Technology leadership in phenol hydrogenation to cyclohexanone/KA-oil

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versalis route to Caprolactam

**Conventional route**
- Benzene → Hydrogenation → Cyclohexane → Oxidation Dehydrogenation → Cyclohexanone → Oximation

**versalis route**
- Phenol → Vapour Hydrogenation → Cyclohexanone → Ammoximation → Cyclohexanone Oxime → Beckmann Rearrangement & purification → Caprolactam

- KA-oil (option)
versalis Cyclohexanone/KA-oil experience

Over 50 years of cyclohexanone/KA-oil production experience
Over 25 years of cyclohexanone/KA-oil plant design experience

Development
- Start-up

Technology Bayer
- Phenol hydrogenation (Ni catalyst) + cy-olo dehydrogenation (Zn/Fe)

Capacity
- 10 kty

Development
- New technology

Technology Proprietary
- Phenol hydrogenation
  Flexible technology for co-production of cy-one and cy-olo + KA-oil

Capacity
- 150kty

Development
- Revamping

Technology Proprietary
- Phenol hydrogenation

Capacity
- 250 kty

Development
- Revamping

Technology Proprietary
- Phenol hydrogenation

Capacity
- 150 kty

Development
- Revamping

Technology Proprietary
- Phenol hydrogenation

Capacity
- 195kty

Development
- Revamping

Technology Proprietary
- Phenol hydrogenation

Capacity
- 270kty
### Technology: Vapor phase phenol selective hydrogenation

- (Pd or Ni based catalysts)

### Main advantages compared to cyclohexane oxidation technology:

- Higher purity of cyclohexanone product up to 99.97% wt
- Higher purity of KA-oil product up to 99.96% wt
- Great flexibility of product mix without the need to implement the dehydrogenation step (cy-one/cy-ol and KA-oil if required)
- Effective recovery of reaction heat as low pressure steam (internally consumed)
- Low hydrogen consumption
- Mild operating conditions
- Long catalyst life
- Simpler distillation and reaction scheme
- Reliable and safe operation (on-stream factor higher than 99%)
- Lower Capex (1/3 compared to conventional cyclohexane oxidation technology)
- Lower Cash cost (15-20 % less compared to conventional cyclohexane oxidation technology)
An additional column can be considered if the co-production of KA-oil is required.
Summary

- Versalis can offer an unrivalled technology in terms of product quality, production cost, reliability and industrial proven experience.

- Versalis selective phenol hydrogenation technology can be applied for the production of cyclohexanone and/or KA-oil.

- Cyclohexanone content in KA-oil can be fixed at the desired figure without any need of implementing the dehydrogenation step.

- Versalis selective phenol hydrogenation technology has much better Opex, Capex and product quality compared to the conventional cyclohexanone technology based on cyclohexane oxidation.