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Crude Unit Optimization at Refineria Isla, Curacao

A ROMeo Case Study

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Talk Outline

- Real-time optimization of a crude unit… what's new??
- Project overview
- ROMeo overview
- Process MRA overview
- CD3 Crude Unit Case Study
- Conclusions

Project Overview

What's new??

- **Real-time optimization… issues:**
  - Implementation efficiency/time required
  - Maintainability
  - Availability of model for off-line uses

Who can participate? How much effort is required?

- **Use of Invensys' new Process MRA (Magnetic Resonance Analysis) for on-line composition and property analysis**

Overview: Refineria Isla

- **Refineria Isla (Curacao) S. A.**
  - **Curacao, Netherland Antilles**
  - **Affiliate of PDVSA, Venezuela**
  - **Crude Distillation Unit-3 capacity : 180,000 bbls/day**
  - **Crude switch every 2-3 days for 2 modes of operation:**
    - paraffinic crude blend for lube oil production
    - general purpose blend for fuel production.
- **Scope of CD3 optimization model**
  - **Atmospheric unit**
  - **Vacuum unit**
  - **Preheat train including furnaces**
  - **Gas plant**

Overview: Highlights

- Real-time Optimization: ROMeo
  - State-of-the-art equation-based modeling/real-time optimization package
  - Enhanced usability features for faster implementation/ ease of maintenance
- Invensys Process MRA
  - Reliable, robust online NMR technology
  - Crude, kerosene and naphtha stream analysis for improved APC and optimizer performance

Overview: Highlights

Project execution

- lead engineers: 1.5 refinery engineers
  - experienced process, control engineers
  - prior PRO-II sequential modular simulation experience
  - no prior experience in RTO or open-equation based modeling
- motivation for participation by plant engineers:
  - exploit process/simulation knowledge/experience
  - familiarize themselves with ROMeo: maintenance, off-line use of model, additional projects.

Overview: Highlights

Project execution

- 0.25 Invensys engineer (consulting only)
- Principal areas of consulting input:
  - functional design document
  - flowsheet model design (i.e, level of detail)
  - data reconciliation transitions
  - configuration of real-time tasks, e.g. lineup changes

Overview: Milestones

- MRA Analyzer
  - Test Installation Nov 2000
  - Final Installation including Crude August 2001
- ROMeo
  - Started June 2001
    - Model building/application configuration performed entirely by refinery staff; consulting from Invensys
  - Online, open-loop since Jan, 2002
    - Optimization moves reviewed before being implemented by operations staff
  - Online, closed-loop since March, 2002
    - Optimization moves transmitted to DCS and implemented automatically

ROMeo Overview

- ROMeo: Rigorous On-line Modeling and Equation-based Optimization
  - Joint development project between Invensys/SimSci and Shell U.S.A
  - Implemented worldwide in FCCUs, Hydrotreaters/Hydrocrackers, Crude units, Ethylene crackers
  - Common look/feel for all stages of model configuration, real-time automation, maintenance and off-line studies
  - Enhanced usability features cut down implementation time, improve maintainability

ROMeo Overview

ROMeo: Examples of enhanced usability features

- model/flowsheet customization; preserving squareness
  - ROMeo library models: common specifications accessible via GUI; specific set of equations
  - Customization:

    add equations, variables and/or fix/free variables on an individual unit, or at the flowsheet level

    issue: preserving squareness:
  - ROMeo keeps track of added equations, variables, fix/free changes and advises user if flowsheet becomes non-square

ROMeo Overview

ROMeo: Examples of enhanced usability features

- powerful Tcl-based scripting (macro) language
  - ROMeo models/flowsheet management system is *object oriented*
  - *scripting language* can access and manipulate system or model objects
  - macros written in Tcl scripting language can be executed on command from the GUI, or automatically from a *Task* Real Time System (RTS)

ROMeo Overview

ROMeo: Examples of enhanced usability features

- efficient algebraic modeling language (Milano)
  - modeled after GAMS, but specialized for chemical engineering models.
  - All ROMeo library models written in Milano
  - Users can write flowsheet customizations using Milano
  - Milano is object oriented (e.g. inheritance)
  - user custom models can inherit off of Milano base classes that provides base behavior at no programming cost to user, e.g. feed/product ports, data connectivity to external data bases, ability to connect measurements, etc.
  - for Milano models, system takes care of derivative determination

ROMeo: Examples of enhanced usability features

- 'flowsheet' based sequencing system (Real Time System,RTS) for automation of real time tasks
  - User configures Sequences, consisting of library and/or custom tasks.
  - Library tasks: common activities such as import data to flowsheet, screen measurements, run flowsheet model in data rec mode, save case, etc.
  - custom tasks: run a macro in the flowsheet model, e.g. to detect lineup changes are reconfigure model appropriately
  - selected tasks provide branching:
    - on data rec succeed: proceed with next task in sequence to switch to opt mode
    - on data rec fail, example: save case, modify something in model, solve flowsheet in parts, resolve entire flowsheet… etc.

ROMeo Overview

ROMeo: Examples of enhanced usability features

- automatic configuration of economic objective function
  - terms for bulk prices of feed/product stream automatically added to economic objective function
  - ob. function easily extended from GUI to include quality (composition, property) based pricing terms

Process MRA Overview

- Previous IR-based analyzer technology gave a picture of the functional groups in an organic molecule, but provided little information on its hydrocarbon portion.
- Process MRA fills this gap by developing information on the hydrocarbon structure at the atomic level.
- Minimal need for temperature preconditioning or chemical pre-treatment, and is equally applicable to refinery black streams.
- Works with a non-invasive sample probe. The resulting sample system is simple, non-invasive and reliable, all but eliminating the sampling problems that plagued earlier generation on-line analyzers in the refinery environment.
- Summary: advances in sampling technology, use of chemometric algorithms, and sophisticated electronics allowed high resolution laboratory magnetic resonance to be used successfully in the process environment

CD3 Crude Unit Case Study

Real-time Optimization Objectives

- **Crude switch every several days:**
  - Operators expend considerable energy and place their priority on stabilizing plant operation
  - Guidelines available to operators for each operating mode, but considerable leeway in choosing final operating point. Considerable variation in operating philosophy between shifts.
  - Off-line studies indicated significant potential to improve economic performance by locating and pushing optimal constraint set inbetween crude switches

Real-time Optimization Objectives

- Maximize most valuable products like kerosene, heavy gasoil, LPG
- Adjust circulating reflux flows to maximize heat integration with the gas section
- Adjust the crude and vacuum furnace duties
- Adjust column pressure, reboiler and reflux in gas section to minimize fuel gas
- Achieve uniform operating philosophy acceptable to all shifts

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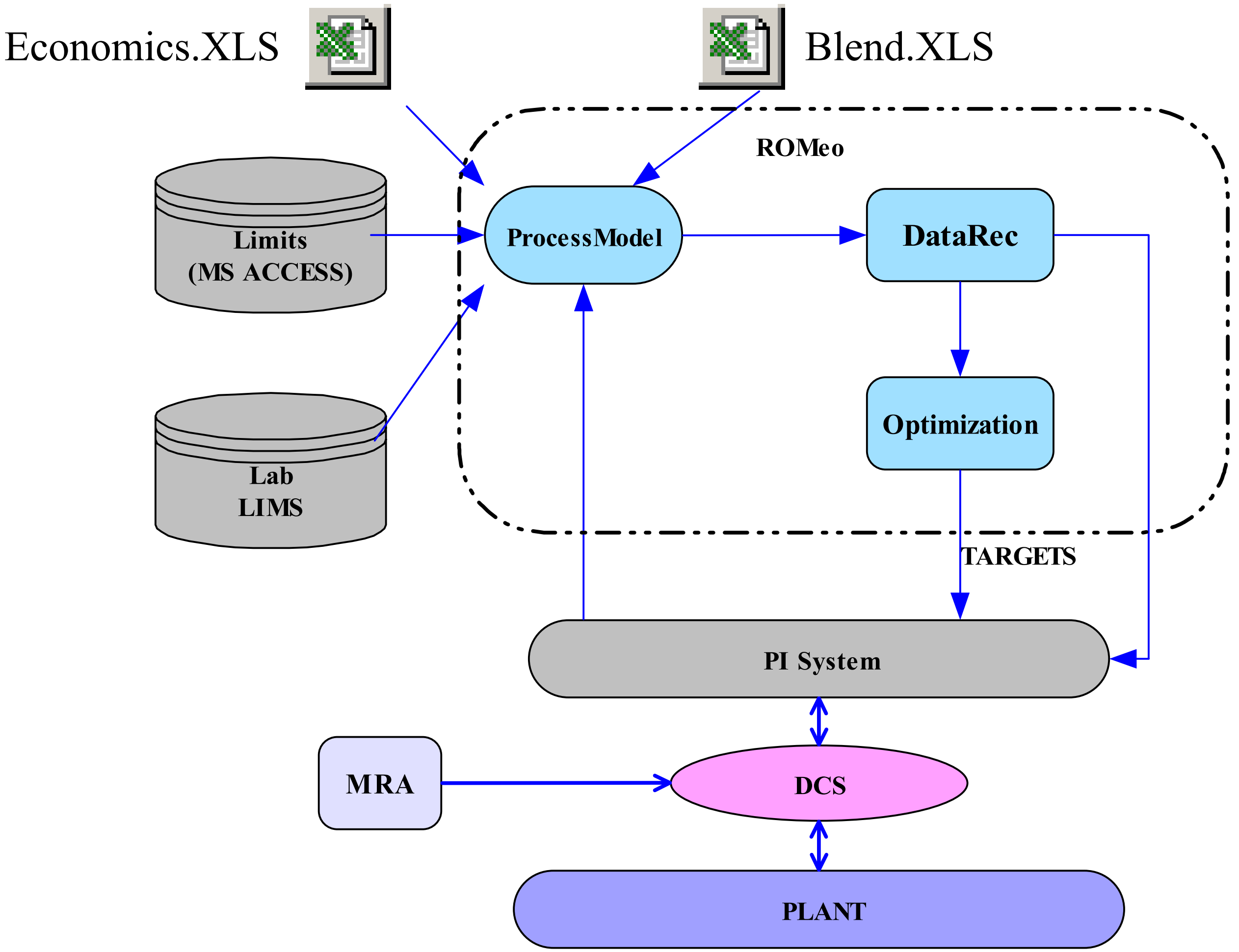
System Overview



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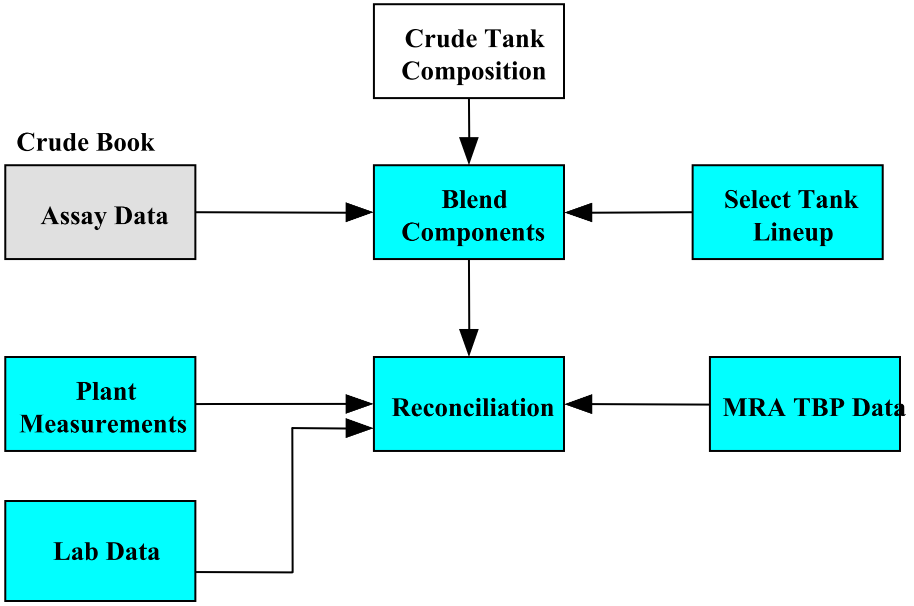
Problem Size, Platform and Performance

- Size
  - 252 Measurements
  - 26,000 Equations
  - Degrees of Freedom
    - 170 in Data Reconciliation (tuning parameters)
    - 31 in Optimization (targets to APC/DCS)
- Platform
  - Dell PC with dual 1-GHz CPUs , 2 GB RAM.
  - Windows NT Enterprise server
  - Networked to Foxboro I/A, PI, LIMS.
- Performance
  - Reconciliation: 10 minutes
  - Optimization: 5 minutes

On-line MRA data

- MRA supplies real-time measurements to APC and ROMeo
- Crude Feed:
  - 5 pt TBP, API density, paraffins, naphenes and sulfur content
  - TBP data imported into ROMeo, used in data reconciliation
- Kerosene product:
  - freeze pt, flash pt, Iso and n-paraffins
- Heavy naptha product:
  - 7 pt distillation, iso and n-paraffins and napthenes
- ROMeo: TBP data on crude feed used in data reconciliation --- improved feed composition adjustment
- APC: where soft sensors in place, analyzer data used to update prediction correction factors -- better predictions allows closer operation to constraint boundaries

Feed Characterization



Legend:

Real Time

Daily

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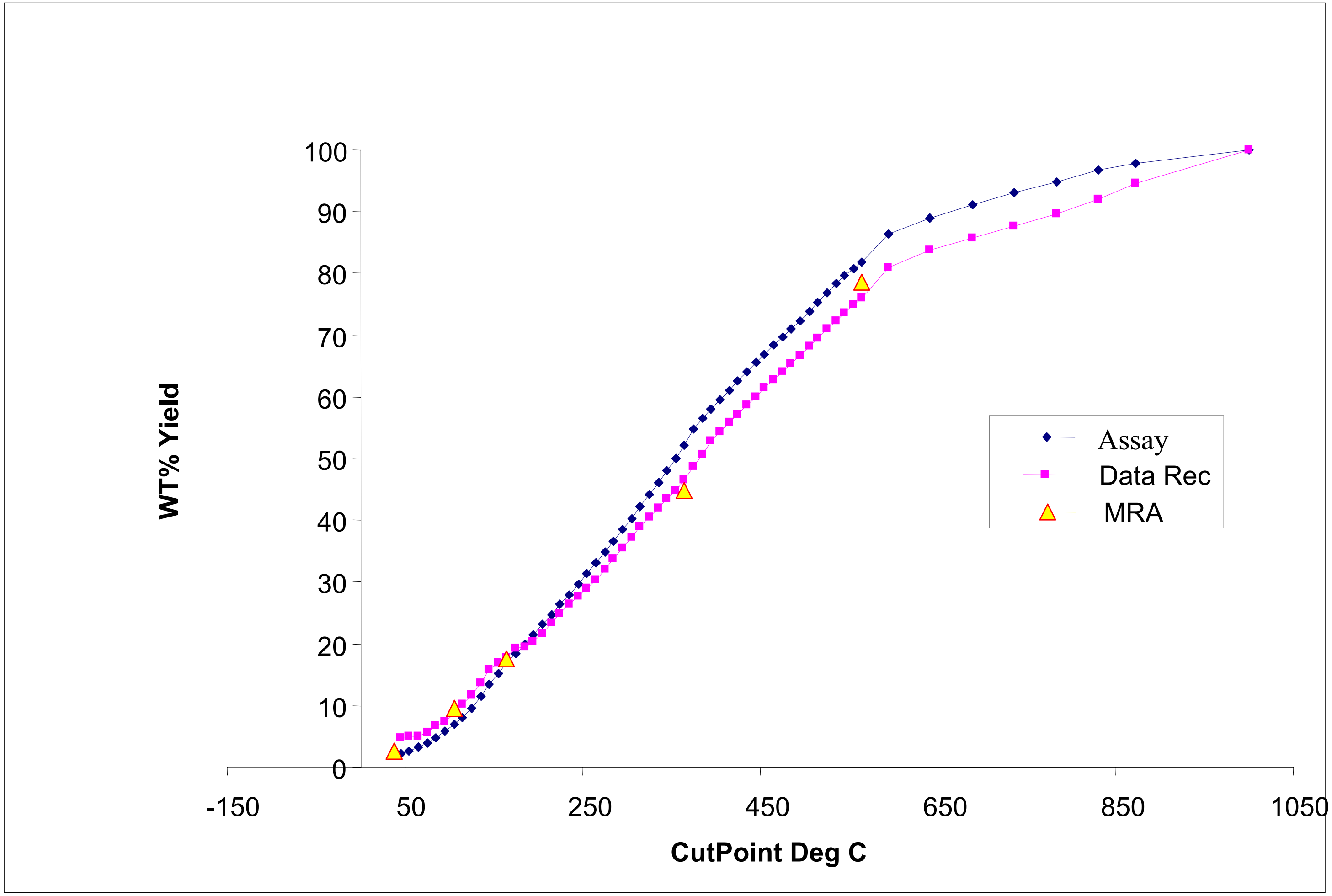
On-line Feed Characterization with MRA



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Production Management

Benefits

- **Online:**
  - Preliminary benefit estimate: 7-12 K $US/Day
  - benefits derived primarily from:
    - kero maximization
    - improved heat integration
- **Off line:**
  - Several circulating reflux flows were moved from their traditional operating levels
  - Avoided unnecessary opening of columns and exchangers during short turn around
  - Understand the impact of crude switch on downstream units

Conclusions

- **The usability features of ROMeo allowed application to be configured by plant engineers on time (4 months) and within budget**

- **On-line optimization provides a set of operating guidelines to capture the benefit in real time instead of running the unit on preset operating guidelines that may be suboptimal**

- **Process MRA provides valuable real-time measurements to enhance APC and ROMeo performance**