HYSYS-based Operator Training Simulator for a new Cumene & Phenol plant

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Outline

- Piloting a process plant
- Project background
- Why OTS investment
- The OTS
- OTS value
Piloting a process plant

If your process plant were the Saturn V,
your panel operators will be the astronauts

Now, think about the training hours of an astronaut
## Process plant vs. Saturn V

<table>
<thead>
<tr>
<th></th>
<th>Ethylene plant</th>
<th>Saturn V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput</td>
<td>800 kty ~ 90 t/h of Naphta</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Stage burns 14200 t/h (Kerosene) with 32200 t/h Liquid Oxygen</td>
</tr>
<tr>
<td>Working time</td>
<td>~ 50 years</td>
<td>4 hours, 20 min</td>
</tr>
<tr>
<td>Instruments</td>
<td>~ 5000 AI/DI</td>
<td>Stage-1 about 900 instruments, Stages 2&amp;3 ?</td>
</tr>
<tr>
<td>Cost</td>
<td>~ 1.5 Billion$</td>
<td>Per launch: $494 million in 1964–73 dollars (~$3 billion today)</td>
</tr>
<tr>
<td>PID loops</td>
<td>~ 800 loops in ICSS</td>
<td>~ 20 faceplates in Command Module</td>
</tr>
<tr>
<td>Training time before launch</td>
<td>3-9 months</td>
<td>Two years for Apollo missions (they are test pilots before)</td>
</tr>
<tr>
<td>OTS cost</td>
<td>0.8 – 1.2 Million$</td>
<td>All simulators &gt; 50 million$</td>
</tr>
</tbody>
</table>

OTS is a multiplier of every hour invested in training

Source: [https://www.hq.nasa.gov/alsj/NASATND7112.pdf](https://www.hq.nasa.gov/alsj/NASATND7112.pdf)
CEPSA Chemical Shanghai (“CCS”) is building the new Cumene and Phenol plants in the Shanghai Chemical Industry Park (SCIP), with a capacity to produce: 250kMt of phenol and 150kMt of acetone.

CCS is using OTS to reinforce the training for all the operation staff, with plenty of scenarios, to improve the economical operation of the plant, such as normal operations, start-up and shutdown, equipment malfunction and emergency conditions.

Inprocess Technology and Consulting Group (“Inprocess”) has rich modeling and project experiences for OTS (Operator Training System).

www.youtube.com/watch?v=NJxIXR3ZAKs
Why OTS investment

The OTS overall objectives were:

• Train the chinese/spanish operation staff on the process and the DeltaV system in Shanghai and Huelva (Spain).
• Reduce the risk of major operational incidents
• Reduce start-up time
• Increase plant on-stream time and performance
• Verify Process Control & Safety Systems operation
• Avoid equipment damages
• Provide a test-bed system for engineering analysis
The OTS: Concept

<table>
<thead>
<tr>
<th>Process Plant</th>
<th>Real World</th>
<th>Direct-Connect OTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Operator</td>
<td>Aspen HYSYS Dynamics Model</td>
<td></td>
</tr>
<tr>
<td>AIs, DIs, AOs, DOs</td>
<td>ICSS Hardware &amp; Software</td>
<td>AIs, DIs, AOs, DOs</td>
</tr>
<tr>
<td>Download Database</td>
<td>ICSS Emulation Software</td>
<td></td>
</tr>
<tr>
<td>Panel Operator</td>
<td>Panel Operator</td>
<td>Instructor Station &amp; Field Operator Devices</td>
</tr>
<tr>
<td>Human Machine Interface</td>
<td>ICSS Console &amp; Graphics</td>
<td></td>
</tr>
</tbody>
</table>

ICSS Console as in Control Room
The OTS: Model Scope

Simulation Scope Cumene
- Equipments: 60
- Isolation valves: 20
- Control valves: 91
- Relief valves: 20
- PID loops: 90
- I/O Count: 1000
- Component List: 28

Simulation Scope Phenol
- Equipments: 132
- Isolation valves: 62
- Control valves: 210
- Relief valves: 41
- PID loops: 204
- I/O Count: 2000
- Component List: 35

Challenge
Multiple chemical reactions, many separation units (18 distillation columns) and large recycles
Cumene HYSYS model

Subflowsheet helps to work in parallel
Phenol HYSYS model
The OTS: modeling highlights

• Reactor Dynamics
  The HYSYS CSTR reactor was used with rigorous kinetics. Reactors parameters and kinetics constants were adjusted to obtain accurate dynamics.

• Hydraulics Effects in Reactor Dynamics
  Compressors push air to the bottom of the Oxidizers and the liquid mass is in suspension, but HYSYS CSTR is an ideal homogenous reactor. These dynamics were modeled, therefore when compressor trips the Oxidizers levels are affected.

• Calorimeters DeltaT
  They are the sensors of the reaction. They were calibrated with the same dynamics that the existing Huelva (Spain) plant was providing.
The OTS: Architecture

An OTS replica was installed in Huelva complex (Spain)

DCS Operator Workstation
- Plant Control System Emulator
- DeltaV Simulate Pro
- Operator HMI, DCS DeltaV

Instructor Workstation
- Plant Dynamic Model (HYSYS Dynamic model)
- Inprocess Instructor Station
  - HMI for Field Operated Devices
  - Simulation Management
  - Communication

Ethernet
OPC Protocol
The OTS: DeltaV Operate
The OTS: Instructor Station

- ICSS/Simulator Connectivity
- Instructor Functionalities
- Field Devices Operation
The OTS: Scenarios

50 scenarios were developed:

• **Operational scenarios:**
  - change utilities conditions
  - change in raw material quality
  - throughput changes

• **Procedure scenarios:**
  - Start-up
  - Shutdown

• **Safety Scenarios:**
  - Equipment power loss
  - Instrument air failure
  - Critical utilities loss

• **Equipment failures and malfunctions:**
  - Column steam failure
  - Exchangers fouling
  - Instrument failure
OTS value: Debug ICSS code

Important: OTS Vendor acts as an independent auditor of the ICSS functionality
Examples ICSS database review

Loop implementation

Controller Actions

Sensor Ranges

Controller override
OTS value: Operator Training

46 operators have been trained: 1998 hours in total, training table sample

1. GET FAMILIAR:
   - With the process
   - With the procedures
   - With HMI navigation and controls

2. IMPROVE:
   - Operation and safety procedures
   - Uniform skills levels in all operators
   - Rational thinking
   - Time to react

3. RESULTS:
   - Increased Safety
   - Reduce Start-up time
   - Off-spec reduction
In the Shanghai petrochemical area, there were several alternative providers of feed propylene, each with different grades and other distributions of Lights and Heavies components.

CEPSA Operations requested to investigate the process operating constraints (valve saturation, duty limits, impurities accumulations) with different streams compositions of propylene feed.

The model proved that, making certain SetPoint adjust, other propylene grades were able to be handled by the plant.
OTS ownership

There is one important aspect when Operating Companies decide to invest in OTS: **The OTS itself does not do the training and knowledge transfer**

The Operating Company needs to design the operator competency program making use of the OTS as an integral tool of the training programs.

- Like NASA does with astronauts
- Like Airlines do with pilots
- Like Mercedes does with Hamilton

Inprocess helps to design and complement those training programs with the use of the OTS. Resources and workflows need to be defined and budgeted.

Ongoing operator training programs in CEPSA:
- Petrochemical complex San Roque
- Refining business unit
HYSYS as OTS engine

Using HYSYS Dynamics as OTS simulation engine has some advantages:

1. It is a known software inside CEPSA and most of the engineers are familiar with it
2. It can increase the rigor as needed, depending on training objectives
3. It is flexible enough to develop custom items (spreadsheet, UserVar, Extensions)
4. It is powerful enough to handle >5000 I/O tags/sec in realtime in one PC.
5. Models can be taken from the OTS to run other operations/eng. studies
6. It is easy to maintain for typical changes (new instrument, new valves, loop changes, etc)
Conclusions

- OTS improves the ICSS testing and debugging
- OTS could reduce the major operational incidents
- OTS is a good platform to evaluate operator’s skills and to uniform them
- HYSYS-based OTS is a suitable tool to validate raw material planning decisions
- HYSYS-based OTS secures reusability of the process model for analysis
- OTS was executed within time and budget; OTS team was adaptive to the EPC and ICSS schedules.
  - This was the first high fidelity HYSYS-based OTS in CEPSA; as a result CEPSA is considering OTS for new and existing plants. CEPSA is executing the 3rd training simulator with Inprocess.
Thank you

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