



# Safety Analysis of Carbon Dioxide Injection in AN Oilfield Casing Damage Repair Wells

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**Abstract.** In order to achieve green and low-carbon transformation, X Oilfield plans to build a CCUS full industry chain demonstration base, among which the AN experimental area is an important support block for CCUS industrial construction. In response to the issue of whether the repaired casing damaged wells in the AN block of X Oilfield can meet the safety requirements for carbon dioxide injection, a post repair safety assessment of casing damaged wells has been conducted. By analyzing the production parameters of gas injection wells in the CCUS experimental area of AN oilfield, conducting research on the performance parameters of casing damage repair processes, and analyzing the location and geological conditions of casing damage, evaluate whether the casing damage repair wells can meet the safety requirements for carbon dioxide injection. In response to the problem of insufficient targeted safety assessment during carbon dioxide injection in the previous scrapping process of casing damaged wells, innovative efforts have been made to conduct integrated analysis of wellbore formation, mechanical analysis of residual strength of pipe strings, analysis of cement ring sealing ability during supercritical carbon dioxide injection, and safety evaluation of sealing after casing damage repair. At present, there are 34 casing damage repair wells in AN

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test area. According to the current data analysis results, 12 of them meet the subsequent safety production requirements and can be converted to carbon dioxide Injection well to continue production. The remaining 22 wells do not meet the safety requirements and need to be plugged and scrapped to reduce the scrapping rate of casing damage repair wells by 35%. It is recommended to conduct a safety analysis on the conversion of casing damage repair wells to injection before the production of each CCUS experimental area, in order to improve the utilization rate of old wells.

**Keywords:** CCUS · Carbon Capture Utilization and Storage · Casing damage · Supercritical carbon dioxide · Repair · Scrap · Safety analysis

Carbon Capture, Utilization, and Storage (CCUS) is an important technology for PetroChina to achieve green and low-carbon transformation, and also a strategic successor technology for significantly improving oil recovery in low-permeability oilfields. X Oilfield plans to build a CCUS full industry chain demonstration base for carbon dioxide capture, pipeline transportation, oil displacement, and burial. In the process of transforming the development mode of old oil fields to CO<sub>2</sub>, the reuse of casing damaged repair wells can save a lot of well construction costs for updating wells. It is urgent to evaluate the safety status of casing damaged repair wells for injection, and establish standards for the reuse of casing damaged wells for CO<sub>2</sub> injection.

## 1 Introduction

The earliest water injection wells constructed in the CCUS experimental area of AN oilfield were completed in 1995, with a relatively long completion time. In the construction process of the CCUS pilot zone, in order to improve the utilization rate of old wells for CO<sub>2</sub> injection, it is necessary to conduct injection safety analysis on the old wells after casing damage repair. It is necessary to clarify whether the safety status of the casing repair well wellbore can meet the injection requirements, and to analyze and demonstrate in accordance with the integrity requirements of the CCUS wellbore, providing a basis for the subsequent industrial construction of CCUS.

Regarding the transformation of development methods for old wells, China Petroleum Exploration and Production Company has issued the “Technical Requirements for Transforming Production Wells into Development Methods”, which proposed eight technical requirements for carbon dioxide injection into old wells, including casing inspection and evaluation, cementing quality evaluation, and tubing design. However, no targeted analysis has been conducted on the transformation and repair methods of damaged casing wells. In the “Recommended Practice for Maintaining Wellbore Integrity in Carbon Dioxide Drive Gas Injection Wells” released by PetroChina in 2016, an evaluation method combining pipe string and cementing quality was proposed for the reuse of casing damaged wells. However, the analysis did not combine the casing modification method of casing repair wells with the formation situation. The author innovatively conducted wellbore formation integration analysis for the safety assessment of reusing casing damage repair wells, comprehensively analyzing the types, repair methods, location of casing damage, and the relationship between the formation, achieving a refined

evaluation of casing damage repair wells and improving the utilization rate of old wells for injection.

## 2 Establishment of Safety Assessment Method for Casing Damage Repair Well Injection Conversion

X Oilfield plans to build a demonstration base for carbon dioxide immiscible flooding. In order to improve the utilization rate of casing damage repair wells during the process of converting old wells to carbon dioxide injection, it is urgent to conduct a safety analysis of converting casing damage repair wells to carbon dioxide injection. Conduct safety evaluation of casing damage repair wells from three aspects: residual strength analysis of the string, sealing ability analysis of the cement sheath, and sealing safety evaluation after casing damage repair. Establish a specific process from data collection, security assessment, to disposal. (see Fig. 1).

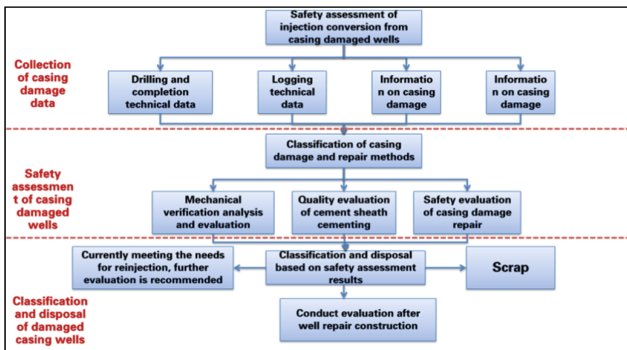
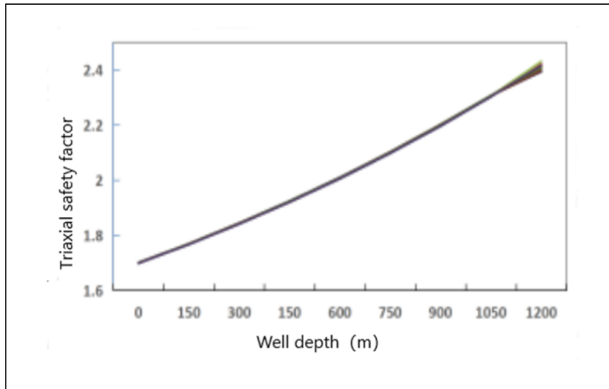


Fig. 1. Safety assessment and disposal process for injection of damaged casing wells

### 2.1 Mechanical Analysis and Evaluation of Residual Strength of Pipe Columns

The insufficient residual strength of the string is the basic requirement for the conversion of old wells to CO<sub>2</sub> injection to ensure the integrity. According to the logging interpretation results of the casing damage repair well, the WellCAT mechanical analysis software is used to establish the calibration model for the casing force of the CO<sub>2</sub> Injection well according to the wall thickness of the weak point. According to the two working conditions of alternating water and gas injection in the CCUS experimental area, mechanical verification analysis of casing strength is carried out separately. According to the structure and strength design standards of the casing column, the triaxial safety coefficient needs to be greater than 1.2, the anti-extrusion coefficient needs to be greater than 1, the anti-internal pressure coefficient needs to be greater than 1.05, and the tensile coefficient needs to be greater than 1.6 to be qualified. Complete the verification analysis of 10 emergency wells in the early stage. (see Fig. 2).

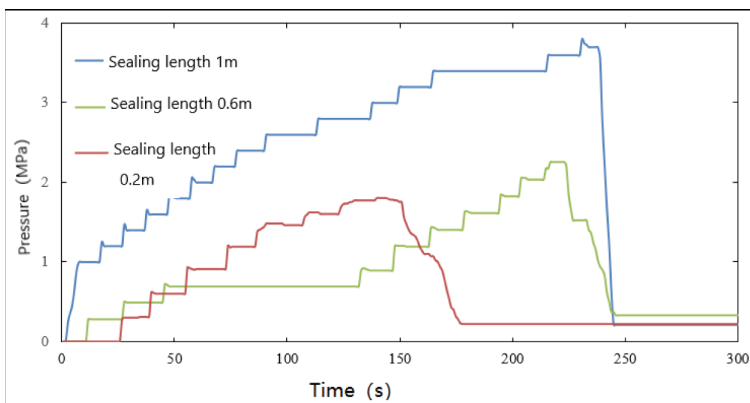


**Fig. 2.** Residual strength verification of 10 casing damage repair wells and triaxial safety factor curve

**2.2 Analysis of Sealing Capability of Cement Ring**

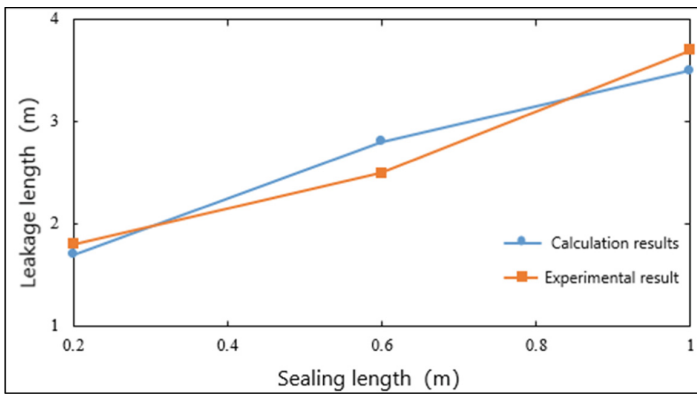
The cement sheath is an important barrier during the carbon dioxide injection process, and it is necessary to ensure that the sealing performance of the cement sheath meets the pressure bearing indicators of the alternating water and gas injection condition during the production process.

Based on the production conditions of the experimental area, the cohesive unit software is used to simulate the casing cement ring bonding interface. Fluid is injected into the lower end of the interface to simulate the sealing failure process. When leakage occurs, the pore pressure of the cohesive unit is the sealing failure pressure. Finally, the breakthrough pressure of the cement ring with different sealing lengths is calculated to establish the cement ring sealing breakthrough curve. (see Fig. 3).



**Fig. 3.** Software simulation of cement ring sealing breakthrough curves with different sealing lengths

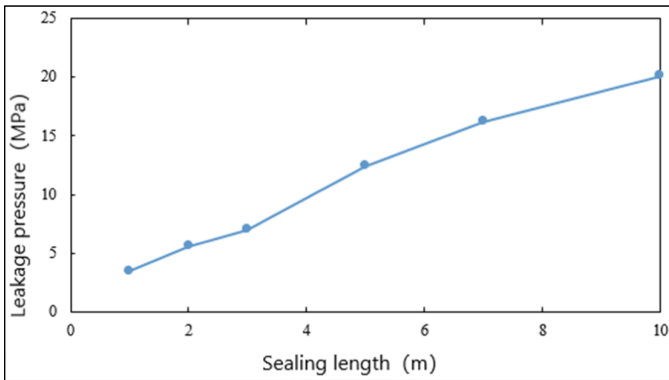
By constructing a full-scale cement ring sealing integrity evaluation system, including a cement ring sealing evaluation device, a supercritical CO<sub>2</sub> generation device, and an eight sector cementing quality detector, experimental testing of the sealing performance of cement rings of different lengths was conducted. According to the cement formula in the experimental area, three types of cement ring styles with lengths of 0.2 m, 0.6 m, and 1.0 m were prepared, and sealing breakthrough experiments were conducted on them. The experimental results showed that when the cement ring length was 1m, 0.6m, and 0.2m, the corresponding leakage pressures were 3.7 MPa, 2.2 MPa, and 1.8 MPa, and a low pressure difference of 0.2–0.3 MPa could be maintained above and below the cement ring after sealing breakthrough. The numerical simulation method was used to compare the results under experimental conditions, and the interfacial bonding strength of the cement sheath was inverted. The results showed that when the hydraulic bonding strength of the cement sheath was 1.8MPa, the trend was consistent with the experimental results of the sample. (see Fig. 4).



**Fig. 4.** Comparison between experimental results and numerical simulation results of cement ring sealing performance

Based on the experimental results, a cement ring sealing capacity analysis model was established, and the sealing breakthrough pressure of the cement ring was simulated and calculated when the sealing lengths were 1m, 2m, 3m, 5m, 7m, and 10m, respectively. Based on this, a curve chart of the sealing capacity of the cement ring was constructed. (see Fig. 5).

Referring to the curve chart of cement ring sealing capacity and the production conditions of gas injection wells in the AN experimental area, an analysis of cement ring safety sealing parameters was conducted. The results showed that when the high-quality sealing section length was 10m, the cement ring sealing pressure reached 21 MPa, which can effectively achieve safety sealing during CO<sub>2</sub> injection.



**Fig. 5.** Cement ring sealing capacity curve plate

### 2.3 Safety Evaluation of Sealing After Repairing Casing Damage

The sealing ability after casing damage repair is an important indicator of whether the damaged well can be reused. It is necessary to conduct targeted evaluation of the safety under gas injection conditions based on the form and repair method of casing damage in AN block wells, including three repair processes: expansion and shaping, grinding and milling shaping, and subsidy and reinforcement after casing damage. For the repair of expanded and milled wells, it is first necessary to determine whether the diameter of the repaired deformation position meets the requirements for subsequent completion tool insertion. Secondly, due to the decrease in strength of the pipe string caused by expansion and milling, it is necessary to conduct a mechanical strength analysis of the pipe string at the repair point. For wells reinforced with subsidies, it is necessary to determine whether the wellbore sealing capacity meets the requirements of gas injection conditions based on the subsidy process. Finally, a targeted analysis will be conducted on the location of casing damage and the geological conditions, in order to determine the impact of perforation intervals and cover layer thickness.

## 3 Safety Assessment of Casing Damage Repair Well Injection Conversion

Collect casing damage data, repair processes, wellbore inspection data, drilling conditions, and production parameters from 10 AN oil fields that have been rushed into operation. Conduct reuse evaluation according to the safety evaluation process for converting casing damage repair wells to injection.

One of the 10 emergency injection wells was selected for injection safety assessment. The well was completed and put into operation in October 2000, with a depth of 1202 m. The production casing steel grade was J55, and the wall thickness was 7.72 mm. The logging results showed that the wall thickness of the weak point casing was 6.2 mm. After injection, the injection pressure was 20MPa, and the injection flow rate was 5 m<sup>3</sup>/d. Wellcat software was used to establish a casing force calibration model based on the

wall thickness of the weak point, and mechanical verification analysis of the safety assessment of the casing damage repair well was carried out. (see Fig. 6).

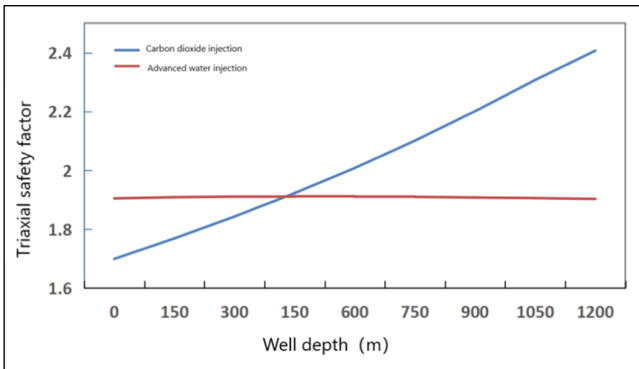


Fig. 6. Mechanical verification analysis results

The results show that the minimum triaxial safety factor of the pipeline under advanced water injection conditions is 2.362, and the minimum triaxial safety factor of the pipeline under supercritical carbon dioxide injection is 2.02, indicating that the strength of the pipeline meets the requirements.

Continue to analyze the sealing capacity of the cement sheath for this well, and establish a bond index curve for acoustic amplitude logging based on logging interpretation data. (see Fig. 7).

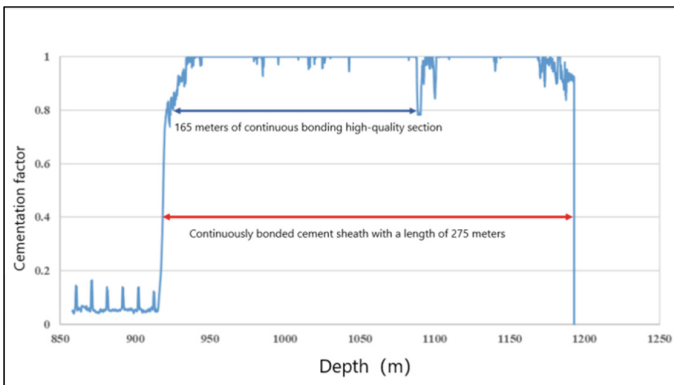


Fig. 7. Bond index curve of acoustic amplitude logging

The length of the continuous cementation cement sheath in this well reaches 275 m between 918 m and 1096 m, with a high-quality continuous cementation section reaching 165 m. Based on simulation experimental results, it is evaluated that the safety sealing conditions are met.

Finally, the sealing safety assessment after the repair of casing damage was carried out. According to the construction summary of the casing reshaping treatment of this well, the casing damage position of this well was below the perforation section, and was designed according to the carbon dioxide injection process scheme. After the well was converted to injection, it was a general Injection well, which met the requirements for running completion tools. The location of casing fracture is located within the perforated section, and all oil layers within the perforated section have been perforated, without any risk of leakage to adjacent layers. Therefore, it is comprehensively judged that this well meets the safety requirements for injection conversion.

## 4 Conclusion

- (1) The variation pattern of cement ring sealing capacity under supercritical carbon dioxide injection conditions was clarified, and a curve chart of cement ring sealing capacity was established through simulation experiments.
- (2) We have established a safety assessment method for converting casing damage repair wells to carbon dioxide injection, and conducted targeted evaluations of safety under gas injection conditions based on the form and repair method of casing damage. This effectively reduces the scrap rate of casing damage repair wells during the transformation of development methods. It is recommended to conduct a safety analysis for converting casing damage repair wells to carbon dioxide injection before the production of each CCUS experimental area, in order to improve the utilization rate of old wells.

## References

1. Yang, L., et al.: Reservoir Evaluation and Development **11**(6), 12 (2021)
2. Shiyi, Y., Qiang, W., Junshi, L., Haishui, H.: Technology progress and prospects of enhanced oil recovery by gas injection. *Acta Petrolei Sinica* **41**, 1623 (2020)
3. Jie, S.Z., Qiang, W., Shi, L.J.: Parameter optimization and effect evaluation of CO<sub>2</sub> flooding after water flooding. *J. Xi'an Petrol. Univ.* **27**(6), 6 (2012)
4. Rungang, W.: CO<sub>2</sub> Injection from Water Wells in Jiyuan Oilfield\_ Research on Wellbore Safety Evaluation: Xi'an University of Petroleum
5. Zhenyou, Y., Guocai, Z., Tao, H., et al.: Exploration and application of horizontal well casing damage repair technology. *China Petrol. Chem. Stan. Quality* (11), 1 (2014)
6. Shaohui, Z., Chengming, Z., Ruosheng, P., et al.: Wellbore integrity analysis and risk assessment of CO<sub>2</sub> drive Injection well. *J. Xi'an Petrol. Univ.* **33**(6), 7 (2018)
7. Zhichao, Z.: Research on the Mechanism of Integrity Change and Leakage Risk Assessment of Carbon Dioxide Storage Well Boreholes: Northeast Petroleum University
8. Jin, S.: Wellbore Pressure Temperature Distribution and Pipe String Check of CO<sub>2</sub> Flooding Injection Production Wells: China University of Petroleum (Beijing)
9. Chi, A., Jing, L., Ziping, L.: Research on the stress integrity of cement sheath during co<sub>2</sub> storage well injection process science. *Technol. Eng.* **8**, 5 (2013)
10. Bin, Y.: Research on Supporting Techniques for Repairing Damaged Wells: China University of Petroleum (East China) (2007)