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BAHRAIN PETROLEUM COMPANY NO.1 HYDROCRACKING UNIT A DECADE OF SUCCESS

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AGENDA

- ▶ Introduction to Bapco
- ▶ Low Sulphur Diesel Production (LSDP) Project
- ▶ No.1 Hydrocracking Unit (1HCU)
- ▶ Early identification of opportunity
 - Lube Base Oil Unit (LBOU) Integration
- ▶ Thinking out of the box
 - Innovative 1HCU fresh feed configuration
- ▶ More changes: Continual Improvement (Operational Excellence)
 - Increased catalyst cycle length
 - Product Stripper revamp
 - Catalyst Selection for 1HCU
- ▶ Concluding remarks

THE BAHRAIN PETROLEUM COMPANY BSC(C)

- ▶ 100% owned by the Government of the Kingdom of Bahrain
- ▶ Established in 1929 - has been the cornerstone of Bahrain's economic development
- ▶ Oil first discovered in the Arabian Gulf in 1932 in Bahrain
- ▶ Refinery started in 1936 - now operating for 82 years
- ▶ Initial capacity 10,000 BPD - one crude unit only
- ▶ Now a world-scale complex refinery - 267,000 BPD
- ▶ Marketing of products locally and internationally

LOW SULPHUR DIESEL PRODUCTION (LSDP) PROJECT

- ▶ In the mid 1990s, countries started to adopt more stringent environmental legislation
- ▶ Bapco foresaw major changes in the diesel specifications
- ▶ Launched a billion dollar Strategic Investment Program (SIP) to meet future market demands and stay competitive
- ▶ US\$680 million Low Sulphur Diesel Production (LSDP) project was part of the SIP
- ▶ project centered around the No.1 Hydrocracking Unit (1HCU)
- ▶ Existing mild hydrocracking unit also converted to 70 MBPD ULS Diesel unit

NO.1 HYDROCRACKING UNIT (1HCU)

- ▶ Commissioned in June 2007
- ▶ Licensed by Chevron Lummus Global (CLG)
- ▶ Feed: Heavy Vacuum Gas Oil (HVGO)
- ▶ Design Capacity: 60 MBPD
- ▶ Two stage with recycle (TSREC) configuration
- ▶ Three operating modes
 - 40 MBPD fresh feed @ 99 vol% conversion
 - 50 MBPD fresh feed @ 80 vol% conversion (Lube Base Oil mode)
 - 60 MBPD fresh feed @ 67 vol% conversion

1HCU OBJECTIVES AND OPERATION

▶ Process Objectives:

- ▶ Maximise middle distillate yield
- ▶ Meet yield & quality for Unconverted Oil (UCO) - routed to LBOU as feed

Salient features:

- ▶ One of largest single train hydrocrackers in the world
- ▶ One of a few TSREC hydrocrackers in the world producing feed for lube production
- ▶ Operates with higher conversion compared to conventional lube hydrocrackers
- ▶ According to major licensors and catalyst vendors, 1HCU feed is atypical in terms of heavy backend; a tough one for producing Group 3 lube base oils feedstock

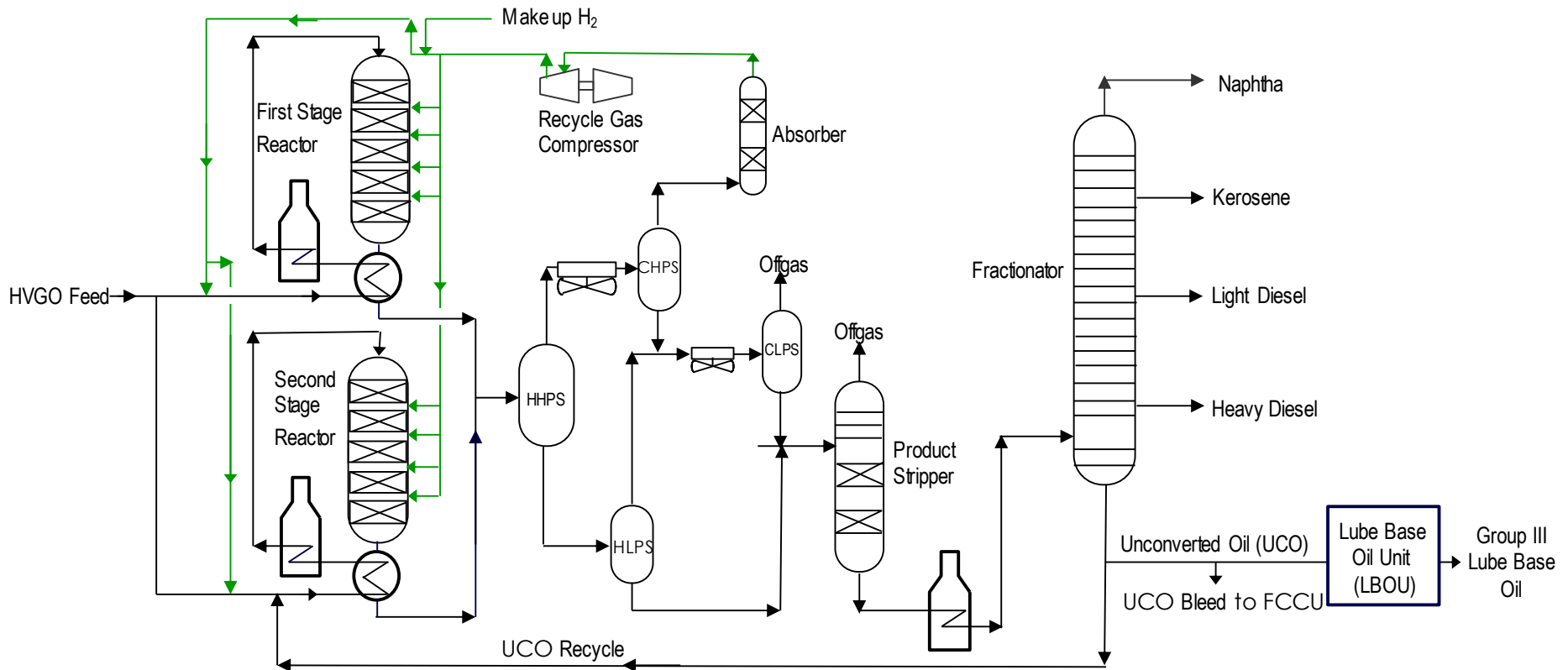
1HCU COMMISSIONING AND OPERATION

- ▶ Extremely successful startup - 36 hours from oil in to products on specification
- ▶ For the last decade, 1HCU has been
 - The most profitable unit in the refinery
 - Improved, modified and enhanced e.g. changes in configuration, operation and catalyst
 - Enhancing overall refinery profitability
- ▶ Various challenges arose; all were dealt successfully

LSDP COMPLEX - 1HCU TODAY



1HCU PROCESS FLOW SKETCH



LUBE BASE OIL UNIT INTEGRATION

Early identification of opportunity

- ▶ In 1HCU design phase Bapco identified the opportunity to produce lube base oils
- ▶ Partnership with Neste Oil, a major Group III base oil producer
- ▶ Strategic study done by CLG
- ▶ Decision - build Lube Base Oil Unit (LBOU) and integrate with hydrocracker to increase profitability
- ▶ Integration with hydrocracker - to save capital and operating cost
 - Hydrogen once-through system in LBOU – no recycle gas compressor
 - By-products from LBOU are routed to 1HCU

LUBE BASE OIL UNIT INTEGRATION

- ▶ LBOU commissioned in 2011 - Operating successfully ever since
- ▶ Joint Venture
 - Government of Bahrain 55% (Bapco, nogaholding - each 27.5%)
 - Neste 45%
- ▶ Nominal Capacity: 400,000 tonnes per year of Group III Lube Base Oil

INNOVATIVE 1HCU FRESH FEED CONFIGURATION

Thinking out of the box

- ▶ As per design for LBO mode, 1HCU was to be operated with all fresh feed to 1st stage reactor, with 2nd stage on recycle only
- ▶ 1st stage average catalyst temperature much higher compared to 2nd stage, leading to different deactivation rates
- ▶ Bapco came up with the idea of routing some fresh feed to second stage: discussed and ratified by licensor
- ▶ Benefits:
 - Uniform catalyst temperatures and deactivation rates in both the stages
 - Better utilisation of catalyst activity and also higher UCO VI
- ▶ Only TSREC HCU producing feedstock for a Group III Lube Base Oil Unit with fresh feed routed to 2nd stage

CONTINUAL IMPROVEMENT

More changes: Continual improvement (Operational Excellence)

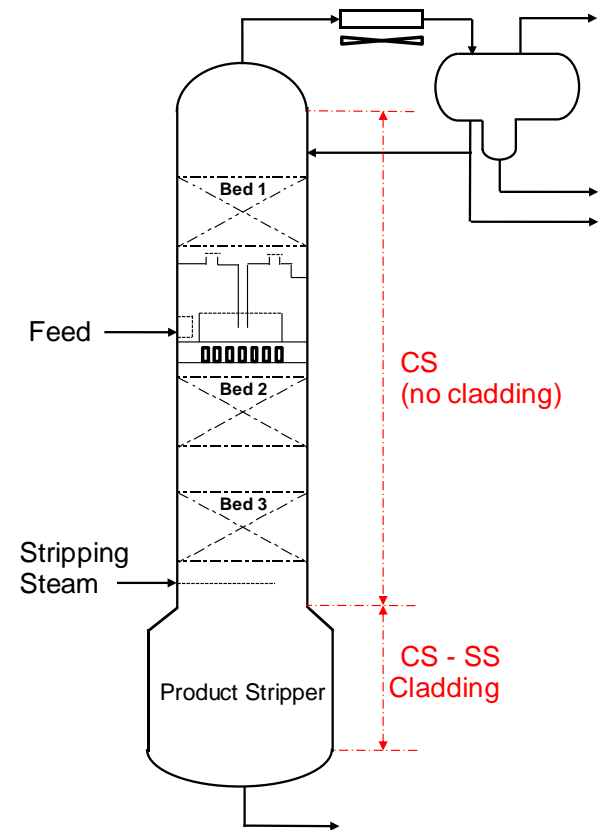
- ▶ Increased catalyst cycle length
- ▶ Modifications to product stripper
- ▶ Catalyst selection

INCREASED CATALYST CYCLE LENGTH

- ▶ 1HCU designed for 2 year catalyst cycle; first two cycles each 2 years
- ▶ During third cycle, based on experience and pilot plant testing, decision made to increase the cycle length to 3 years
- ▶ Closely worked with catalyst vendor to optimise fresh feed split between the stages
- ▶ Successfully increased catalyst life cycle from 2 to 3 years
- ▶ Benefits:
 - one less catalyst changeout shutdown in every 6 years (T&I cycle)
 - lower catalyst costs, reduced downtime
 - increased profitability

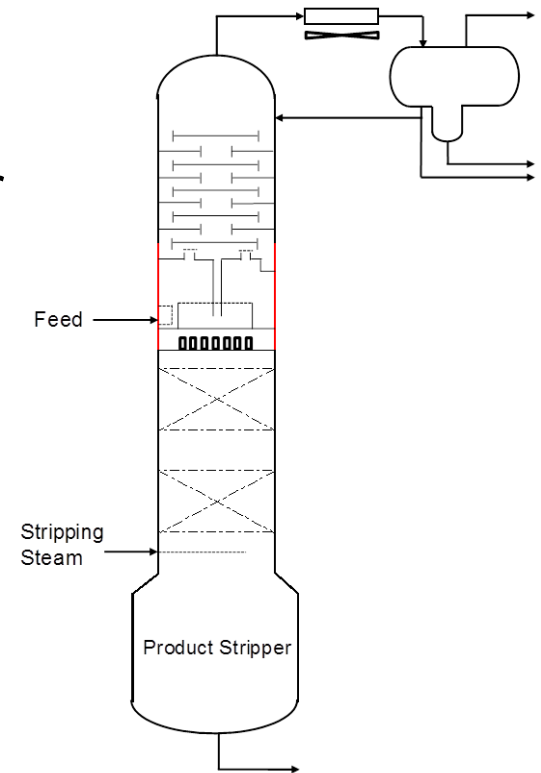
PRODUCT STRIPPER REVAMP

- ▶ Product stripper removes some naphtha, light hydrocarbons and H_2S from the feed
- ▶ Top bed: smaller size random packing compared to beds 2 and 3
- ▶ Repeated high ΔP problem in top bed
- ▶ High ΔP caused by accumulation of corrosion deposits from overhead system
- ▶ Resulted in:
 - ▶ higher H_2S content in stripper bottoms
 - ▶ reduction in feedrate
 - ▶ unit shutdowns to clean top bed packing



PRODUCT STRIPPER REVAMP

- ▶ Bapco proposed replacing top bed with trays
- ▶ Licensor seconded the idea - later advised their revised design stipulates trays at the top for HCU product strippers
- ▶ Replaced bed 1 packing with trays to minimise potential for accumulation of corrosion deposits
- ▶ Revamp very successful.
- ▶ Benefits:
 - Trouble-free operation
 - No downtime due to high ΔP issue
 - No corrosion in flash zone



CATALYST SELECTION FOR 1HCU

- ▶ Catalyst selection is one of the key aspects of successful 1HCU operation
- ▶ The catalyst procurement process:
 - Based on competitive bidding
 - Gated decision-making process
 - Rigorous techno-commercial evaluation including LP model runs
 - Pilot plant testing is important for catalyst selection decision
- ▶ Objectives of 1HCU catalyst system:
 - providing operational flexibility
 - higher UCO VI
 - better 1HCU distillates selectivity
 - improved overall refinery margin

CONCLUDING REMARKS

- ▶ 1HCU has been a success story for 10 years
- ▶ Never satisfied with the status quo: always looked for opportunities.
- ▶ Success has been achieved through:
 - strong in-house process engineering expertise and experience
 - commitment to process monitoring and optimisation - always looking for opportunities to improve
 - being agile - swift response to changes
 - close working relationship with catalyst vendors and the technology licensors

THANK YOU