tce

the chemical engineer

www.tcetoday.com
october 2007

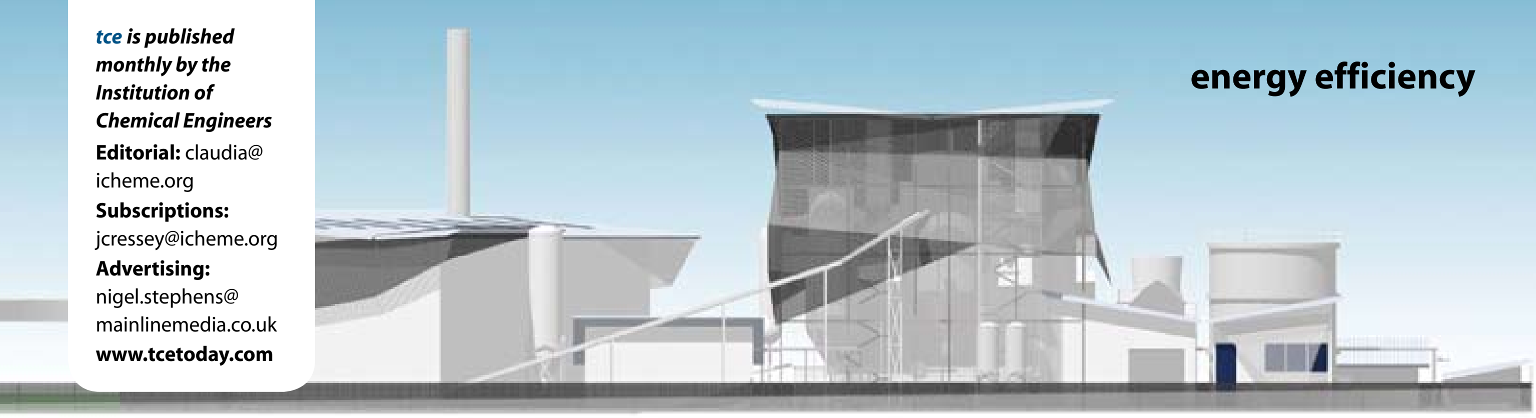
IChemE
Awards 2007
supplement
inside

green energy who will keep the lights on?

nuclear power public perceptions

biomass a plea for common sense

***tce* is published monthly by the Institution of Chemical Engineers**
Editorial: claudia@icheme.org
Subscriptions: jcressey@icheme.org
Advertising: nigel.stephens@mainlinemedia.co.uk
www.tcetoday.com



Reduce your energy use – sustainably

Steve Haywood explains plans for a waste-to-syngas facility in London

THE world has woken up to the challenge of climate change. In East London, UK, a project is being developed that will not only help the government reduce the UK's reliance on fossil fuels, but also reduce the quantities of household waste going to landfill: the sustainable energy facility.

Otto Simon, a process engineering company based near Stockport, UK, with a long history in cokemaking and plenty of experience with handling dirty product gas and recovering chemicals, has been involved with this project from the start. In addition to being part of the team responsible for obtaining both environmental and planning consents, it has had a significant role in the development of the process and engineering detail.

project background

The UK-based renewable energy company Novera Energy received planning permission for the new sustainable energy facility in September 2006. Based in the London borough of Havering, the facility will convert solid recovered fuel (SRF), manufactured from household residual waste (after recycling and composting), into a synthetic gas which will be used to generate over 10 MW of electricity. It is proposed that the electricity will be supplied to a neighbouring site of the Ford Motor Company or the national grid.

The site for the facility is currently used by Ford as part of its vehicle holding centre and lies on the northern bank of the river Thames. Approximately 100 m away is the Shanks East London bio-materials recovery facility (Bio-MRF) where residual household waste collected in the East London Waste Authority area is treated.

As well as obtaining planning permission, the facility has received IPPC (Integrated Pollution Prevention Control) authorisation.

technology

The facility uses a fluidised bed gasification process developed by the Canadian gasification specialist Enerkem Technologies, Novera Energy's exclusive technology partner for the UK.

The facility is designed to gasify 13 t/h of SRF and produce a total of approximately 13 MW of electricity. There will be a single-stream gasification and gas conditioning island plus a single-stream power generation island. Critical locations will have standby equipment as backup to ensure that plant availability targets are met.

material handling

The SRF used will mainly consist of small particles from biotreated biomass plus shredded paper and plastics. This will typically comprise pieces 100 mm x 100 mm x 3 mm, with a moisture content of 12–15% and a bulk density of approximately 150–200 kg/m^3. The SRF feed material typically contains:

Water	14%
Ash	20%
Biomass	50%
Plastics	16%
Chlorides	0.9%
Sulphur	0.6%

The SRF is mixed with dry hydrated powdered lime before entering the gasifier. Lime reacts with sulphur and chloride components in the gasifier to form calcium salts that will be removed in the gasifier solid residues (GSR).

gasification

Once the fluidised bed has been heated up to operational temperature and SRF fuel is introduced, the violent turbulent regime makes sure that the gasification reactions proceed in a controlled and responsive environment. The inert fluidised bed material acts as a thermal mass to transfer heat to the SRF.

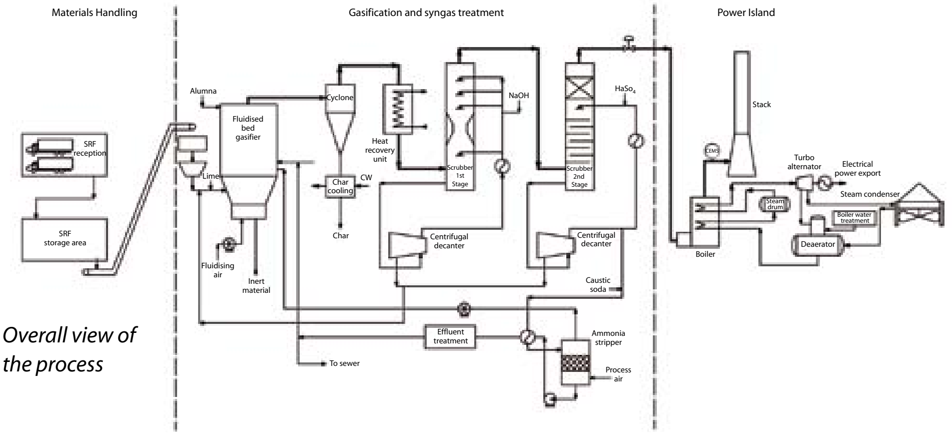
The residence time in the freeboard zone above the fluidised bed will be sufficient to ensure that all the gas-phase reactions reach completion. The essential reactions in the gasification process are:

- Thermal decomposition of the organic material producing reactive intermediates, carbon (char) and gases – mainly CO$_2$ and steam.
- Controlled cracking of the intermediates to yield low molecular weight volatiles hydrocarbons. A fraction of the hydrocarbons will be converted to aldehydes and alcohols by partial oxidation.
- Steam reforming of the cracked intermediates, yielding low molecular weight hydrocarbons – mainly methane and ethylene, as well as H$_2$, CO and CO$_2$.
- Steam and carbon react to H$_2$ and CO.
- Partial oxidation of intermediates and char occurs in the fluidised zone where the air is introduced. These oxidation reactions generate the heat to sustain the gasification.

The gasifier typically operates at 2 bar and at between 700 ºC and 760 ºC to produce the desired composition of synthetic gas. The intermediate compounds formed in the partial oxidation and cracking reactions, will be reformed and further cracked in the freeboard section of the reactor.

The resulting synthetic gas consists mainly of N$_2$ (55–60 vol%), CO$_2$ (13–15 vol%), CO (10–12 vol%), H$_2$ (6–10 vol%), light hydrocarbons (5–8 vol%), "tar" components (1 wt% of the feed) and particulate matter (char, <5% of carbon in the SRF "coating" the inerts).

Top: East elevation of the proposed plant at Havering



Overall view of the process

A proportion of the inert material present in the feed, the granular fraction of ash, accumulates in the fluidised bed, and is withdrawn continuously from the base of the gasifier. Finer particulate material (char) is entrained with the syngas stream and exits the gasifier reactor to be separated in the downstream gas cleaning processes.

Air and water/steam are essential reactants in the gasification process. They are added separately to optimise the temperature profile and gasification reactions.

Tars formed in the gasification process are condensed from the syngas in the gas treatment operation to form an emulsion with water condensate from the syngas. This emulsion, containing around 75% water and 25% tar/solids, is then re-injected into the gasifier as a source of water for the gasification process and to further convert the tar into gaseous components and carbon (coating the inerts).

syngas treatment

The syngas treatment section of the plant comprises cyclones for particulate material (ie the "char" as per the synthetic gas composition) removal, syngas cooling/heat recovery, and a two-stage wet scrubbing process.

Any chars contained in the syngas leaving the gasifier are removed in cyclones located immediately downstream of the gasifier. Fine particles not captured by the cyclones will be removed in the first stage of the wet scrubbing, and to a lesser extent in the second stage.

The syngas exiting the cyclones will contain particulates and tar. It flows through a heat recovery unit, cooling it to about 400 °C – still too hot for the tar to condense. The heat recovery unit is designed to use thermal fluid as the heat transfer medium which will transfer heat to the power island to improve overall thermal efficiency.

After the heat recovery unit, the syngas is adiabatically cooled to around 80 °C in the first stage of the gas scrubbing process.

The first stage scrubbing system incorporates a multi-stage spray column acting as a quencher and a venturi followed by a packed column acting as a demister. The syngas from the first stage scrubber flows into the second stage scrubber, which is operated at neutral pH. The second stage scrubber is a multistage absorbing column, which further cools the gas to 30 °C, and removes ammonia.

The sludge/emulsion formed in the scrubber circuits are separated and returned to the gasifier. Ammonia is separately stripped from the liquors and returned to the gasifier where it is converted into N_2 and H_2. The excess effluent is treated before discharge to sewer.

power generation

The cleaned synthetic gas from the gasifier passes to the power island where it generates 13 MWe of electricity, the majority going to export.

The synthetic gas is burned in a single-stream boiler plant to generate superheated steam. The concentration of pollutants in the flue gas will comply with the emission benchmarks required by the European Waste Incineration Directive.

The steam produced will then be used in a condensing steam turbine to generate electrical power. The exhaust steam from the turbine is condensed at a pressure of 0.1 bar in an air-cooled condenser unit, and returned, after dearation and preheating to the boiler plant to generate steam.

Practical experience is key

Throughout the development of this important project Otto Simon has been Novera's process design partner. This has involved applying significant practical engineering knowledge and thermal treatment experience in gasification, syngas treatment, gas cleaning, heat recovery/power generation and material handling to work together with Novera and its technology partner Enerkem to develop the project. Some key activities over the last 2.5 years include:

- Technical input to IPPC.
- Process/technical assistance for planning application.
- Development of layout and engineering drawings.
- Assist and work together with Enerkem to develop and value engineer the project.
- Development and optimisation of material handling and heat recovery/power generation.
- Development of specifications and project estimate.

John Howson, Novera's project director for the East London project, says that Otto Simon's practical experience in thermal treatment and gasification was key to its involvement: "Their engineers have significant 'hands on' knowledge for all aspects of the process while their background in coke oven syngas treatment puts them in a unique position to help overcome some of the traditional problems of waste gasification," he says.

current status

At the time of writing, Novera Energy is in the process of finalising the construction philosophy and obtaining project finance. The current timetable anticipates that this prestigious project will be processing solid recovered fuel and generating electricity during 2009.

the future

The future for the Enerkem technology and Novera looks very bright indeed. Enerkem has several very interesting projects in North America and has already developed the process to use the syngas for its chemical value by converting it to methanol and the next generation of clean fuels. While in the UK, the next obvious step for Novera is to improve the overall thermal efficiency even further by directly producing electricity in a gas engine or gas turbine.

In fact, these options highlight some of the key advantages of the Enerkem process. The majority of gasification processes burn the gas before cleaning but the Enerkem process is true gasification because the gas is cleaned in its raw state. This improves thermal efficiency or enables the chemical value of the syngas to be utilised, and will become increasingly important as pressure increases to reduce CO_2 and reliance on fossil fuels. **tce**

Steve Haywood (shaywood@ottosimon.co.uk) is managing director of Otto Simon