INEOS TECHNOLOGIES

EDC OXYCHLORINATION CATALYSTS

Vinyl India 2015

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Ineos Technologies website

Follow us on:
INEOS Technologies Vinyls – Solutions to the Vinyls Industry.

We develop and license worldwide our EDC / VCM & PVC technologies.

- INEOS: 3rd largest Vinyls producer.
- 70+ yrs experience in the Vinyls sector
- Worldwide scale PVC & EDC pilot plants.
- Multi-million tons operating Globally under INEOS Licenses.
- We provide lifetime services to our Customers.
Our target is to Add Value for our Customers.

- Develop innovative additives for PVC & catalysts for Oxychlorination.
- Optimise clients operating / process conditions.
- Develop optimised PVC recipe.
- **Dedicated** Customer support:
  - Application trial.
  - Additive / catalyst testing.
  - Process development.
  - Customer Specific studies / trainings.

INEOS Technologies Vinyls – Solutions to the Vinyls Industry.
The Balanced EDC/VCM Production Process

\[ \text{C}_2\text{H}_4 + 0.5 \text{O}_2 + 2 \text{HCl} \rightarrow \text{C}_2\text{H}_4\text{Cl}_2 + \text{H}_2\text{O} \]

\[ 2 \text{C}_2\text{H}_4\text{Cl}_2 \rightarrow 2 \text{C}_2\text{H}_3\text{Cl} + 2 \text{HCl} \]

\[ \text{C}_2\text{H}_4 + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_4\text{Cl}_2 \]

 FIXED & FLUID BED

 HTC & LTC
WHERE INEOS CATALYST IN THE WORLD (PAST and PRESENT)

- Fixed Bed
- Fluid Bed
- INEOS Fixed Bed
- INEOS Fluid Bed (before SOLVIN – INEOS JV)
Our EDC/VCM R&D team is located near Venice, Italy:

- Research & development of new Oxychlorination Catalytic systems (fluid and fixed bed) and related pilot testing
- Catalyst Production Control and Catalyst Quality Control
- Technical support for Customers (world-wide) and INEOS production plants (UK, Germany, Norway, Sweden)
- Optimization of Technologies and Processes for Oxychlorination
Fluid Bed Oxy Pilot Plant

Features

- 4m Oxychlorination reactor (Nickel 200), condensation system, on-line vent gas analyser and vent gas treatment

- Mass balance:
  Vent gas, Acidity, EDC purity
Fixed Bed Oxy Pilot Plant

Features

- Two reactors
- On line vent gas analysis, off line analysis of EDC and water
- Fully automised under DCS control
R&D Catalysts: Oxychlorination Technologies

HCl Conversion
C₂H₄ Selectivity to EDC
Pressure Drop
Catalysts Life

HCl Conversion (C₂H₄ conversion – Air)
C₂H₄ Selectivity to EDC
Fluid Dynamic behavior - Sticking
Catalysts Losses

Ethylene
HCl, Oxygen

Steam
Boiling Water

EDC & By-Products

EDC + by-products

Ethylene HCl
air/oxygen

TIC
Catalyst

RC
INEOS OXYCHLORINATION FIXED BED CATALYSTS AND DILUENT

IVOCL – P CATALYSTS:
P1D – P2 - P3 - P3P (NEW)
P1DT – P2T – P3T

IVOD-1 STANDARD DILUENT

IVOD-2F HIGH PERFORMANCE DILUENT
Fixed Bed oxychlorination catalysts Key Factors:
INEOS catalysts CAN BE SUPPLIED ALREADY MIXED

MIXING HAS TO BE OPTIMIZE TO MAXIMISE HOMOGENEITY

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Fixed Bed oxychlorination catalysts Key Factors:
INEOS catalysts CAN BE SUPPLIED ALREADY MIXED

Simulation of a 1st reactor (O2 Technology)
TEMPERATURE PROFILE

NOT HOMOGENEOUS MIXING

DIFFERENT CONDITIONS IN DIFFERENT TUBES
Fixed Bed oxychlorination catalysts Key Factors:
INEOS catalysts CAN BE SUPPLIED ALREADY MIXED

• Mixing is an important step to ensure homogeneity of activity and then good performance in terms of catalysts life and selectivity.

• INEOS has optimized the production of mixed materials (CATALYST – IVOD-1/IVOD-2F) than can be loaded as they are directly in the reactor
Fixed Bed oxychlorination catalysts Key Factors:

PRESSURE DROP

Second Reactor Pressure Drop

<table>
<thead>
<tr>
<th>Reactor's Pressure Drop</th>
<th>% capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%</td>
<td>70%</td>
</tr>
<tr>
<td>80%</td>
<td>90%</td>
</tr>
<tr>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

INEOS CATALYSTS 5x5 mm standard Catalyst

UP TO 20% REDUCTION

LOW PRESSURE DROP  HIGH CAPACITY
The new high performance IVOD-2F diluent:

- **Low dP for High Capacity Plant**
- **Higher reactor homogeneity for better performance at hardened conditions**
Fixed Bed oxychlorination catalysts Key Factors:

**CATALYST LIFE**

**LOW FOULING RATE**
**LOW COKE PRODUCTION RATE**

**LONG CATALYST LIFE**
Fixed Bed oxychlorination catalysts Key Factors:

- **CATALYST LIFE**

**LOW FOULING RATES**

and

**LONG STABLE ACTIVITY**

**HIGH CAPACITY FOR LONGER TIME**

**HIGHER FLEXIBILITY TO BUSINESS REQUIREMENTS**

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### Reactor's Pressure Drop

- **CASE B**
- **CASE A**

Three years run without change catalysts

### Catalyst's Activity

- **Steam to O2 ratio**
- **Reactor outlet temperature**

Three years run without change catalysts

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**INEOS Technologies**
Fixed Bed oxychlorination catalysts Key Factors:

ACTIVITY AND SELECTIVITY

- QUALITY OF RAW MATERIAL: HIGH PURITY ALUMINAS
- CHEMICAL COMPOSITION: COPPER – ADDITIVE
- SURFACE AREA AND PORE VOLUME – DISTRIBUTION OF ACTIVE SITES
Fixed Bed oxychlorination catalysts Key Factors:

ACTIVITY AND SELECTIVITY

INEOS CATALYSTS - PILOT PLANT RESULTS

HCl Conversion
% Ethylene to COx

OLD GENERATION  NEW GENERATION
Fixed Bed oxychlorination catalysts Key Factors:
ACTIVITY AND SELECTIVITY

EXCELLENT RESULT CAN BE OBTAINED AT CAPACITY 10-20% ABOVE THE DESIGN
INEOS Oxychlorination Fluid bed catalysts

Ineos Fluid bed catalyst portfolio

[Diagram showing temperature range for different catalysts: FB2*, FB2, FB4*, FB1]
Main physical-mechanical features of our Catalysts

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Particle Size (microns)</td>
<td>55</td>
</tr>
<tr>
<td>Less than 20 microns (%)</td>
<td>2</td>
</tr>
<tr>
<td>Bulk Density (g/cc)</td>
<td>1.00-1.20</td>
</tr>
</tbody>
</table>

- Very Low fines and moisture content

INEOS fluid bed catalysts can be also added to the already present charge of catalyst. Mechanical properties and formulation allow mixing during top up without adverse influence on the reactor functioning.
Main Fluid Bed Catalyst Aspects

Catalyst agglomeration (sticking)
Active catalyst converts HCl and prevents the loss in fluidization

Corrosion
Accumulation of Iron increases the by products formation.
Main Fluid Bed Catalyst Aspects

Erosion
Support hardness

Catalyst losses
The attrition test measures the tendency of a catalyst to generate fines.

Top up of the catalyst
catalyst is periodically added to the reactor depending on the catalyst losses.
Fluid Bed Oxychlorination Catalysts: Activity

High reactant conversion:
Ethylene Conversion > 99.5%
HCl Conversion > 99.5%

50% increase in rate  same performance
Fluid Bed Oxychlorination Catalysts: Selectivity

**High Selectivity**
Reduced combustion rate
EDC Purity > 99% (V/V)

![Graphs showing combustion, rate, and EDC purity over time.](image-url)
High reaction stability/ No sticking
Able to operate at different reactant ratios without any fluidization problem

Ethylene Yield

Cl/C molar ratio
What impact could have Fluid Bed Catalysts?

Example & some assumptions:

- 300 ktpa VCM plant, 50 tons of catalyst hold-up, 15 tons/year of catalyst losses
- Operating rate 90%
- Assume cost of ethylene 0.75 USD/kg
- Assume EDC margins 100 USD/ton
- Assume 100% Ineos FB Catalyst and an increase in Ethylene Yield by 5%
What impact could have Fluid Bed Catalysts?

Results:

- Increasing output by 10%: more than 2 M USD/yr
- Oxygen+ethylene saving: more than 0.65 M USD/yr
- Caustic savings: more than 0.25 M USD/yr
- Increase of the operating rate estimated in 5 days of more production: 0.29 M USD/yr
Our Technical Service Offer for FIXED AND FLUID BED CATALYSTS

- **On-site plant visit** by INEOS catalyst expert to improve plant optimisation and discussions

- **Training** *(fluid bed)* of plant personnel during 3 to 5 days in our R&D facilities and pilot plant **in Italy**.

- **Pilot plant tests** at particular operating conditions following customer requests

- **Studies** concerning: Metal analysis (poisoning), Particle size distribution, Catalyst hardness (attrition/erosion) and mechanical strength, Stickiness, Catalyst activity-pilot plant testing, Operating parameters optimization,