Leaps of innovation

Two new chemical manufacturing processes developed by BP (and both recently becoming award winners) are at the heart of a restructuring of the company's UK chemicals business. *Michael Johnson* learns more

The redeployment of BP Chemicals' manufacturing capacity around Europe at fewer and more efficient sites in the 1990s sounded like trouble for some product areas. Uncertain futures loomed for vinyl acetate and ethyl acetate production as their facilities at Baglan Bay in the UK and the Italian sites of Porto Maghera and Priollo were targeted for closure.

Aidan Hurley, process technology manager for vinyl acetate monomer (VAM) production, based in the UK at Hull, recalls: 'We had three choices: justify staying put, move to one of the advantaged sites, or exit the business.'

Staying in Baglan Bay in South Wales was not a real option because the site was scheduled for eventual shutdown. But moving to BP's chemical complex at Saltend near Hull in the north of England implied heavy investment in new plant – too costly if a manufacturing facility were to be built based on a traditional fixed bed reactor for the VAM chemical process. And the exit route was the least attractive of all.

At the same time, the orders from senior management in BP Chemicals were clear: ‘No repeats in technology.’ This meant that any facilities being rebuilt would have to incorporate improved processes.

Both Hurley and David Flatley, process technology manager for ethyl acetate (ETAC), looked at their options. They soon came to the same conclusion: ramp up development of new technologies they already had under way, and demonstrate that state-of-the-art facilities in Hull – where they could find the required feedstocks plus competitively-priced power and heat from the new on-site combined cycle gas turbine power station owned by the Saltend Cogeneration Company – would make economic sense. But it was not to be an easy task.

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The two chemical products serve related markets. VAM, which is in the company’s acetyls business unit, is essential to emulsion-based paints, wallpaper paste and wood glue. ETAC is in the solvents and industrial chemicals unit, and is used in surface coatings, inks and pharmaceuticals.

To achieve today’s end result of two sophisticated full-scale operating chemical processes demanded seven years of highly focused effort. To the outside world, a time scale of seven years from the first glimmer of an idea to commercial production may seem extensive. But developing new chemical manufacturing processes and taking them to full commercial operation is a step-wise procedure involving many interlinking stages, one of these being a demonstration plant, to check that the process works at large scale. Ensuring that the very large capital sums required for a new manufacturing plant are being invested wisely is critical – many new processes in the chemical industry take 10-15 years to bring to fruition.

Baglan Bay’s conventional VAM facility used a fixed bed reaction process, as do all other VAM plants worldwide, to bring together the three feedstocks required to make VAM – acetic acid, ethylene and oxygen. In the late 1980s BP Chemicals was already looking to the future and had developed a new fixed bed catalyst, incorporating this into a proprietary fixed bed process design for a joint venture plant in Ulsan, Korea. But the cost of building such a VAM plant in the higher-cost environment of Europe did not generate investment economics attractive enough to compete with other BP projects.

Consequently the team called on a wide range of resources to work on developing the VAM fluidised bed route as a more cost-effective solution. The savings in the new process – branded as Leap technology – come from process simplification and intensification made possible by the use of a fluidised bed process, requiring only a single reactor compared with the two reactors usually needed by fixed bed processes. The research and development work was based in Hull but drew on expertise from BP Chemicals in the USA, Sunbury in the UK, and Lavéra in France, with significant input from BP’s acrylonitrile and polyethylene businesses.

Hull proved to be the optimum location for the commercial-scale plant. Acetic acid was already produced there, an ethylene supply pipeline from Teesside was approved for construction, and industrial gas specialist Air Products was brought in to build an air separation unit to produce the oxygen.

‘We were determined to access the right skills wherever they existed in the BP group and not try to recreate them at one research centre,’ says Hurley. ‘We reached out not only to chemical stream technologists but also to downstream fluid catalytic cracker experts. I’m not proud – I’m an engineer and I hate reinventing wheels. It was a great feeling to be able to tap into the depth of resources in our company.’

Fluid solution

What provided the breakthrough for Leap was progress in two areas: fluidised bed technology, led by engineering technology manager David Newton, based in Sunbury, and work on a new precious metals catalyst.

In a fixed bed reactor, the catalyst which promotes the reaction is in the form of spheres which are packed into tubes. The reaction gases pass through the tubes and around the catalyst particles in the spaces between the spheres without moving them. In a fluidised bed reactor the catalyst is in the form of a fine powder, similar to talcum powder, and as the reaction gases flow upwards through the reactor they blow the fine catalyst around, rather like the balls in a bingo blower. This gives much better mixing and contact between the gases and the catalyst, improving heat transfer and allowing the catalyst to be removed and replenished without having to shut down the reactor.

While fluidised beds are cheaper and easier to build, they are difficult to scale up from laboratory tests. In the case of VAM, Newton employed X-ray imaging

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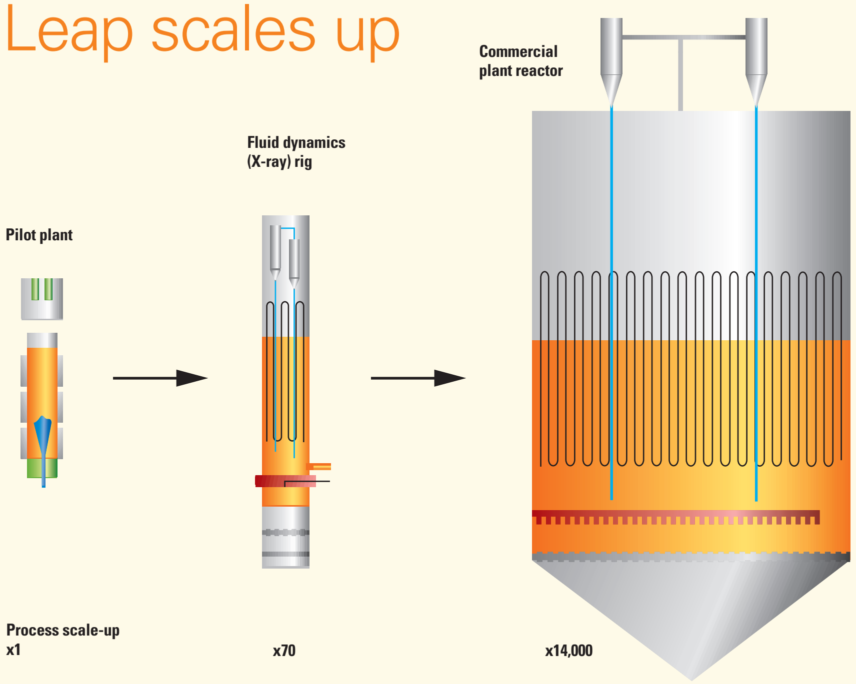
Award-winning processes

BP’s VAM plant (below) at Hull uses the new Leap process, while its ETAC plant (right) uses the Avada process

In June, the Leap and Avada processes were acknowledged by the industry with two prestigious awards in the highly competitive 2002 Institution of Chemical Engineers Awards programme in the UK. Leap won the AspenTech Award for Business Innovation, given for a new process, design technology, or way of working which generates significant business value. Avada netted the AstraZeneca Award for Excellence in Green Chemistry and Engineering – new this year – presented for the best development, design and use of a new process, showing an interdisciplinary approach, which is robust and viable while minimising or eliminating pollution at source and risk to health and the environment.

Leap scales up



One key to the successful development of the Leap process lay in the innovative scale-up method used by BP. Rather than build a demonstration plant as the intermediate stage – adding up to $30 million in cost and four years to the project cycle – X-ray imaging was used to evaluate fluid dynamics in the process. The X-ray investigation was carried out in BP's VIPA (visualisation, imaging and process analysis) centre, believed to be unique in its ability to evaluate large-scale processes.

>> in BP's unique VIPA (visualisation, imaging and process analysis) centre – previously at Sunbury and now at Hull – to view and understand the fluid dynamics of a commercial-scale reactor. Fluid dynamics are affected by the reactor's geometry and the internal equipment such as cooling coils and baffles. Optimising the process scale-up required meticulous, frame-by-frame inspection of the X-ray video.

Without X-ray data, a $20-30 million demonstration plant would have been necessary, along with another three to four years of development experience before attempting the commercial stage.

Moving from a fixed to fluidised operation also required a new catalyst. The VAM catalyst development programme employed a virtual-team approach, with BP technologists in Hull and Sunbury in the UK, and Warrensville (and later in Naperville) in the USA, working on different aspects of catalyst screening, preparation and testing. By exchanging results electronically, with email and audio/video conferencing, the team selected promising catalyst formulations and prepared them in fluidised bed form for testing at larger scale. Having selected the preferred catalyst – a gold/palladium mix in the form of very fine spheres, so minuscule that they seem to flow almost as a liquid – the next step was to scale up the catalyst preparation to commercial batch size.

In collaboration with leading catalyst manufacturer Johnson Matthey, BP technologists worked out new techniques to prepare the catalyst at commercial scale and control the location of the active metals in the support material.

A small pilot plant for the Leap technology made clear the viability of the chemistry, but to put the chemistry and the large-scale process dynamics together, the team relied solely on a computer model. This meant directly scaling up by a size factor of 14,000 without intermediate stages of expansion. 'We put our faith in the modelling techniques and our ability to manipulate and understand the data,' Hurley notes.

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The first time the full process was put to the test was when the plant was started up at the end of 2001, and naturally tensions ran high. 'Nobody actually knew what would happen,' says Hurley. Monitoring data on six screens, including a wall-sized display, the team held its breath. 'We added the oxygen, watched the temperatures rise, and within two hours we were making on-specification vinyl acetate and moving it into bulk storage.'

The decision to go to a fluidised bed process had saved 30% in capital costs. 'This helped turn a difficult decision into an easier one,' he adds.

The plant, the world's first fluidised bed process for VAM, is rated at an annual capacity of 250,000 tonnes, and output volume can be boosted further in line with market penetration. Research work has continued, and options for further capacity increases are being developed. With over 80% of today's VAM plants being more than 20 years old, the Leap competitive edge will increase as other VAM producers face similar decisions on investing in new plant, based on costly fixed bed facilities.

Eliminating ethanol

Separately, David Flatley's team also came up with a new solution for ETAC production, trademarked Avada (for AdVanced Acetates by Direct Addition). The new technology converts ethylene and acetic acid gases directly into ETAC using a heteropolyacid (HPA) catalyst, without the usual intermediate stage of esterification – this would have required another feedstock chemical, ethanol.

'By avoiding the need to build new ethanol facilities, costs were kept down,' Flatley points out. 'The resultant technology represents a significant advance in chemistry terms, a true step change.'

The Avada plant was constructed under such time pressure that the commercial engineering design was carried out in parallel with the commissioning of a fully integrated pilot plant at BP's Hull research centre. The design was then modified in real time as experience from the pilot plant was logged.

Flatley says the ETAC development work was also widely collaborative like that on the VAM project, calling on chemists, chemical engineers, process developers, catalyst manufacturers and research departments in several universities, particularly the Leverhulme centre of Liverpool University in the UK and Waterloo University in Canada.

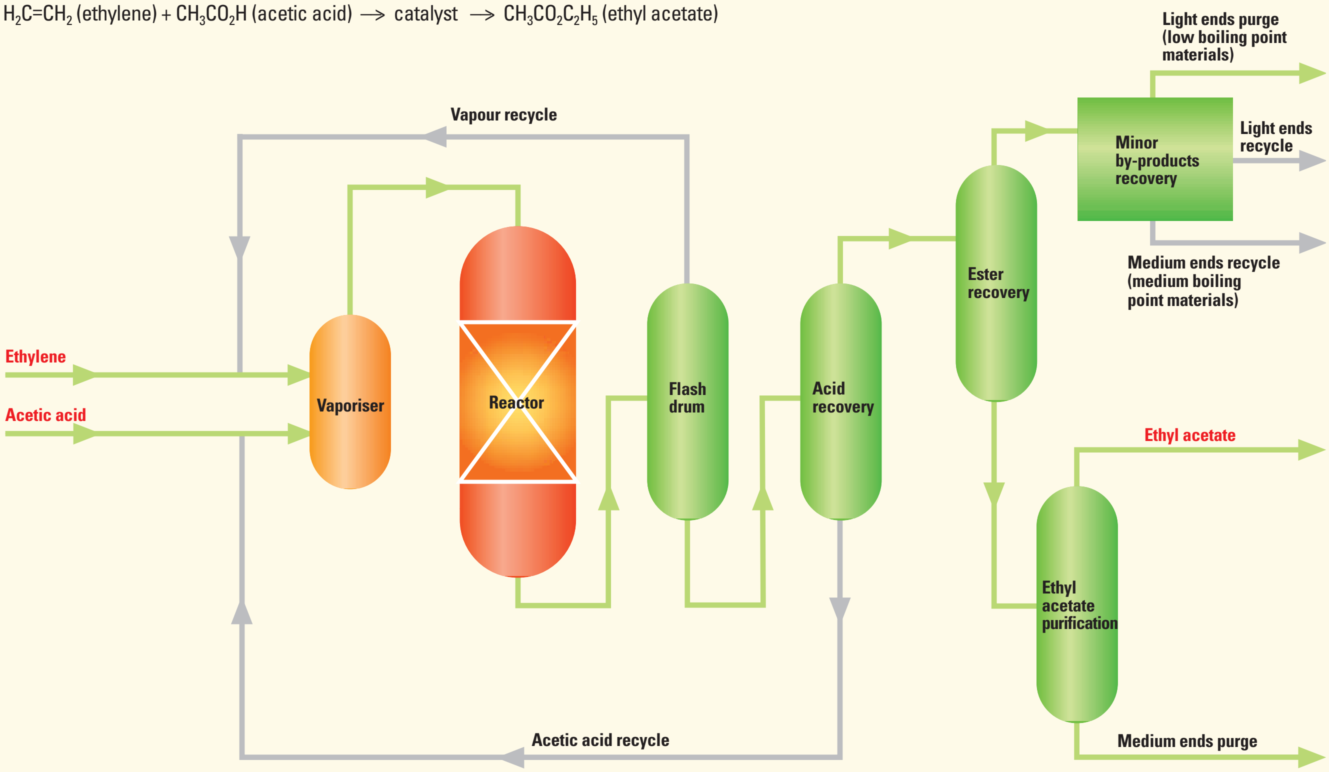
Long life catalyst

Interestingly, the chemistry of using HPAs for this type of reaction was well known but had

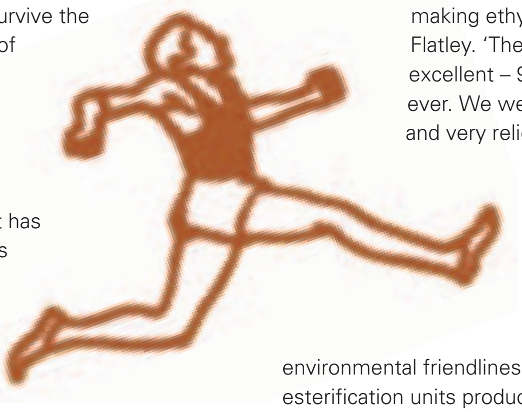
BP's new Avada process

Avada enables ethylene and acetic acid to be combined directly using a hetero polyacid catalyst, to produce ethyl acetate without an intermediate esterification stage. The reaction is:

$H_2C{=}CH_2$ (ethylene) + CH_3CO_2H (acetic acid) ⟶ catalyst ⟶ $CH_3CO_2C_2H_5$ (ethyl acetate)



never been successfully commercialised. The problem had always been catalyst lifetime, which suffered rapid ageing and loss of activity. The new Avada catalyst consists of a bed of silica beads, in the surface pores of which sits the HPA liquor. The HPA itself is an optimal balance of low-volatility silico-tungstic acid, known as a superacid, which in combination with the ideal silica bead produces long-term activity. The low volatility of the HPA helps the catalyst survive the reactor's extremes of heat and pressure, thus allowing long periods of uninterrupted operation for the plant. The Hull plant has achieved continuous sustained operation during its first year in commercial production.



Along the road to operation, the Avada team introduced several improvements and innovations, including a method for reducing the reactor's pressure drop and thus saving on gas recompression costs, and improving the energy efficiency of the process.

The start-up was as dramatic as that of the Leap team but stretched over two weeks while the control system on the ethylene feed and a few other teething problems were resolved. But on a warm afternoon in June 2001 the plant went live, and the team monitored its progress.

'When we saw the temperature gains across the beds, we knew we were making ethyl acetate,' recounts Flatley. 'The purity was excellent – 99.98%, the best ever. We were very emotional and very relieved. Also enormously pleased and proud.'

The Avada process also beats conventional processes in environmental friendliness. Traditional esterification units produce as much water as ethyl acetate and therefore require treatment and disposal of aqueous effluent. The other main technology in the market, Tischenko condensation, uses an acetaldehyde feedstock. This is less efficient than producing ETAC directly from a modern ethylene cracker, and Tischenko also produces waste streams from the aluminium salts used as catalyst.

Already the world leader in ETAC production, BP Chemicals will now extend its lead with the high efficiency Avada plant, designed to produce 220,000 tonnes per year, making it some 50% larger than its nearest competitor, Japan's Showa-Denko plant. In the first ten months of operation the plant at Hull produced around 100,000 tonnes of ETAC. At full capacity it will produce about two-and-a-half times as much ETAC as does conventional technology, measured in tonnes produced per operating employee. Compared to conventional processes, energy savings are about 20% lower and feedstock losses some 35% less. The technology is potentially interesting for other acid-catalysed processes such as the manufacturing of fuels, detergents and lubricants.

BP expects that the superior performance of its new Leap and Avada plants will begin to distinguish the company's technology in the market-place even more as older chemical manufacturing facilities reach the end of their days. ■

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