An efficient numerical simulation platform has been developed in order to test the thermo-mechanical performance of different Thermal Energy Storage systems: two-tank and single-thermocline tank. A parallel object-oriented code solves and couples all the components of the system by considering the heat transfer, fluid dynamics and thermoelastic phenomena involved. Having proved its validity with experimental cases, CCTC-UPC has carried out valuable studies on TES focused on the transient annual storage response, parametric analysis, optimal tank sizing, structural integrity, phase change materials, multi-layered solid-PCM, etc.

**Two-Tank Storage**

Mathematical formulations and physical phenomena

- Multi-physic nature of the system: 3D turbulent currents of the molten salt, 3D conduction heat transfer (tank walls, filler material, voids, etc.), thermal radiation inside the tanks and with the external ambient, passive cooling in the foundation, mechanical and thermal stresses, unsteady behavior, gas, slag, etc. A modular object-oriented methodology has been developed: STEScode.
- Multi-scale phenomena: advanced CFD analysis using LES turbulence models (see instantaneous streamlines below).
- Design aspects: thermal losses control, optimization of the storage (cost reduction), how to scale-up the system.

**Thermo-fluid dynamics performance**

- Comparison of two different foundations: FDN 1 and FDN 2 located in Sevilla.
- Temperature field distribution in the foundation after 7 months (a) and after 43 months of operation (starting January 1st).
- Table: heat and cost reduction of FDN 2 respect to FDN 1.

**Mathematical & Numerical model**

- Different thermocline storage concepts: packed-bed, Encapsulated phase change material (PCM), Multi-layered solid-PCM.
- Dynamic coupling of all system elements by means of a parallel object-oriented code (HEST). Mass, momentum and energy balances are solved and discretized with Finite Volume numerical method. A modular object-oriented methodology has been developed: STEScode.
- Fluid and filler material:
  - Fluid dynamics at the fluid flow (axial direction) and in the heat transfer inside particles (radial distribution).
  - Heat conduction considering molecular diffusion and thermal dispersion.
  - Thermal losses through lateral walls and top and bottom surfaces.

**Tank-wall stresses**

- 3D-thermomechanical model for the wall.
- Bulk cold active gas pressures with particle settlement and thermal expansion.

**Thermo-mechanical performance**

- Features:
  - Diameter x height: 43.7 m x 13 m
  - Storage capacity: 970 MWh / 6.9 h
  - Thermal capacity: 30.5 MWh
  - Mass contained: 36,020 ton molten salt
  - 0 ton PCM

- Temperature maps during an average discharge.

**Conclusions**

- Suitable numerical simulation tools for the thermal and mechanical performances are considered important for CSP systems. The two-tank and the thermocline system. They have been developed and used for design and performance evaluation purposes. Parameters such as meteorological data, insulation, foundation, tank geometry or operating conditions can be modified, and variables like dynamic temperature maps, thermal losses, energy exchanges, efficiencies, thermal stresses or structural safety factors can be measured.

**References**


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