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State of the art of drilling — career layout from production target to industrial delivery and geothermal transition

The state of the art of drilling is organised from the final production expected from the well or, when the objective is solely geological appraisal for later development, from the data required to unlock that future. In oil and gas the practical objective remains recovery of hydrocarbons while limiting water dilution; reservoir pressure is sustained by controlled injection of water at rates lower than production so that the hydrocarbon front advances without excessive water cut. The wellbore skin created by drilling-fluid invasion can mask original porosity, capillarity and recoverable reserves. Modern practice therefore aims to enter the reservoir underbalanced or under managed-pressure conditions with rotating control heads, thereby preserving the near-wellbore properties that govern ultimate recovery.

Casing design constitutes the master constraint that fixes both the steel grades selected and the depths at which successive strings are set. Well-control certification for normally pressured intervals and for occasional high-pressure high-temperature or high-pressure zones defines the safe operating window; when that window narrows an additional intermediate string is frequently required. More than eighty specific failure-mode load cases covering burst, collapse, axial, triaxial, thermal and trapped annular pressure drive the optimisation that guarantees the minimum design factors against burst and collapse. The Shell Casing and Tubing Design Manual and industrial standards such as those applied in Petroleum Development Oman formalise this load-case discipline. Barrier policy remains the non-negotiable starting point of every design. In the French regulatory setting illustrated by AULNERGIE-type prefectoral prescriptions, only bentonite or biodegradable polymer muds are permitted, cementation quality must be verified by Cement Bond Log or equivalent under prior DRIEAT agreement, and critical operations require forty-eight-hour advance notification together with weekly progress reporting and immediate incident notification. Pressure-control and well-control incident reporting follow the discipline set out in the Shell Pressure Control Manual and the associated Well Control Incident reporting template, ensuring that any barrier compromise is classified, potential assessed and learnings captured systematically.

Multiple well architectures are employed to meet production expectations: vertical, J-shaped, S-shaped and high-angle trajectories, together with multilateral wells geosteered to within one metre of the carbonate reservoir top. Operational excellence in sections inclined above sixty-five degrees in twelve-and-a-quarter-inch hole includes rigorous hole cleaning, continuous monitoring of wellbore collapse and active management of pore-pressure penetration. These practices were industrialised through the writing of the first standard drilling programmes for Petroleum Development Oman and through support of large field campaigns such as Yibal, which exceeded three hundred wells. That massification demonstrated that a ten-fold increase in well count typically yields a three-fold reduction in unit well cost through standardised synergies and justified the systematic introduction of rotary-steerable systems. The same industrial learning curve and Perfect Well metrics constitute transferable capital for scaling deep geothermal campaigns under European programmes such as France 2030.

Zone isolation between reservoirs and the protection of aquifers, continuous improvement of cement-bond quality for long-term well longevity, and the use of glass-reinforced-epoxy lined or coated steel pipes form established integrity practices. Empirical evidence from nearly two thousand wells and seven hundred and fifty kilometres of coated casing in Oman confirms the effectiveness of external coating against corrosion when intervals are correctly selected. These materials and practices reduce long-term dependence on imported solutions and support multi-decade reuse of wells, including possible conversion from hydrocarbon to geothermal service. Priority is therefore given to national and European supply chains for tubulars, coatings and high-performance cements. Well abandonment and plug-and-abandonment practices form an integral part of the same integrity continuum, ensuring permanent barrier isolation at end of life.

A complete new seven-hundred-and-fifty-tonne AC IP15 explosion-rated drilling-rig unit built to New Zealand standards and an associated one-hundred-person mobile camp suitable for both gas-well and industrial geothermal operations were supervised through design, construction and commissioning. In project management the full contract cycle from tender initiation through execution to close-out has been held for high-value high-risk packages. Collaboration with exploration departments and public-procurement ministries included rapid review of dossiers exceeding five hundred pages, extracting the essential safety, technical and budgetary elements within a few hours. Performance management adopted a 4DX cadence of action tracking and closure of investigations; archival analysis over multiple years demonstrated the primacy of change management and continuous-improvement plans conducted with humility and determination. Perfect-well-ratio metrics were applied to rank operational performance while the overriding frame remained the protection of lives and of values.

The same body of practice has been extended to the modelling of complex modern down-hole radiator systems of the Eavor type using competitive software platforms such as Techdrill DSP-One, which integrates directional, casing, string and optimisation centres. The CERBERUS concept combines gas-turbine generation with heat-recovery steam generation, large-bore lobster-shaped geothermal doublets and the future option of closed-loop thermoloops, thereby converting what would otherwise be wasted flue-gas heat into additional power while offering the possibility of long-term heat and carbon storage in the formation under the applicable European taxonomy and geological-storage directives. Experience gained on conventional industrial programmes therefore transfers directly to the design, integrity and operational requirements of deep geothermal doublets such as the AULNERGIE GASB-1/GASB-2 pair on the Dogger aquifer and to the broader European geothermal development path. Data models and software environments are preferably hosted under European sovereign frameworks to limit external jurisdiction risk.

The professional trajectory described above is underpinned by a constant requirement: every well begins with the production target that justifies it and ends with the integrity that is left in the formation, the barriers and the people who executed the work. The more than eighty failure-mode load cases are not abstract calculations; they constitute the collective operational memory of events that must not be repeated. Industrial massification, as demonstrated on the Yibal programme, is valuable not only for the threefold cost reduction it enabled but for the proof that shared standards and continuous improvement conducted with humility can simultaneously raise efficiency and care. From conventional oil and gas development through to geothermal doublets and closed-loop systems, the non-negotiable constants remain the protection of life, the protection of aquifers and reservoir quality, and the preservation of the well for possible future use. Technology and architectures evolve; the duty of care does not. Humility and determination remain the design factors that never yield. This body of practice constitutes a transferable asset for the industrialisation of deep geothermal systems under European regulatory and sovereignty requirements, supporting national champions in tubulars, services and data while reducing external dependencies.

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Definition of acronyms

4DX: Four Disciplines of Execution — action-tracking and closure cadence.

AFE: Authorization for Expenditure.

CBL: Cement Bond Log — logging tool used to verify cementation quality.

DRIEAT: Regional and Interdepartmental Directorate for the Environment, Planning and Transport (Île-de-France).

EMDS: Electromagnetic Defectoscope Survey — casing corrosion logging method.

GRE: Glass Reinforced Epoxy — epoxy resin coating or lining reinforced with glass fibre.

HPHT: High Pressure High Temperature.

HRSG: Heat Recovery Steam Generator.

IP15: Ingress Protection rating 15 (explosion-rated equipment classification).

MPD: Managed Pressure Drilling.

ORC: Organic Rankine Cycle.

PCM: Pressure Control Manual.

PDO: Petroleum Development Oman.

RSS: Rotary Steerable System.

SRC: Steam Rankine Cycle.

UBD: Underbalanced Drilling.

WCI: Well Control Incident.

TVD: True Vertical Depth.

MD: Measured Depth.