



HTTES

High Temperature Thermal Energy Storage pilot- and test facilities in the enolcon/STORASOL-laboratory





The following slides provide an **overview** about the pilot- and test HTTES-facilities which have been built and operated by enolcon and STORASOL GmbH. With the exception of the large scale demonstration HTTES-plant at University Bayreuth all pilot plants are operated in the enolcon laboratory in Bietigheim-Bissingen (close to Stuttgart, Germany).

The pilot- and test plants are part of a structured R&D-program of enolcon for the development of the HTTES-technology.

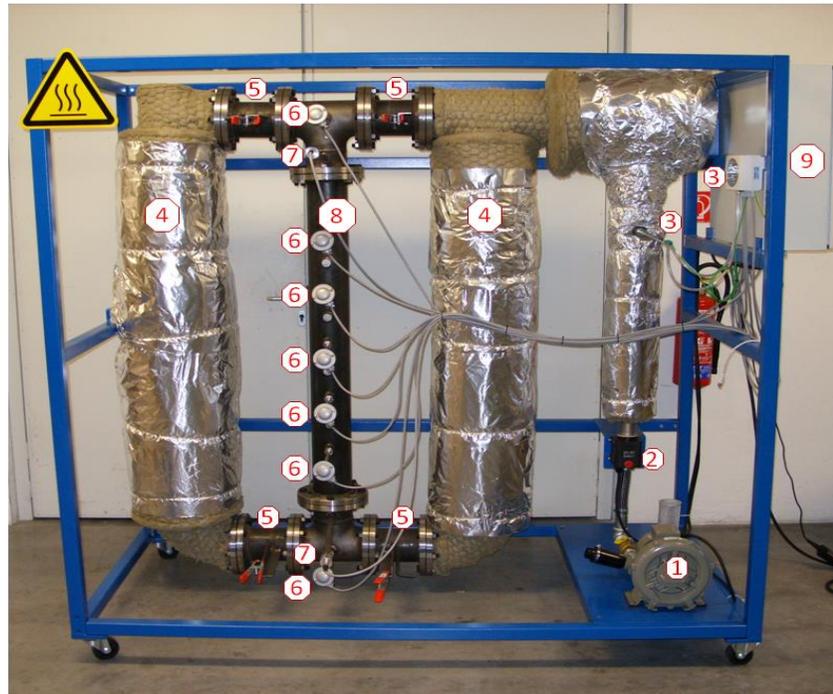
Beside these test plants many studies have been performed ranging from detailed behavior of the thermocline in a fixed bed to modelling of the charging- and discharging of HTTES-modules and are also covering the implementation into industrial- and power plant processes.

As result the **key design parameters** have been determined for the design of large scale HTTES-systems. These parameters have been applied in the large scale HTTES-demonstration plant at University Bayreuth (project name ORCTES).

Enolcon and STORASOL are now ready to offer large scale HTTES-systems on commercial basis. Beside the commercialization activities the improvement of the HTTES-technology is going on (design optimization, cost reductions etc.).



The pilot- and test plant TESS001 (year 2010/2011):



Test facility TESS001:

- 1: Seitenkanalverdichter
- 2: Luftheritzer
- 3: Staudrucksonde mit Temperaturkompensation
- 4: Luftkanal
- 5: Klappen
- 6: Thermoelemente
- 7: Drucksensoren
- 8: Reaktorrohr
- 9: Schaltschrank

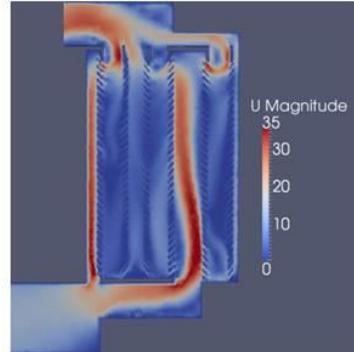
With the TESS001 first tests of sensible heat storage material took place. Verification of theoretical models with regard to charging- and discharging and thermocline behaviour. Also pressure loss measurements have been made and verified.



The air flow test plant (year 2011 and year 2012):

The air flow test plant consisted of:

- 1: Radialgebläse
- 2: Zulaufrohrleitung
- 3: Einlaufstrecke
- 4: Speichermaterial (Glaskügelchen)
- 5: Messöffnungen
- 6: Abströmhaube und Abströmrohr



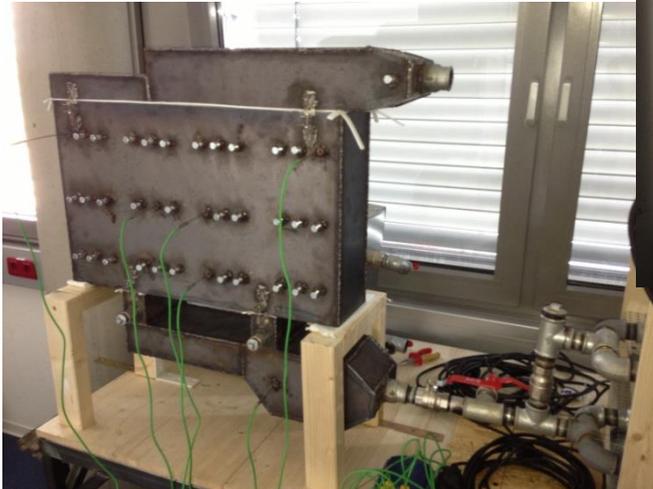
CFD-Strömungsberechnungen



With the air flow test plant know-how has been collected with regard to air flow through several storage material 'walls'. The results have been used for verification of calculation models.



The pilot- and test plant TESS002 A (year 2012):



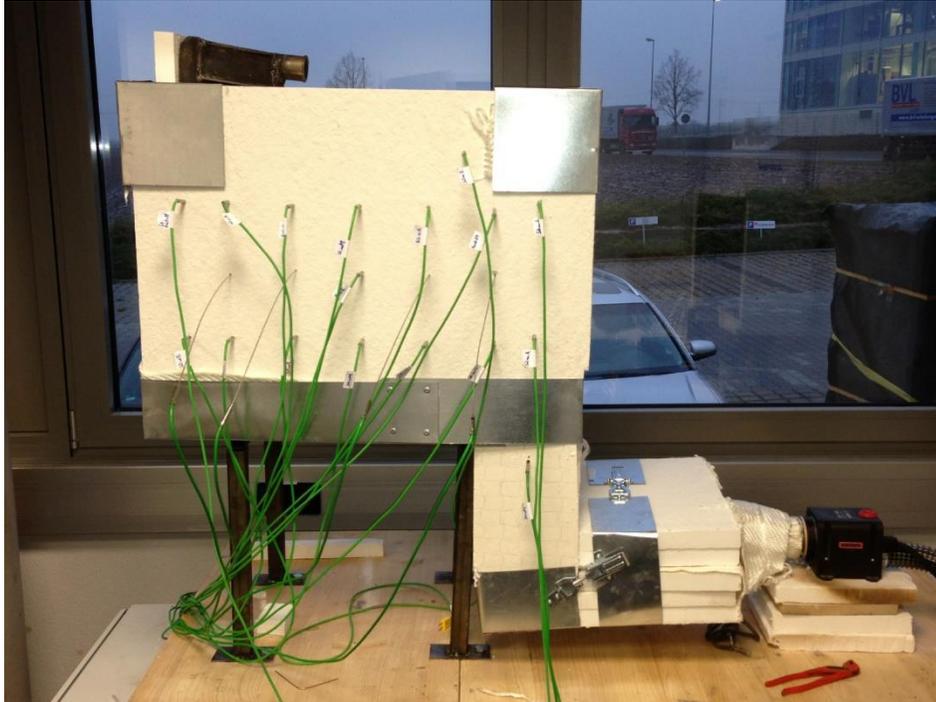
The test plant TESS002 A consist of:

- 1: Seitenkanalverdichter
- 2: Lufterhitzer
- 3: Luftkanal
- 4: 4 Speicherschichten zu je ca. 120 mm
- 5: Lamellenkonstruktion
- 6: Thermoelemente
- 7: Schaltschrank

The **TESS002 A** is already containing main elements of a large HTTES-module, such as several layers/storage material walls (4) where air is flowing through in parallel at the same time, stats/lamellas etc. and is operated at approx. 450 – 600°C. With the TESS002 knowledge and information has been built up about charging and discharging, and also different storage materials have been used.



The pilot- and test plant TESS002 B (year 2013 - 2014):



The test plant TESS002 B consists of:

- 1: Seitenkanalverdichter
- 2: Lufferhitzer
- 3: Luftkanal
- 4: 1 Speicherschicht 500 mm
- 5: Lamellenkonstruktion
- 6: Thermoelemente
- 7: Schaltschrank

The **TESS002 B** contains already main elements of a large scale HTTES (as the TESS002), but only one thick storage material wall/layer (500 mm) with stats/lamellas etc. and has been operated also at temperatures between 450 – 600°C.

The focus has been on the behaviour of the thermocline and discharging behaviour and different materials have been tested (especially silica sand).



The pilot- and test facility TESS002 C (year 2013 – 2017):



The test facility TESS002 C consist of:

- 1: Seitenkanalverdichter (größer)
- 2: Lufferhitzer 16 kW
- 3: Luftkanal (innenisoliert)
- 4: 1 Speicherschicht 400 mm, innenisoliert
- 5: Lamellenkonstruktion
- 6: Thermoelemente
- 7: Schaltschrank

TESS002 C is designed as *'fit for purpose'* in large scale HTTES-applications. The storage material wall/layer has a thickness of 400 mm and the operational temperatures are ranging up to 600 °C. TESS002 C is built with an inner isolation, allowing for cheaper and more simple steel qualities and thinner walls. TESS002 C is equipped with a much stronger air fan and electrical heater than the other TESS - test facilities, allowing operation in a broad spectrum of air mass flow and temperature, thus high thermal charging- and discharging capacities. A dense temperature measurement grid allows for detailed analysis of charging-/discharging behaviour and thermocline observations.



The pilot- and test facility TESS002 D (year 2017 and 2018):



TESS002 D: On request of an enolcon-client a thermal energy storage has been built for lower temperatures ($< 350^{\circ}\text{C}$) with a different arrangement of the storage material (also in the patents). A demonstration module has been sold to a client in Korea.



After the HTTES-technology development has achieved successfully the level to enter into large scale, the **STORASOL-HTTES** with more than $> 1,4 \text{ MWh}_{\text{th}}$ has been built as **demonstration plant** at University Bayreuth. It is successfully in operation since end of year 2015. Flexible charging and discharging power and temperatures up to max. 600°C are key design features. During discharging electricity is produced by an ORC-turbine (therefore project name ORCTES).

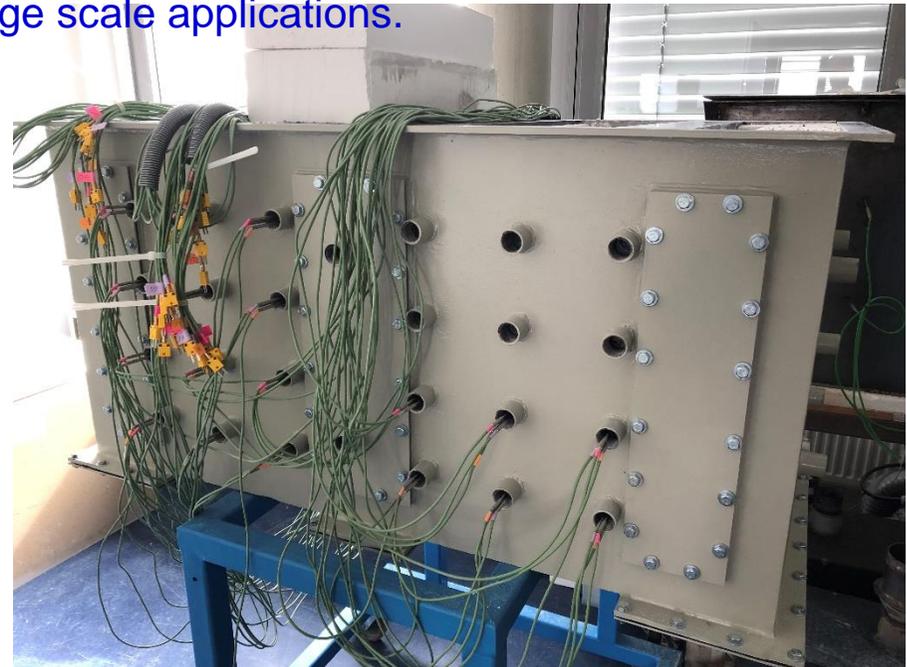




TESS003 A: This test plant is in the enolcon laboratory under preparation for planned tests. Commissioning is scheduled for end of Q3 2019.



The TESS003 A consists of two (2) storage material walls/layers, where each layer has a thickness of approx. 450 mm. It has all properties as in large scale HTTES and is used for tests of new promising storage material and also to determine and optimize design parameters for large scale applications.



Thank you very much for your attention!

STORASOL



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