

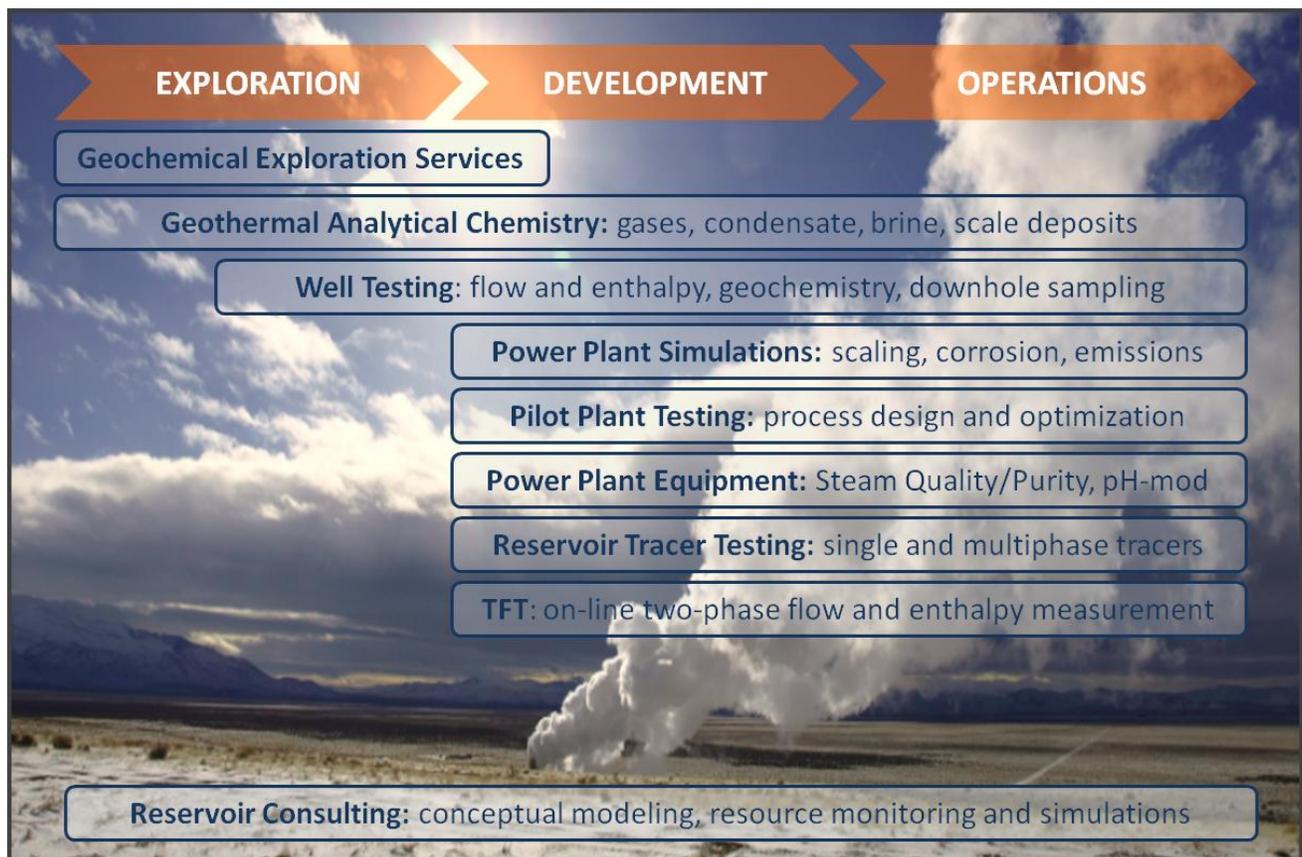
THERMOCHEM GEOTHERMAL PRODUCTS AND SERVICES

Thermochem is a vertically integrated consultancy, service, and OEM instrument firm with over 30 years' experience in the geothermal energy industry. Our specialties are well testing, analytical and process chemistry, instrumentation, engineering and geochemistry. We provide solutions to our clients from the ground up, from exploration and production well testing, through plant design, reservoir management and operations.

Our experienced team has delivered solutions to geothermal projects in over 30 countries throughout the globe. Our mission is to maximize the return on assets of our clients, by ensuring the most efficient use of their resources and equipment, through well testing and resource monitoring, prevention of corrosion and scale damage to facilities and providing early detection and sustainable solutions to long-term resource problems.

CHEMICAL SOLUTIONS FROM THE GROUND UP

Our comprehensive suite of products and services provide solutions from exploration through operations:



THERMOCHEM®

Empowering Energy Industries since 1985

GLOBAL REACH, HIGHLY RESPECTED INDUSTRY LEADER



Thermochem delivers solutions to geothermal projects throughout the globe, from bases in the USA and Indonesia. Our clients are major oil companies, utilities, governments, national labs, EPC contractors and start-up exploration firms. Our clients include the leading geothermal energy companies such as Chevron, Ormat and Calpine.

We strive to deliver robust, high-quality and responsive solutions for our clients to meet their specific needs.

“Just wanted to send you a short note thanking you and the Thermochem team for your performance during the...Minas interwell tracer testing. I could not have imagined a better execution for planning, tracer injection and sampling. I would rate Thermochem very high in planning, safety and execution. I sincerely hope we have the opportunity to utilize Thermochem again in our future tracer work.”

Bruce Smith
Subsurface Manager
PT. Chevron Pacific
Indonesia

“I wanted to thank you for the dedicated (and high quality) service. Obviously your involvement in our projects is part of your business but I do feel (and I am sure other people at ORMAT and perhaps the entire Geothermal industry feels the same) that the service you provide is above and beyond just business.”

Zvi Krieger
Senior Vice President
Geothermal Engineering
Ormat Technologies, Inc.

“The quality of services provided by Thermochem for the last nine (9) years has been excellent. Thermochem, Inc. provides specialty well testing services...including enthalpy and flow rate measurements, downhole sampling, tracer analysis, interpretations of tracer data...they evaluated our steam scrubbing systems and supported our Carbon Emission Reduction certification. Chevron and previously Unocal have contracted with Thermochem since 1994. Thermochem has consistently provided high quality results at a reasonable cost.”

**Darajat Resource
Technology Team**
Chevron Geothermal
Indonesia Ltd.

MULTIDISCIPLINARY TEAM

Thermochem has 64 employees based in offices and laboratories in Santa Rosa, California, USA, and Bandung and Tarutung, Indonesia. Our multidisciplinary team includes chemical engineers, geochemists, chemists, reservoir engineers, and technicians. The team's collective technical knowledge and practical experience in well testing, chemical process engineering, chemical modeling, geochemistry, electronics, CADD design and manufacturing, and well testing, combined with core competencies in analytical chemistry, engineering and geosciences enables us to deliver total package solutions for all phases of geothermal projects, from exploration through operations.



THERMOCHEM[®]

Empowering Energy Industries since 1985

THERMOCHEM COMPANY PROFILE

Thermochem provides chemical engineering, laboratory analysis, geochemistry, well testing and reservoir engineering services to the geothermal and oil and gas industries. Thermochem also supplies equipment and instrumentation to these and power generation industries. From base operations in the Western USA and Indonesia, Thermochem has served oil and gas, power generation and renewable energy companies for over 30 years. The company's full-time staff consists of engineers and chemists with extensive experience in chemical process engineering, chemical modeling, analytical chemistry, geochemistry, electronics, CAD design, well testing, and manufacturing. A key mission of Thermochem is to protect our client's resources and assets, and help provide for their most efficient use. This is achieved through consulting and testing services, and innovative chemical process development, designed to optimize resource utilization, energy extraction and power generation operations. Thermochem has the broad expertise and experience to provide a unique perspective in resource and asset management, with a focus on safety and long-term asset protection. From initial exploration and resource evaluation, through process design, start-up and continued optimization and trouble-shooting, Thermochem can help ensure the development and operation of successful energy projects.

Laboratories

Thermochem analytical laboratories provide comprehensive analytical services for the energy industry. The laboratories specialize in the analysis of trace-level constituents in steam for purity analysis, noncondensable gas analysis, cooling water, brine chemistry, and corrosion/scale deposit analysis. Thermochem is a leader in chemical tracer analysis, with a wide variety of non-radioactive tracers available for liquid, vapor-phase and two-phase applications in enhanced oil recovery (waterflood and steamflood), geothermal reservoir engineering and surface process evaluations. Most analytical methods employed have been developed by Thermochem to accommodate the analytical interferences common to the difficult fluid matrices often encountered in natural geochemical and complicated chemical process samples.

Thermochem has the only commercial laboratory in the world specializing in geothermal geochemistry. We provide chemical analysis, consulting, field surveys and testing services to all major geothermal operators and most consulting groups in the industry. During our inception 30 years ago we had worked closely with the USGS to develop a commercial geothermal laboratory. Since then we have developed many techniques on our own, written and maintained ASTM standards, and collaborated with most of the National Labs on geothermal research projects.

Field Services

Thermochem provides well flow testing services around the world, including supply of mufflers, piping systems and instrumentation. Sampling of multi-phase flow streams, at high-temperature and pressure, is routinely performed using custom designed equipment. The Tracer Flow Test process (TFT[®]) used worldwide for water and steam two-phase flow measurement in geothermal and steam-flood applications was invented by Thermochem, Inc. Steam purity and quality testing is performed at power plants for initial performance testing, routine monitoring and investigations related to turbine damage and scaling. Thermochem has also developed on-line instrumentation to measure steam quality and purity at geothermal, fossil-fuel and nuclear plants. Source-testing for atmospheric pollutants from power plants, drilling rigs and well sites is also conducted.

Downhole (wellbore) samples are collected using Two-Phase Wellbore Samplers and Pressure – Temperature – Velocity profiles measured in wells using PTS logging tools designed and built by Thermochem. Corrosion and scale monitoring is performed and Pilot Tests are conducted to evaluate corrosion/scaling and develop new process control strategies. Thermochem performs all aspects of geochemical prospecting and exploration for geothermal resources, including soil gas, hot spring and fumarole sampling, plus bathometric surveys in lakes using oceanographic instruments and samplers. Our Senior Geologists and Geochemists, many formerly with Unocal and Chevron, have worked on the largest geothermal exploration programs in the world.

Quality Control

The importance of high-quality testing services, including geochemical sampling analysis, has profound impacts on the ultimate interpretation of production well characteristics, geothermal reservoir processes and geochemistry. PT. Thermochem Indonesia is an ISO- and KAN-certified laboratory, and has the full technical support of the parent company, Thermochem, Inc. in the USA, offering the most advanced laboratories for geothermal fluid analysis in the world. Thermochem routinely participates in blind Round-Robin laboratory performance studies and is the top-performing lab in these studies (performance data available on request).

Safety

Thermochem has a Class A rating by the Chevron CHESM program, the highest possible safety score. Thermochem has a comprehensive safety program for its laboratory and field personnel including H₂S safety training and SCBA training. Thermochem maintains strict compliance with OSHA regulations and provides all employees with training in illness and injury prevention, chemical hygiene, emergency response, hazardous waste management, hazardous materials management, and fire safety. Thermochem has 30 years' experience handling and shipping hazardous materials. With extensive knowledge of USDOT, IMDG, and ICAO/IATA regulations, Thermochem has developed special packaging systems that are certified for aircraft shipment of corrosive materials, including noncondensable gas samples.

Resource Evaluation and Modeling

Thermochem geochemists, geologists and reservoir engineers have many decades experience in resource evaluation, conceptual modeling, geochemical process modeling and numerical simulations. Applications include exploration data analysis, resource feasibility evaluation, well test analysis, reservoir maintenance strategy, evolution of gas and corrosive fluids, decline predictions, and enhanced recovery through injection. Reservoir simulations are performed to design and interpret tracer tests for geothermal and enhanced oil recovery projects using both water and steam.

Thermochem has project management experience for large-scale interdisciplinary resource evaluation projects, including conceptual model construction, numerical model development, production forecast scenario simulations, and feasibility studies for power plant installations. Recent experience includes resource evaluations for the Ulubelu geothermal field operated by Pertamina Geothermal Energy in Indonesia, and the Kawerau field operated by Mighty River Power in New Zealand.

The major outcomes of the Ulubelu numerical reservoir simulation modeling highlighted critical field management issues, including injection strategy, make-up well targeting, long-term forecasts, and the feasibility of a binary bottoming cycle installation. The resource and power plant evaluations for Kawerau included a multi-disciplinary approach to understand injection declines for the 100 MW dual-flash facility. The root cause of injection declines was identified through detailed chemical evaluations of produced and injected brine and gas analyses, including formation minerals and deposited scale materials, reactive transport modeling, chemical process modeling, on-line TFT[®] measurements, production and injection Pressure-Temperature-Spinner (PTS) analysis, and the study of reservoir simulation results. After implementation of the recommendations by Thermochem, injection declines were reversed which saved Mighty River Power tens of millions of dollars in injection well workovers and make-up wells.

Research and Development

Thermochem has conducted research for the US Department of Energy (DOE) and California Energy Commission (CEC) for the development of improved power conversion and enhanced resource recovery technologies. These projects are conducted under grants issued directly to Thermochem and through collaboration with the National Energy Labs at Berkeley (LBL), Livermore (LLNL), Brookhaven (BNL), Idaho (INEEL), the National Renewable Energy Lab (NREL) in Colorado and Sandia National Lab (SNL) in New Mexico. These R&D projects include advanced steam purification technology for removal of corrosive vapors from superheated steam, testing of laser-based instrumentation for steam quality and purity, fouling mitigation for brine heat exchangers, evaluations of new polymer coatings for steel, high-temperature deep wellbore logging and fluid sampling tools, and vapor/liquid reservoir tracer research. Research projects have been also

been performed for the Japanese geothermal industry under the New Energy and Industrial Technology Development Organization (NEDO) and Electric Power Research Institute (EPRI).

Thermochem developed a two-phase on-line flow measurement technology (TFT®) for true mass flow rate measurement of steam and water phases for steam qualities from 1 to 99%. This on-line chemical tracer technology is the primary flow measurement technique used in geothermal energy fields around the world. Thermochem provides this measurement service, manufactures and sells the equipment, and has provided training and consultation to clients from Iceland to Indonesia for over 25 years.

Thermochem designs and builds low emissions, compact well test mufflers (LECM) that are fabricated from shipping containers. The LECM can be transported by standard trucking and ocean freight shipping lines worldwide and to very remote areas. An LECM can be designed for very high capacity, up to 1000 ton/h. The internal structures are heavily fortified with steel bracing, lined with steel plates and seal-welded to hold water. CFD-designed baffle plates help separate brine from steam in the lower container, while the upper steam stack is designed to enable droplet settling given the low steam velocity through the large cross-sectional area. Finally, commercial stainless steel mist elimination pads remove fine droplets and aerosols, resulting in very low brine carry-over up to high flow rates. Brine flow is measured with high-accuracy and wide turn-down using Magnetic liquid flowmeters in a drain piping manifold.

In deep wells drilled for geothermal, oil and gas, Thermochem has developed advanced downhole logging and fluid sampling tools. These tools can be used at temperatures over 350 °C to log pressure, temperature, velocity and fluid conductivity. Samples of steam, hydrocarbon, and water can be collected under single or multi-phase conditions. An integral high-accuracy calorimeter allows the collection of known quantities of steam and water under two-phase flow conditions. The PTS tools are field-convertible between Memory and surface Read-Out (SRO) type.

For the measurement of trace levels of moisture in steam, or traditional steam quality measurement, Thermochem has greatly improved on the conventional Ellison throttling calorimeter and the ASTM-type isokinetic steam sampling probe. Thermochem manufactures and sells an ultra-low heat loss calorimeter using vacuum Dewar technology, and a true isokinetic sampling probe that minimizes flow disturbances and impurity losses. This system is also available as an automatic on-line monitor for both quality and steam purity (SiO₂, Na and NCG). Laser-based quality measurement is currently under development.

Thermochem also builds custom laboratory instrumentation for gas and liquid chemical tracer analysis applications, including ultra-low level detection of reservoir tracers, and on-line flow and process monitoring tracers. Some of these instruments are also available in field portable versions.

Thermochem strives to find solutions to chemical process control problems without the use of toxic, hazardous or expensive specialty chemicals. Chemical processes developed by Thermochem include H₂S abatement for atmospheric steam and gas emissions without the use of peroxide, Dry Steam Scrubbing to remove HCl from superheated steam using dry packed beds of calcium carbonate, polishing treatment HCl in superheated steam using amine/oil mixtures which can be captured and recycled, benzene scrubbing from gas streams with high-pressure water, silica scale inhibition through pH-reduction by NCG injection and thermal quenching.

General Qualifications

The president of Thermochem, Paul von Hirtz, is the chairman of ASTM committee E44.15 which develops and standardizes chemical testing procedures and materials selection for the geothermal energy industry. The ASTM standard E 1675 (two-phase fluid sampling) was derived from internal Thermochem procedures developed over many years and published as an ASTM standard practice. New ASTM standards for steam purity and quality measurement are currently in progress. Mr. von Hirtz is an associate editor for the Geoscience journal *Geothermics*, and has served many years as a board member for the International Geothermal Association (IGA) and Geothermal Resource Council (GRC). Mr. von Hirtz and his staff have published over 100 technical papers related to the geothermal energy industry.

Thermochem currently employs 64 people, including highly qualified scientists with extensive energy project experience. Thermochem employs field testing personnel with experience in chemical testing services at well sites, drilling rigs, power plants and remote exploration areas. Thermochem maintains two analytical laboratories (USA and Indonesia) where samples from around the world are shipped for analysis. Both facilities provide a base for field testing activities, with storage of test equipment, instrumentation, TFT® apparatus and downhole tools. These facilities maintain temperature, pressure and flow calibration instrumentation.

The USA facility includes manufacturing and assembly capabilities for instrumentation and electronics. Mass flow controllers for gas, steam and liquid are used for primary flow calibration and testing of field equipment and on-line monitors. A steam generator facility is also maintained to provide saturated and superheated steam for calibration and testing. Precision machining and welding is performed off-site at specialty manufacturing companies. Design and drafting is performed on-site by mechanical engineers.

Thermochem also designs pressure vessels for geothermal and oil/gas well testing, certified by ASME and ABSA (Canadian) standards. These vessels are built by heavy-equipment fabrication shops in the USA and overseas as needed. The Low Emissions Container Mufflers (LECM) are designed by our mechanical engineers and fabricated by the same shops, located near major sea-ports to facilitate shipping to other countries on container ships.

Company Statistics

Year of Formation: 1983 (USA office)
1997 (Indonesia office)

Year of Incorporation: 1986 (USA office)
2000 (Indonesia office)

Officers/Stockholders: Paul von Hirtz
President Thermochem, Inc.; Commissioner PT. Thermochem Indonesia

Building Size: 19000 square feet (USA office)
8500 square feet (Indonesia offices)

Number of Employees: 64

Locations:

United States

3414 Regional Parkway
Santa Rosa, CA, 95403, USA
Phone: +1 (707) 575-1310
Fax: +1 (707) 575-7932

Indonesia

Bandung Office

Kompleks Cimareme Indah Blok A4 No. 14
Bandung 40552 Indonesia
Phone: +62 22 686-8110
Fax: +62 22 686-6999

Jakarta Office

Eighty Eight at Kasa Blanka Level 32 C
Jln.Casablanka Raya Kav 88, Jakarta Selatan 12870
Phone : +62 21 29820282
Fax : +62 21 29820283

Tarutung Office

Jl. Ir Mananti No 7
Komplek Graha Kartini Blok B
Tarutung – Tapanuli Utara 22416
Sumatera Utara

THERMOCHEM EXAMPLES OF RECENT PROJECT EXPERIENCE- WELL TESTING AND RESOURCE ASSESSMENT

Puna Geothermal Project, Hawaii, for Ormat

Designed, supervised and executed flow tests for wells KS-5, KS-6, KS-10 and KS-11 from 2002 to 2007. Responsible for H₂S abatement, noise control and brine aerosol emissions in a very environmentally and culturally sensitive area with residential neighborhoods near the test site. Conducted all flow rate measurements and geochemical sampling for high-pressure, high flow rate wells (25 bar, 500 ton/hr) that require careful control for safe testing.

Tolhuaca Geothermal Project, Chile, for GeoGlobal Energy

Designed and fabricated the flow test muffler (LECM) and the flow line piping system and supplied and all instrumentation for Wells Tol-3, Tol-4 and Tol-5. Supervised and executed flow tests in 2012 and responsible for H₂S emissions control to ensure worker safety, flow rate measurements and geochemical sampling.

Laguna Colorada Geothermal Project, Bolivia, for WestJec

Designed and fabricated the flow test muffler (LECM), the flow line piping system and supplied all instrumentation with data-loggers and solar power for Wells SM-1, SM-2, SM-3, SM-4 and SM-5 in 2013. Conducted flow rate measurements and geochemical sampling.

Montserrat Geothermal Project, for the Government of Montserrat

Designed, supervised and executed flow tests for wells MON-1 and MON-2 from 2013 to present. Supplied flow test data-logging instrumentation, conducted all flow rate measurements and geochemical sampling, and supervised well PTS logging.

Walker Ranch Geothermal Project, Idaho, USA, for AMG Bank

Designed, supervised and executed the flow test for well RRDP-10. Supplied flow test data-logging instrumentation, conducted flow rate measurements and geochemical sampling, and supervised PTS logging.

Kawerau Resource and Power Plant Evaluation Project, New Zealand, for Mighty River Power

Performed testing, analyzed process and geochemical data, identified causes for injection declines through geochemical and process modeling. Advised on instrumentation upgrades and modifications and created mitigation strategy that ultimately reversed effects of injection decline.

Sarulla Geothermal Project, Indonesia, for Halliburton / SOL

Designed and fabricated flow test mufflers (LECM), flow line piping system and supplied all instrumentation with data-loggers, including capillary tubing pressure equipment and instrumentation for monitoring wells, and SRO / memory PTS logging tools. Currently performing all well testing, TFT[®], geochemistry and well test data interpretation for up to 34 wells, plus Pilot Testing for power plant silica scale control.

Coso Geothermal Field Geochemistry Database and Resource Evaluation, US Navy GPO

Analyzed and upgraded the Coso geochemistry database for quality control parameters, including addition of Microsoft Access based data storage for quality control purposes. Performed a detailed analysis of the geochemical data from the field to understand injection breakthrough, production of injection-derived steam, and boiling processes in the reservoir. Developed partial boiling models for the field using noncondensable gas chemistry to understand the evolution of boiling in the Coso reservoir.

Ulubelu Conceptual and Numerical Modeling Study, for Pertamina Geothermal Energy

Analyzed the entire Ulubelu field geoscientific dataset for data quality and created a multi-disciplinary conceptual model using geological, geochemical, geophysical, and reservoir engineering data. Integrated conceptual model into a numerical reservoir model in order to create production forecasting scenarios to understand field response to changes in injection strategy, expanded production, and makeup well drilling strategy. Forecast scenarios and field chemistry data were used to evaluate the feasibility of a binary cycle unit installation.

Geochemical Well Testing, Consulting, and Resource Evaluation, Magma Nusantara Limited

Collected and analyzed comprehensive geochemical data for the Wayang Windu geothermal field in West Java, Indonesia. Constructed geochemical conceptual models and interpretation on reservoir structure and processes. (2006 – 2011)

Geochemical Well Testing, Consulting, and Resource Evaluation, for Pertamina

Collected and analyzed comprehensive geochemical data for the Lahendong geothermal field in North Sulawesi, Indonesia. Constructed geochemical conceptual models and interpretation on reservoir structure and processes. Additional contracts include the Ulubelu and Sibayak fields for well testing and consulting services. (2010 – current)

Numerical Model, Geophysics, and Well Targeting Peer Review, for Star Energy Geothermal Limited

Performed high level review of the Wayang Windu numerical models and well targeting program. Review included geological, reservoir engineering, and geophysical data. (2010 – 2013)

Resource Monitoring Programs for Salak and Darajat, for Chevron Geothermal Indonesia, Ltd.

Collected comprehensive geochemical data from production wells, reservoir tracer studies, power plant chemistry, and tracer flow testing. Constructed geochemical interpretations and historical trend analysis.