Technical Note: The Omega (Ω) M50-1700 Furnace — Architecture and Gas Dynamics in Heating Ruby-Sapphire

Author: Ted Themelis -*Developer of the Omega (Ω) Furnace Architecture*
Affiliation: Independent Researcher / Gem Lab, Bangkok, Thailand
ORCID: 0000-0002-4493-6623
Email: ted@themelis.com

Keywords: *Corundum treatment; Sapphire; Ruby; Controlled atmosphere furnace; Oxygen partial pressure (pO_2); Quasi-isochoric assembly; Diffusion-controlled environment; Alumina muffle; High-temperature processing*

Abstract

The Omega (Ω) M50-1700 furnace architecture is a vertical closed-one-end (COE) alumina muffle system designed for controlled thermochemical treatment of corundum at temperatures up to 1700 °C. By integrating bottom-fed axial gas injection, thermal buoyancy, and a diffusion-restricted gas exchange assembly, the system establishes a stable recirculating flow field—the "gas umbrella"—and a quasi-isochoric microenvironment. This configuration enables precise regulation of oxygen partial pressure (pO_2), gas residence time, and cooling kinetics, thereby promoting reproducible high temperature processing conditions.

1. Definition of the Omega (Ω) Furnace Architecture

The Omega (Ω) furnace architecture, as developed by Ted Themelis, is defined as a bottom-fed, vertical closed-one-end (COE) muffle system in which the process gas rises along the central axis, impinges on a slightly curved dome, and is redirected into a downward recirculating flow field ("gas umbrella"**),** coupled with a diffusion-restricted quasi-isochoric assembly**,** thereby establishing a stable thermochemical domain with controlled oxygen partial pressure (pO_2).

This configuration, herein referred to as **the** Themelis Omega (Ω) architecture**,** represents a coupled system of convective flow control and diffusion-limited atmosphere stabilization

2. System Architecture and Gas Flow Dynamics

The Omega (Ω) furnace utilizes a vertical COE alumina muffle to isolate the reaction environment from external contamination. The process gas **is** blended at the inlet stage (P1) and introduced through bottom-fed axial injection via an alumina pincer.

Driven by injection momentum and thermal buoyancy, the gas rises through the crucible and contacts the gemstone load. Upon reaching the slightly curved dome, the gas is redirected radially and downward, forming a unified recirculating flow field ("gas umbrella" or thermochemical cloud).

This controlled convective flow stabilizes the internal atmosphere between the inlet (P1) and outlet (P2), ensuring high purity and minimizing interaction with refractory materials and heating elements.

3. Thermochemical Quasi-Isochoric Control

The Omega architecture operates under a quasi-iso
horic regime established by a diffusion-restricted assembly. This configuration limits gas exchange between the internal reaction zone and the external flow path, allowing the internal atmosphere **to** approach equilibrium within a near-constant-volume domain**.**

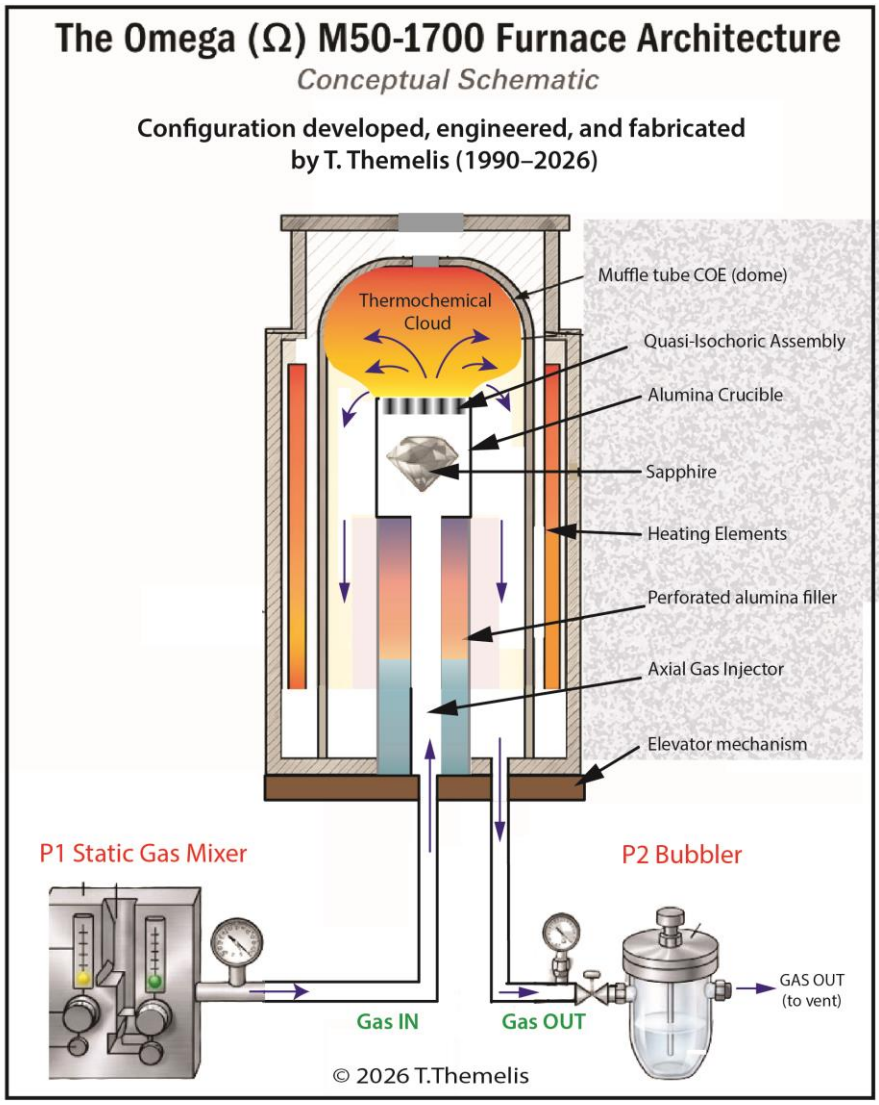

Fig.1. Conceptual schematic of the Omega (Ω) M50-1700 furnace architecture (Themelis). The system consists of a bottom-fed axial gas injection into a vertical closed-one-end (COE) alumina muffle, where the gas rises, impinges on the curved dome, and is redirected into a recirculating flow field ("thermochemical cloud" or gas umbrella). A diffusion-restricted quasi-isochoric assembly stabilizes the internal atmosphere, enabling controlled oxygen partial pressure (pO_2) and gas-phase equilibrium conditions. Arrows indicate predominant gas flow paths between the inlet (P1) and outlet (P2) stages. The configuration defines a controlled

Gas transport and equilibrium behavior follow established principles of thermodynamics and transport phenomena, governing diffusion-limited exchange and redox stability. The underlying quasi-isochoric reduction framework has been described in detail elsewhere [4, 5, 6].

4. Supported Gas Regimes

Under these conditions, the system operates across a wide range of controlled gas environments, enabling adjustment of oxygen partial pressure (pO_2) and gas-phase equilibrium conditions. The supported gas systems correspond to established thermodynamic equilibria and non-equilibrium regimes at high temperature.

Hydrogen, as the principal reducing agent, is employed in the following systems:

- **Buffered systems:** CO–CO_2 *(pO_2 defined by equilibrium, typically ~10^{-4} to <10^{-15} at high temperature)*, H_2–CO_2, H_2–H_2O *(pO_2 governed by gas ratio and temperature)*
- **Non-buffering reducing and inert mixtures:** H_2–Ar, H_2–N_2 *(pO_2 dependent on gas purity, leakage, and residual oxygen/moisture)*
- **Hydrocarbon-based systems:** LPG–N_2, LPG–Ar *(thermal decomposition generates reducing species such as H_2 and CO)*

For oxidizing and mixed systems (O_2, O_2–N_2, O_2–Ar), the Omega (Ω) architecture provides precise control of the purged gas atmosphere.

For carbon-based buffer systems (C–CO, C–H_2O, and COM (carbon–oil mixture)), the Omega (Ω) design minimizes chemical interaction between the hermetically enclosed capsule (crucible) and the surrounding muffle environment by maintaining an external inert gas blanket (N_2 or Ar).

The attainable thermochemical conditions are bounded by gas-phase equilibrium constraints and system parameters; however, the Omega (Ω) architecture enables stable and reproducible operation within these defined limits.

5. Functional Features

- **Gas Umbrella (Thermochemical Ceiling):** Recirculating flow eliminates stagnation zones and maintains uniform atmospheric conditions.

- **Controllable Gas Residence Time:** Differential pressure and flow control between P1 and P2 regulates gas interaction time within the reaction zone.

- **Diffusion-Restricted Microenvironment:** The quasi-isochoric assembly stabilizes gas composition and suppresses external atmospheric fluctuations.

- **Precision Cooling Elevator:** Enables controlled cooling trajectories critical for defect stabilization and phase stability.

Summary
The Omega (Ω) furnace, developed by Ted Themelis, represents a controlled thermochemical reactor system distinct from conventional open-volume furnaces. By combining bottom-fed gas injection, recirculating flow dynamics, and diffusion-limited atmosphere control, the system provides a reproducible and stable platform for high-temperature processing of corundum. The Omega (Ω) furnace is presented here for identification and reference within the field.

References

1. Gaskell, D.R.(2017). *Introduction to the Thermodynamics of Materials.* 6th ed. Boca Raton: CRC Press.

2. Bird, R.B., Stewart, W.E., Lightfoot, E.N. (2007).*Transport Phenomena* 2nd ed. New York: John Wiley & Sons

3. Fermi, E. (1956) *Thermodynamics.* New York: Dover Publications.

4. Themelis, T. (2026a). *Introductory Note: High-Temperature Quasi-Isochoric Gas-Phase Reduction (HT-QIGPR): Hydrogen Fugacity-Driven Electronic Reduction in α-Alumina.* Author's Monograph Series. Available at: https://www.researchgate.net

5. Themelis, T. (2026b). *Introductory Note - HT-QIGPR: Operational Interpretation for Reducing Sapphire Treatment.* Author's Monograph Series. Available at: https://www.researchgate.net

6. Themelis, T. (2026c). *Introductory Note: Quasi-Isochoric Reduction in Sapphire Heating—Conceptual Framework and Practical Furnace Configurations.* Author's Monograph Series. Available at: https://www.researchgate.net