people, lingering like nightmares, accompanied by environmental pollution caused by high-speed development, The sword of Damocles, which has become the wheel of restraining the economy from further advancing, has been counted by relevant institutions as a significant environmental pollution event that has had a significant impact in China in recent years, with an average of three incidents per year. The Songhua River major pollution event in 2005, the Zijin Mining copper acid water leakage accident in 2010, the Dalian Xingang crude oil spill accident in the same year, and the Bohai Penglai Oilfield oil spill accident in 2011, The 2012 Longjiang River Pick Pollution Incident in Guangxi, a typical and major environmental pollution accident, is a well-known case that can be traced back to petrochemical enterprises.

As an important component of China's modern industry, petrochemical enterprises play a crucial role in the national economy and social development. However, the current development trend shows that the petrochemical industry has entered a high-risk period of environmental pollution, exhibiting characteristics such as wide impact range, serious damage consequences, and diverse types of pollution. As one of the driving forces for the development of basic industries and other industries, We do not have the determination and conditions to "tear down Ma Su", but we will not allow it to develop and expand freely and without restraint. How will it develop in the future? Corporate social responsibility: During the production and operation process, oil companies inevitably face potential or existing environmental pollution infringement risks and accidents. The sources of infringement are also diverse, such as environmental pollution infringement accidents caused by improper management during the exploration, development, and transportation of oil and natural gas, and third-party infringement caused by negligent damage to oil and gas facilities and equipment by criminals, These all fall within the scope of risk management by the legal/ compliance department of petroleum enterprises. Therefore, in the context of the frequent occurrence of environmental pollution accidents in petroleum enterprises, it is particularly urgent and important to conduct in-depth research on the operational mechanism of their legal risk management.

When formulating a risk prevention and control system, enterprises should consider the risks identified in the risk tree as a whole, and develop a risk prevention and control system for each risk to form an institutional system. This article focuses on establishing a three-dimensional framework for legal risk management of petroleum environmental pollution based on the three dimensions of risk management: objectives, elements, and management levels.

4 Aircraft Fuel System Fault Maintenance Case

Analysis

4.1 Failure and Analysis of Left Engine Fuel Supply

4.1.1 Fuel Supply Principle and Normal Flow Condition

Generally, during fuel delivery to the engine, the preferred fuel supply system is the fuel portion of the respective side tank. The two booster pumps in each wing tank deliver fuel from the tanks, ultimately reaching the engine fuel supply manifold. Fuel transfer between the two tanks can be facilitated by the fuel discharge system. By opening the transfer valve, identifying the tank from which fuel needs to be pumped, and activating the respective booster pump, fuel can be transferred between the two tanks.

4.1.2 Fault Troubleshooting Process

Firstly, check for fuel leakage in the fuel supply pipeline, but no leakage is found. Secondly, replace the left engine fuel supply check valve, then recheck if the left engine resumes normal fuel supply. Through these steps, it can be confirmed that the issue lies in the tank supply. Subsequently, replacing the left AC fuel pump core and repairing or replacing it eliminates the fault. Another scenario encountered during work is intermittent faults. Intermittent faults imply that if a fault is not promptly addressed, it will continue to occur intermittently. The aircraft manual does not explicitly provide solutions for such faults. Generally, intermittent faults are addressed by incorporating engineer opinions and maintenance records to formulate detailed work plans. After treatment, if the fault reoccurs, alternative methods are employed to solve the problem. Therefore, this study does not include intermittent faults [19].

4.2 Blank Fault of Fuel Quantity Indicator on Refueling Panel and Analysis

While refueling an ARJ21 aircraft for a certain airline, staff noticed that the refueling panel did not display aircraft fuel quantity on the flow meter as expected. Upon analyzing the cause of the fault, it was found that there are two subsystems in the fuel indication system, namely the flow indication system and the temperature indication system. The indicator did not display relevant metrics due to abnormalities in the fuel quantity indication system. Both the fuel quantity indication circuit and the fuel system's own components can affect the final display, leading to complex fault causes that are difficult to resolve.

4.2.1 Working Principle of Fuel Quantity Indicator

The fuel quantity indication system is used to measure fuel quantity, fuel temperature, and fuel pressure, and to indicate fuel system information through avionics systems, refueling/discharge indicators, etc. Each tank is equipped with a set of capacitive fuel probes, with capacitance varying with fuel depth. The fuel quantity measurement sensor detects fuel level and transmits the information to the respective FQC processor. The FQC calculates the fuel quantity based on the fuel level and transmits the information via the 429 bus to the EICAS display and the fuel summary page of the multifunction display. The FQC also monitors low fuel level sensors and the calculated fuel quantity to provide low fuel level warning information. Any triggering of the warning will result in the fuel system transmitting low fuel level warning information to the avionics system and displaying it on the EICAS and fuel system summary pages. See the schematic diagram in Figure 2 for details.

4.2.2 Fault Tree Analysis

When the refueling/discharge panel displays blank, it fails to reflect the corresponding tank's fuel quantity. There are four aspects that could lead to such a failure: the first is damage to the refueling/discharge panel, the second is a problem with the fuel quantity indication system, the third is an issue with the lines between the fuel computer, the refueling/discharge indicator, and the ground screw, and the fourth is a failure of internal unit components in the tank.

Reasons for problems with the refueling/discharge

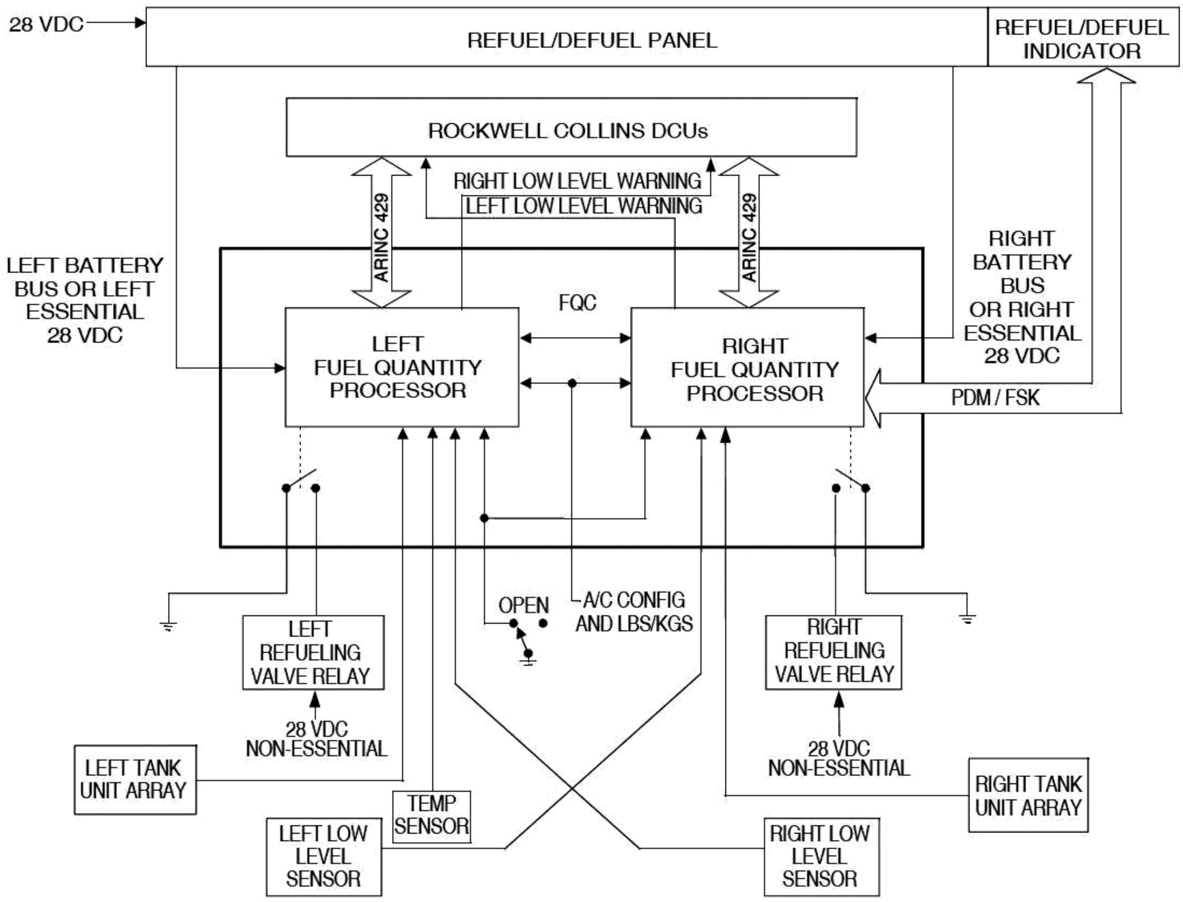

Figure 2 Principle diagram of fuel quantity indication system

panel include: abnormal state of the power control switch or control relay of the refueling/discharge panel, causing the relay-to-panel circuit to fail to maintain a connected state. Therefore, if the refueling power control relay is faulty, the panel will be affected. If some lines between the refueling/discharge panel and the fuel quantity computer are in an abnormal state, the indicators cannot emit light.

Common causes of problems with the fuel quantity indication system include: problems with the refueling/discharge fuel quantity indicator circuit, and faults in the fuel quantity processor components, which will cause problems with the indicators for the corresponding two tanks.

If ranked by the occurrence rate of faults, the most likely fault scenarios are: abnormal connection of certain components within the refueling/discharge panel itself, and abnormalities in the fuel quantity indicator itself. In contrast, it is relatively rare for the refueling fuel quantity indicator circuit to be in an abnormal state or for the fuel quantity processor components to malfunction. Overall, this type of fault is closely related to the wiring connected to the refueling panel. Meanwhile, other components and lines can also cause failures, such as the fuel quantity processor and components and lines related to refueling/discharge quantity, where each component can lead to a failure. In actual practice, the fault tree structure does not have multiple layers of faults. Airlines may choose to directly replace system components for troubleshooting efficiency.

For the analysis of the refueling fuel quantity indicator, a fault tree is created based on the reasons for its blank failure, as shown in Figure 3. See Figure 3 for details.

T - Fuel quantity indicator displays blank

M1 - Fuel quantity indicator malfunction

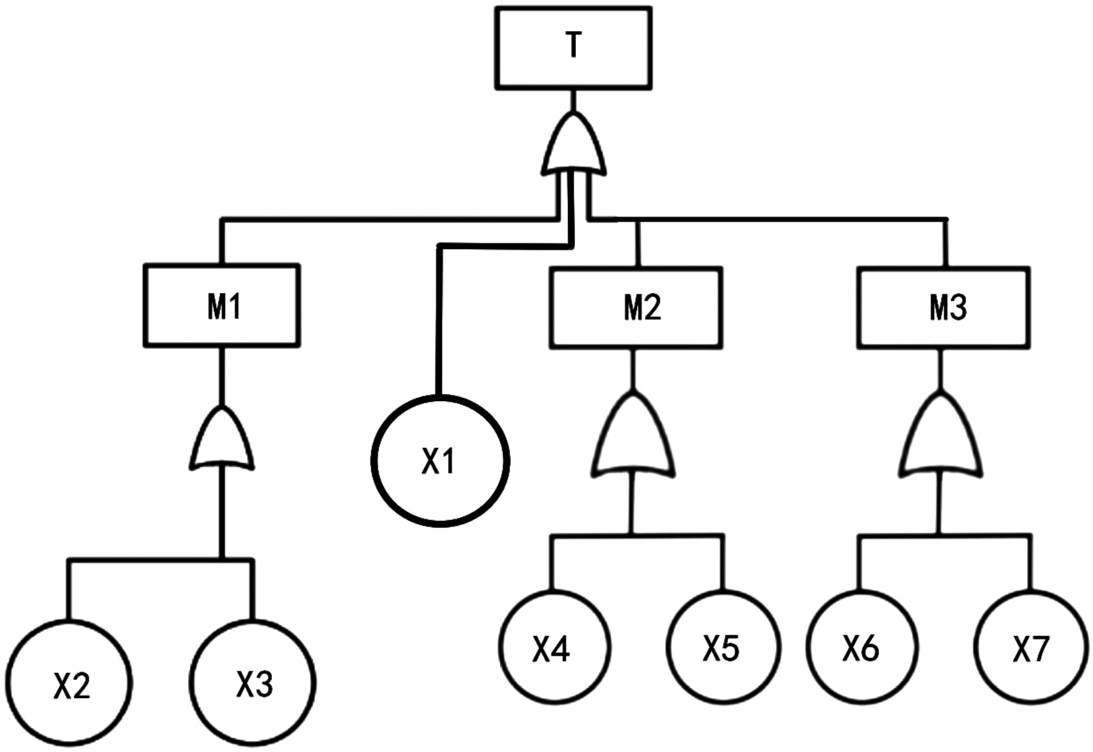

Figure 3 The fuel level indicator on the refueling station shows a blank fault tree

M2 - Fuel computer malfunction

M3 - Malfunction of internal components in the fuel tank

X1 - Wiring between fuel computer and refuel/defuel indicators and ground studs

X2 - Abnormal status of power control switch or control relay in refuel/defuel panel

X3 - Some wiring between refuel/defuel panel and fuel quantity computer is in abnormal status

X4 - Problem with wiring of refuel/defuel fuel quantity indicator

X5 - Malfunction of fuel quantity processor component

X6 - Malfunction of fuel quantity sensor

X7 - Disconnection of fuel quantity sensor wires

The reasons for the fuel quantity indicator malfunction, fuel computer malfunction, and malfunction of internal components in the fuel tank are quite similar. Further simplifying the fault tree, the events on the left branch and the right branch of the tree are essentially the same. Finally, the minimal cut set is obtained, and this type of fault occurs because:

There is a problem with the internal wiring of the fuel system, the power control switch or control relay in the refuel/defuel panel is malfunctioning, the fuel quantity sensor is malfunctioning, and the fuel quantity processor component cannot function properly.

4.3 Fuel Control Panel "L PUMP 1" switch Fault Indicator Constant Illumination Fault and Analysis

Throughout the flight of the aircraft, there are significant variations in the aircraft's center of gravity and attitude. However, large changes in attitude can trigger the Low Pressure (LP) Pump 1 fault indicator light due to the activation of the low fuel level sensor.

4.3.1 Fuel Tank Fueling Principle

When the indicator light illuminates, it signifies that the fuel in the corresponding tank has not been conveyed by the left-side boost pump to its destination, which is the engine fuel supply manifold. This indicates insufficient fuel supply to the engine, potentially leading to fuel leakage, which if not addressed promptly, can result in engine flameout.

4.3.2 Event Tree Analysis

Combining system principles, when the cockpit's left No.1 fuel pump is activated, electrical signals sequentially pass through the fuel control panel and the data concentrator unit. The fuel pump relay is then activated to start the fuel pump, with feedback from the pressure transducer of the fuel pump returning to the Data Concentrator Unit (DCU).

There are two main reasons for this fault: one occurring when the fuel pump is malfunctioning and another when the fuel pump is operating normally.

If the fault light continues to illuminate even with the AC fuel pump functioning properly, a likely cause could be a fault in the wiring between the Light Drive Unit (LDU) and the fuel control panel, resulting in erroneous warning light indications. Another possible cause of the fault is a malfunction in the fuel control panel or the LDU itself, leading to the constant illumination of the fault light. In the event of AC fuel pump failure, if faults in the wiring and transducers are ruled out, a malfunction in the fuel pump relay could result in the illumination of the fault indicator light, indicating an inability to function properly. If all other equipment lines are checked and confirmed to be normal and the fault persists, it is likely due to a fault in the fuel pump itself. The event tree is constructed as shown in Figure 4.

T——L PUMP 1 Pressed

X1——Fuel Control Panel

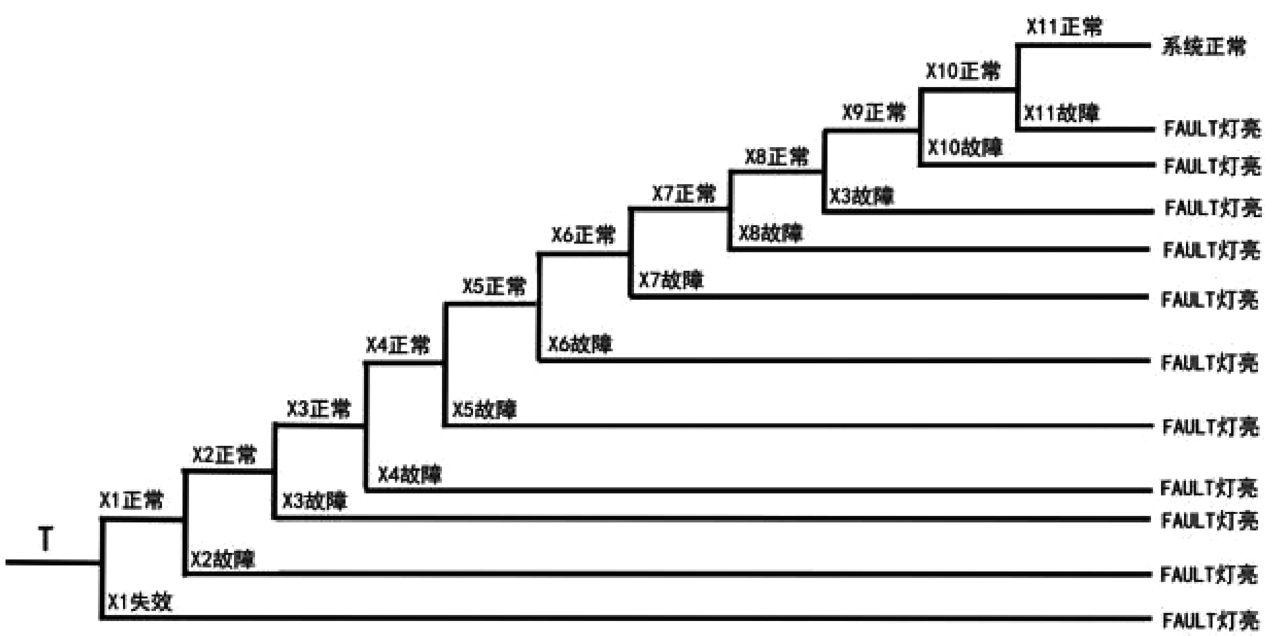

Figure 4 Event tree of left booster pump low pressure indicator light on

X2——Wiring between the Fuel Control Panel and DCU-2

X3——Wiring between the Fuel Control Panel and Left AC Fuel Pump 1 Relay

X4——DCU-2 (Data Concentrator Unit)

X5——Busbar and Wiring between Left AC Fuel Pump 1 Relay, Left AC Fuel Pump 1 Relay, and Left AC Fuel Pump 1 Pump Core

X6——Wiring between Left AC Fuel Pump 1 Relay and DCU-2

X7——Left AC Fuel Pump 1 Relay

X8——Left AC Fuel Pump 1 Pump Core

X9——Left AC Fuel Pump 1 Pressure Transducer

X10——Wiring between Left AC Fuel Pump 1 Pressure Transducer and DCU-2

X11——LDU (Light Drive Unit)

Event tree analysis is a systematic method of studying how initial events acting as sources of danger are temporally related to subsequent events, ultimately leading to failures. Compared to fault tree analysis, event tree analysis can only yield relatively vague conclusions, as the system can only function properly when all corresponding components in the tree are working correctly.

5 Systematic Analysis of Civil Aviation Electrical Systems Based on Neural Network Method

5.1 Design of BP Neural Network Fault Diagnosis System

There are many models of artificial neural networks, commonly including adaptive linear elements, Hopfield networks, Boltzmann machines, perceptrons, feedforward networks, and self-organizing competitive networks. Considering the Back Propagation (BP) network as a means for multi-aircraft electrical system fault diagnosis, its research aims to compare the relevance of BP networks and improve algorithms, widely applying them in fault diagnosis.

5.1.1 Back Propagation Network

5.1.1.1 Model and Construction

In short, the artificial neural network (ANN) simulates the structure and function of the human brain using physical components, systems, or computer media, thereby constructing a relatively complete artificial system. Its composition mainly consists of many structurally simple neurons, interconnected extensively to form a computational structure. In some dimensions, it can simulate the neural system of the human brain and form corresponding workflows.

The premise of artificial neurons is based on the structure and working characteristics of biological neurons. We consider a neuron as a single nonlinear component with multiple inputs (assumed to be n in number) and a single output. The relevant input-output relationship can be expressed as the following functional equations:

$$S_i=\sum_{j=0}^{n} w_{ij}\cdot x_j-\theta_i \qquad (5\text{-}1)$$

$$y_i=f(s_i) \qquad (5\text{-}2)$$

It is important to note that the parameter xj (j=1-n) represents the output signal of the neuron; the parameter θ_i represents the threshold of this neuron; the parameter represents w_{ij} the persistent weight from neuron unit j to neuron unit i; thus naming the neuron's output function or activation function. For simplicity, we rewrite the above equation as:

$$S_i=\sum_{j=0}^{n} w_{ij}\cdot x_j \qquad (5\text{-}3)$$

where the parameter $w_{i0}=-\theta_j$, $x_0=1$.

Various expression patterns of the activation function involved in the neuron model structure include: clipping linear function, Gaussian function, threshold unit model, Sigmoid function, and probability neuron model, among others. The primary function used in BP networks is typically the Sigmoid function. Neural networks generally construct a complete network system by extensively connecting many neurons. Based on the difference in connection patterns, the main structures of neural networks include two types: layered structure and mesh structure. Among them, the former mainly consists of several layers, with one layer being the network's input layer and another layer being the network's output layer, while the layers between the input and output layers are the network's hidden layers. Each layer contains a certain number of neurons. Within connected layers, neurons are connected unidirectionally, with no associative relationship between neurons within the same layer. Based on whether there are feedback connections within different layers, layered neural networks can be further refined into two types: feedforward networks and feedback networks. Among them, the former, also known as feedforward networks, are characterized by the ability of neurons in adjacent layers to be connected to each other, without feedback relationships between neurons within different layers. A single neuron can accept multiple inputs from the previous layer, producing a single output, which is then transmitted to different neuron objects in the next layer. Information can only be transmitted forward layer by layer through the input layer. Feedforward networks consist of multiple layers, but it has been proven that a 3-layer feedforward network can satisfy practical requirements. The backpropagation network belongs to a typical feedforward network. The Back Propagation (BP) network mainly targets nonlinear differentiable functions and conducts weight training based on this, belonging to a multi-layer feedforward network. The activation function corresponding to the BP network must reflect the differentiability everywhere, hence most commonly using the Sigmoid function (i.e., the S-shaped function) as shown in equations 5-4 and 5-5 below. Typically, there are two main types of Sigmoid functions:

$$f(x)=\frac{1}{1+e^{-x}} \quad (5\text{-}4)$$

$$f(x)= th(x)\ \frac{e^{x}-e^{-x}}{e^{x}+e^{-x}} \quad (5\text{-}5)$$

As a type of continuously differentiable function, f(x) possesses a first-order derivative. Due to its multilayer structure, the range distinguished by such activation functions is not limited to linear separation. Therefore, compared to classification and linear partitioning, it is more reasonable and accurate, while also exhibiting outstanding fault tolerance. Another important feature of f(x) is its strict utilization of gradient descent for computation, with a clear analytical expression for weight correction. This computation method is called error backpropagation (BP algorithm), and the network is also known as a BP network.

As the S-shaped function itself highlights nonlinearity and amplification factors, the range of signals input into f(x) extends from negative infinity to positive infinity, while being transformed to the range of -1 to +1 for output. Larger inputs correspond to smaller amplification factors, while smaller inputs correspond to larger amplification factors. Thus, utilizing the S-shaped activation function can handle and approximate the inherent correlations between nonlinear inputs and outputs. However, if the S-shaped function is used at the output layer, the outputs are constrained to a very narrow range. Using a linear activation function at the output layer ensures that the network system can output any value. Therefore, to only constrain the network output, such as within the range of 0 to 1, the output layer must contain S-shaped activation functions. In most cases, S-shaped activation functions are used in the hidden layers, while linear activation functions are used in the output layer.

5.1.1.2 Calculation Method of Backpropagation Network

The main focus of the BP network lies in obtaining the BP algorithm. Categorically, the BP algorithm belongs to the S algorithm, which is a supervised learning algorithm. Its core idea is as follows: Given q input learning samples: pl p2,…, pq, and the corresponding output samples as T1,T2,…, Tq. The aim of learning is primarily to modify the weights within the network channels based on the errors within the actual output samples, A1,A2,…,Aq and the target vectors T1,T2,…,Tq, ensuring that the difference between An (where An(n = 1,2,…,9) and the expected Tn tends towards proximity, i.e., ensuring that the sum of squared errors of the network's output layer is minimized. This involves continuously calculating changes in network weights and biases in the direction of decreasing slope of the relative error function, gradually approaching the target. Each change in weights and biases is proportional to the impact of network errors and is propagated through each layer via backpropagation channels.

The BP calculation method mainly consists of two parts: forward propagation of information and backward propagation of errors. In the former, the input information is passed from the input layer through the hidden layer to the output layer, and the output of each layer's neurons influences the input of neurons in the next layer. If the output layer does not match the expected output, the corresponding error change value for the output layer is calculated, and the calculation is reversed to propagate errors, transmitting the error signal along the original connection path through the network channel for necessary modifications. This involves adjusting the weights of neurons in each layer to ultimately match the expected target.

5.1.2 Design of BP Neural Network

In designing the BP neural network, this section primarily analyzes the dimensional aspect of the network layers. According to relevant theoretical content, it has certain bias characteristics, while also having a single S-type hidden layer structure, and should also be supplemented with a single linear output layer structure to achieve any rational function. Based on this, principles for designing a single basic BP network are proposed. Increasing the number of layers is crucial for reducing errors and enhancing accuracy, but it also leads to increasing complexity of the network, thereby increasing the training time of network weights. Enhancing error accuracy can also be achieved by increasing the number of neurons within the hidden layer, with its training effect being more convenient and adjustable compared to increasing the number of layers. Therefore, in most cases, the focus should be on increasing the number of neurons within the hidden layer.

Furthermore, can the problem be resolved using only a single-layer network with nonlinear activation functions? According to research conclusions, this is unnecessary or ineffective. The reason is that potential problems can be perfectly resolved through a single-layer nonlinear network system, and problems can be smoothly resolved through an adaptive linear network, with faster computation speed. Additionally, relying solely on nonlinear functions for problem resolution is insufficient, and single-layer accuracy is also not high, thus requiring an increase in the number of layers to achieve the desired objectives.

5.1.3 Optimization of BP Network Algorithm

Resolving the deficiencies in training the BP network system also requires training the computational methods.

(1)Additional Momentum Method

This method enables the network to consider not only the functionality of error at the gradient level during the process of weight correction but also the impact of changes in the direction of the error surface. Its function resembles that of a single low-pass filter, allowing the network to ignore minor variations. Without the influence of additional momentum, the network may enter into a partially limited system of local minima. However, with the functionality of additional momentum, it may slide into the category of local minima. This method is based on the premise of backpropagation, where an additional term proportional to the previous weight change is added for each weight change. The formula for adjusting weights with an additional momentum factor is as follows:

Essentially, the additional momentum method transmits the last changed weights and their effects through a single momentum factor. When the momentum value is zero, weight changes are primarily based on gradient descent. When the momentum value is 1, the new weight change must be set to the last changed weight. The changes caused by the gradient method are ignored. Therefore, the adjustment and change of weights tend to the average axis of the error surface base after increasing the momentum term. When the network weights enter a relatively flat range of the error surface base, the parameters become very small, thus avoiding overshooting. When a new error change rate occurs and exceeds the maximum error change rate set in advance, the calculation of weight changes must gradually be stopped. The maximum error change rate can be defined as any value greater than or equal to 1, with a typical value being 1.04. Therefore, in the design process of training using the additional momentum method, conditional judgments are added to more accurately apply the relevant weight correction formulas. The inference conditions for the training process related to the momentum method are as follows:

(2)Adaptive Learning Rate

Selecting an appropriate learning rate for a particular problem is not simple. It is generally obtained through experience or experimentation. However, having a good learning rate determined at the beginning of training does not necessarily benefit future training. To address this issue, it is often suggested to allow the network to automatically adjust the learning rate during the training process. The general principle for adjusting the learning rate is as follows: check the correction value of the weights to determine if it actually reduces the error function. If so, it means the numerically determined learning rate is decreasing, and another quantity can be increased. If not, and overfitting occurs, the learning rate needs to be reduced.

Similar to the inference conditions corresponding to the additional momentum method, if new errors exceed a certain multiple of old errors, the learning rate will decrease. Conversely, the learning rate will remain stable if new errors are lower than old errors. This method ensures that the network always trains within the maximum acceptable learning rate range. If a relatively large learning rate still allows the network to learn in a stable state and reduce errors, the learning rate increases, thus starting learning at a higher rate. If the learning rate adjustment is too large but cannot ensure a continuous decrease in error, the learning rate will gradually decrease until a stable state is maintained during the learning process.

The initially determined range for the learning rate exhibits a large degree of arbitrariness.

(3)Elastic BP Calculation Method

BP networks generally use Sigmoid activation functions in the hidden layer. Typically, Sigmoid functions are known as "squashing" functions, compressing an infinite input range into a limited output range. Their characteristic is that when the input value is large, the slope tends toward zero, resulting in very small gradient magnitudes within the algorithm, effectively halting the correction of network weights.

The elastic BP calculation method only considers the sign of the partial derivative and does not consider its magnitude. The sign of the partial derivative has a decisive influence on the direction of weight updates, while the magnitude of weight changes depends on a single independent "update value". If, during two consecutive iterations, the partial derivative sign of a particular weight does not change, then the corresponding "update value" is increased, for example, by multiplying by 1.3 based on the previous "update value". If a sign change occurs, the corresponding "update value" decreases, for example, by multiplying by 1.05 based on the previous "update value".

In the process of using the elastic BP algorithm, if significant oscillations occur during training, the corresponding weight change will decrease. If, in multiple iterations, the direction of weight change remains consistent, the weight change will increase.

5.2 Integration of MATLAB 6.1 and Visual Basic 6.0

The development environment for the development of electrical system fault diagnosis and treatment software for the new type of civil aircraft based on neural networks mainly operates on the Windows 98 operating system. The process of diagnosing and treating accidents is mainly programmed using MATLAB 6.1, while Visual Basic 6.0 is used for handling databases and setting interfaces. Due to the considerable number of layers in the neural network, as well as the significant number of neurons in each layer, and the considerable number of input vector groups, using ordinary programs would result in nested loops and complicated processes. This would lead to time-consuming programming and difficulty in debugging, making it challenging to design a more superior network system structure. In this regard, the MATLAB Neural Network Toolbox can comprehensively demonstrate its advantages. All computations are performed using matrix operations, thus simplifying the training process. It allows the main body of network configuration to break free from highly complex programming, enabling more focus on thinking and resolving relevant issues, thereby enhancing efficiency.

However, MATLAB has the following shortcomings: firstly, it is difficult to run without a compilation environment; secondly, although it has interface writing functionality, compared to more comprehensive and complex software, its interface appears relatively simple and rough, and cannot match the directness and convenience of VB writing. VB graphical pages have very comprehensive programming functions, whether it's shortcuts, menus, or toolbars, implementation is not difficult, and the resulting application can operate independently of the VB compilation environment.

By integrating the relatively comprehensive neural network toolbox functionality of MATLAB 6.1 with the advantages of Visual Basic 6.0 in the development of the entire graphical user interface and database, seamless integration of the new type of civil aircraft electrical system accident diagnosis and treatment software package based on the neural network system is achieved, thereby effectively reducing the development cycle and optimizing the performance of the entire system.

5.2.1ActiveX Components

The development of this component is primarily undertaken by Microsoft, mainly providing new protocols for application in plate integration. It is an extension component of the Visual Basic toolbox. ActiveX components comply with the ActiveX specification and belong to executable code development, such as single .exe, .dll, or .ocx files. When an ActiveX component is added to a program, it becomes a part of the development and specific operating environment, providing functionality for new application processes. The component maintains some general Visual Basic control methods, properties, and events. The specialized methods and properties of ActiveX components greatly enhance the functionality and flexibility of process designers.

Microsoft names all technologies based on COM as ActiveX technologies. Intelligence is a prerequisite for most ActiveX technologies, allowing interpretive macro languages (such as Visual Basic) to complete related details without knowing the application process, while also controlling intelligent objects. On some level, the related technologies and applications of ActiveX are similar to DDE links, but their functionality is superior to DDE links, thus, after the emergence of ActiveX, the use of DDE links is no longer popular. Linking with ActiveX becomes the core linking method. ActiveX essentially serves as a class of calling media for components, without requiring the component-related processes to be in an operational state, thereby enhancing the related functionality.

Most new software now supports the embedding of ActiveX components, allowing current process designs to be not only isolated processes but also software integrations that excel in different aspects. This is indeed a key reform in the software industry. MATLAB has completed the task of supporting ActiveX intelligent services, and through the ActiveX intelligent interface in the Visual Basic environment, MATLAB can be invoked as an ActiveX component in Visual Basic.

MATLAB supports two layers of ActiveX, including: (1) Operating MATLAB ActiveX components in the Visual Basic process; (2) Operating Visual Basic process ActiveX components in the MATLAB environment. Generally, the first method is used in this software.

5.2.2 Implementation Method

The core function of MATLAB ActiveX intelligent services is to execute relevant MATLAB commands in the MATLAB workspace and directly access related matrices, etc., from the workspace. The following are some core methods supported by MATLAB intelligent services, described in types determined by the ActiveX intelligent protocol and independent of the language:

1. `BSTR Execute([in]BSTR Command)`: The `BSTR` represents a wide string type, which is consistent with the data format used for storing strings in VB. This method mainly receives string commands executed within MATLAB and then returns the results in string format.

2. `void GetFullMatrix([in]BSTR Name, [in]BSTR Workspace, [in,out]SAFEARRAY(double)*pr, [in,out] SAFEARRAY(double)*pi)`: This method determines a relatively complete one-dimensional or two-dimensional real or complex mxArray in the specified workspace. Its real and imaginary parts are placed in two separate `Double` type arrays.

3. `void PutFullMatrix([in]BSTR Name, [in] BSTR Workspace, [in]SAFEARRAY(double)pr, [in] SAFEARRAY(double)pi)`: This method stores a single mxArray in the specified workspace. The meanings of different parameters and their calling methods are similar to those of the `GetFullMatrix` method.

5.2.3 Software Implementation

This software is of a general type and applies six types of BP network improved calculation methods, including adaptive learning rate method (mainly `traingda` function), conjugate gradient method (`trainscg` function), Levenberg-Marquardt method (`trainlm` function), additional momentum method (`traingdm` function), elastic BP algorithm (`trainrp` function), and quasi-Newton method (`trainbfg` function). Based on these methods, relevant accident diagnosis and treatment are conducted, and the summarized diagnosis results are compared, researched, and summarized.

This section mainly analyzes the programming of the `trainlm` function diagnosis and treatment process, while the programming of the diagnosis and treatment processes for the other five functions is similar and therefore omitted. This software mainly includes the following four modules:

5.2.4 Training Module

To conduct accident diagnosis and treatment based on BP networks, it is necessary to first define the relevant number of neurons in the input layer, hidden layer, and intermediate layer based on the diagnosis system. Then, experimental samples for training are obtained and passed to the `trainlm` function to conduct network training. If the training results match the requirements, the trained network is stored; otherwise, relevant samples must be selected for new training until they match the predetermined requirements.

(1) Verification Module

This module is crucial for testing the well-trained network, checking whether it matches the performance requirements. If the validation samples pass, ensuring at least an 80% match with the performance requirements, the network can be determined as successfully trained; otherwise, it must be retrained.

(2) Knowledge Base Module

This module is mainly implemented through a database compiled by VB, with the key purpose of storing trained and validated networks for use during diagnosis and treatment. The module needs to store the number of neurons in the hidden layer corresponding to each network, the name of the diagnostic system, learning rate, number of neurons in the input/output layer, minimum variance required for training, and the name of the MATLAB .mat file, etc.

(3) Diagnostic Module

After establishing a complete neural network knowledge base, data texts prepared for diagnosis can be inputted. From these texts, the module retrieves data from the knowledge base that can be used for diagnosis, and then outputs the diagnosis results.

5.3 Implementation of System Fault Diagnosis**

5.3.1 Fault Diagnosis in Electrical Load Management Center**

There are several types of fault diagnosis as follows:

(1) Fault Diagnosis of the 270V Bus Bar

Firstly, analyze the training results. The hardware circuit diagram for collecting data from the 270V ± 15V DC bus bar in the Electrical Load Management Center is analyzed as follows: the high voltage is divided by resistors to obtain a lower voltage, which is then transmitted to the microcontroller. The voltage division formula is given by (input voltage value X 5 / 275). Under voltage division, voltage values within 0~4.6363V indicate under-voltage faults, values within 4.6365-5.1818V range indicate normal conditions, and values exceeding 5.1818V indicate over-voltage faults. The collected data is transmitted from the Electrical Load Management Center to the power supply system's processing unit, where it is studied and processed. If it is determined to be fault data, the power supply system's processing unit sends control commands to the Electrical Load Management Center to switch the bus bar.

Any set of collected data can be selected as training samples and trained, with the unit being volts. If the training results do not meet the requirements, multiple rounds of training are required until the best training effect is achieved. The number of neurons in the hidden layer obtained after training the 270V bus bar is 11. Regarding convergence speed, the acceptable sum of squared errors and the corresponding number of training steps can be obtained through the network channel. In practice, when the target sum of squared errors equals 0.001, the number of training steps for trainlm function is 6, for trainbfg function is 509. If the target sum of squared errors equals 0.01, the number of training steps for trainscg function is 134, for trainrp function is 1087, for traingda function is 3421. If the target sum of squared errors equals 0.011, the number of training steps for traingdm function is 11084. Therefore, different training methods have different convergence speeds. The convergence speed of the trainlm function is the fastest, followed by trainbfg function and trainscg function. The convergence speed of trainrp function is slower than the first three functions, while the convergence speed of traingda function is even slower. Due to its calculation method, significant oscillations exist, and traingdm function has the slowest training speed.

(2) Verification Results

As for verification results, the performance of different functions meets the requirements, thus the trained networks are stored in the knowledge base and diagnosis is carried out accordingly.

(3) Diagnosis Results

Based on the trained network model, other voltage data collected are inputted into the network, and simulation is conducted using the Sim function to obtain the network's output vector. Regarding diagnosis results, the network training exhibits significant success. Data within the range of 0-4.6363V can be diagnosed as under-voltage faults, data within the range of 4.6365-5.1818V can be diagnosed as normal, and data exceeding 5.1818V can be diagnosed as over-voltage faults.

5.3.2 Fault Diagnosis of the 28V Bus Bar

(1) Fault Diagnosis of the 28V Bus Bar

The principle of training the 28V bus bar is similar: the high voltage is divided by resistors to obtain a lower voltage, which is then transmitted to the microcontroller. The voltage division formula is (input voltage value X 5/32). After voltage division, voltage values within the range of 0-5.59375V indicate under-voltage faults, while values within the range of 5.59375V-5.15625V indicate normal conditions, and values exceeding 5.15625V indicate over-voltage faults. The collected data is transmitted from the Electrical Load Management Center to the power supply system's processing unit, where it is studied and processed. If it is determined to be fault data, the power supply system's processing unit sends control commands to the Electrical Load Management Center to switch the bus bar.

Any set of collected data can be selected as training samples and trained, with the unit being volts. If the training results do not meet the requirements, multiple rounds of training are required until the best training effect is achieved. The convergence speed of different training methods varies. Comparatively, the trainlm function has the fastest convergence speed, followed by the trainbfg function and the trainscg function. The trainrp function has a slower convergence speed than the first three functions, while the convergence speed of the traingda function is even slower. Due to its calculation method, significant oscillations exist, and the traingdm function has the slowest training speed.

(2) Verification Results

The performance of different functions meets the requirements, and thus the trained networks are stored in the knowledge base for diagnosis.

(3) Diagnosis Results

Based on the trained network model, other voltage data collected are inputted into the network, and simulation is conducted using the Sim function to obtain the network's output vector. In terms of simulation results, the network training exhibits significant success. Data within the range of 0-5.59375V can be diagnosed as under-voltage faults, while data within the range of 5.59375-5.15625V can be diagnosed as normal.

5.4 Fault Diagnosis of Solid-State Power Controllers

(1) Data Collection

The composition of solid-state power controllers mainly includes an A/D converter, microcontroller, current signal extraction circuit, and protection circuit. In the schematic diagram of the current signal extraction circuit, a single resistor with a resistance value of 50M is connected in series in the load circuit of the solid-state power controller. This resistor collects the current signal in the load circuit in the form of voltage. The collected signal is transmitted to the computer via amplifiers and followers and then to the A/D converter. The MOSFET controls the shutdown effect of the solid-state power controller, disconnecting the circuit after a load current fault occurs. The solid-state power controller can be connected to a single variable resistor to simulate operations on the corresponding actual load.

When collecting data, two categories of situations are collected: normal load and fault. The normalized current value is typically 101A, and the product of the current value and 0.05m is the normalized voltage value, typically ranging from 0.45-0.55V, which is considered normal. When the voltage value is within 0-0.45V, it indicates an undercurrent fault, and when it exceeds 0.55V, it indicates an overload fault.

(2) Training Results

Any set of detected values can be arbitrarily selected as training samples. After training using the six calculation methods adopted in this paper, it is found that the number of neurons in the hidden layer is 11 for all different functions. Regarding convergence speed, the network model can be used to represent the sum of squared errors within an acceptable range and the corresponding number of training steps. In practice, it is observed that when the target sum of squared errors equals 0.001, the number of training steps for trainlm, trainbfg, trainscg, and trainrp functions are 27, 126, 401, and 2189 respectively. When the target sum of squared errors equals 0.002, the number of training steps for traingda function is 32134. When the target sum of squared errors equals 0.005, the number of training steps for traingdm function is 9110. Therefore, different training methods have different convergence speeds.

(3) Verification Results

The functionality of each function matches the requirements based on actual verification results. Therefore, storing the trained networks in the knowledge base enables diagnosis.

(4) Diagnosis Results

Using the trained network model structure, the collected current data is inputted into the network, and simulation is performed using the Sim function to obtain the network's output vector. In terms of simulation results, the network training is successful. Data within the range of 0-0.45V can be diagnosed as undercurrent faults, data within the range of 0.45-0.55V is considered normal, and data exceeding 0.55V is diagnosed as overload faults.

5.5 Number of Neurons in the Hidden Layer

The number of neurons in the neural network's input and output layers can be determined based on the research object, primarily including input and output information. To enhance the accuracy of network training, increasing the number of neurons in the hidden layer can be implemented. From a structural implementation perspective, increasing the number of neurons in the hidden layer is superior. However, there is academic controversy regarding the number of neurons in the hidden layer. If the number of hidden neurons is too small, the network will be difficult to train. If it is adequate, the network can be trained normally, but its robustness is poor, especially in terms of noise resistance, making it difficult to identify past paradigms. If the number of hidden neurons is too large, in addition to the necessary training samples, a single "grandmother" type network system must also be constructed, which has all the paradigms and is difficult to identify new content. Moreover, it will inevitably consume more time and occupy more memory space during the specific training process. In the concrete setting process, a more realistic and feasible approach is to train with different numbers of neurons in the hidden layer and then add some margin appropriately.

5.6 Selection of Desired Error

During the setup of network training, the desired error value must be compared and determined through training to define an appropriate value. This value depends on the required number of hidden layer nodes, as achieving a smaller desired error value may require increasing the number of hidden layer nodes and training time. Typically, training is conducted by simultaneously training two networks with different desired error values, and the final network is determined based on comprehensive considerations.

5.7 Determination of Algorithms

The application of backpropagation (BP) shows an expanding trend, but it has some drawbacks due to its use of gradient descent, primarily manifested in the non-deterministic aspects of training.

5.7.1 Lengthy Training Time

For some complex problems, BP calculations may take several hours or even longer for training. This is mainly due to the use of a learning rate that is too small. Therefore, improving training can be achieved by using modified or adaptive learning rates.

5.7.2 Inability to Converge

This occurs due to network paralysis. During training, if weight adjustments are too large, it may cause the sum of weighted inputs of all or most neurons to be too large, resulting in the activation function, especially the derivative f'(s) within the saturation region, becoming too small, leading to a halt in the process of adjusting network weights. To avoid this, smaller initial weights are generally chosen. Additionally, using a smaller learning rate increases training time.

5.7.3 Local Minima

The BP algorithm may converge network weights to specific solutions, but it cannot guarantee that the obtained error is greater than the global minimum solution in the entire space. It may converge to a local minimum instead. This occurs because the BP method uses gradient descent, training based on gradually matching the error minimum along the slope of the error function from a starting point. In complex networks, the error function is typically a curved surface in multidimensional space, resembling a bowl with a minimum value at the bottom. However, the bowl's exterior is rugged, so during training, it may enter a small valley inducing a specific local minimum. Changes along different directions may cause the error to increase, ultimately making it difficult for training to escape local minima. Due to the shortcomings of BP networks, six improved calculation methods of BP networks are selected in this paper to diagnose faults in the electrical systems of new civil aircraft and optimize the deficiencies of BP networks themselves.

5.8 Network Training Calculation Methods Based on Numerical Optimization

For relatively simple problems, first-order gradient methods can quickly converge to the expected value. However, when applied to complex real-world problems, except for the resilient BP calculation method, other calculation methods for convergence speed may encounter more or fewer issues.

Training BP networks fundamentally involves optimizing nonlinear objective functions. Many traditional numerical optimization methods converge quickly. Therefore, training BP networks and their weights are optimized based on numerical optimization methods. Unlike gradient descent, numerical optimization methods not only use information related to the first derivative of the objective function but also utilize information from the second derivative of the objective function.

6. Systematic Analysis of Civil Aviation Electrical Systems Based on Knowledge Methods

6.1 Construction of a Systematic Model Based on Civil Aviation Aircraft Experts

The expert system includes a well-designed human-computer interaction interface, facilitating communication between humans and machines. The knowledge base includes model libraries, rule libraries, and case libraries. The system combines signal processing, feature analysis, and symbol-based reasoning based on expert knowledge, enabling intelligent identification and diagnosis of crew operation information.

6.2 Knowledge Representation and Organization

The composition of new civil aviation aircraft mainly includes more than 30 primary subsystems such as landing gear, flight control, and engines. Each primary subsystem also includes lower-level subsystems, resulting in a complex hierarchical structure.

Therefore, in constructing the knowledge base, considering the characteristics of accident patterns, it is necessary to avoid the knowledge base having too many rules and cases, which would increase the depth of search and reduce the speed of reasoning. Several knowledge bases are set up for different subsystems of new civil aviation aircraft, each module containing a limited number of cases to optimize the organization of knowledge.

The knowledge base of the expert system adopts relational database technology and mainly consists of the following parts:

6.2.1 Data Dictionary Table

The function of the data dictionary table is to represent all conditions and conclusions as single symbols. Then, all records in the knowledge base use corresponding symbols to express conditions and conclusions. Its advantages mainly lie in simplifying the representation by using symbols instead of textual information, which saves space and facilitates the writing of SQL statements, especially when the knowledge base contains a massive amount of data.

6.2.2 Rule Library

The rule library is constructed by comprehensively studying maintenance manuals, reliability reports, troubleshooting manuals, and maintenance outlines, based on the system structure, functions, and accident mechanisms of the aircraft. A series of rules within the reasoning premises and their goals are constructed into a tree-like structure based on reverse reasoning, which can represent the accident patterns of different subsystems as a class of tree-like logical structures. The knowledge content of the rule library is represented using a production rule notation that matches its characteristics. The rule table is generally considered a core component of expert systems, combining the features of knowledge and rule libraries. It is assumed that the maximum number of premises for some rules is 5 (when the number of premises is less than 5, the Null field needs to be filled), and the information is expressed as: IF Cond1 Cond2 Cond3 Cond4 Cond5 THEN Conclusion. The Repair field provides maintenance suggestions or steps based on the conclusion of the accident situation.

6.2.3 Case Library

The case library represents the prerequisite data for case reasoning. Based on an understanding of the obtained diagnostic information, and following relevant rules, the system interprets and describes the problems to be studied using a language (model) that the system can recognize, establishing a relatively standardized structure. Cases are mainly comprehensive descriptions based on specific individual problems. They describe the specific problem, its environment, circumstances, and the solution to the problem, constituting a set of attribute collections that lead to the corresponding results. The knowledge of accident cases represents the characteristic attributes and their extraction process, providing a detailed description of the specific situation of the accident to obtain more complete accident information. The system constructs corresponding query cases based on this and uses it as the starting point for case retrieval. When describing cases, appropriate representation methods should be adopted to enhance the accuracy of case retrieval.

7. Evaluation

7.1 Comparison of Improved Algorithms and Related Functions

In the analysis of three improved calculation methods based on standard gradient descent, the following observations can be made:

1. Momentum Addition Method (Traingdm Function):** This method considers not only the current gradient direction but also takes into account the previous gradient direction when updating weights and thresholds. This reduces the sensitivity of the network function to parameter coordination, effectively reducing local minima. However, the convergence speed of the momentum addition method is the slowest among the three.

2. Adaptive Learning Rate Method (Traingda Function):** This method adaptively adjusts the learning rate during the network training process, enhancing the efficiency of network training. Although the convergence speed of this method is faster than that of the momentum addition method, it may suffer from oscillations due to its

computational method.

3. Elastic BP Algorithm (Trainrp Function):** This method considers only the gradient sign when updating weight dimensions and adjusts the magnitude primarily based on the process, enhancing the learning rate of the network on the flat range of the functional surface. The convergence speed of the elastic BP algorithm is much faster than the previous two methods, and its computational method is not difficult, requiring less memory space.

While there is no significant difference in storage requirements among these three improved algorithms, each method shows an increasing trend in convergence speed. The elastic BP algorithm's convergence speed is much faster than the others. Based on the data from the fault diagnosis results, it is evident that the elastic BP algorithm is highly effective.

7.2 Comparison of Expert Systems and Neural Network Diagnosis Methods

Expert systems are widely used for fault diagnosis and have several advantages:

- Integration of expertise from multiple experts.

- Strong logical reasoning and symbolic processing capabilities.

- Ability to handle fault diagnosis efficiently.

However, expert systems also have limitations:

1. Difficulty in accurately describing expert knowledge.

2. Inability to manage large volumes of knowledge effectively.

3. Limited ability to handle uncertainties in fault diagnosis.

4. Slow reasoning speed and low efficiency.

On the other hand, neural networks have the following advantages:

- Unified internal knowledge representation.

- Adaptive learning and ability to handle changing environments.

- Parallel numerical calculation process, leading to faster reasoning speed.

- Ability to work beyond learned knowledge domains.

However, in the context of fault diagnosis for complex systems like new-generation aircraft electrical systems, relying solely on neural networks may not be practical due to the large number of subsystems and inputs required. Therefore, a combination of expert systems and neural networks may offer a more comprehensive approach to fault diagnosis, leveraging the strengths of both methodologies.

The aircraft fuel system is an essential component of the aircraft's power system, and its failure can significantly affect the safety of flight. In the face of increasingly complex realities of failures, research on fault diagnosis methods becomes crucial. You have adopted the fault tree analysis method to analyze the causes of failures in aircraft accidents and reached the following conclusions:

The fault tree analysis method can accurately and directly identify the causes of failures, with rigorous logic. In contrast, the conclusions from event tree analysis may be more ambiguous and less scientifically rigorous.

Fault tree analysis requires proficiency in the system and involves significant workload, sometimes requiring repetitive work; whereas event tree analysis has lower requirements for analysts and generally involves smaller workloads.

In summary, troubleshooting aircraft fuel system failures requires a considerable amount of manpower, resources, and time, as well as repair and inspection personnel with strong sense of responsibility. The troubleshooting process is often complex and cumbersome, but using appropriate methods to analyze the source of faults can simplify the problem and improve efficiency. In practice, staff need to strictly adhere to manual procedures, work diligently, and improve their work level through summarization to create a favorable working environment. Equipping with state-of-the-art maintenance equipment can also improve troubleshooting efficiency.

Therefore, fault diagnosis of aircraft fuel systems using methods such as fault tree analysis is highly effective, but it also requires adherence to procedures, improvement of work proficiency, and provision of advanced equipment to ensure smooth operation. As the power source of the propulsion system, the aircraft fuel system largely affects the safety of flight. Each subsystem is interconnected, and this correlation is becoming increasingly complex, with various and changing causes of failures. In the face of such complex and severe realities of failures, it is important to carefully study fault diagnosis methods, making fault analysis particularly important. This paper uses fault tree analysis to analyze the causes of failures in aircraft accidents and draws the following conclusions:

1. Fault tree analysis can accurately and directly identify the causes of failures with rigorous logic. In comparison, using event trees for analysis may only yield relatively vague conclusions that are less scientifically rigorous.

2. Fault tree analysis requires proficiency in the system and involves significant workload, sometimes requiring repetitive work; whereas event tree analysis methods have lower requirements for analysts and generally involve smaller workloads.

In conclusion, troubleshooting aircraft fuel tanks requires a significant investment of manpower, resources, and time. Repair and inspection personnel need to possess a strong sense of responsibility to ensure smooth resolution of tank failures. The troubleshooting process is often complex and cumbersome, but using appropriate methods to analyze the source of faults can simplify the problem and improve efficiency. Throughout the process, personnel need to strictly adhere to manual procedures, work diligently, and improve their work level through summarization to create a favorable working environment. In practice, providing staff with state-of-the-art maintenance equipment can also improve troubleshooting efficiency.

As the power source for aircraft propulsion systems, the aircraft fuel system significantly impacts the safety of flight operations. Each subsystem is interrelated, leading to increasingly complex interdependencies and fault causes. Faced with the reality of ever more complex and challenging faults, it is crucial to thoroughly study fault diagnosis methods, making fault analysis essential. In this paper, fault tree analysis was used to analyze the causes of aircraft accidents, leading to the following conclusions:

1. Fault tree analysis can accurately and directly identify the causes of faults with rigorous logic. In contrast, using event tree analysis often results in relatively vague conclusions that lack scientific rigor.

2. Fault tree analysis requires a significant amount of work and expertise in understanding the system. It may involve repetitive tasks. On the other hand, event tree analysis requires minimal effort and expertise from the analyst.

In summary, troubleshooting aircraft fuel systems requires substantial human and material resources and time. Repair and inspection personnel must have a strong sense of responsibility to ensure the smooth resolution of fuel system faults. The troubleshooting process is often complex and tedious, but using appropriate methods to analyze the source of faults can simplify the process and improve efficiency. Throughout the process, personnel must strictly adhere to manual procedures and diligently complete tasks. Through continuous learning and improvement of skills during practical work, creating a conducive work environment, and equipping with the most advanced maintenance equipment, the efficiency of troubleshooting can be maximized.

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