Test facilities and initial results for the improved Enefit © technology for processing different oil shale types

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Agenda

• Investigation of Enefit280 key process units in Outotec’s existing pilot plants in Frankfurt/Germany
  – Combustion of semi-coke
  – Drying of oil shale in a venturi dryer

• Enefit bench scale plant for pyrolysis and oil winning
  – Flow sheet and key data
  – Results for Estonian oil shale, influence of heat carrier
  – Results for Jordanian oil shale

• Realization of a Enefit© demonstration plant for a capacity of 350 kg/h throughput of oil shale
New Enefit280 process
Key units of Enefit280 process investigated in Outotec’s and EOT’s pilot/bench scale plants

I. Oil shale drying with process offgas (venturi dryer)
II. Combustion of semi-coke in circulating fluidized bed (CFB)
III. Pyrolysis and Oil Winning
Key units of Enefit280 process investigated in Outotec‘s pilot and bench scale plants

• I. Oil Shale drying
  – Pilot venturi dryer was integrated in Outotec‘s existing 700 mm CFB pilot plant
  – Three day test campaign with combustion offgas and 650 kg/h oil shale feed (Estonian oil shale: < 6mm, 12% moisture)
  – Investigation of temperature, gas velocity, retention time on emissions (to meet EU environmental standards), residual moisture (~ 0%), grain size

• II. Semi-coke combustion
  – Two test campaigns in existing 700mm CFB pilot plant with Estonian semi-coke
  – Investigations: control of emissions, namely $\text{SO}_2$, CO, $\text{NO}_x$, TOC (EU standards)
  – Organic carbon burnout, carbonate decomposition
  – Particle breakage and abrasion, grain size of ash
  – Ash discharge distribution: bottom ash – flue ash

• III. Pyrolysis & oil winning – Enefit bench scale plant
  – Outotec and EE’s joint venture, Enefit Outotec Technologies (EOT), commissioned the Enefit bench scale plant at Outotec’s R&D center in Frankfurt in November 2010.
I. Oil Shale drying - results

- no CO emissions for venturi temperatures < 210°C
- CO emissions increase for venturi temperatures > 210°C
- venturi design temperature (160°C) is well below critical temperature
II. Semi-coke combustion – results

- **Test 1:** 790 °C, 400 kg/h semi-coke, **45 min** solids retention time
- **Test 2:** 755 °C, 400 kg/h semi-coke, **32 min** solids retention time
- **Test 3:** 790 °C, 600 kg/h semi-coke, **22 min** solids retention time
- lower carbonate decomposition degree at lower combustions temperatures and shorter retention times
- less flue ash at lower carbonate decompositions degrees
Enefit bench scale unit for the solid heat carrier process
Basic flow sheet

- Ash Preheating
  - FB reactor

- Ash (combusted oil shale from stock)

- Oil Shale

- Pyrolysis - Retort -

- Dust Chamber

- Dedusting

- Condensation I

- Condensation II

- Shale Oil
  - Heavy Fraction

- Shale Oil
  - Light Fraction

- Offgas

- Post combustion

- Gas sampling

- Semi-Coke

- Dust
Enefit bench scale unit for the solid heat carrier process

**Enefit® Bench Scale Plant**
- Designed by Enefit & Outotec
- Erected in Outotec's R&D center in Frankfurt/Main, Germany
- Operated by Enefit Outotec Technology
- Commissioned in November 2010
- Tests carried out with Estonian, Chinese and Jordanian oil shale

**Key data**
- Oil shale feed < 6mm: 4 – 12 kg/h
- Ash feed to preheater: 10 – 25 kg/h
- Ash temperature preheated: 700 – 800 ºC
- Pyrolysis temperature: 440 – 530 ºC
- Shale oil (dependent on yield): up to 2 l/h
Influence of Heat Carrier
Test run in bench scale unit with ash and quartz sand as heat carrier

- Heat carrier properties significantly influence oil quality at the same pyrolysis temperature and retention time
- Important to use the „right“ oil shale ash in order to investigate a specific oil shale
Influence of Heat Carrier
Test run in Enefit bench scale unit with ash and quartz sand as heat carrier

- Significant influence of heat carrier properties on semi coke gas composition
Results for Jordanian (Attarat) Oil Shale
Ultimate analysis and assay results

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<th>Sample: Oil shale Attarat #41/11</th>
<th>wt.-%</th>
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<tr>
<td>Cl</td>
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<tr>
<td>Oil yield (Fisher-Assay, 520 °C)</td>
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</tbody>
</table>

Assay-yields for Jordanian (Attarat) Oil Shale

- Yield @ 520 °C: 7.5 wt.-%
Results for Jordanian Oil Shale
Tests in Enefit bench scale unit

- Determine optimum pyrolysis temperature
- Slight decrease of yield at lower temperatures
- Strong decrease of yield at higher temperatures
Results for Jordanian Oil Shale
Enefit bench scale unit

Oil properties, summary

- Water content
  - 0.12 % centrifuge
  - 0.35 % decanted
- Ash content
  - 60 ppm
- Density@15 °C
  - 16 API°/ 960 kg/m³
- Viscosity@40 °C
  - 3.5 mm²/s
- TAN
  - 0.02 mg KOH/g
- Recovery@360 °C
  - 65 – 70 % (SIM-DEST !!)
- N+O content
  - ~ 2 %
- Sulphur
  - 8 – 10 %
Realisation of a Enefit© Demonstration Plant

- Outotec and EE’s joint venture, Enefit Outotec Technologies (EOT), concluded a contract on building a new oil winning demonstration plant at Outotec’s R&D center in Frankfurt.
- The Demo Plant will employ the solid heat carrier technology with a capacity of 350 kg/h throughput of oil shale.
- The Demo Plant will be built to test specific oil shales and their properties (yield, oil quality, solids behaviour and ash characteristics).
- Production of shale oil (approximately 4000 kg) for further oil quality investigations (up-grading tests).

![Diagram of the process cycle](image)
Enefit© Demonstration Plant
Integrated in Ouotec’s 700mm CFB Pilot Plant

- Combustion CFB Pilot Plant
- Pyrolysis
- Condensation unit

Flowchart:
- Oil Shale → Combustion CFB Pilot Plant → Ash
- Oil Shale → Pyrolysis → Ash
- Pyrolysis → VGM
- Pyrolysis → Semi-Coke
- Condensation unit → Shale Oil

Images of equipment and facility.
Conceptual arrangement for Enefit Demo Plant

General

- Connection to existing plant: Duct for hot recycle ash (solid heat carrier) from existing seal-pot of CFB cyclone to new retort
- Two-stage concept for the condensation unit; winning of a heavy and light oil fraction (similar to in Enefit Bench Scale Plant)
- Spent shale (semi-coke) will be fed to the CFB combustion reactor

Project status

- Basic process design completed considering local boundary conditions
- Arrangement design developed
- Possible suppliers/vendors have been contacted
- Various equipment cannot be bought from the market as standard solutions → own design
Summary

- Key process units of Enefit280 technology were investigated in Ouotec‘s and EOT’s pilot plants and test facilities.

- A bench scale unit with a capacity of 4 – 12 kg/h throughput of oil shale for the pyrolysis and oil winning has been developed and built by Enefit and Outotec‘s joint venture company.

- Various oil shale types have been tested in the Enefit bench scale plant - oil yield, quality and optimum process condition can be determined. Heat carrier properties significantly influence oil quality and semi coke gas composition.

- An Enefit© demonstration plant with a capacity of 350 kg/h throughput of oil shale is currently being developed for integration into Outotec‘s existing CFB pilot plant.

- Enefit © demonstration plant will enable the production of shale oil (approximately 4 t) for further up-grading tests.