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Drilling and surface installation specifications for lithium production from formation fluid, CO2 reinjection and heat-extraction circuits, white-hydrogen exploration and development, and closed-loop Eavor-type radiator systems

This dossier presents, in the requested order, the technical drilling, completion and surface specifications for four distinct domains. Each domain is treated separately. No geometric hybridisation is proposed between open systems for brine production and closed multilateral radiator systems.

1. Drilling specifications for producing lithium from formation fluid exploited at surface, probable completion type and management of surface installations

Lithium production from geothermal brines relies on an open doublet system. The typical architecture resembles a lobster antenna: the injector and producer wells are drilled from the same pad, separated by approximately ten metres at surface, then diverge progressively to reach sufficiently distant injection and production points in the reservoir. This geometry is that of classic Parisian doublets (Dogger) and of Upper Rhine Graben projects. It is not to be confused with a multilateral network of intersecting fingers.

Drilling sections progress conventionally to an open hole or a slotted liner of 7 to 9⅝ inches in the reservoir (sandstone or fractured basement). The probable completion uses a production casing in API steel (P110 or L80) or, preferably for corrosive brines rich in chlorides, CO_2 and H_2S, mechanically lined tubulars (MLT) in Alloy 625 or 680. The latter have demonstrated no measurable corrosion after eighteen months of exposure at 360 °C under conditions analogous to those of the Salton Sea. High-temperature metal packers, expansion joints and, where required, a high-temperature electrical submersible pump complete the production equipment. Production tubing is selected in duplex or nickel alloy.

At surface the hot fluid first passes through a train of heat exchangers. Lithium extraction (DLE by adsorption, ion exchange or electrochemical processes) then occurs, followed by precipitation as carbonate or hydroxide. The principal risk of heat-exchanger fouling arises from silica, carbonates and sulphates that precipitate on cooling. The strategy for continuous operation consists in installing banks of heat exchangers in parallel (two to four independent trains). Each train can be isolated, cleaned chemically or mechanically and returned to service while the others continue to produce. This dimensioning increases CAPEX by 25 to 40 % but maintains operational availability above 95–98 %, limiting maintenance stoppages to partial interventions. Scale inhibitors and pH control are injected continuously. The depleted brine is reinjected.

A known limitation of Parisian-style gelule doublets is that, over successive years, the cooled water plume reaches the production well, causing a progressive decline in the temperature of the extracted fluid. Certain management methods (adapted flow rates, injection sequencing, optimised spacing) can slow this phenomenon. The technical objective is to ensure that the longevity of the casings and surface equipment becomes the limiting factor for the duration of exploitation rather than the thermal capacity of the reservoir.

2. CO2 reinjection (cryogenic or otherwise) and creation of a circuit exploiting ground heat by circulating CO2, possibly supercritical, with thermodynamic formulae

Carbon dioxide may be reinjected in cryogenic form for pure geological storage (CCS). For heat extraction the supercritical regime (critical point 31.1 °C and 73.8 bar) is preferable. In a closed circuit the dense cold CO_2 is injected down the injection well, heats by conduction along the horizontal sections, and rises in the production well with a markedly lower density. The density difference (which can reach several hundred kg/m³) generates a thermosiphon.

The driving force of the thermosiphon is expressed as $\Delta P \approx (\rho\_cold - \rho\_hot) \cdot g \cdot \Delta z - \Sigma$ frictional losses, where the losses are calculated with the Darcy–Weisbach factor or the Haaland equation. Fluid enthalpy is taken from the Span–Wagner equation-of-state tables. The recovered thermal power is $Q = \dot{m} \cdot (h\_out - h\_in)$. Net power after turbine expansion and recompression is expressed as $\dot{m} \cdot [\eta\_turbine \cdot (h\_turbine\_in - h\_is) - (1/\eta\_compressor) \cdot (h\_comp\_out - h\_comp\_in)]$. Simulations indicate an injection optimum around

12–16 MPa that maximises both thermosiphon flow rate and outlet temperature. The closed cycle avoids any chemical contact with the formation, eliminates the risks of reservoir depletion and induced seismicity, and generates no solids requiring treatment.

3. Drilling of a white-hydrogen exploration well and associated testing

Exploration of native hydrogen is performed by vertical or slightly deviated wells drilled to depths of 1 000 to 3 655 m. The PTH-2 well of La Française de l'Énergie in Moselle, drilled to 3 655 m, currently represents the deepest dedicated well. The programme includes systematic mud-logging of free gases, sampling of gas and fluids, sealed cores and production tests (DST or flow tests after perforation). Measured concentrations reach several tens of percent hydrogen in certain intervals. Completion must account for the risk of hydrogen embrittlement: casing and tubing materials are selected from austenitic steels with high nickel content (316L minimum 12 % Ni) or nickel alloys, and cements are formulated for low permeability. After initial testing the well may be equipped with down-hole probes (SYSMOG for dissolved concentration, SYSPROG for separation membranes).

3.1 Development well for white-hydrogen exploitation

A development well reuses the same construction principles but optimises production diameter and architecture for a sustainable commercial flow rate. Completion may incorporate down-hole hydrogen–water separation membranes in order to bring an enriched stream to surface. At surface the gas is purified, compressed and conditioned. Material and cementation standards remain critical for long-term integrity. The French regulatory framework currently rests on the Mining Code (mineral-substance titles) in the absence of a dedicated European regime for native hydrogen. First pilot-production projects are anticipated in France around 2028–2029.

4. Compilation of details of Eavor-type drilling programmes begun in 2019 in Canada with Shell, and of corresponding German projects

The Eavor-Lite demonstration project, drilled in 2019 near Rocky Mountain House (Alberta) in partnership with Shell New Energies and Precision Drilling, constitutes the first commercial-scale multilateral closed-loop system. Two sites 2.5 km apart each received a vertical well to 2 400 m TVD, equipped with 7-inch casing. Two laterals of approximately 1.7 km were drilled in 6⅛-inch open hole and intersected toe-to-toe by magnetic ranging. The Rock-Pipe system, a chemical treatment of the wellbore wall while drilling, sealed the laterals without steel casing, guaranteeing hydraulic isolation and limiting losses and collapse risk. A surface pipeline closed the loop. The thermosiphon was demonstrated with uptime above 95 % and thermal performance within 2 % of prediction. More than 11 250 MWh of thermal energy were produced during the first two years of operation.

Commercial projects, notably Geretsried in Bavaria, are drilled from a single pad or from closely spaced pads. Laterals reach 3 km and more, for measured depths exceeding 8 000 m. Hole diameters of 8 to 8.5 inches are now preferred in order to increase exchange surface area. The same principle of wellbore-wall treatment (Rock-Pipe or equivalents) is applied so as to approach a continuous closed cycle with minimal motorisation and no solids treatment.

The illustrated multilateral profile (vertical sections at 349 degrees, TVD of the order of 4 200 to 4 500 m, horizontal branches in a fan with multiple intersections and sidetracks forming a network of fingers) represents the densest configuration of this type of closed subsurface radiator. One branch supplies a denser, cooler fluid that successively intercepts the hotter branches of lower density. The fluid remains entirely isolated from the formation. The connection is purely thermal. This architecture maximises the volume of rock contacted while preserving a continuous closed cycle, without reservoir depletion and with motorisation reduced to the minimum by means of the thermosiphon. It constitutes the reference model for low-impact, high-availability deployment.

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Definition of acronyms

CAPEX: Capital Expenditure.

CCS: Carbon Capture and Storage.

CRA: Corrosion-Resistant Alloy.

DLE: Direct Lithium Extraction.

DST: Drill-Stem Test.

MLT: Mechanically Lined Tubular.

NZIA: Net-Zero Industry Act.

OPEX: Operational Expenditure.

sCO2: supercritical Carbon Dioxide.

TVD: True Vertical Depth.

URG: Upper Rhine Graben.