INEOS TECHNOLOGIES

EDC OXYCHLORINATION CATALYSTS

Vinyl India 2015
INES 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.
The Balanced EDC/VCM Production Process

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

- FIXED & FLUID BED

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

- HTC & LTC

\[ \text{C}_2\text{H}_4 + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_4\text{Cl}_2 \]
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 and Fixed Bed Oxy Pilot Plants

Features
Fluid Bed:
- One reactor
- Condensation system
- On-line vent gas analyser and vent gas treatment
- Fully automated under DCS control

Features
Fixed bed:
- Two reactors
- On line vent gas analysis, off line analysis of EDC and water
- Fully automated 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

Diagram:
- Ethylene
- HCl, Oxygen
- Steam
- Boiling Water
- EDC & By-Products
- EDC + by-products
- Catalyst
- TIC
- R0
INEOS OXYCHLORINATION FIXED BED CATALYSTS AND DILUENT

IVOC – 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
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

![Graph showing temperature profile](image-url)
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) that can be loaded as they are directly in the reactor.
Fixed Bed oxychlorination catalysts Key Factors:

PRESSURE DROP

Second Reactor Pressure Drop

Reactor’s Pressure Drop

% capacity

INEOS CATALYSTS  5x5 mm standard Catalyst

UP TO 20% REDUCTION

LOW PRESSURE DROP  →  HIGH CAPACITY
Fixed Bed oxychlorination catalysts Key Factors:

**PRESSURE DROP**

The new high performance IVOD-2F diluent:

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

**CATALYST LIFE**

- Temperature profile and coke formation
- New Generation - Temperature Profile
- OLD Generation - Temperature Profile
- New Generation - coke formation
- OLD Generation - coke formation

**LOW FOULING RATE**

**LOW COKE PRODUCTION RATE**

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

**CATALYST LIFE**

- **LOW FOULING RATES**
- **LONG STABLE ACTIVITY**

**HIGH CAPACITY FOR LONGER TIME**

**HIGHER FLEXIBILITY TO BUSINESS REQUIREMENTS**
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
Fixed Bed oxychlorination catalysts Key Factors:
ACTIVITY AND SELECTIVITY

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

*Ineos Fluid bed catalyst portfolio*
INEOS Oxy Catalysts

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%

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

**High reaction stability/ No sticking**
Able to operate at different reactant ratios without any fluidization problem
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/y
- Caustic savings: more than 0.25 M USD/y
- Increase of the operating rate estimated in 5 days of more production: 0.29 M USD/y
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,