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Research on Casing Damage Prevention and Remediation Techniques in the a Oilfield

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Abstract: The HSJ Oilfield faces increasing casing damage due to geological factors, sand production, stimulation measures, and corrosive environments, particularly in blocks with produced water reinjection and saltwater intrusion. Casing damage disrupts injection-production balance, reduces water drive efficiency, increases operational costs, and hinders stable production. This paper proposes a systematic methodology integrating prevention, accurate identification, graded treatment, and daily management for casing damage wells. A "prevention-oriented" strategy is emphasized, including cathodic protection via deep-well anodes, DPC internal coating with non-metallic wear protection, sacrificial anode short sections, and regular corrosion inhibitor injection. Accurate identification combines engineering logging with dynamic analysis, revising key indicators such as liquid volume, salt content, water cut, and dynamic fluid level. Notably, casing damage does not always cause water breakthrough, and water breakthrough may originate from sources other than the damaged section. Treatment follows a graded approach: for effective seating positions, LEP long-term packers are preferred; for damaged sections, chemical sealing (<100 m), alloy composite patching (100–400 m), or small casing cementing (>400 m) are applied; well pattern reconfiguration via sidetracking is used for challenging cases. Daily management includes comprehensive wellbore treatment (anti-corrosion, anti-scaling, anti-wear), 2-hour performance graph monitoring, ten-day fluid level tests, and strict construction quality control. Application in the HSJ Oilfield has significantly reduced the casing damage rate from 13.6% to 2.1% in water injection wells and decreased the annual number of new casing damage cases, supporting stable production and economic benefits. This integrated approach provides a practical reference for similar mature oilfields facing casing integrity issues.

Keywords: HSJ Oilfield; Casing Well; Corrosion; Prevention and Control Methods.

1. Introduction

The HSJ Oilfield has been affected by factors such as the previous geological structure, sand production from the oil layers, measures for increasing production of oil and water wells, and well repair operations. As a result, casing deformation and rupture have occurred, especially cases of corrosion and perforation, leading to an increasing number of casing damage wells [1]. Casing damage is caused by geological factors, engineering factors, and corrosive environments [2, 3]. It usually occurs near salt layers and perforation layers [4], which can lead to imbalances in the injection and production well network, reduced water drive efficiency, and difficulties in extracting residual oil reserves. At the same time, it is impossible to obtain dynamic monitoring data normally, thereby increasing measures and management costs, and having a significant impact on the stable production and development benefits of the oilfield [5, 6]. The H151X block of the HSJ Oilfield, due to the return injection of produced water, has difficulty in determining the initial stage of casing damage in the same layer. The main characteristics include a stepwise increase in water content, frequent well repair due to faults, and severe corrosion of the tubing and rods. In the A21 block and Y166X block, the main characteristics are a periodic decrease in salt content to the Jurassic oil layer and frequent well repair due to faults, as well as severe corrosion of the tubing and rods. With the extension of the oilfield's development period, if no reasonable prevention and treatment measures are taken, it will seriously affect the production of oil wells. In addition, the normal increase in water content of the oil wells, the influence of edge and bottom water, and the injection water often occur simultaneously with casing damage "simultaneously", which brings great difficulties to the judgment of casing damage, especially the identification of the water-producing section. The existence of casing damage wells restricts the stable production of the oilfield, disrupts the injection and production balance relationship of the oilfield [7, 8], restricts the further adjustment of the injection and production structure of the oilfield [9], and greatly affects the improvement of economic benefits [10, 11]. This paper proposes a set of methods applicable to the HSJ Oilfield for accurately identifying casing damage wells and effectively preventing and treating them, which is of great significance for increasing production and maintaining stable production of oil wells within the jurisdiction.

2. Countermeasures for Preventing Blowout Incidents

The purpose of treating casing damage wells is to enable water injection wells to resume water injection and oil wells to regain a certain production capacity. The wells should be shut down only when the production drops to the economic limit according to the curve pattern [12]. In response to the high incidence of casing damage wells in HTS Oilfield, a management approach of prevention-oriented and combination of prevention and treatment was proposed. To address the issue of identifying casing damage wells solely through engineering logging, a combination of engineering logging and dynamic analysis was adopted to comprehensively determine whether the oil and water wells are damaged. In terms of the management strategy, the previous approach of mainly using conventional inter-well separation to quickly restore production was transformed into a large-scale and long-term management strategy, with the aim of achieving long-term benefits through a single treatment.

2.1. Prevention First

To prevent the corrosion of the casing, the prevention of casing damage in the oil and water wells within the HTS Oilfield mainly relies on the protection of the casing anti-corrosion layer, the introduction of anodes and cathodes into the tubing, the injection of corrosion inhibitors into the casing, etc.

2.1.1. Cathodic Protection Management

In areas with dense or relatively concentrated oil and water wells, one anode deep well is drilled within a certain number of oil and water well areas to serve as the anode of the system. A strong current is applied through the potentiostat to provide uniform and sufficient cathodic protection current for the casing. Then, the current flows back to the cathode of the potentiostat through the junction point near the wellhead, forming a closed loop. This enables the casing of the oil and water wells to undergo full cathodic polarization, thereby avoiding or reducing the corrosion of the casing. The H151X block and Y166X block within the area apply cathodic protection technology. In 2020, 3 wells were implemented, and the protection effect was good.

2.1.2. Coating Protection Inside the Tubing

The inner coating of DPC has the characteristics of thin coating, excellent corrosion resistance and mechanical properties. It is suitable for the anti-corrosion of casing in oil wells with high corrosion in the Jurassic series, wastewater injection wells, and oil pipes in high-corrosion and low-yield wells. However, in the water of Luoheshi layer, due to the presence of a large amount of Cl^-, Cl^- adsorbs on certain points on the metal surface, which causes damage to the coating. In the damaged areas, it becomes the anode of the galvanic cell, while the undamaged parts are the cathode. This forms a passivation/activation battery [13]. Therefore, to prevent damage to the inner wall of the casing during the operation of tubing running and pulling, all wells are equipped with non-metallic anti-wear mother plugs and tubing correctors. For wells with a length of 2 meters and above in the shallow layers, the entire section from the upper end of the DPC anti-corrosion casing to the non-metallic mother plug is equipped with tubing correctors to prevent coating damage; for wells with a length of 3 meters and below and a full-angle variation rate of ≥ 3° and a 25-meter section, tubing correctors are equipped in the section within the well where the full-angle variation rate is 25 meters. The use of internal coating protection of the casing is often combined with technologies such as epoxy cold wrapping sacrificial anodes. The technologies have been promoted and used in the H151X block, Y166X block, and Y113X block in the jurisdiction, and the anti-corrosion effect is good.

2.1.3. Anode Sacrificial Section

The principle of sacrificial anode protection is the same as that of impressed current cathodic protection, both of which cause the protected metal to undergo cathodic polarization to the protection potential [13]. However, the latter relies on the current from an external direct current power supply for polarization, while sacrificial anode protection achieves polarization by the current generated between the sacrificial anode and the protected metal with a large potential difference. The anode can be placed below the bottom hole pressure of the inspection pump, and the single anode has an effective action distance of 40 meters. The elastic contact wall continuously provides protection current to the casing, thereby delaying casing corrosion. Since 2019, in the jurisdiction area, the YQY-NW anti-corrosion anode tool brought through the tubing has been used for anti-corrosion treatment inside the casing. Currently, for wells with daily oil production of more than 2 tons in the H151X block, 2 well instances have applied an anode short section to slow down the internal corrosion of the casing.

2.1.4. Additive Dosage

For shallow wells with unsealed casing damage, all were treated with corrosion inhibitors. The maintenance team carried out centralized drug addition in accordance with the prescribed procedure on a regular basis. With the diversification of well damage prevention technologies, the number of well with casing damage has decreased year by year in the past three years. Within the jurisdiction, there are a total of 49 wells with casing damage (29 are in operation, with a casing damage rate of 13.6%), 2 water injection wells with casing damage, 1 well has stopped water injection, and 1 well has resumed normal water injection with a smaller casing. The casing damage rate is 2.1%.

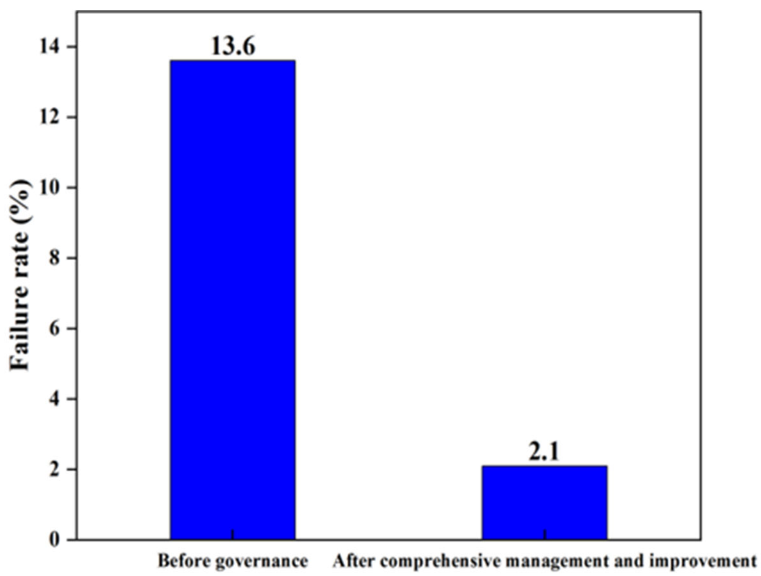

Figure 1. Comparison of Casing Damage Rate Before and After Integrated Prevention

Table 1. Four Anti-Corrosion Prevention Process Comparison

Antifungal treatment process	Construction method	Applicable area/block	Protective advantages
Cathodic protection	Drill an anode deep well + Connect the potentiostat to power on	H151、Y16	Long-term protection for the entire area's pipelines
DPC inner coating	Inner wall spraying of the casing + Matching centering device	Jurassic highly corrosive wells, wastewater injection wells	Prevent chloride ion corrosion of the inner wall
Sacrificial anode short section	The pump inspection is carried out along with the pipe string being lowered. Each single section is 40 meters long and is protected.	H151 Well with daily oil production > 2 tons	No need for an external power source
Fixed-point addition of corrosion inhibitor	Regularly add chemicals to the wellhead	Deep section without casing penetration throughout the well	Easy to operate and low in cost

2.2. Accurately identify casing damage wells

To accurately identify casing damage wells, based on the previous analysis experience of casing damage wells within the jurisdiction, the following experience-based judgment methods for casing damage wells have been derived from three aspects: dynamic data, wellbore conditions, and the current situation of reservoir development, as shown in Figure 1 and Table 1. Normal increase in water cut of the oil well and the influence of bottom and edge water and injection water often occur concurrently with casing damage and water leakage. Therefore, in addition to casing damage, when edge and bottom water cone-in or injection water is observed in the oil well, the dynamic behavior also shows an increase in water cut. There is a slight change in salt content before and after casing damage in the oil well. The salt content in shallow layers (Luohe, Zhiruo) decreases significantly due to casing damage, while the salt content in the same layer remains stable; the salt content in adjacent layer casing damage varies. Apart from the change in salt content, the position of casing damage can also be determined based on the changes in liquid volume and dynamic liquid level: in shallow layers (Luohe, Zhiruo), the liquid level rises and the liquid volume suddenly increases; in the same layer and adjacent layer casing damage, the liquid level rises as the casing damage point increases, and the liquid volume is basically stable in the same layer casing damage. Currently, from the current wellbore conditions of oil and water wells within the jurisdiction, due to the high content of CO_2 and SRB (sulfate-reducing bacteria) in the oil and water wells, the casing is prone to internal corrosion. The corroded section is concentrated within 350 meters above the perforation section, and the perforation section is concentrated within 300 meters above the perforation section. The length is mainly 0.1 to 1.0 meters. In addition to using the experience-based judgment method for casing damage wells, it should also be combined with engineering logging interpretation to determine whether the oil well has casing damage and the location of the casing damage.

2.2.1. The tear in the suit does not necessarily come into contact with water.

Taking Well HS185 as an example, this well is located in the Yan'an Formation of the Jurassic System and was put into production in July 2017. During the initial production period, the daily liquid output was 12.2 m3, with a salt content of 16,775 mg/L. From September 2020, the water content rate increased from 78% to 100%, while the salt content decreased from 23,380 mg/L to 4,510 mg/L. Based on the experience of casing damage wells, it is preliminarily judged as shallow or adjacent layer casing damage. According to the engineering logging interpretation, the slightly corroded section of the Zhiluo Formation in this well is 10.3 m, and there is 1 perforation of the Yanzhou 8 casing (1.1 m). The corresponding injection well of this well is produced water. Combining the dynamic data changes before and after the inter-well separation, based on the judgment method of casing damage wells, it is analyzed that the increase in water content is mainly due to the influence of the shallow slightly corroded section, and not the corrosion perforation section. Therefore, casing damage does not necessarily manifest as an increase in liquid volume.

2.2.2. Seeing water doesn't necessarily mean it's just breaking through the surface and spilling out.

Taking Well H42-10 as an example, this well is located in the Yanchang Formation of the Triassic Series and was put into production in July 2002. During the initial production period, the daily liquid output was 14.65 m3, with a salt content of 16,775 mg/L. After repeated fracturing in July 2015, the water content increased from 52.7% to 90.7%, and the salt content decreased from 59,035 mg/L to 41,500 mg/L. This well showed casing damage during engineering logging in September 2016. In the same month, separate production was carried out. The salt content basically recovered (53,170 mg/L), but the water content did not show significant changes (91.6%). The analysis suggests that the normal increase in water content after the measures and the relatively strong intensity of the lower section measures were caused by the communication of bottom water.

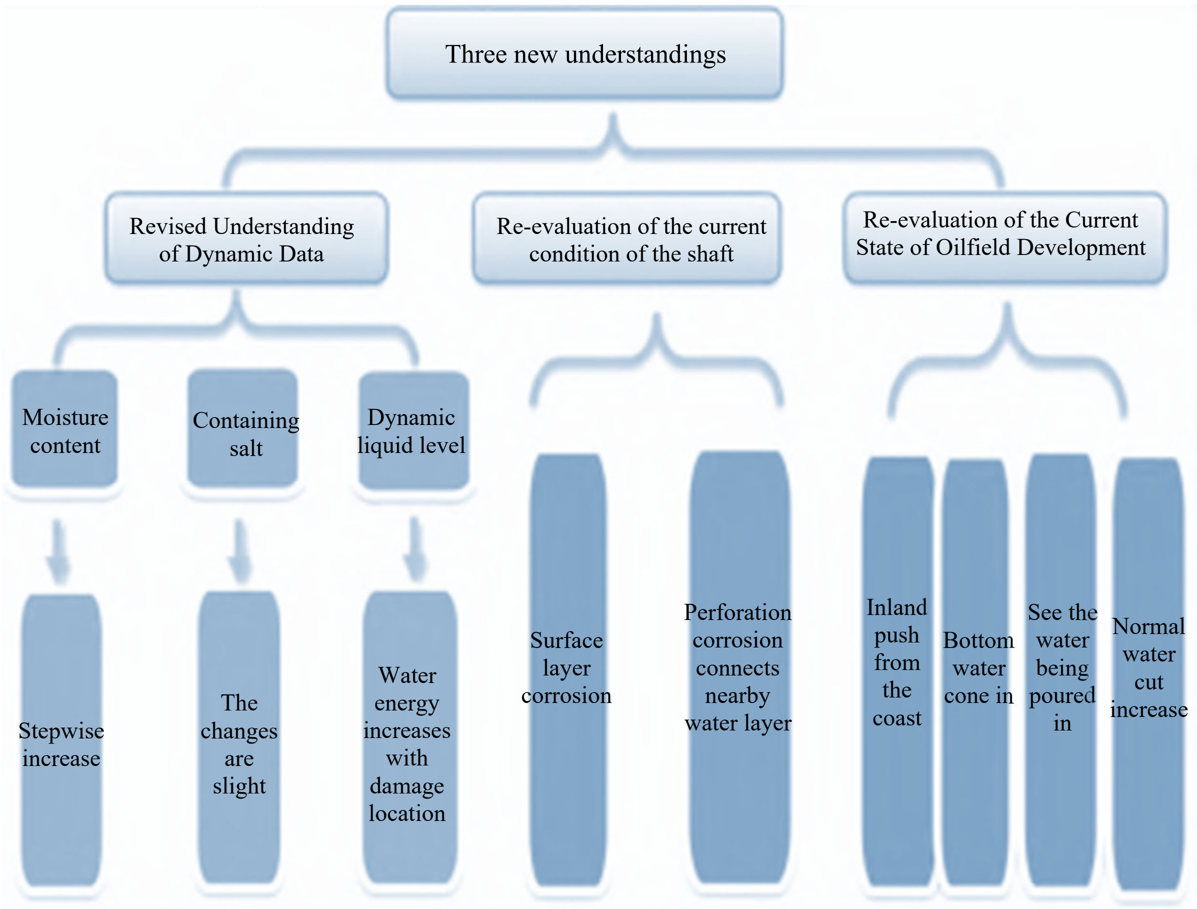

Figure 2. Three Core Understandings for Casing Damage Diagnosis

Table 2. Dynamic Diagnostic Indexes for Classified Casing Damage

Indicators	Dynamic judgment elements of wellbore damage
Liquid volume	(1) The amount of leakage fluid in the shallow layer (Luo River, Zhiluo) suddenly increased. (2) The amount of leakage fluid in the same layer remained basically stable.
Containing salt	(1) The salt content in the shallow (Luo River, Zhiruo) layer has significantly decreased. (2) The salt content in the same layer remains stable. (3) The salt content in the adjacent layer shows both an increase and a decrease.
Moisture content	(1) The casing is damaged and water is present, resulting in a sudden increase in the water content. (2) When edge and bottom water or injection water is encountered, the water content suddenly rises.
Liquid level	(1) The surface of the shallow (Luo River, Zhiruo) leakage fluid rises. (2) The leakage fluid levels rise along with the increase of the leakage points in the same layer and adjacent layers.

2.3. Preferred Process

Based on the three key elements of "production classification, efficiency ranking, and wellbore integrity", and by considering the corrosion condition of the wellbore and the adaptability of the treatment techniques, we have continuously summarized and explored, and have thus formed three types of well damage well treatment technology systems.

2.3.1. Decentralized Governance

When there is an effective seating position in the wellbore, a long-term isolation method using packers can be adopted. The LEP long-term packer effectively addresses the shortcomings of conventional packers [14]. For casing damage wells with severe casing damage problems and high seating accuracy requirements, when choosing the isolation position for engineering logging, combining with the original curve of engineering logging is a good basis for selecting the seating position. The seating position should be selected in the relatively smooth casing section, avoiding casing couplings, and prioritizing the middle position between the upper and lower couplings for seating. The position of the packer is based on the center point of the rubber sleeve, and the data error rate is relatively high, which is of great help in improving the success rate of seating. The cost of isolation through separation is lower, and it can reduce reservoir damage. However, multiple separations will shorten the validity period. Taking the H43-4a well as an example, this well was put into production in August 2011, and in October 2017, it underwent isolation separation due to casing failure. Before engineering logging, a total of 7 isolation separations had been implemented, with an average seating validity period of 90 days. In April 2021, engineering logging showed that there were 16 perforations from 1720 to 1920 meters. The severe corrosion of the casing in the previous seating position led to a short seating validity period. The upper seating position was raised from 44.1 to 1950.9 meters. After LEP isolation separation, the daily liquid production was 4.76 m3, with a salt content of 68,335 mg/L. As of now, the seating validity period is 198 days and remains valid.

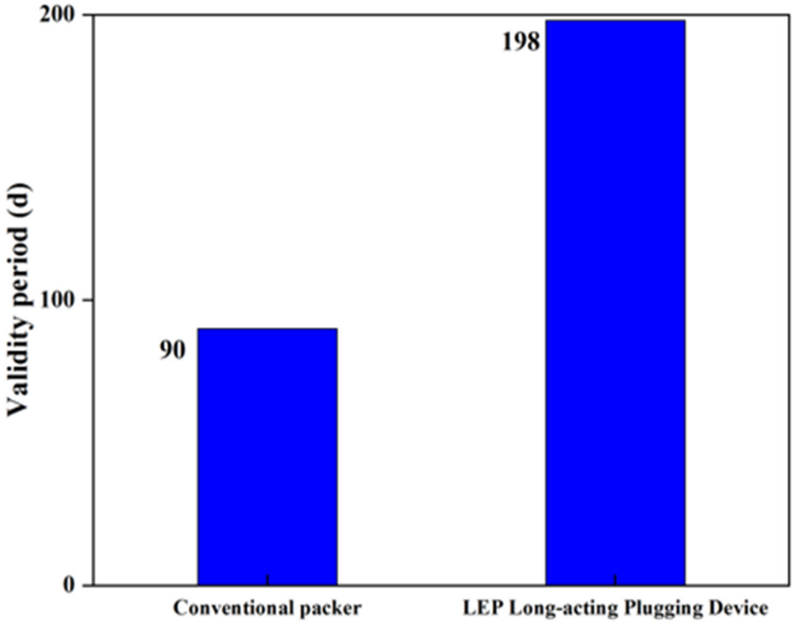

Figure 3. Service Life Comparison: Conventional vs. LEP Long-Term Packers

When choosing the seating position for blind isolation wells, attention should be paid to the following: within 300 meters above the perforation section, the corrosion condition is generally the most severe for the entire well. Therefore, isolation separation using the perforation section as a barrier is only applicable to the water-producing section (perforations may not necessarily produce water, and the judgment should be combined with the cementing quality). For wells of other types of casing damage, isolation separation should try to avoid the same layer and adjacent water layers and select the mud rock section far from the perforation section for seating.

If the dynamic data of the casing damage isolation well shows that the seating has failed, first, it is necessary to verify whether there is a corrosion perforation in the liner. To avoid blind isolation separation leading to cost waste, if there is a perforation, the LEP packer well can directly complete the well by pumping, the long rubber sleeve isolation separation well can continue to use the original seating position for isolation separation, and the Y211 isolation separation well needs to consider the damage to the casing by the original seating position slip clamp and re-determine the seating position. If it is necessary to retrieve the LEP packer, if the entry time of the packer into the well is > 1 year, it is recommended to prioritize handling the wellbore to the top of the packer before implementing the retrieval to prevent stuck drill pipes causing major repairs. Taking the H41-8 well as an example, this well was put into production in August 2002. In the initial production stage, the daily liquid production was 17.6 m^3, with a salt content of 77,571 mg/L. After isolation separation, the daily liquid production was 10.56 m3, with a salt content of 67,105 mg/L. In July 2021, the indicator diagram changed from insufficient supply to full, the water content increased from 57.9% to 97.8%, and the salt content decreased from 63,131 mg/L to 22,390 mg/L. It is preliminarily judged that the seating has failed. First, arrange for the oil pipe pressure test when pulling out the pipe string. It was found that the second pump was corroded and perforated. This well has a history of inserting the LEP packer, so the oil pipe was replaced for pumping completion. The dynamics returned to normal. Currently, the daily liquid production is 11.38 m3, the water content is 59.0%, and the salt content is 68,335 mg/L.

2.3.2. Repairing the casing

When the damaged section is less than 100 meters, the chemical leak sealing technology is adopted. The main process is that the high-pressure pump unit injects the prepared leak sealing agent into the damaged area. The leak sealing agent solidifies after a certain period of time to achieve the purpose of sealing the leak; when the damaged section is between 100 meters and 400 meters, the alloy composite patch sealing technology is used. In the misaligned area of the damaged well, the composite material is injected, a plug is formed or a solidification ring similar to the performance of the steel pipe is formed, which can not only connect the upper and lower casing to achieve sealing, but also effectively repair the damaged cement ring [15], preventing secondary damage to the casing; when the damaged section is more than 400 meters, the small casing cementing technology is adopted. After inserting an 88.90 mm small casing into the original wellbore and completing the cementing operation, the well section is repaired and recreated, maximizing the restoration of wellbore integrity. The repair casing technology can completely treat the wellbore and restore the wellbore integrity, but as the damage range increases, the difficulty and cost of treatment also increase.

Table 3. Graded Casing Repair Technologies by Damaged Interval Length

Classification	Length of the damaged section	Repairing process	Brief principle of the process
Preliminary diagnosis	—	Overall damage inspection	Detect the location of the damage, the form and length of the damage, and provide a basis for classification-based treatment
Path One	<100 m	Chemical leak sealing technology	High-pressure pump injects the leak-filling agent. The agent penetrates and solidifies at the damaged area, sealing the leakage channels in the wellbore
Path Two	100 m≤L≤400 m	Alloy composite sealing technology	Inject the composite material, allowing it to cure and form a high-strength cured ring. Then, repair the casing + the damaged cement ring
Path Three	>400 m	Small liner cementing technology	A small casing was lowered into the wellbore, and the annulus was cemented to seal it. The complete wellbore passage was then reconstructed
Governing objectives	—	Commissioning / Well pattern reconfiguration	Restore the production capacity of the oil wells, and optimize the well network when necessary, to achieve efficient utilization of the oil reservoir resources

2.3.3. Well pattern reconfiguration

When there is a concentration of remaining oil and the wellbore treatment becomes challenging, side drilling and updating the well pattern can be employed to reconfigure the well pattern. Well pattern reconfiguration can update the wellbore and completely solve the casing damage problem, but it faces the challenge of difficult understanding the distribution of remaining oil.

3. Daily Management Methods for Well with Wellbore Damage

3.1. Implement Comprehensive Wellbore Treatment for Well with Wellbore Damage

To address the prominent problems of corrosion, scaling, and eccentric wear in well with wellbore damage, integrate and apply the comprehensive anti-corrosion technologies including inner liner tubing + anti-corrosion coupling + anti-corrosion pump; solid anti-scaling device anti-scaling technology; inner liner tubing + small anti-wear blocks cast plastic sucker rod + anti-corrosion and wear-resistant coupling + rotating stabilizer comprehensive anti-wear technology. Form a "combination punch" for wellbore treatment of well with wellbore damage to reduce the impact of non-separating device factors on the operation.

3.2. Establish Daily Monitoring System for Well with Wellbore Failure

Through person-specific, regular, and fixed-point management, implement key monitoring for well with wellbore failure, promptly detect and promptly address. The 2-hour well performance graph monitoring serves as an important means for monitoring abandoned wells, effectively improving the timely detection rate of abandoned wells. The liquid volume monitoring in the well damage dense area is particularly important. Combining the 2-hour well performance graph investigation with the oil well production curve and dynamic liquid level test, the dynamic monitoring of well with wellbore damage is relatively effective. Daily tracking of the well performance graph and production curve of well with wellbore failure, promptly detecting abnormalities; conducting liquid level tests on well with wellbore failure every ten days, sorting out the treatment effect, and analyzing the effect.

3.3. Strengthen Construction Quality Control

Enhance technical assistance for contractors and well repair supervision, as well as on-site construction quality control. Adopt the "training + examination, theory + on-site" "2 + 2 training mode", jointly with the process research institute, actively carry out technical training such as tool inspection, pressure seat sealing, seat sealing data calculation, etc., to improve on-site construction level and ensure the sealing effect of separation wells.

4. Conclusions and Insights

(1) A series of complementary processes such as anti-corrosion layer protection, oil pipe introduction into the anode, cathodic protection, and injection of corrosion inhibitors into the casing can delay the corrosion of the casing and effectively reduce the number of casing damage wells within the area.

(2) As the development years of the oil reservoir increase, the normal increase in water content of the oil well and the influence of bottom and edge water and injection water often occur simultaneously with casing damage and water breakthrough. The dynamic performance of the oil well often shows an increase in water content. Based on on-site analysis, casing failure does not necessarily manifest as an increase in liquid volume, and water breakthrough does not necessarily only occur at the casing breakage section. The determination of whether the oil well is casing damaged and the location of the casing damage can be made through the experience-based judgment method combined with engineering logging, taking into account the casing damage well.

(3) When choosing the seating position for engineering logging, using the original curve of engineering logging as a good basis for seating position selection is advisable. The relatively smooth section of the casing should be selected, avoiding the casing coupling, and the middle position between the upper and lower coupling should be prioritized for seating. The position of the packer can be determined based on the center point of the rubber sleeve, with a relatively high data error rate and significant help to increase the success rate of seating.

(4) When choosing the seating position for blind separation

wells, it should be noted that the corrosion condition within 300 meters above the perforation section is generally the most severe for the entire well. Therefore, the separation of the perforated section only applies to the water-producing section (perforation may not produce water, and the judgment should be combined with the cementing quality). For wells with a distance of too close to the perforation section or no other seating positions, the mud rock section far from the perforation section should be selected for seating.

(5) If the dynamic data of casing damage separation wells shows that the seating fails, the first step should be to verify whether there is a corrosion perforation phenomenon in the tail pipe to avoid blind separation leading to cost waste. If there is a perforation, the LEP packer well can directly complete the well by inspection and completion, the long rubber cylinder separation well can continue to use the original seating position for separation and completion, and the Y211 separation well needs to consider the damage to the casing by the original seating position of the slips and re-determine the seating position. If it is necessary to fish the LEP packer, if the entry time of the packer into the well is > 1 year, it is recommended to prioritize handling the well from the bottom to the top of the packer before implementing fishing to prevent stuck drill pipes after successful fishing from causing major repairs.

(6) The 2-hour wellhead pressure diagram monitoring is an important means for monitoring lying wells and can effectively improve the timely detection rate of lying wells. The monitoring of liquid volume in the casing damage dense area is particularly important. The 2-hour wellhead pressure diagram on the same day, combined with the oil well production curve, dynamic liquid level test, is particularly effective for the dynamic monitoring of casing damage wells.

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