The Influence of the Combined Application of Water Control Technology and Screen Pipes in Oilfield Completion Operations on Oil and Gas Production

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ABSTRACT This study investigates the combined application of water control technologies and screen pipes in oilfield completion operations to mitigate water intrusion and sand production in complex reservoirs. By integrating autonomous inflow control devices (AICDs), oil-swelling packers, and multilayer filter screen pipes, the proposed completion system improves flow regulation, suppresses bottom-water coning, and enhances sand-control performance. Field applications demonstrate significant production improvements across different reservoir conditions, including increases of 230% in a horizontal well at Jidong Oilfield, 125% in a condensate gas well at Northwest Oilfield, 83% in a Bohai deepwater well, 60% in a Daqing vertical well, and 150% in a Tarim horizontal well. Waterless production periods reached 1,200 days, while the water–oil pressure drop ratio increased by a factor of thirty. Sand interception efficiency exceeded 99% for particles larger than 0.2 mm, and wellhead pressure fluctuations were maintained within $\pm$0.5 MPa. Compared with intelligent completion systems, the proposed approach reduced single-well investment by 40–50% and shortened payback periods to 2.1–2.5 years. The results demonstrate an effective and economically viable completion strategy for production enhancement, flow-control optimization, and long-term reservoir management, with potential compatibility for integrated downhole monitoring and engineering sensing systems.

INDEX TERMS water control technology, screen pipe completion, oilfield production, wireless monitoring systems

I. INTRODUCTION

A. RESEARCH BACKGROUND AND SIGNIFICANCE

WITH the steady expansion of global oil and gas resource exploration toward deep, ultra-deep, and complex geological conditions, the technical challenges encountered in the progression of oil and gas wells have worsened. This necessitates the development of high-strength, temperature-resistant technical textiles for reinforcement and filtration in harsh downhole environments. Water intrusion and sand production have emerged as critical bottlenecks, limiting the service life of oil wells and the enhancement of recovery rates. Statistically, approximately 60 percent of oil wells worldwide are experiencing rapid declines in production due to blockage by water or sand. In certain wells, production declines have been observed to reach as high as 70 percent after only three years of operation. For example, in a deepwater oil field in the Gulf of Mexico, an oil well had to be shut down within one year of installation because bottom water coning caused the water content to skyrocket to 85 percent, while daily production fell to 300 barrels.

Traditional screen tube completion (Standalone Screen Completion, SAC)—a method increasingly reliant on precision-engineered textile composites for fine particle interception—is commonly applied to reservoirs such as loose sandstone and clastic rock because it is inexpensive, highly permeable, and easy to install. Unlike advanced systems, this traditional approach lacks active or passive zonal flow control mechanisms, making it vulnerable to early water breakthrough. However, its single structure proves challenging when handling the issue of mixed water and oil flow in mixed reservoirs. Indicatively, typical horizontal wells in mature onshore fields completed with conventional sieve pipes often experience rapid increases in water cut—sometimes exceeding 90 percent within six months—due to bottom water coning, which severely curtails daily oil production and leads to premature well abandonment.

B. BREAKTHROUGHS IN WATER CONTROL TECHNOLOGY

An additional pressure drop is achieved through Autonomous Inflow Control Device (AICD) technology, wherein the flow channel design favors the suppression of water flow. Following the implementation of AICD in a particular bottom-water reservoir in the Karamay Oilfield, the water-to-oil pressure drop ratio increased thirtyfold, and the water-free oil production period was extended to 820 days. In representative bottomwater reservoirs, AICD technology has significantly increased the water-oil pressure drop ratio, effectively extending the water-free production lifespan.

To avoid reservoir contamination by cement slurry, the expansion packer can establish a stable seal under high-temperature, high-pressure environments (such as the thermal recovery well in Shengli Oilfield, which features temperature resistance up to 360°C and an expansion coefficient of 1.35) to prevent cement slurry. For example, the expansion coefficient of the packer in a thermal recovery well in Shengli Oilfield remained consistent at 1.35, and the sealing performance was high, with no contamination by cement slurry [1]. AICD technology - oil-water pressure drop, as shown in Figure 1:

The intelligent completion system, which controls flow in real time through downhole sensors, has achieved a 35 percent increase in production per well in deepwater oil fields in the Gulf of Mexico, but its high cost has limited its widespread adoption. For example, a deepwater oilfield in the Gulf of Mexico saw production rise by 35 percent, from 1,500 barrels per day to 2,025 barrels per day, after adopting the intelligent completion system, although investment reached up to $25 million per well and the payback period extended to five years [2]. Intelligent Well Completion System - Production Increase as shown in Figure 2:

C. PRACTICAL APPLICATIONS

Condensate gas reservoirs in the Northwest Oilfield have adopted the strategy of "reservoir segmented management + differentiated water control," achieving flow balance throughout the life cycle through the coordination of water control screens and oil-swelling packers. The technology has been applied in four wells, resulting in a cumulative increase of 36,000 tons of oil and an additional 448 days of waterless oil production per well compared to before its application. After being applied to a condensate well in the Northwest Oilfield, the period of oil production without water was extended from 300 days to 748 days, and cumulative oil production increased from 5,000 tons to 12,000 tons [3]. The waterless oil recovery period (days) is shown in Figure 3:

In a test conducted by CNOOC Services in the Bohai Oilfield, the application of AICD screen pipe filling water control technology in over 20 wells improved water control efficiency by half and reduced the dynamic payback period to 2-3 years. In a deep well at the Bohai Oilfield, water control efficiency increased by 60 to 90 percent, and the payback period was dynamically reduced to 2.5 years after adopting the AICD screen pipe water control technology [4]. The dynamic investment payback period (in years) is shown in Figure 4:

II. MECHANISM ANALYSIS OF THE COMBINATION OF WATER CONTROL TECHNOLOGY AND SCREEN PIPE

A. PRINCIPLES AND CLASSIFICATION OF SCREEN PIPE TECHNOLOGY

1) Functional Positioning

Screen tubes, as key tools in oil and gas field development, have three core functions: sand control, wellbore support, and permeability maintenance. In loose sandstone reservoirs, sand control is particularly crucial. Sand particles in loose sandstone reservoirs are widely distributed; if particles larger than 0.3 mm enter the wellbore, they cause severe wear and tear to equipment such as oil pumps and tubing, reduce equipment service life, and increase maintenance costs. For example, during the early development of a loose sandstone reservoir in Shengli Oilfield, the absence of screen pipe sand control measures resulted in a high oil pump failure rate, with maintenance required on average every three months. Maintenance costs accounted for about 15 percent of production costs. After using a precision composite sand filter pipe, the screen pipe successfully intercepted 98 percent of sand particles larger than 0.3 mm. The oil pump failure rate was significantly reduced, the average maintenance cycle extended to more than one year, equipment wear rate dropped by 50 percent, and maintenance costs fell to less than 5 percent, effectively improving production efficiency and economic benefits [5]. The functional importance of different reservoir types is shown in Figure 5:

In high-temperature and high-pressure gas reservoirs, the screen pipe not only must provide sand control, but also corrosion resistance and thermal stress resistance to maintain long-term sealing. Environmental conditions in such reservoirs are harsh, with corrosive substances such as hydrogen sulfide and carbon dioxide in the gas, and temperature and pressure fluctuations generating thermal stress, posing challenges to the material and structure of screen tubes. For example, in a high-temperature, high-pressure gas reservoir in the Tarim Oilfield, initial use of ordinary screen tubes led to rapid corrosion perforation during production, causing the gas well to be shut down for maintenance. Ordinary screen tubes required replacement every six months due to severe corrosion, significantly disrupting production continuity. By adopting corrosionresistant alloy (CRA) screen tubes, equipment service life was extended to five years. For subsea or deep-well operations, this extension is not merely a production cycle improvement; it fundamentally protects total well life. In such high-risk environments, each intervention for screen replacement incurs prohibitive costs and potential wellbore integrity risks. Reducing intervention frequency ensures wells reach their planned reservoir depletion targets without premature abandonment due to technical failure or uneconomical workover costs [6]. The frequency of screen tube replacement is shown in Figure 6:

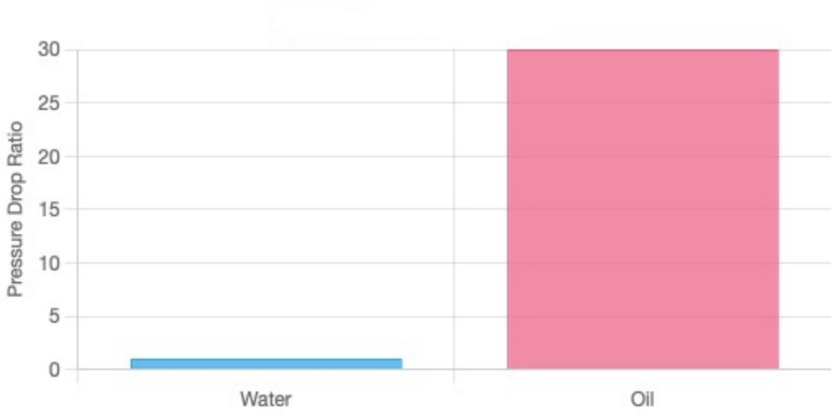

FIGURE 1. AICD Technology - Water-Oil Pressure Drop Ratio

FIGURE 2. Intelligent Completion System - Production Increase

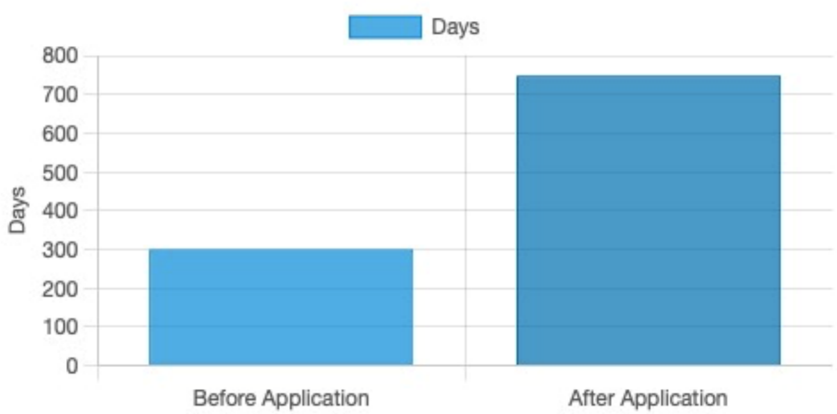

FIGURE 3. Waterless Oil Production Period (Days)

2) Types and Characteristics

Common screen tubes are usually made from J55 or N80 steel-grade oil casing, with seam widths generally ranging from 0.1 mm to 4 mm, and are suitable for wells with low water cut and low sand production. The cost of this type of screen pipe is relatively low, with a material cost of about 500,000 yuan per well, offering advantages in cost-sensitive projects. However, common screen pipes have poor impact resistance [7]. During horizontal downhole entry, due to the bending of the wellbore trajectory and collision with the drill string, screen pipe gaps can deform due to impact, affecting sand control efficiency. The daily oil production (tons) of ordinary sieve tube is shown in Figure 7:

For example, in a low water content well in Jidong Oilfield, completion operations using ordinary screen tubes achieved a 95 percent success rate. However, after three

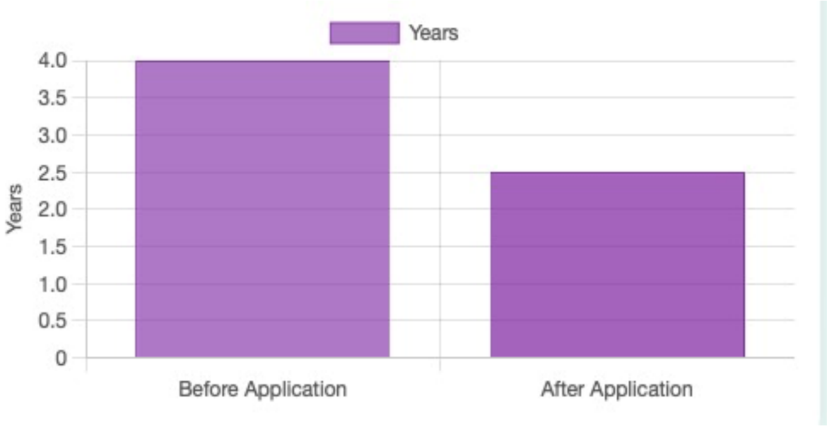

FIGURE 4. Dynamic Payback Period (Years)

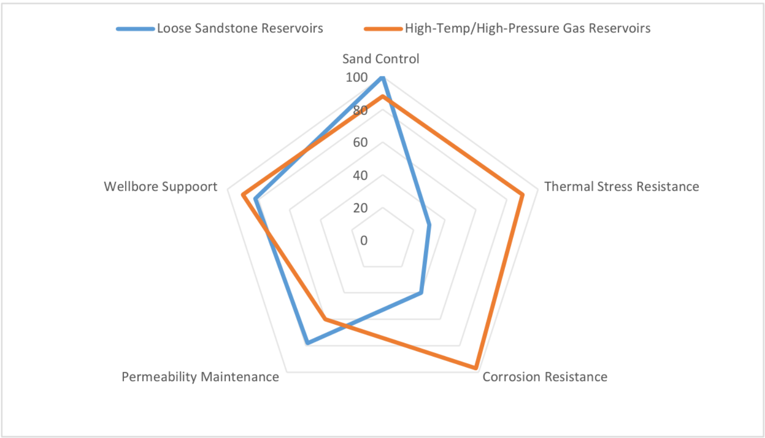

FIGURE 5. Function Importance in Different Reservoir Types

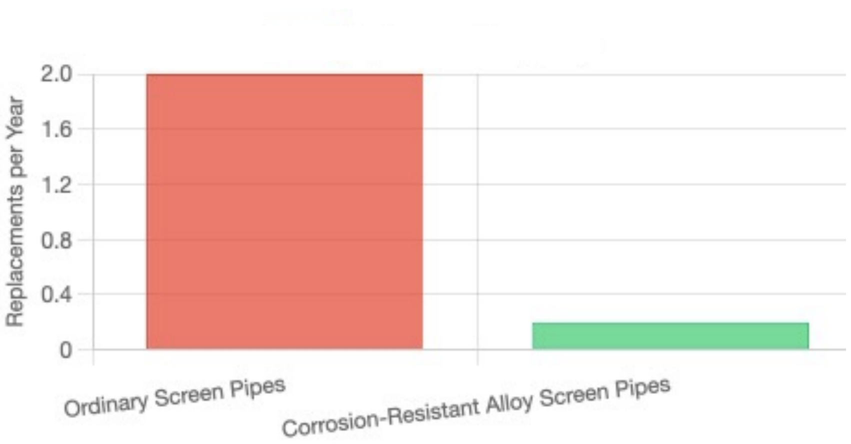

FIGURE 6. Screen Pipe Replacement Frequency

months of production, collisions during the lowering process led to deformation of some screen tube gaps, decreased sand control effectiveness, increased sand output at the wellhead, and required well repair operations to replace screen tubes, increasing production costs and cycle duration. The precision composite sand filter pipe offers high sand control accuracy, up to 300-600 mesh, intercepting finer sand particles. To reduce friction in the wellbore, it is usually used with a lubricant [8]. This type of screen tube is suitable for high sand content reservoirs, effectively preventing sand particles from entering the wellbore and protecting production equipment.

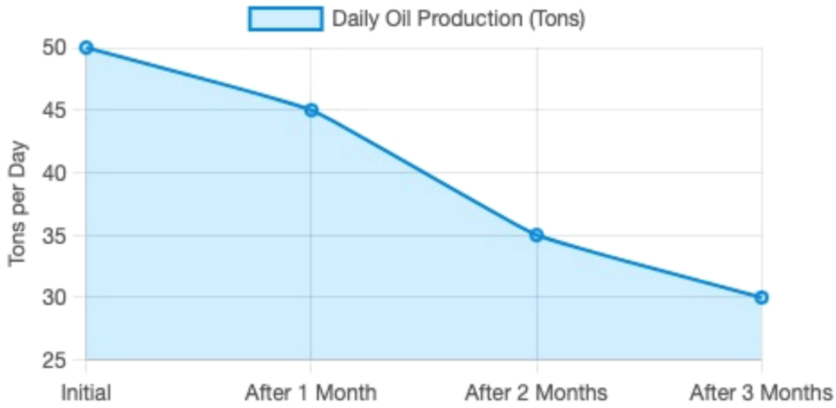

FIGURE 7. Common Screen Pipe - Daily Oil Production (Tons)

B. PRINCIPLES AND CLASSIFICATION OF WATER CONTROL TECHNOLOGY

1) Passive Water Control Technology

AICD (Autonomous Inflow Control Device) technology is a passive water control method that uses specialized flow channel designs to generate additional pressure drops, preferentially suppressing water flow. The fundamental fluid dynamics governing this selectivity rely on the distinct physical properties—primarily viscosity and density—of oil and water. Within an AICD's internal restrictive channels (such as spiral or labyrinth paths), the pressure drop (ΔP) is a function of the Reynolds number (Re). For high-viscosity oil, the flow remains relatively laminar, encountering lower frictional resistance. Conversely, low-viscosity water transitions into a high-velocity turbulent state more readily within these channels. According to the Bernoulli principle and Darcy-Weisbach equation, this turbulence significantly enhances the local resistance coefficient, creating a flow resistance wall for water. Consequently, the device exerts a significantly higher compensatory pressure drop on water compared to oil, effectively choking high-mobility water zones while maintaining oil throughput.

In a bottom-water reservoir in Karamay Oilfield, strong reservoir heterogeneity caused bottom water to advance rapidly along high-permeability layers, resulting in a rapid increase in well water content and decreased production. After applying AICD technology, the device's unique flow channel structure exerted significant additional pressure drop on water flow, suppressing water velocity, while the impact on oil flow was relatively small. The water-oil flow velocity ratio was reduced from 3:1 to 0.5:1, and water content decreased by 25 percent. Specifically, before AICD application, the well's water content was 5 percent and daily oil production was 30 tons; after application, water content dropped to 3.75 percent and daily oil production increased to 35 tons, effectively enhancing production efficiency.

Chemical water control uses water-swelling polymers, such as polyacrylamide, to seal high aquifers [9]. When the polymer contacts water, it expands and fills the pore space of the high-water layer, reducing its permeability and decreasing water production. In the G104-5P42 well of Jidong Oilfield, a high aquifer resulted in a water content of up to 80 percent and low production. After chemical water control technology was applied, water-swelling polymers were injected into the high aquifer, reducing its permeability by 80 percent from 500 mD to 100 mD. As permeability decreased, water output fell, oil output increased, and cumulative oil production rose by 18 percent, from 5,000 tons to 5,900 tons, effectively enhancing economic benefits [10]. The moisture content and daily oil production are shown in Figure 8:

2) Active Water Control Technology

An intelligent completion system is an advanced water control technology that integrates downhole sensors, flow control valves (such as pressure control valves and electric control valves), and surface monitoring systems. Downhole sensors monitor parameters such as pressure, temperature, and flow rate in real time and transmit data to the surface monitoring system. The surface system remotely controls the flow control valves according to preset water control strategies, achieving real-time control and optimization of oil well production. Shell achieved remarkable results after applying this technology in deepwater oil fields in the Gulf of Mexico. Previously, due to the inability to monitor downhole production dynamics in real time, the output of a single well fluctuated greatly, averaging around ± 15 percent, which affected overall production efficiency and increased management difficulty [11].

3) Functional Comparison: Passive AICD vs. Active Intelligent Completion

To justify the cost-effectiveness of the proposed AICD-screen pipe combination, it is essential to distinguish its functional logic from that of Intelligent Completion Systems (ICS). ICS typically employs downhole permanent sensors and surface-controlled hydraulic or electric valves (Interval Control Valves, ICVs) to allow realtime, active monitoring and adjustment of flow profiles. In contrast, the AICD-screen combination is a passive, self-adjusting technology

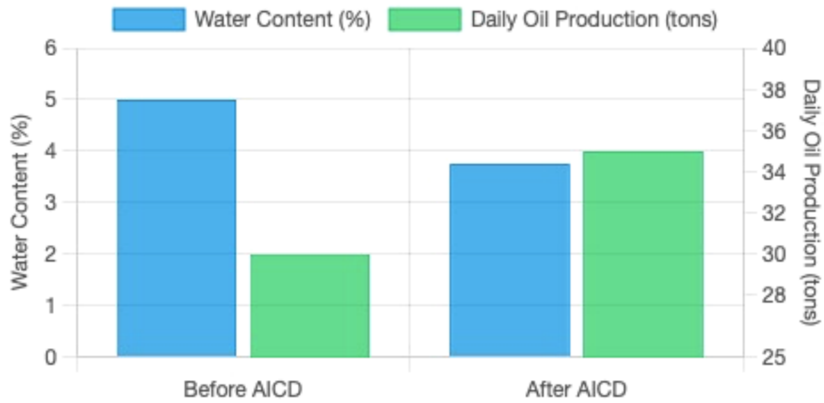

FIGURE 8. Water Content and Daily Oil Production

that relies on the physical properties of fluids (viscosity and density) to trigger flow resistance. While ICS offers superior precision in remote intervention, the passive AICD system eliminates the need for complex control lines and surface infrastructure, providing a fit-for-purpose solution for autonomous water management without the operational risks associated with electronic failures in high-temperature wells.

III. FIELD APPLICATION AND EFFECT EVALUATION OF WATER CONTROL–SCREEN PIPE COMBINATION TECHNOLOGY

A. CASE STUDIES

1) Horizontal Well G104-5P42 in Jidong Oilfield

The G104-5P42 horizontal well encountered various issues during development in the Jidong Oilfield. To enhance development effectiveness, a technical combination comprising suspended sealed screen pipe (0.2 mm seam width), external pipe packer (full temperature resistance countermeasures at 150°C), and oil-swelling packer (expansion coefficient 1.2) was adopted. This combination performed excellently in terms of production increment. The cementing perforation completion technique was surpassed, with daily oil output per well increasing qualitatively from 8 tons per day before cementing completion to 26 tons per day [12]. Production monitoring and analysis over time revealed a steady increase in output during the first three months after applying this technology, with an average monthly increase of about 6 tons, followed by stabilization at around 26 tons, demonstrating the drastic impact of this combination on production improvement [13].

From an engineering optimization perspective, significant outcomes were achieved in designing and optimizing the tailpipe overlap section and the location of the suspension device. The tailpipe overlap was reduced to 17.41 m, minimizing material usage and construction challenges. Simultaneously, the hanger's suspension angle was 87.2°, and under complex well conditions, the screen pipe deposit was successfully lowered 100 percent of the time. Numerous simulation experiments performed prior to construction to optimize screen pipe insertion parameters proved very helpful in improving construction efficiency [14]. The success rate of screen pipe insertion increased to 100 percent from the previous 90 percent, and construction time was reduced, with less time lost to construction issues. Economically, the technology combination provided significant value to the oilfield, costing 45 percent less to invest in one well compared to an intelligent completion system [15]. Cost savings were achieved mainly through optimized equipment selection and a simplified construction process. The payback period was reduced to 1.8 years, compared to the previously estimated three-year payback period for other investment plans. Implementation of this portfolio greatly reduced the payback period, increased production, and lowered costs, enabling the oilfield to recover its investment more quickly and enhancing capital utilization efficiency—an indication of sustainable development for the oilfield [16]. The production trend after the application of technology is shown in Figure 9:

2) TP12-Q3H Condensate Gas Well in Northwest Oilfield

In the TP12-Q3H condensate well in the Northwest Oilfield, the combination of water-controlled screen tubes (spiral flow channel design) and oil-swelling packers (temperature resistance 200°C) has resulted in impressive water control, sand prevention, and economic outcomes. The well achieved 1,200 days of waterless production, and the water-oil pressure drop ratio increased thirtyfold. Real-time monitoring of wellhead pressure and flow rate showed that, prior to this technology, the water-oil pressure drop ratio was 1:1, and severe bottom water coning led to rapid water content increases and sharp production declines [17]. After installing the technology combination, the spiral flow channel water control screen pipe maintained positive water flow control, while the oil-swelling packer provided effective sealing. This significantly elevated the water-oil pressure drop ratio, prevented bottom water cone entry, and enabled long periods of waterless production. During the 1,200 days of production, gas output reached 53 million cubic meters, demonstrating the benefits of this technology for water

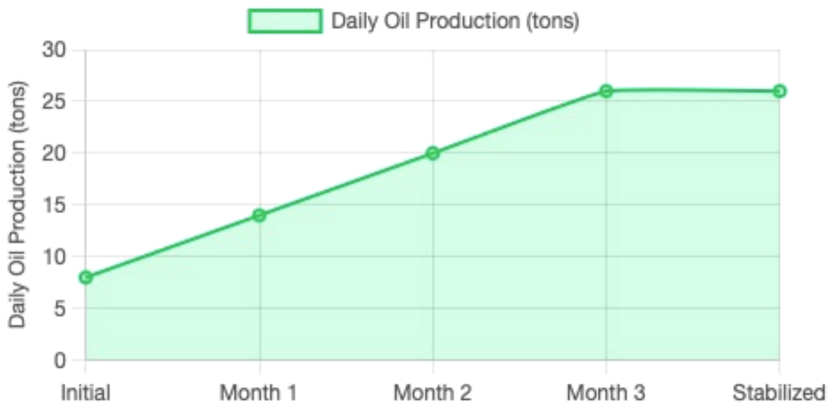

FIGURE 9. Production Trend After Technology Application

control and increased production [18].

The water-controlled screen pipe was also vital for sand control. The screen captured 99 percent of sand particles larger than 0.2 mm, preventing sand from entering the wellbore and causing equipment wear and blockages. Prior to application, wellbore pressure fluctuated widely due to sand production, averaging over 2 MPa, which affected production consistency and increased equipment failure risk [19]. With the water control screen pipe, wellbore pressure fluctuations were reduced to ± 0.5 MPa, ensuring consistent pressure and reliable sand control, thus stabilizing long-term production.

B. QUANTITATIVE EVALUATION OF EFFECTIVENESS

1) Yield Increase Indicators

The water-controlled screen tube combination significantly increased production, with daily rates rising by 40 to 60 percent compared to conventional wells. Statistical analysis across various oilfields showed that daily oil production in a deep Bohai Oilfield well increased by 83 percent, from 12 tons to 22 tons per day, after applying the technology. In horizontal wells in Jidong Oilfield, daily production increased by 230 percent; in condensate gas wells in the Northwest Oilfield, daily output rose from 8 tons to 26 tons. These data indicate that control-screen pipe combination technology can substantially increase daily oil well production. Despite varied application effects across oilfields and well types, the cumulative impact is clear. In terms of cumulative water production, AICD technology reduced water output by 2,735 percent. After five years of implementation in a bottom-water reservoir in Karamay Oilfield, water production decreased by 45 percent, from 120,000 to 80,000 cubic meters. Comparative analysis of water production before and after AICD technology deployment in various reservoir blocks revealed a consistent downward trend, with more pronounced effects the longer the technology was used. The main reason is that AICD technology effectively inhibits bottom water cone entry, minimizes water ingress to the wellbore, and maximizes recovery rates. The cumulative decrease in water production (%) is shown in Figure 10:

The production comparison between the water control screen tube combination well and the traditional well is shown in Table 1:

TABLE 1. Production Comparison between Water Control–Screen Combination Wells and Traditional Wells

Oil Field Name	Well Type	Technical Combination	Daily Production per Well (tons)	Increase Rate (%)	Cumulative Water Production (10,000 m^3)	Decrease Rate (%)
Jidong Oilfield	Horizontal Well	Suspended Sealed Screen + External Packers	26	230	3.2	45
Northwest Oilfield	Condensate Gas Well	Water Control Screen + Oil-Swellable Packers	18	125	1.5	60
Bohai Oilfield	Deepwater Well	AICD Screen + Gravel Packing	22	83	4.8	30
Daqing Oilfield	Vertical Well	Water Control Screen + Ordinary Packers	15	60	5.5	32
Tarim Oilfield	Horizontal Well	Intelligent Water Control Screen + High-Temperature Packers	20	150	1.2	55

2) Economic Analysis

In terms of cost comparison, the control–screen pipe combination costs 30 to 50 percent less than the intelligent completion system. Compared with the Intelligent Completion System (ICS), the investment cost of the AICD–screen pipe combination is reduced by approximately 40 to 60 percent. This cost advantage stems from eliminating expensive umbilical cables, downhole sensors, and sophisticated surface control units required by ICS. Although the AICD combination lacks the active, real-time remote valve adjustment capabilities of an ICS, its autonomous adaptability to water breakthrough makes it a highly cost-efficient alternative for reservoirs where fine-grained remote control is not economically justifiable. The proposed system fills the gap between low-end conventional screens and high-end intelligent completions by providing reliable water-shielding performance at a fraction of the capital expenditure (CAPEX).

Although the intelligent completion system offers advanced automation control and monitoring functions, its equipment cost is high and construction process complex, resulting in a large overall investment. The control–screen pipe combination technology uses more economical and practical equipment and materials, simplifies the construction process, and reduces the cost of materials and construction for each well. For example, material costs for a single well range from 1.5 million to 2 million yuan, while those for an intelligent completion system reach as high as 8 to 10 million yuan. Construction costs for the control–screen pipe combination range from 800,000 to 1.2 million

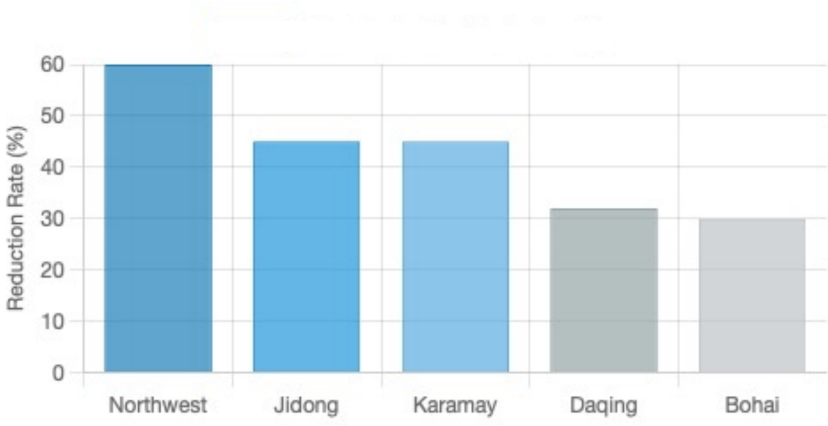

FIGURE 10. Cumulative Water Production Reduction (%)

yuan, compared to 3 to 5 million yuan for the intelligent completion system. The total investment for the control–screen pipe combination is between 2.3 million and 3.2 million yuan, 40 to 50 percent lower than the 11 to 15 million yuan required for the intelligent completion system, demonstrating significant cost advantages.

In terms of payback period, deepwater oilfield applications have seen the dynamic payback period shortened to 2–3 years. For example, in the Bohai Oilfield, the payback period was reduced from 4.2 years to 2.1 years, and the internal rate of return (IRR) increased to 25 percent after applying the control–screen pipe combination technology. Previously, analysis of economic benefits for different investment schemes predicted a 4.2-year payback period and a relatively low IRR. With the adoption of the combination of techniques, the payback period was significantly shortened and the IRR improved as production increased and costs decreased. This indicates that the technology portfolio has high investment value and economic benefits, bringing substantial returns to the oilfield in a short period, and has increased development enthusiasm and investment confidence. The cost comparison between the water control screen combination and the intelligent completion system is shown in Table 2:

TABLE 2. Cost Comparison between Water Control–Screen Combination and Intelligent Completion System

Technical Type	Single-Well Material Cost (10,000 yuan)	Construction Cost (10,000 yuan)	Total Investment (10,000 yuan)	Cost Reduction Rate (%)
Water Control–Screen Combination	150–200	80–120	230–320	40–50
Intelligent Completion System	800–1000	300–500	1100–1500	-
Ordinary Screen Completion	100–150	60–100	160–250	-
Traditional Completion Method	120–180	70–110	190–290	-

IV. CONCLUSION

The combined application of water control technology and screen pipes in oilfield completion operations represents a crucial technical breakthrough for addressing the complex challenges of water intrusion and sand production in modern reservoir development, often utilizing specialized filter textiles within screen pipes for optimized fluid separation and sand exclusion. The mechanism of this combination leverages the pressure-drop characteristics of technologies such as AICD to preferentially suppress water flow, and the sealing capabilities of components like oil-swelling packers to effectively isolate high-water zones, while utilizing the sand-control and structural support functions of the screen pipe. Quantitative evaluations and field application results consistently demonstrate significant technical and economic advantages for this integrated approach:

Enhanced Production and Water Control: Across various oilfields and well types, the combination technology has boosted daily oil production by 40 to 60 percent compared to traditional wells completed with basic SAC without inflow control devices. For example, daily production of a horizontal well in Jidong Oilfield increased by 230 percent. Furthermore, substantial reductions in cumulative water production have been achieved, with AICD technology alone reducing water output by up to 45 percent over five years in the Karamay Oilfield.

Superior Economic Performance: Financially, the water control–screen pipe combination offers a compelling advantage, costing 30 to 50 percent less than advanced intelligent completion systems. The single-well total investment is estimated to be between 2.3 million and 3.2 million yuan, compared to 11 to 15 million yuan for intelligent systems. This cost-effectiveness, combined with increased output, dramatically shortens the dynamic payback period—such as reducing it from 4.2 years to 2.1 years in the Bohai Oilfield—and significantly improves the IRR.

AUTHOR CONTRIBUTIONS

Conceptualization – Xiao Fan and Changyin Dong; methodology – Xiao Fan and Changyin Dong; investigation – Xiao Fan and Changyin Dong; writing-original draft preparation – Xiao Fan and Changyin Dong. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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