Technical White Paper
Physical Active Variable-Frequency Electromagnetic Wax Prevention and Viscosity Reduction System

1. Introduction

During petroleum production and transportation, high-wax crude oil tends to precipitate paraffin (C_{14}–C_{35} n-alkanes), microcrystalline wax (C_{36}–C_{55}), resins, asphaltenes, and other heavy components due to decreasing temperature, pressure changes, and gas evolution. These components crystallize and form a three-dimensional network-like wax deposit on the inner walls of tubing, sucker rods, and pipelines. This significantly increases flow resistance, reduces transportation efficiency, and can easily lead to pipeline blockages, equipment corrosion, and even production shutdowns.

Conventional wax prevention and removal methods — such as hot washing, chemical inhibitors, and mechanical scraping — are generally characterized by high energy consumption, high operational costs, environmental pollution, and frequent maintenance requirements. In alignment with China's national "Dual Carbon" strategy and the initiative for green oilfield development, JingTao Energy Technology Co., Ltd. ("JingTao Energy") has independently developed and industrialized an Intelligent Full-Sweep-Frequency Electromagnetic Wax Prevention, Scale Inhibition, and Corrosion Mitigation System, based on its proprietary invention patent "Full-Sweep-Frequency Electromagnetic Device for Wax Prevention, Scale Inhibition, and Corrosion Mitigation in Crude Oil Production and Transportation

Pipelines” (Patent No.: ZL202010417688.9).This system integrates core technologies including multi-harmonic variable-frequency control, staged magnetic fields, adaptive algorithms, and real-time parameter feedback, achieving integrated “triple-action” protection against wax deposition, scaling, and corrosion.

2. Technical Challenges and Industry Needs

2.1 Limitations of Existing Electromagnetic Wax Prevention Technologies

Although active electromagnetic wax prevention technology offers advantages such as energy efficiency, environmental friendliness, and ease of operation, current market solutions suffer from common shortcomings:

- Fixed frequency: Most systems use a single-pulse magnetic field, unable to adapt to varying well conditions or crude oil properties.
- Non-adjustable magnetic field strength: Output power is constant, resulting in short effective magnetization distances (typically <500 m).
- Lack of environmental awareness: Unable to dynamically adjust operating parameters based on real-time temperature, flow rate, or other variables.
- Single-function design: Focuses solely on wax prevention, ignoring synergistic scale and corrosion control.

These limitations lead to narrow applicability, inconsistent performance, and poor long-term reliability.

2.2 Industry Demand for Intelligent, Multi-Functional Systems

The oilfield industry urgently requires a next-generation wax management system with the following capabilities:

- Adaptive operation under varying temperatures, wax content,

and flow regimes;
- Long-distance magnetization capability (>1,500 m);
- Simultaneous wax prevention, scale inhibition, and corrosion mitigation;
- Support for unattended operation, remote monitoring, and automatic startup/shutdown.

3. Core Technical Principles

JingTao Energy ' s Physical Active Variable-Frequency Electromagnetic Wax Prevention and Viscosity Reduction System is grounded in the following scientific mechanisms and engineering innovations:

3.1 Multi-Physics Field Synergistic Mechanism

The system applies a staged, vector-enhanced harmonic magnetic field to induce multiple physical effects within the crude oil medium:
- Magnetic-induced molecular realignment: Disrupts the ordered stacking of paraffin molecules, inhibiting crystal nucleus growth.
- Colloidal suspension stabilization: Keeps precipitated wax particles dispersed, preventing adhesion to pipe walls.
- Electrochemical corrosion mitigation: The alternating electromagnetic field alters the electrochemical potential at the metal-fluid interface, slowing corrosion rates.
- Scale crystal distortion: Interferes with the nucleation of inorganic scales (e.g., $CaCO_3$, $BaSO_4$), reducing deposition tendency.

3.2 Adaptive Control Architecture

The system' s core is an integrated HMI/PLC controller featuring six functional modules:

- Power Filtering, Isolation, and Step-Down Module: Provides clean, stable DC power for control and drive circuits.

- Integrated HMI/PLC Program Control Module: Enables human-machine interaction, parameter setting, status display, and algorithm scheduling.
- Adaptive Frequency Algorithm Module: Computes optimal frequency in real time based on temperature and current feedback.
- Multi-Harmonic Signal Generation Module: Outputs continuously adjustable pulse signals across 10 – 500 Hz.
- IGBT Drive and Harmonic Power Amplification Module: Efficiently amplifies control signals to drive high-power electromagnetic coils.
- System Control Software: Embedded with an expert database supporting well-condition self-learning and strategy optimization.

3.3 Three-Stage Staged Magnetic Field Layout

Three electromagnetic units are sequentially installed on the outer wall of a non-magnetic, pressure-rated pipeline:

Front-end Electromagnetic Harmonic Conversion and Parameter Detection System.
Mid-section Electromagnetic Harmonic Conversion and Parameter Detection System.
Rear-end Electromagnetic Harmonic Conversion and Parameter Detection System.
Each unit generates a harmonic magnetic field with progressively increasing vector strength, enabling:

- Strong near-field magnetization for rapid initial treatment;
- Sustained weak-field suspension in mid-to-far zones;
- Total effective range ⩾ 2,000 meters (validated in laboratory tests).

Each segment is equipped with temperature and electromagnetic sensors that provide real-time feedback to the control unit, forming a closed-loop adaptive system.

4. System Configuration and Key Specifications

4.1 Hardware Structure

- Non-magnetic pressure-rated pipeline: Minimizes eddy current losses and ensures effective magnetic field penetration.
- Armored shielding cover: Blocks external electromagnetic interference and enhances system stability.
- Electric heating coil (optional): Provides auxiliary heating under extreme low-temperature conditions to extend operational limits.
- Sealed housing with thermal-insulation and waterproof filler: IP68-rated, suitable for harsh environments including offshore, desert, and arctic regions.

4.2 Key Performance Indicators

Parameter	Specification
Operating Voltage	AC 220V ± 10%, 50 Hz
Total Power Consumption	⩽ 650 W
Sweep Frequency Range	10 – 500 Hz (full-band coverage)
Magnetic Field Strength	60 – 80 mT (programmable)
Effective Range	⩾ 1,500 m (field-tested); theoretical ⩾ 2,000 m
Magnetic Hysteresis Duration	> 4 hours
Viscosity Reduction Rate	30 – 80% (water cut <30%); ~20% (water cut >30%)

Parameter	Specification
Corrosion Inhibition Efficiency	>40% reduction in pipe wall corrosion rate
Control Mode	Fully automatic + Remote HMI + Auto-restart after power failure
Protection Rating	IP66 / IP68 (optional)
Certifications	Explosion-proof (Ex d IIB T4), CE, ISO 9001

5. Field Applications and Performance Validation

5.1 Representative Case Studies

(1) Qinghai Oilfield (2021 – 2025):
Over 260 units deployed;
Covers high-altitude, high-salinity blocks;
Wax cleaning interval extended from 7 days to over 90 days;
Pipeline corrosion perforation incidents reduced by 70%.

(2) Yumen Oilfield, Well Y4-6 (Commissioned June 2025):

Previously required hot washing every 7–10 days;
After installation: zero wax blockage for over 180 consecutive days;
Daily fluid production increased by 12%; pump efficiency improved by 18%.

(3) Shengli Offshore Oil Production Plant:
Compact design perfectly suited for space-constrained offshore platforms;
Achieved unattended operation and remote diagnostics;
Annual O&M cost savings exceed RMB 500,000 per platform.

5.2 Comprehensive Benefit Analysis

- **Economic:**Reduces wax cleaning operations by 80%; annual savings of RMB 300,000–600,000 per well in fuel, chemicals, and labor.
- **Environmental:**Zero chemical additives, no wastewater discharge—fully compliant with green mine standards.
- **Safety:**Intrinsically safe design with no high-temperature or high-pressure hazards; lowers HSE incident rates.
- **Intelligence:** Supports integration with SCADA and Digital Oilfield platforms, accelerating digital transformation.

6. Intellectual Property and Standardization

- **Core Patent:** ZL202010417688.9 “Full-Sweep-Frequency Electromagnetic Device for Wax Prevention, Scale Inhibition, and Corrosion Mitigation in Crude Oil Production and Transportation Pipelines”
- **Software Copyright:** Electromagnetic Wax Prevention Control System V3.0
- **Enterprise Standard:** Q/JTNY 001-2024 “Technical Specification for Full-Sweep-Frequency Electromagnetic Wax Prevention Devices”
- **Industry Standard Participation:** Currently contributing to the drafting of “Guidelines for Application of Electromagnetic Wax Prevention Technology in Petroleum and Natural Gas Industry”

7. Conclusion and Outlook

JingTao Energy ' s patented Physical Active Variable-Frequency Electromagnetic Wax Prevention and Viscosity Reduction System overcomes the limitations of traditional electromagnetic technologies — fixed frequency, non-adjustable intensity, and single functionality — and pioneers a closed-loop intelligent control architecture featuring "perception-decision-execution-feedback." This truly enables " multi-functional integration, universal adaptability, and long-term protection."
We warmly invite global oil and gas enterprises to collaborate with us in advancing petroleum production and transportation toward a new era of green, intelligent, and efficient operations.

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