THE WORLDWIDE
BUSINESS FORMULA

Thermo-solar Salts

SQM is the largest producer of 100% natural nitrate salts of the world

SQM has a worldwide sales network which allows to cover the needs of each specific market in the globe

SQM owns mines and installations that allow production within the lowest possible CO2 emissions

SQM has access to abundant reserves of nitrate salts

POWERED BY ELEMENT Q SQM

SQM's Thermo-Solar Salts: The proven & reliable energy storage medium

An eco-friendly solution to your CSP plant

CSP* CONCENTRATED SOLAR POWER

SQM
THE WORLDWIDE BUSINESS FORMULA

SQM's

Thermo-solar Salts

ECO-FRIENDLY ADVANTAGES

Non-toxic

100% natural nitrate salts

Non-flammable

Highly refined, low content of impurities

High chemical stability

Virtually maintenance free

High specific heat

Produced with much **lower CO_2 emissions** and far less enviromental impact compared to synthetically produced salts

SQM's Thermo-solar salts:
The proven & reliable
Energy storage medium

SQM's Sodium nitrate & Potassium Nitrate

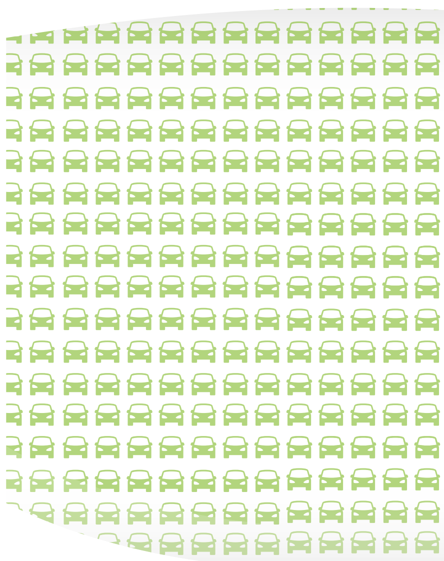
Annually, SQM produces around 1,5 million MT of sodium and potassium nitrate from Caliche Ore and Solar Brines, two natural resources found in northern Chile. Caliche is mined from surface deposits in the Atacama Desert; derived products including sodium nitrate and iodine. The salar brines are pumped from the underground in the Salar de Atacama (Atacam Salt Flat) after which they are transferred to large solar evaporation ponds to physically separate the desired elements. Main derived products are: lithium chloride, potassium chloride, magnesium chloride, boric acid and potassium sulphate. Nitrates are produced after the caliche mineral is crushed and exposed to a leaching process with water. Sodium nitrate is obtained from this leached solution by crystallization. Part of the obtained sodium nitrate goes through another stage of processing during which potassium chloride, from the Salar de Atacama is added. The mixture is then subject to other processes such as crystallization, refining and drying to yield potassium nitrate.

> *"Synthetic nitrate salts may increase life-cycle GHG emissions by 52% compared to mined salts"* [1]

Caliche Ore
Iodine Nitrates

Salar Brines
Potassium Lithium

$NaNO_3 + KCl = KNO_3 + NaCl$



SQM's potassium nitrate production process results in **20% to 40% less GHG emissions**, equivalent to removing up to **155 000 cars** from the highways each year

[1] John J. Burkhardt, III, Garvin A. Heath, and Craig S. Turchi. Life Cycle Assessment of a Parabolic Trough Concentrating Solar Power Plant and the Impacts of Key Design Alternatives, 2011.

PHYSICAL PROPERTIES

PHASE CHANGE PROPERTIES OF NITRATE SALTS

SQM's Molten Thermo-Solar Salts can be used over a temperature range of 260 °C (500 °F) to approximately 621 °C (1150 °F). As temperature decreases, the salts start to crystallize at 238 °C (460 °F) and solidify at 221 °C (430 °F).Heat of fusion (based on the average of heat of fusion of each component): hsl = 161 kJ/kg.- Change in density upon melting: ΔV/Vsolid = 4.6% => Vliquid = 1.046 Vsolid

Reference: A.V. Zavoico, SAND2001-2100 Solar Power Tower Design Basis Document - Courtesy of Sandia National Laboratories Albuquerque, New Mexico 87185 and Livermore, California 94550 - July 2001).For this specific application, Sodium Nitrate and Potassium Nitrate are mixed in 60%/40% by weight ratio. The mixture is stable in air and has a low vapour pressure.

Thermal and fluid properties of Molten Thermo-Solar Salts mixture (60% $NaNO_3$ + 40% KNO_3) as a function of temperature.

PHYSICAL PROPERTIES IN FUNCTION OF TEMPERATURE (°F - °C)

TEMP. (°f)	DENSITY (lb_m/ft^3)	SPECIFIC HEAT (btu/lb_m-f)	ABSOLUTE VISCOSITY (lb_m/t-hr)	THERMAL CONDUCTIVITY (btu/hr-t-f)	TEMP. (°C)	DENSITY (kg/m^3)	SPECIFIC HEAT (Joule/kg °C)	ABSOLUTE VISCOSITY (mPa-sec)	THERMAL CONDUCTIVITY (W/m-c)
500	120.10	0.356	10.506	0.285	260	1924.64	1488	4.343	0.492
550	118.98	0.358	8.607	0.288	288	1906.97	1492	3.558	0.498
600	117.87	0.359	7.085	0.291	316	1889.31	1497	2.929	0.503
650	116.76	0.360	5.894	0.294	343	1871.64	1502	2.436	0.508
700	115.65	0.361	4.987	0.297	371	1853.97	1507	2.062	0.514
750	114.54	0.362	4.320	0.300	399	1836.31	1512	1.786	0.519
800	113.43	0.363	3.845	0.303	427	1818.64	1516	1.589	0.524
850	112.32	0.364	3.518	0.307	454	1800.97	1521	1.454	0.529
900	111.21	0.366	3.291	0.310	482	1783.31	1526	1.361	0.535
950	110.10	0.367	3.121	0.313	510	1765.64	1531	1.290	0.540
1000	108.99	0.368	2.960	0.316	538	1747.97	1535	1.223	0.545
1050	107.88	0.369	2.762	0.319	566	1730.31	1540	1.142	0.550
1100	106.77	0.370	2.483	0.322	593	1712.64	1545	1.026	0.556

PROPERTIES OF FLUID SOLAR SALTS IN FUNCTION OF TEMPERATURE BETWEEN 300°C (570 °F) AND 600°C (1110 °F)

Density

ρ (lbm/ft³) = 131.2 - 0.02221 x T (°F)
ρ (kg/m³) = 2090 - 0.636 x T (°C)

Cp (Btu/lbm-F) = 0.345 + (2.28 x 10-5) x T (°F)
Cp (J/kg-°C) = 1443 + 0.172 x T (°C)

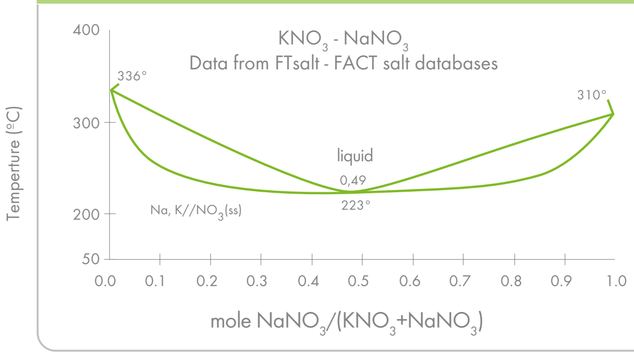
Thermal Conductivity

k (Btu/hr-ft-°F) = 0.253208 + 6.26984 x 10-5 x T (°F)
k (W/m-°C) = 0.443 + 1.9 x 10-4 x T (°C)

Absolute Viscosity

μ (lbm/ft-hr) = 60.28440 - 0.17236 x T (°F) + (1.76176 x 10-4) x (T (°F))2 – (6.11408 x 10-8) x (T (°F))
μ (mPa-sec) = 22.714 - 0.120 x T (°C) + 2.281 x 10-4 x (T (°C))2 – 1.474 x 10-7 x (T (°C))

PHASE DIAGRAM



PROPERTIES OF SOLID SALTS.

Absolute Density (ρ) at ambient temperature.

$NaNO_3$	2260 kg/m³
KNO_3	2190 kg/m³

Heat Capacitance (Cp) near the melting point.

$NaNO_3$	37.0 cal/°C-mol = 1820 J/kg - °C
KNO_3	28.0 cal/°C-mol = 1160 J/kg - °C

SPECIFICATIONS

SQM offers to the CSP industry high quality sodium nitrate and potassium nitrate grades to match the specific requirements of each CSP power plant developer.

CHEMICAL SPECIFICATIONS OVERVIEW					
PARAMETERS		UNITS		THERMO-SOLAR GRADE PRODUCTS	
				$NaNO_3$ Refined	KNO_3 Refined
Purity		%	min	99.5	99.6
Chlorine	Cl	%	max	0.08	0.10
			typical	0.05	0.05
Perchlorate	ClO_4	%	max	0.035	0.01
Magnesium	Mg	%	max	0.02	0.01
Nitrite	NO_2	%	max	0.02	0.02
Sulphate	SO_4	%	max	0.10	0.05
Carbonate	CO_3	%	max	0.10	0.02
Hydroxil	OH	%	max	0.05	0.05
Moisture (2)	H_2O	%	max	0.1	0.1

(1) The product does not contain other relevant sources of halogen compounds (iodide, bromide, iodate, bromate or any other).
(2) Moisture measured at SQM production site. Some absorption of moisture may occur during transportation.

Particle size guaranteed: 2mm. Insoluble particles between 0.85 mm and 2 mm represent typically less than 0.05% of the product.
Classification according to Regulation (EC) No 1272/2008 and the Globally Harmonized System of Classification and Labelling of Chemicals (GHS).
Potassium nitrate: Oxidising solid, category 3.
Sodium nitrate: Oxidising solid, category 3. Irritating to eyes, category 2.

Experience about **CORROSION**

The level of corrosion of SQM's Thermo-Solar Salts has been proven to be acceptable since the Nineties. In more recent measurements, Sandia National Laboratories (USA) has concluded that at 600°C bulk molten salt temperature, the average corrosion rate ranged less than 16,5 microns per year for 13 different alloys after 3000 hours of test with only one alloy exceeding 25 microns. Most industrial applications would label that as **excellent corrosion performance** (ref. SAND 2013-2526, March 2013).

RESULTS OF THE STUDY CONDUCTED BY SANDIA NATIONAL LABORATORIES (USA)			
ALLOY	ALLOY DENSITY [g/cm³]	DESCALED LOSS [mg/cm²]	METAL LOSS [µm/year]
321SS	7.94	4.59	15.9
347SS	8.03	2.59	10.4
253MA	7.8	10.31	38.6
HA556	8.23	5.9	20.8
RA330	8.22	4.8	16.2
S35140	7.96	2.4	8.8
332Mo	8.13	3.4	12.2
HR120	8.07	4.97	18
HR224	8º	2.27	8.3
HA230	8.97	7.25	23.6
HA214	8.05	1.56	5.7
In625	8.44	4.86	16.8
HA242	9.05	5.88	18.98

SQM's THERMO-SOLAR SALTS

PROVIDE CLEAN ENERGY TO EMBRACE AN ECO-FRIENDLY FUTURE

Most renewable energy technologies such as wind and PV suffer from a discontinuous energy supply and an unpredictable output due to altering weather conditions and/or energy demands. Concentrated solar power (CSP) plants, equipped with a Molten Salts Storage System, store excess heat and stay operational also during evening hours and cloudy days, which significantly increases their electricity output. The generated electricity from thermal storage is completely dispatchable: its power can be connected to the electrical grid at any time.

The economic value

OF THERMAL ENERGY STORAGE:

NREL (National Renewable Energy Laboratory) conducted a study that clearly demonstrates that it was economically equivalent to remunerate 5 US cents/kWh to a new PV plant and 10 US cents/kWh to a CSP plant with storage.

The result of the study incorporates these two values related to thermal storage:

Operational value

Represents the avoided costs of conventional generation at their respective dispatching along with related ancillary service costs, such as spinning reserve, etc. Savings on emission costs are also taken into account.

Capacity value

Reflects the ability to avoid the costs of building new conventional generation in response to growing energy demands or plants retirements

Thermal storage based on molten nitrate salts is stable for at least 30 years while the lifetime for batteries is shorter and rather uncertain.

And beyond CSP...

Thermal storage can be applied in other cases wherever thermal energy is used and not only in CSP plants. It can be implemented in industrial processes and even deployed for grid applications where the excess of electricity is converted to heat and stored in a solar salts thermal storage unit.

An environmentally friendly solution from SQM that optimizes the efficiency of your industry.

100 MW Xina Solar Plant.
Photo courtesy of Abengoa S.A.

50 MW Bokpoort Solar Plant.
Photo courtesy of Sener.

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Another SQM solution
for the Global challenges

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