FLUID CATALYTIC CRACKING PROCESS

- **Operational upsets** can cause production loss or equipment damage.
- **Proper detection of abnormal conditions and automated responses** can assist operations avoid damage or injury.
- **Immediate and direct response:**
  - Minimizes unit downtime
  - Minimizes personnel and equipment damage
  - Helps ensure faster operational recovery.
**FCCU CONSIDERATIONS**

- Hydrocarbon – Oxygen Atmospheres (reversals)
- Temperatures 510 – 700°C (950 - 1300°F)
- Catalyst containment
- Coke deposition
- Coke combustion
- CO Boiler
- Electrostatic Precipitator
- Direct Fired Air Heater
- Steam Generation Equipment
- Main Air Blower
- Instrument purges
THE EMERGENCY INTERLOCK SYSTEM (EIS)

What is it? Electronic Logic Solver that:

• Automates most emergency actions previously delegated to the operator.

• Moves the FCC Catalyst Section to a safe condition.

• Permits safe, fast restart of process AFTER event is resolved.

• Follows UOP recommendations for safe operation.
THE EMERGENCY INTERLOCK SYSTEM (EIS)

Why would a refiner need one?

Safety:
• Protect personnel
• High temperature process (> 500°C).
• Hydrocarbon and Oxygen atmospheres
• Dynamic operation

Economics:
• Each shutdown is costly
• Fast restarts are important.
• FCC is key to other processes.
• Potential for severe equipment damage

Predictable Operations:
• Operator experience is rapidly declining
EMERGENCY INTERLOCK SYSTEM DESIGN

History
Many, Well-Trained Operators
• Experience level high
Reliability of field devices was low
• Simple designs, minimum field devices
• Systems designed to prevent spurious trips
Relay logic commonly used
• Complex logic difficult to implement
Programmable systems not reliable
## HUMAN RESPONSES TO “ABNORMAL EVENTS”

<table>
<thead>
<tr>
<th>Device Name</th>
<th>Unavailability</th>
<th>Failure Freq</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator response</td>
<td>0.1</td>
<td>&lt; 20 minutes</td>
<td>&lt; 20 minutes to respond (immediate)</td>
</tr>
<tr>
<td>Operator response</td>
<td>0.01</td>
<td>&gt;20 minutes</td>
<td>&gt;20 minutes to respond (non-immediate)</td>
</tr>
<tr>
<td>Operator error</td>
<td>0.01</td>
<td></td>
<td>Error by operator doing a manual task.</td>
</tr>
<tr>
<td>Pump Failure</td>
<td>0.25</td>
<td></td>
<td>This value is based on all causes.</td>
</tr>
<tr>
<td>Power Failure</td>
<td>0.20</td>
<td></td>
<td>General Power failure is modeled as once per 5 years.</td>
</tr>
<tr>
<td>Fuel Gas Supply</td>
<td>0.05</td>
<td></td>
<td>Fuel Gas supplies are considered very reliable.</td>
</tr>
<tr>
<td>Regulator</td>
<td>0.05</td>
<td></td>
<td>Mechanical device.</td>
</tr>
<tr>
<td>Check Valve</td>
<td>0.05</td>
<td></td>
<td>Normal service check valve leaking.</td>
</tr>
<tr>
<td>F.G. Header low pressure</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inerts in Fuel Gas</td>
<td>0.01</td>
<td></td>
<td>Once in facility lifetime</td>
</tr>
<tr>
<td>Loss of Flow from Main Air Blower</td>
<td>0.2</td>
<td></td>
<td>Equipment Shutdown</td>
</tr>
<tr>
<td>SIS Installed</td>
<td>0.0001</td>
<td></td>
<td>For interaction between systems this number of 1 in 10000 is used.</td>
</tr>
</tbody>
</table>
EMERGENCY (SAFETY) INTERLOCK SYSTEM DESIGN

Acceptable Risk Level

Inherent Process Risk

PSV, etc.  SIS  BPCS  Mechanical Design

PROCESS

RISK

Risk Reduction
EMERGENCY INTERLOCK SYSTEM DESIGN

ANSI / ISA S84.01 / IEC 61508-511
Application of Safety Instrumented Systems for the Process Industries

• Safety Life Cycle
• Process Hazard Analysis
• Define Safety Integrity Level’s (SIL’s)
  • Identify safety equipment performance levels required to reduce risks to an acceptable value.
• Design SIS to meet SIL’s
• Management of Change Procedures

Standards
## Cross Reference Between SIS Class and Standards

<table>
<thead>
<tr>
<th>Percent Availability</th>
<th>PFD (probability of failure on demand)</th>
<th>Risk Reduction</th>
<th>SIL ANSI/ISA S84</th>
<th>SIL dIEC 1508</th>
<th>TUV Class (AK)</th>
<th>Din V 19250</th>
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</thead>
<tbody>
<tr>
<td>99.999</td>
<td>0.00001</td>
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<td></td>
<td></td>
<td>AK8</td>
<td>8</td>
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<tr>
<td>99.9</td>
<td>0.0001</td>
<td>10000-100000</td>
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<td>4</td>
<td>AK7</td>
<td>7</td>
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<tr>
<td>99.90</td>
<td>0.001</td>
<td>1000-10000</td>
<td>3</td>
<td>3</td>
<td>AK6/5AK5</td>
<td>6/5</td>
</tr>
<tr>
<td>99.0</td>
<td>0.01</td>
<td>100-1000</td>
<td>2</td>
<td>2</td>
<td>AK4/3AK4</td>
<td>4</td>
</tr>
<tr>
<td>90.0</td>
<td>0.1</td>
<td>10-100</td>
<td>1</td>
<td>1</td>
<td>AK2/1AK2</td>
<td>2/1</td>
</tr>
</tbody>
</table>
REACTOR STRIPPER LEVEL SIL DETERMINATION

Safety?
- Loss of containment to atmosphere?
- Injury to personnel?

Economic?
- Main column circuit plugging?

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</tr>
<tr>
<td>90.00</td>
<td>0.1</td>
<td>10-100</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
EMERGENCY INTERLOCK SYSTEM DESIGN

1. Start
   - Conceptual Process Design
   - Perform Process Hazard Analysis & Risk Assessment
   - Apply non-SIS protection layers to prevent identified hazards or reduce risk.

2. SIS required?
   - NO
     - STOP
   - YES
     - Define target SIL
     - Develop Safety Requirements Specification (SRS)
     - Perform SIS Conceptual Design & Verify it meets the SRS
     - Perform SIS Detail Design
     - SIS installation, commissioning, and pre-startup acceptance test.

3. Safety Life Cycle Model
   - Establish Operation & Maintenance Procedures
   - Pre-Start-up Safety Review Assessment
   - SIS start-up, operation, maintenance, periodic functional testing.
   - Modify or Decommission SIS?
     - Modify
     - Decommission
   - Decommissioning SIS
   - Conceptual Process Design


Colors:
- Orange - UOP/Owner/ Contractor
- Black - ISA S84.01
- Yellow - Owner responsibility
EMERGENCY INTERLOCK SYSTEM DESIGN

Availability

- A measure of system success as a %, e.g. 99.8%
- System does WHAT it needs to do, WHEN asked to do it.
- Function of: Failure Rates of Individual Devices, Time to Repair Devices, Test Interval

Lack of Availability Means:

Covert (Hidden) Failures

- System does NOT trip when asked to trip.
- Failures are hidden and unknown
- Normal programmable logic controllers (PLC’s) are susceptible to high incidence of covert failures

Availability
Reliability

- A measure of (safety) system failures
- Lack of reliability causes spurious trips

Spurious trips cause downtime and lost profits!!
EMERGENCY INTERLOCK SYSTEM DESIGN

How to achieve Reliability and Availability?

- Use fault-tolerant systems
  - Multiple processors and self-diagnostics
- TÜV AK 6 Certification (99.9 % availability)
  - Honeywell Safety Manager
  - Triconex
  - Siemens/Moore “Quadlog”
  - HIMA
- Use “smart” transmitters
- Use redundant field devices
  - 2 out of 3 voting for transmitters
  - Multiple shutdown valves
  - Multiple Solenoids
VARIOUS EIS CONSIDERATIONS

- Robust Design (redundant, fault-tolerant)
- Slide Valves (dedicated shutdown hydraulics)
- Solenoids (parallel, 2-oo-3)
- Transmitters (2-oo-3, 2-oo-2D)
- EIS-BPCS Interfacing
- Testing (Pre-Startup and Interval)
- Bypasses
- Staged Responses
- Enforced Restart Procedures
EIS – BPCS INTERFACING

- EIS can place associated BPCS controller in manual and set output to predetermined value
- For example, for FCC feed control valve, the EIS directs the DCS to put the feed controller in manual and set the output to 10% in a single shot to the DCS
- Supplements process isolation, and controller and valve are set for restart
- No credit in taken in the Safety Instrumented Function analysis as these are software links
• Both pre-startup and interval test crucial to EIS performance.
• UOP build a customer specific process simulator for input to output terminal testing.
UOP discourages the use of bypasses unless specifically required by the process design.
STAGED RESPONSES

- Keep the Regenerator operating if unaffected (maintains catalyst heat)
- If the Regenerator is too cold, stop torch oil (use DFAH instead)
ENFORCED RESTART PROCEDURES

Operator must first identify and remedy cause.
In UOP EIS, critical steps are enforced and unit P, T, cat circ, inventory must all be ready before feed-in.

- Flue Gas Steam Generation Level
- Main Air Flow
- Slide Valve ΔP’s
- Slide Valve Positions
- Reactor Temperature
- Reactor Level
- Purge Gas Pressure
- Raw Oil Flow is at low rate
Typical EIS Trips

- Low Air to Regenerator – FSLL – 30% of flow scale
- Low Level in Flue Gas Steam Generator – LSLLT – 50%
- Low Feed to Reactor – FSLL^T – 30% of flow scale
- Low Slide Valve DP – PDSLL^T – 1.0 psi (0.07 kg/cm^2)
- Low Slide Valve Position – ZSLL^T – Set in Field
- Low Reactor Temperature – TSLL – 900°F (485°C)
- T = Time delay
FCC EMERGENCY INTERLOCK SYSTEM

Typical EIS Trips

- High Reactor $T$ – TSHH – 10°F (5°C) < Vessel Design
- High Regenerator $T$ – TSH – 1500°F (815°C)
- High Regenerator $T$ – TSHH – 1600°F (870°C)
- Low Purge Gas $P$ – PSLLT – 5 psig (0.35 kg/cm²g) > Spent Cat SV Inlet Pressure
- High Reactor Level – LSHHT – Calculated based on VSS or diplegs height
- Also trips for DFAH, cat cooler(s), CO Boiler, etc.
- $T$ = Time delay
“ABNORMAL EVENTS” IN AN FCCU

Low Riser Temperature
(Also Feed Outage, SV dP, High Rx T, Stripper High Level, etc.)

Typical Responses - Automated by EIS

• Divert feed to main column at low rate / close feed to riser
• Close lift gas and all other hydrocarbons to the reactor
• Increase riser lift steam to maximum and feed nozzle steam to start-up rate
• Close spent and regenerated slide and catalyst cooler slide valves (Recirculation valve can remain in service)
• Decrease cat cooler fluidization air to minimum (Minimum duty but keep lances from plugging)
“ABNORMAL EVENTS” IN AN FCCU

Low Riser Temperature (also Feed Outage, SV dP, High Rx Temp, Stripper High Level, etc.)

Typical Responses - Operator action DCS/Field

- Adjust Establish negative differential P (Reactor > Regen)
- Add fuel gas to LCO Stripper to help maintain pressure
- Monitor WGC for surge and be prepared to shut down
- Adjust air flow rate to maintain regen cyclone velocities
- Switch purge gas riser to nitrogen
- Switch flushing oil supply from LCO/HCO to raw oil
BENEFITS OF INSTALLING AN EIS

Benefits

• Protection of personnel (safety)
• Protection of equipment (economics)
• Environmental
• Supplements operator actions
• Predictable operations
• Faster recovery from trips
• On-stream efficiency (economics)
THANK YOU FOR YOUR PARTICIPATION

Q&A