H-Oil in general : 50 years of experiences

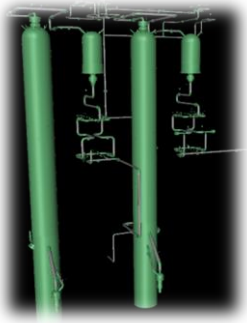
Jean-Philippe Toupance
Alexandre Javidi

Axens H-Oil® Commercial Experience

12 units already in operation
First unit started in **1963**
Recent unit start in **2015**

9 H-Oil®$_{RC}$ units Under design/construction

6 awards since **2012**
10 awards since **2007**



Axens has the most Operating Cumulated Experience:

> 200 unit-years

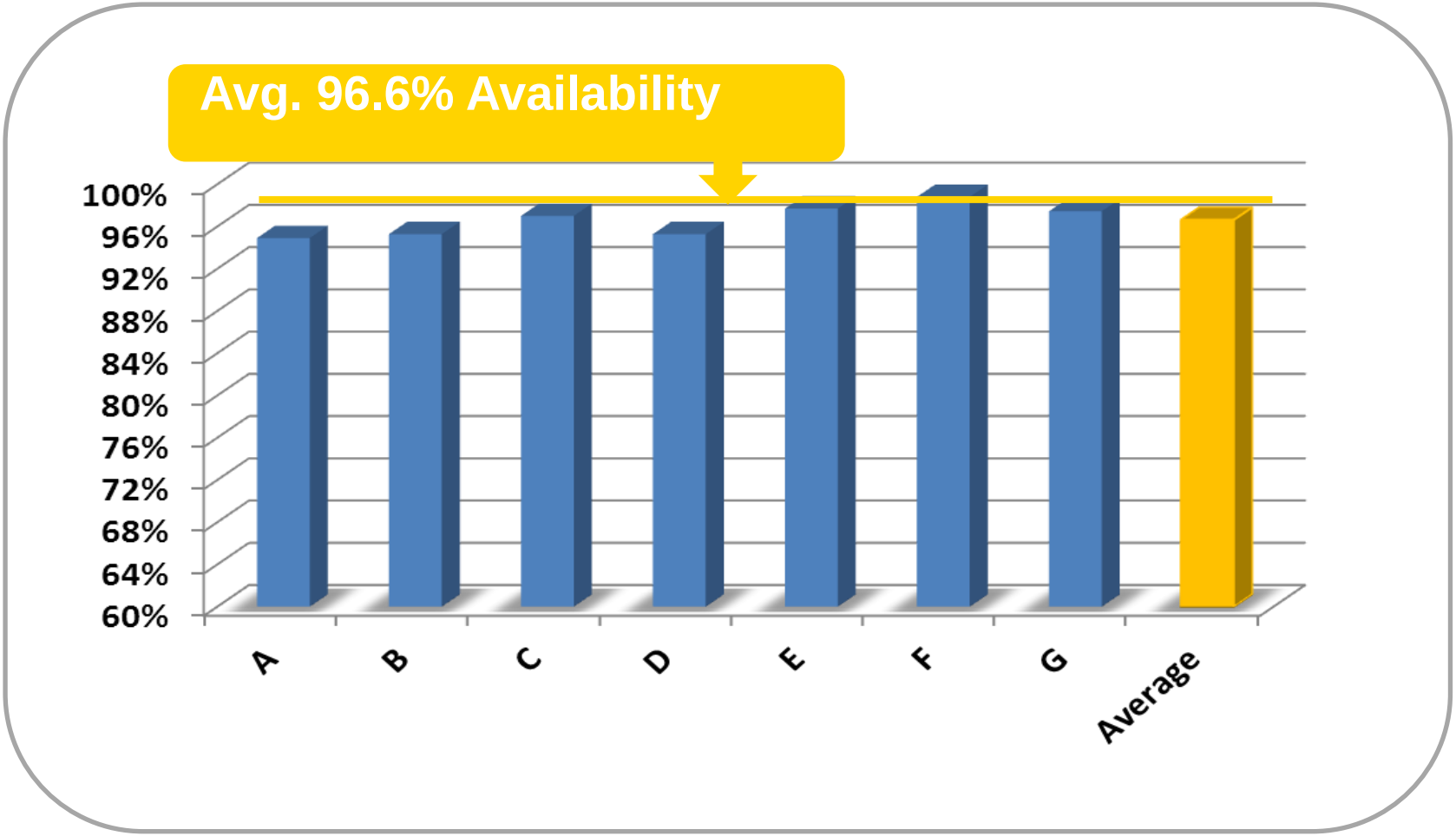
Total Capacity:

> 1,000,000 BPSD

Axens has continuous relationship with Detail Engineering Compagnies

Axens selected over competitor technologies by better than 2 to 1 margin in most recent biddings

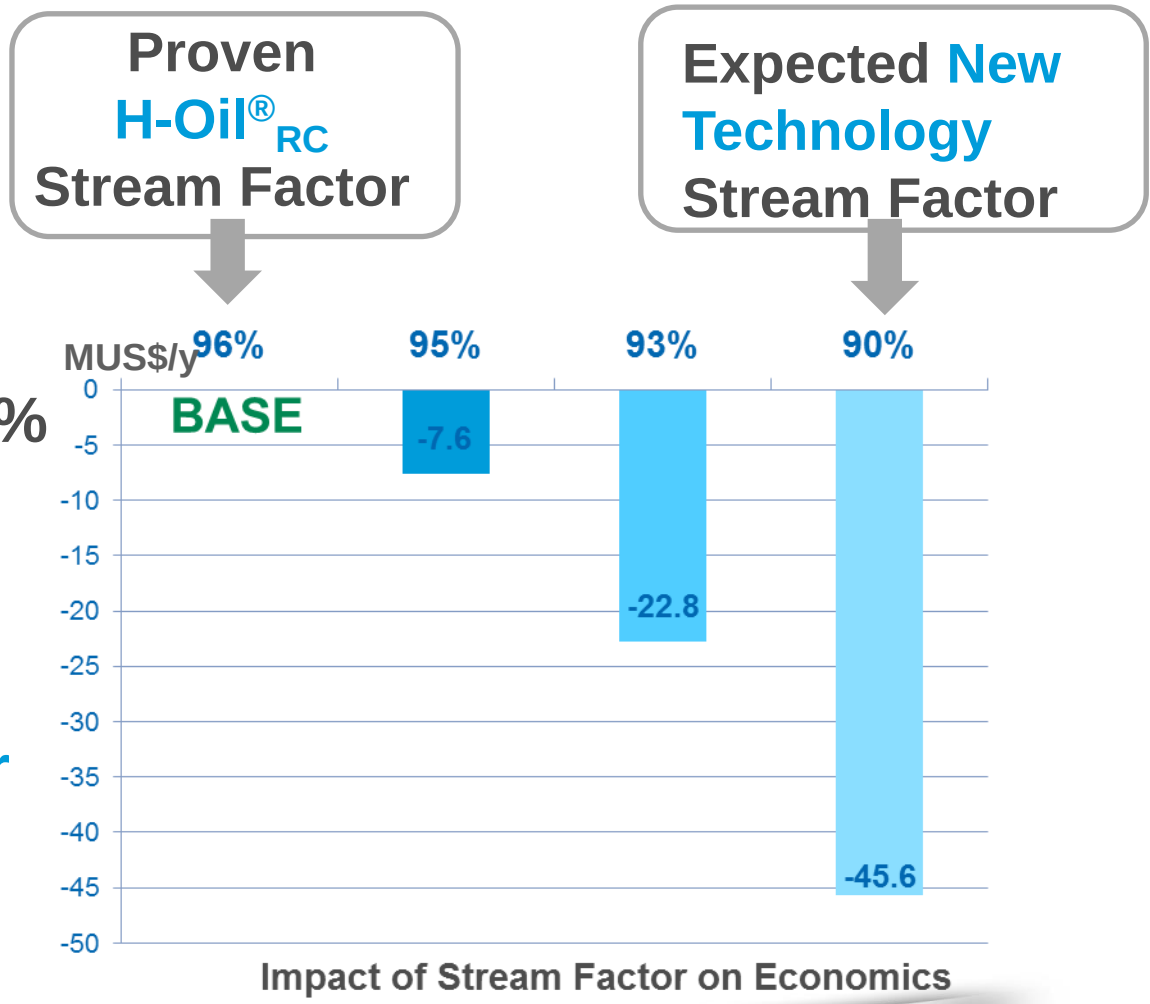
Average Availability of H-Oil® Units (2001-2010/13)



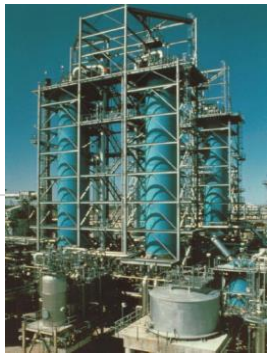
On-stream Factor Impact for VR Conversion Units

- **Product Cost hypothesis**
  - Extra Heavy Crude Oil: 70 US$/Bbl = 440 US$/ton
  - Same price for VR
  - Middle distillates objectives
  - Naphtha: 903 USD/ton
  - Diesel: 933 USD/ton
- **Same conversion level: 90wt%**
- **Capacity: 2500kTA**

45 MUS$/year loss by reduction of stream factor from 96% down to 90%



H-Oil Convent



✓ *Design Feedstock:*

- ***SR VR Arabian Light/Medium***

✓ *Start-up: 1984*

✓ *2 operating modes :*

High Conversion

- **26 300 bpd at 86 wt% Conversion**
- **LHSV = 0.165 h^{-1}**

Maximum Throughput

- **43 000 bpd at 70 wt.% Conversion**
- **LHSV = 0.27 h^{-1}**

August 25, 1986

Mr. David P. Thaler, President
HRI, Inc.
P. O. Box 208
6 Clementon Road
Gibbsboro, NJ 08026

Dear Mr. Thaler:

A performance test on the H-Oil Unit at Convent, LA has been conducted as provided for in Article IV [illegible] the Guarantee Agreement. Analysis of the test result[illegible] dicated that, after adjustment for feedstock and [illegible] strict interpretation of the process guara[illegible] Schedule A of said Agreement have been [illegible], Texaco Inc. is processing the [illegible] in the amount of [illegible] License [illegible] ed in Article IV of the

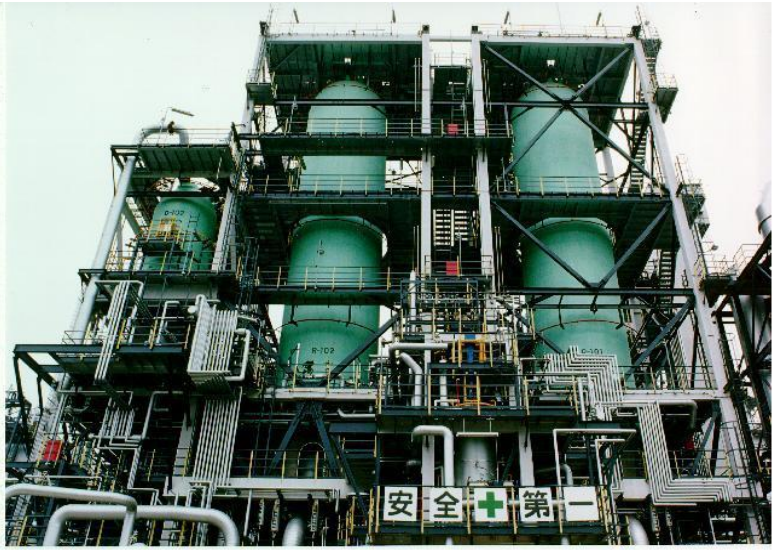
Accepted

Yours ve[illegible]ly,

TEXACO REFINING AND MARKETING INC.

H-Oil Tonen

- ✓ ***Design feed:***
  - ***SR VR Arabian Light/Heavy***
- ✓ ***Start-up: 1997***
- ✓ ***Capacity : 25000 BPSD***



TONEN

Tonen Corp. Kawasaki Refinery
7-1, Ukishima-cho, Kawasaki-ku, Kawasaki-shi, Kanagawa 210, Japan

August 6, 1997

MR.Pierre Bonifay
Chairman,HRI,Inc.
100 Overlook Center,Suite400
Prinston,New Jersey08540
cc Peter Quian
Ed Morrison

Shigeo Sakai
Technical Startup Manager
Tonen Corp. H-oil Project

HRI Assistance in TONEN H-oil Startup

Initial startup of TONEN H-oil was conduc... HUSKY support and black oil has been fed ... with stable operation of the unit,we ... coordinator to close out the startup assista...

We are pleased to ... design throughput over 65% conversion on July 24. We cu... our gratitude to Mr.Tasker and his startup assistance members.Thomas F... Raymond Provencal and Cam Brinston of HUSKY.

A lot of useful suggestions were timely supplied based on actual operation and data. They supported us eagerly from early morning to late night on weekdays. At peak time, shift work was taken by Mr.Cam and Mr.Raymond. Especially Mr.Tasker provided us of many papers over 70 memo to improve operation and about useful information. We are very impressed on his activities and appreciate his continuos support in our project.

Thank you again for all of your support. We believe that TONEN has constructed the No.1 H-oil unit with HRI support.

Best Regards,

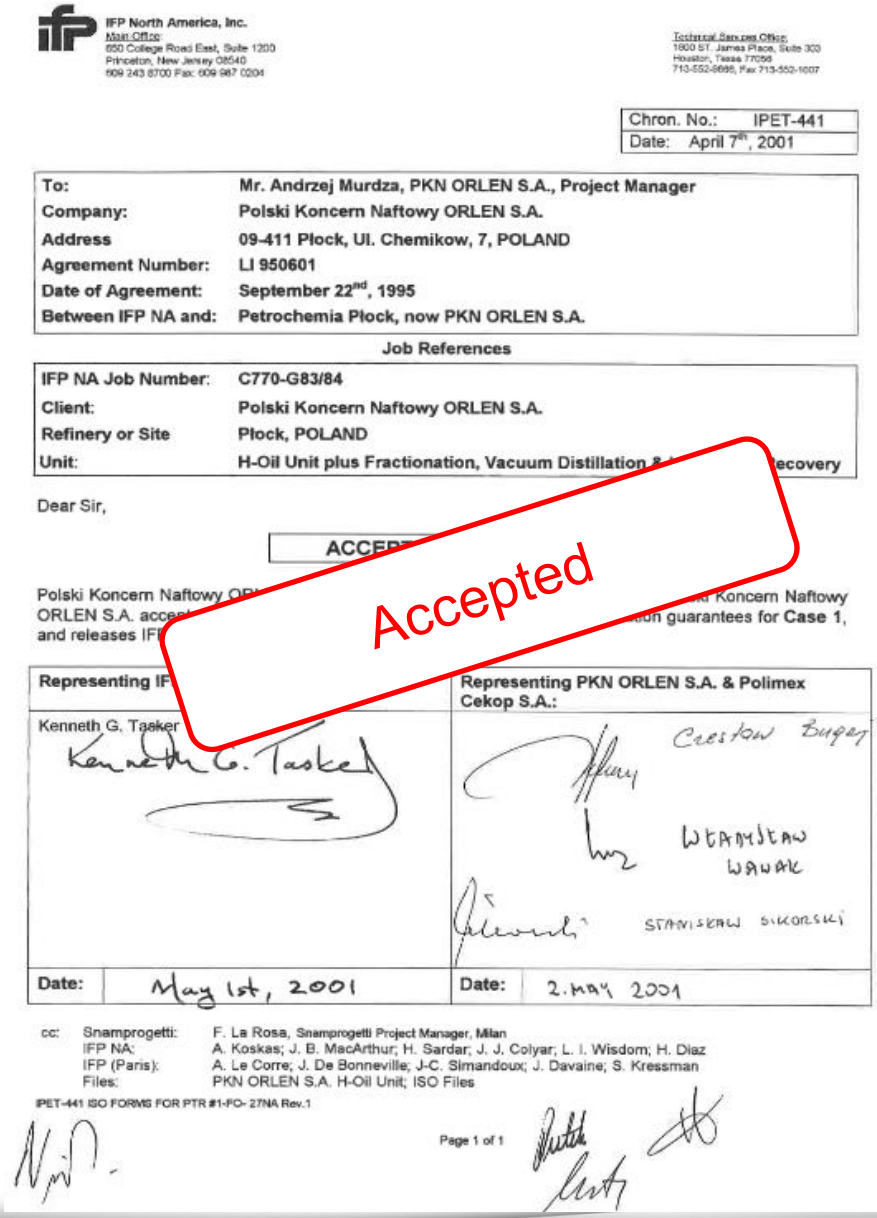
S. Sakai

S.Sakai

Accepted

H-Oil PKN Plock

- ***Design Feedstock:***
  - ***SR VR Ural***
- ***Start-up: 1999***
- ***Capacity: 34 000 BPSD***
- ***2 operating modes :***
  - ***Winter/summer optimized on market demand***
  - ***LSFO sent to power plant***



IFP North America, Inc.
Main Office:
650 College Road East, Suite 1200
Princeton, New Jersey 08540
609 243 8700 Fax: 609 987 0204

Technical Services Office:
1800 ST. James Place, Suite 300
Houston, Texas 77056
713-552-9666, Fax 713-552-1607

Chron. No.: IPET-441
Date: April 7th, 2001

To:	Mr. Andrzej Murdza, PKN ORLEN S.A., Project Manager
Company:	Polski Koncern Naftowy ORLEN S.A.
Address	09-411 Plock, Ul. Chemikow, 7, POLAND
Agreement Number:	LI 950601
Date of Agreement:	September 22nd, 1995
Between IFP NA and:	Petrochemia Plock, now PKN ORLEN S.A.

Job References

IFP NA Job Number:	C770-G83/84
Client:	Polski Koncern Naftowy ORLEN S.A.
Refinery or Site	Plock, POLAND
Unit:	H-Oil Unit plus Fractionation, Vacuum Distillation & ... ecovery

Dear Sir,

ACCEP...

Accepted

Polski Koncern Naftowy OR... ...ki Koncern Naftowy ORLEN S.A. accept... ...tion guarantees for Case 1, and releases IF...

Representing IF...	Representing PKN ORLEN S.A. & Polimex Cekop S.A.:
Kenneth G. Tasker	Czesław Bugaj Wtanisław Wawak Stanisław Sikorski
Date: May 1st, 2001	Date: 2. maj 2001

cc: Snamprogetti: F. La Rosa, Snamprogetti Project Manager, Milan
IFP NA: A. Koskas; J. B. MacArthur; H. Sardar; J. J. Colyar; L. I. Wisdom; H. Diaz
IFP (Paris): A. Le Corre; J. De Bonneville; J-C. Simandoux; J. Davaine; S. Kressman
Files: PKN ORLEN S.A. H-Oil Unit; ISO Files

IPET-441 ISO FORMS FOR PTR #1-FO- 27NA Rev.1

Page 1 of 1

H-Oil Lukoil Perm

- ✓ ***Design feed:***
  - ***SR VGO***
  - ***HCGO***
- ✓ ***Start-up: 2004***
- ✓ ***Capacity : 70 400 BPSD***

ChevronTexaco Global Technology
Services Company
100 Chevron Way
Richmond, CA 94802
P.O. Box 1627
Richmond, CA 94802-0627

December 2, 2004

ChevronTexaco

Completion of Services and
Acceptance of the T-Star™ Unit
LUKOIL Perm Refinery

Gentlemen:

ChevronTexaco Global Technology Services Company (GLOBETECH) and Joint Stock Company LUKOIL-Permnefteorgsyntez (LUKOIL PERM) are pleased to acknowledge the successful start-up of the T-Star™ unit at Perm on September 14, 2004 and the comple… successful Acceptance Test Run conducted from 1000 hours November 23, to 1000 hours … 004.

GLOBETECH and LUKOIL PERM ackno… exceeded its guarantees under the TEXACO T-STAR HYDR… MENT dated October 5, 1993, amended in Letter Ar… sumption Guarantee letter revision dated Septe… ated to the Hydrodearomatization (HDA) section … Charly Wills dated June 2, 2004.

GLOBETECH … ledge the satisfactory completion of the GLOBETECH provided servic… Contract No. 66 and Contract No. 1273.

By signing this le… UKOIL PERM confirms the above and its acceptance of the Texaco licensed T-Star™ unit as meeting all Guarantees specified in the 5 October 1993 Guarantee Agreement, as amended.

Yours very truly,

ChevronTexaco Global Technology
Services Company

Name: B Carlo P Jensen

Position: Vice President

Date: December 2, 2004

Accepted

Attn Charles
Wills
1-510-242-5727

ACCEPTED AND AGREED TO:
Joint Stock Company LUKOIL-Permnefteorgsyntez

By: [signature]

Position: Chief Engineer

Date: January 11, 2005

Axens
IFP Group Technologies

LNB Bourgas – Last EB Started-up

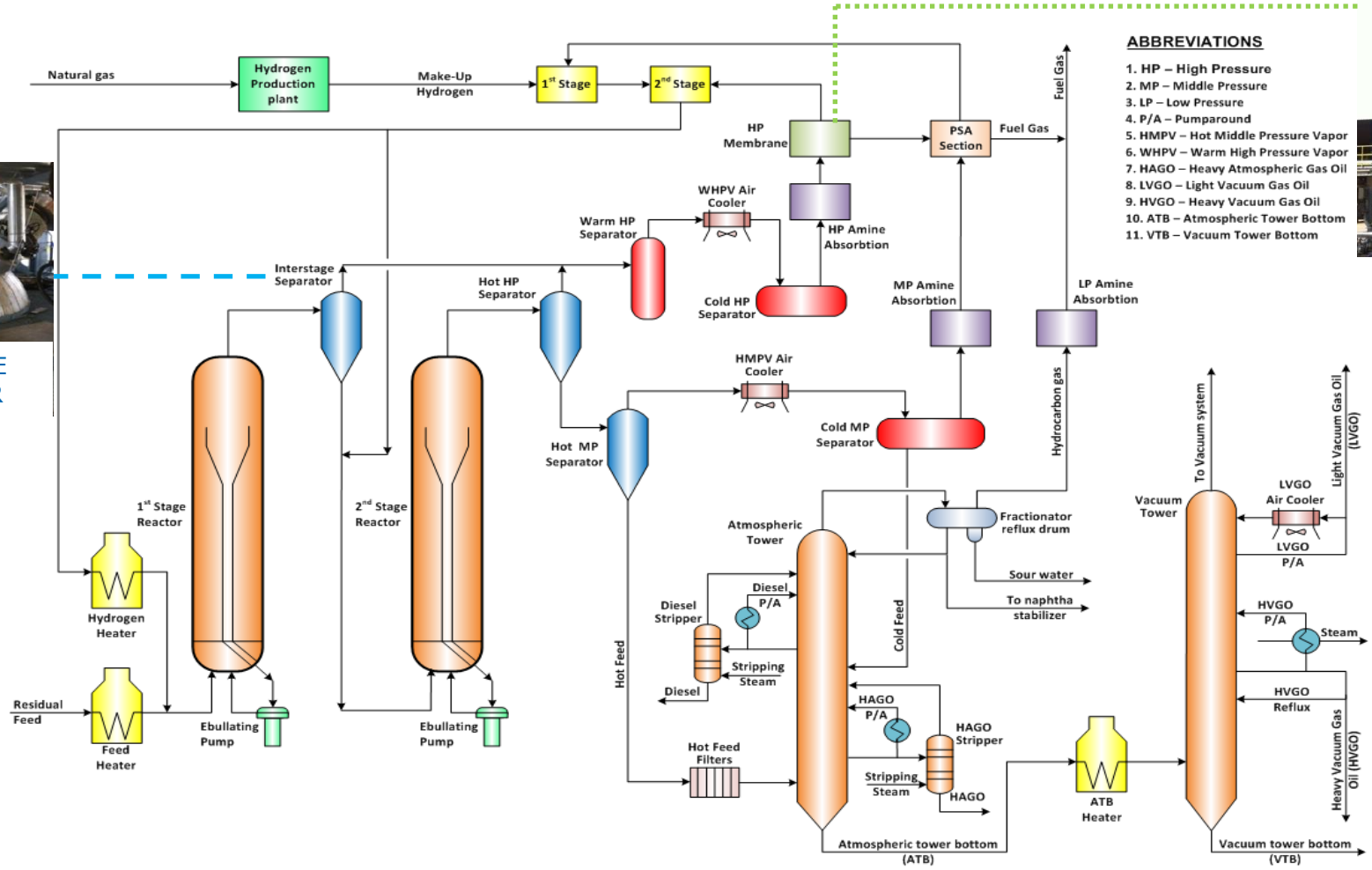
Axens Design	2008
End of Detailed Engineering	2013
End of Construction & Commissioning	2015
Start-up	2015

- **Configuration:** Single Train with 2 H-Oil Reactors in series, ISS and cascading
- **Objective:** Operation 70% conversion (538°C+ Basis) to produce Low-Sulfur Vacuum Residue (S<1.25%)
- **Design Basis:** 312.5 t/h (46000BPSD) Ural VR Feedstock, using 3rd Generation High Conversion Catalyst Criterion TEX-2731

LNB Bourgas – Most Advanced EB in the world

INTERSTAGE SEPARATOR

HP MEMBRANE



Recent H-Oil technology improvements updated for LNB H-Oil Unit: *ISS, H2 management system, C²U*,…

LNB Bourgas – Objectives Outperformed

	Design	Guaranteed (as per TTA)	Test-Run
Feed	100% Ural	100% Ural	70% Ural/30% Arabian
Capacity	100%	100%	100% ✓
H2 consumption	1.95	<1.97	1.93 ✓
Gases, wt%	7.05	7.05	8.60 ✓
Naphtha, wt%	6.57	>4.6	6.65 ✓
Gasoil, wt%	25.23	>23.1	27.57 ✓
Vacuum Gasoil, wt%	35.50	>32.8	33.25 ✓
Net Conversion, wt%	70	>70	70.4 ✓
UCO - IP375, wt%	<0.3	<0.3	<0.3 ✓
UCO - IP390, wt%	Not foreseen	Not guaranteed	<0.1 ✓

To pass this **new demand** (UCO sold as bunker fuel) **with 100% Ural**: Conversion is 65wt%

Lukoil Bourgas -

Performances Test:

- **Formal Test conducted in November 2016.**
- **Unit Accepted in November 2016.**
- **2 years Technical Services Agreement started from March 2017:**
  - → Regular data follow-up.
  - → Regular visits.
  - → Dedicated Studies.
  - → Analytical Support.
  - → Site Assistance for T/A and troubleshooting.

LUKOIL OIL COMPANY

JOINT - STOCK COMPANY
LUKOIL Neftohim Burgas AD

To
Mr. Fabien Lundy
Sales Director
Process Licensing Business Unit
Axens
89, Bd Franklin Roosevelt – BP 50802
92508 - Rueil-Malmaison Cedex - France

TESTIMONIAL LETTER
To whom it may concern

Project: **HEAVY RESIDUE PROCESS COMPLEX FIRST PHASE**
Process: **H-Oil Hydrocracking**
Licensor: **Axens**
Contractor: **Technip Italy S.p.A.**
Owner: **LUKOIL Neftohim Burgas AD**

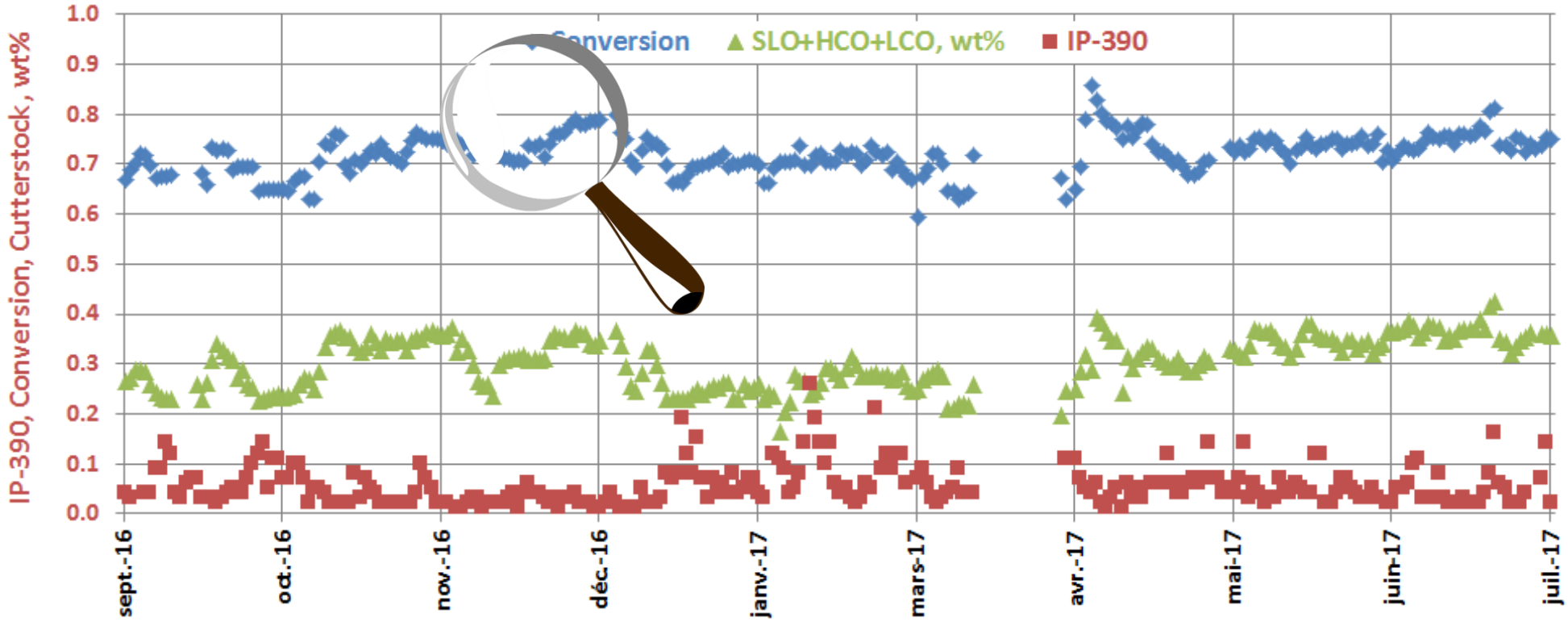
Accepted

Best regards,

Director of Construction R.S.Penev

T.K.Krumov
+359 5511 2135

Main Performances - Conversion



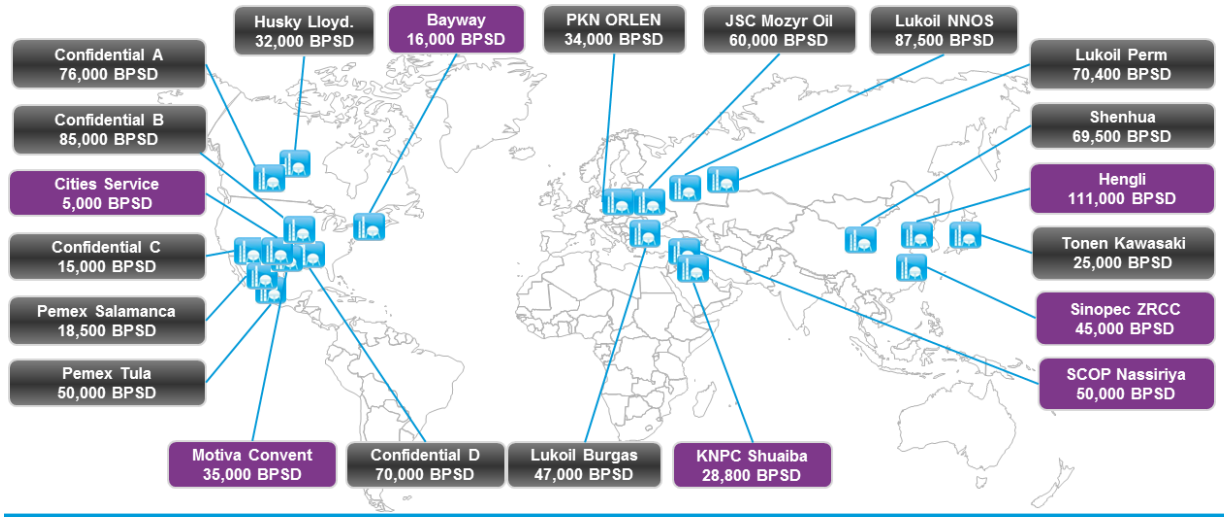
- **Conversion maintained between 65 to 75wt% up to March T/A.**
- **Conversion maintained between 70 to 75wt% after March T/A. Level of severity possible due to processing of ME Crudes (30%) and co-processing of SLO since beginning of May which lead to low level of sediment at the ATB (IP-375) and in in the FO Product (IP-390).**

TESTIMONY

« The conversion and the yields in higher value products were increased with a positive effect on Refinery economics. The project is considered as successful featuring with an attractive economics »

LNB refinery about recent H-Oil implementation
June 20117

H-Oil®: The Residue Conversion Workhorse



- 12 H-Oil® units **operated**
  - 5 with Middle East VR
- 9 H-Oil® units **under Construction/ Design**
  - 4 with Middle East VR

Total Capacity: > 1 MM BPSD

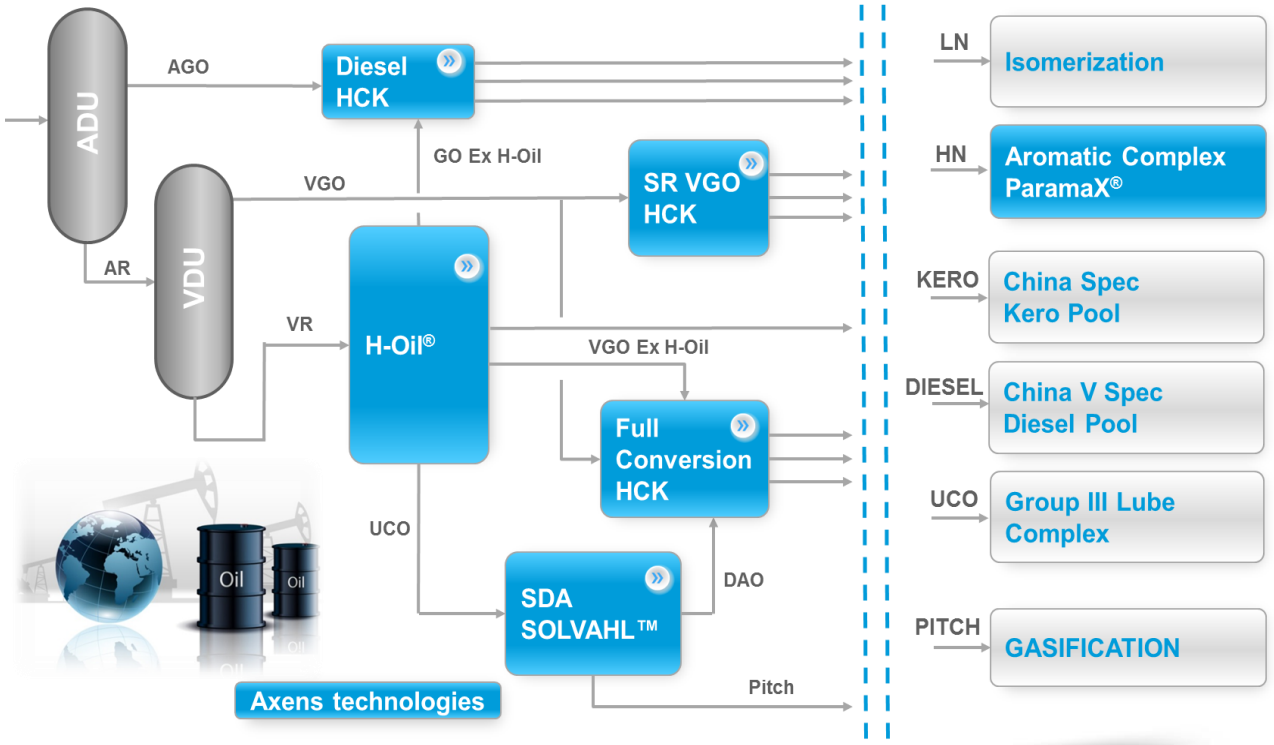
First industrial unit started in 1968

Mature Technology

Repeated satisfied customer

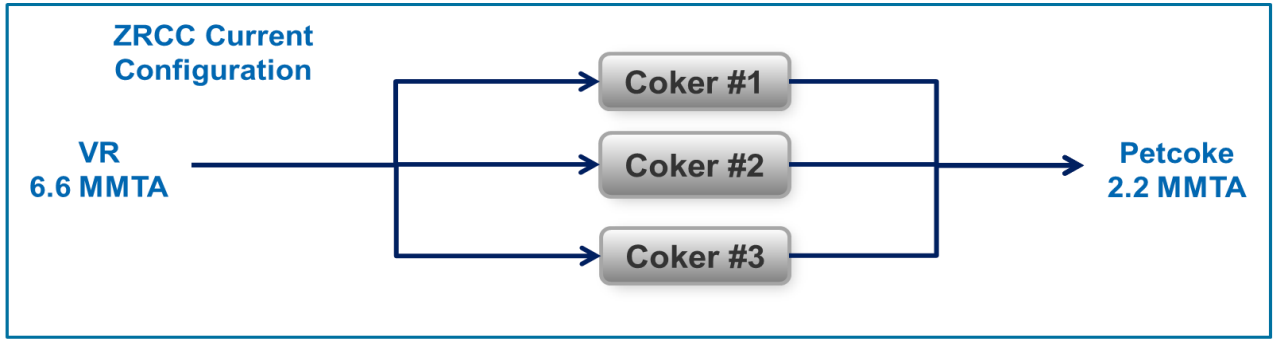
Hengli Project - China

- **Configuration : H-Oil+**
  - Capacity: 110 000 BPSD
  - Nb trains : 2 trains of 2 reactors
  - Feedstock: Arabian/Marlim crude
  - Conversion: 90%
    - 80% H-Oil
    - + SDA unit
- **Status**
  - Start up scheduled for 2018
  - EPC phase. P&ID commented
  - Equipment order phase

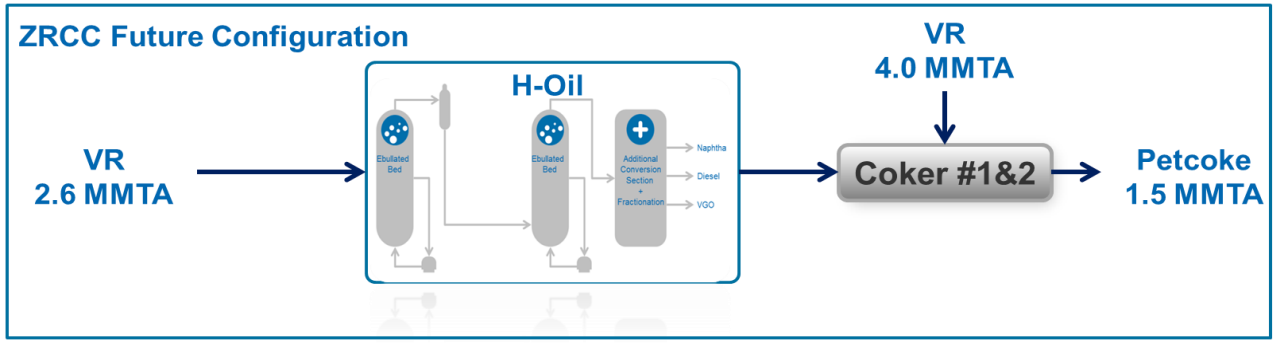


ZRCC Project - China

- **Configuration: H-Oil +**
  - Capacity: 45 000 BPSD
  - Nb trains: 1 train of 2 reactors
  - Feedstock: Mix Arabian crudes
  - Conversion: 85%

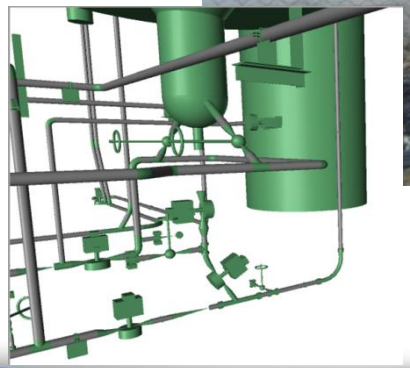


- **Status**
  - Start up scheduled for 2018
  - EPC phase.
  - Classroom/ On-site training in September 2017



Mozyr Project - Belarus

- **Configuration: H-Oil integrated with Prime-D**
  - Capacity: 60 000 BPSD
  - Nb trains: 2 trains of reaction section / 1 fractionation section
  - Feedstock: Urals
  - Conversion: 70 wt%
- **Status**
  - 3D Review done June 2016
  - Reactors on site
  - Start-up procedure revision
  - Start up scheduled for 2019

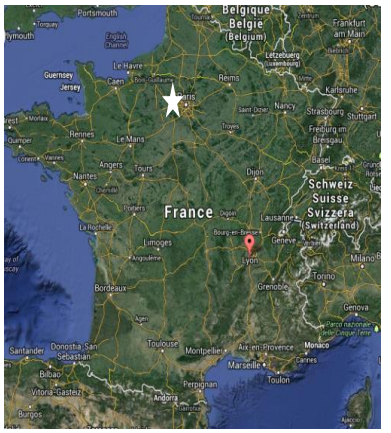


R&D capabilities – IFPEN Identity card

1,660
people
of whom

155
doctoral and post-doctoral researchers

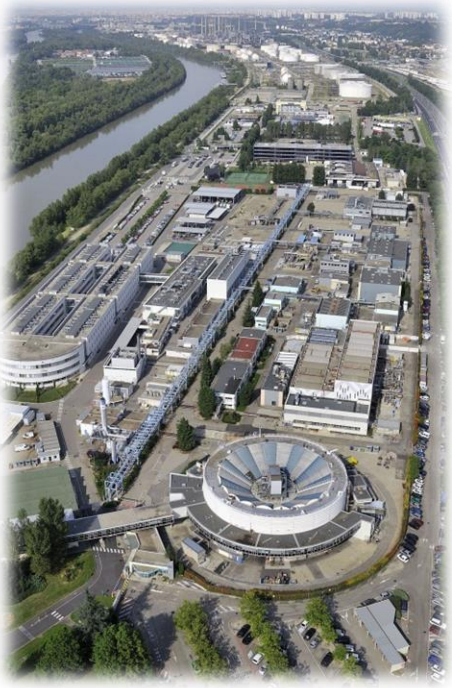
2 sites:
Rueil (near Paris)
and Solaize (near Lyon)



1,146
researchers

A very high-quality technical environment: testing resources, equipment, **110** teraflop supercomputer

More than **50** professions, from geological engineers to powertrain engineers



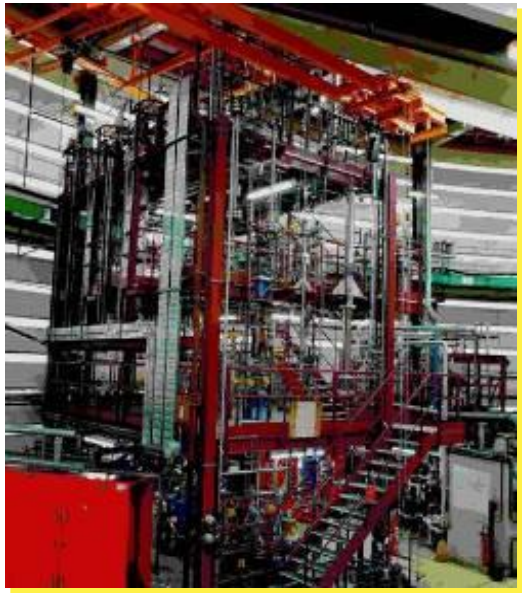
HOil R&D Activities

RESPONSIBLE
OIL AND GAS

- Stability investigation
  - Understanding of Asphaltenes conversion
  - Impact of coprocessing and cutterstoks (LCO+HCO)
- High conversion target
  - Exploring new operating conditions to reach high conversion while preserving the process stability
  - Integration of SDA downstream HOil process
- Active work on process fundamentals
  - CFD study, cold mock up testing
- Process modeling
  - Predictive tool

H-OIL PILOT TOOLS

- **Dedicated Facilities and Staff for Ebullated-Bed R&D**
  - Robinson Mahoney Unit
  - Ebullated-Bed Bench Unit
  - Fixed-Bed Catalyst Evaluation Unit
  - Cold Flow Mock-Ups



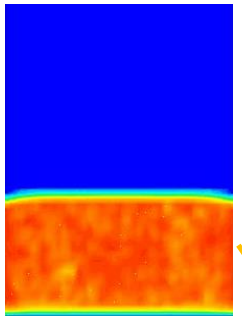
NEW ROBINSON MAHONEY CSTR UNIT U878

First Chemical reactor design by CFD and conceived by 3D printing

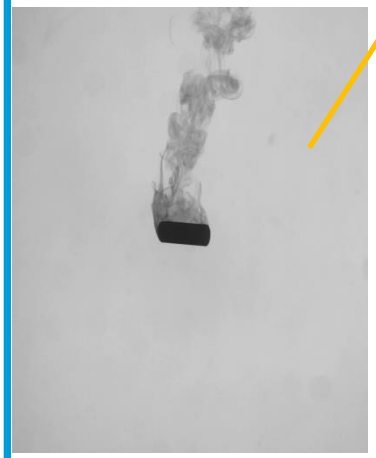
Optimization of reactor design by CFD

Prototype 3D printing

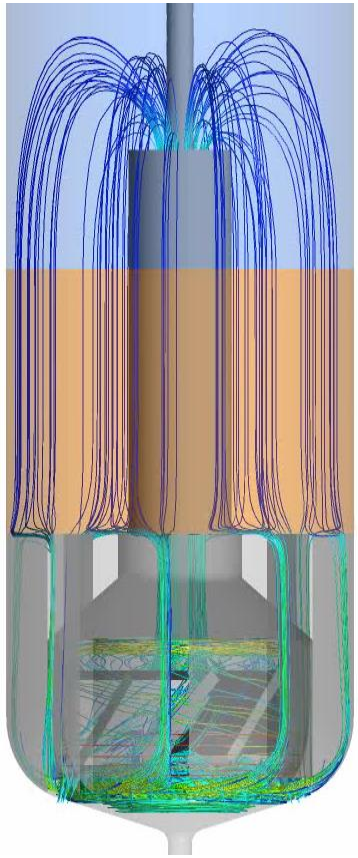
Cold mock-up validation



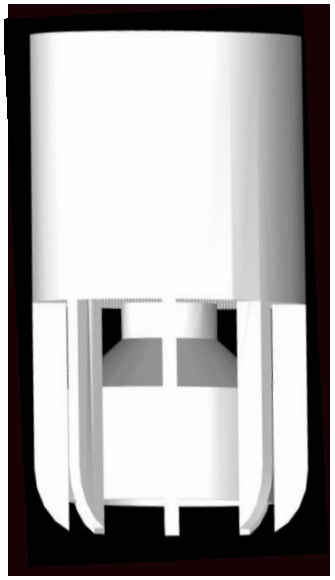
Local approach
Catalyst bed
CFD

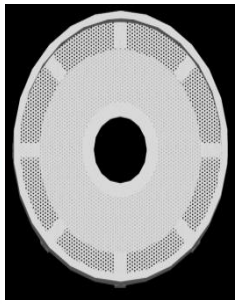


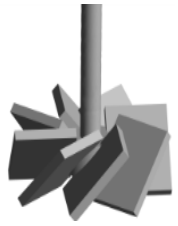
Particle
Experimental



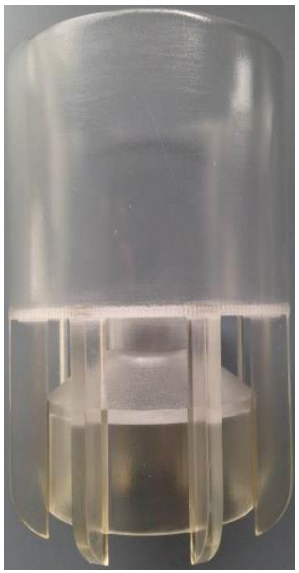
Global Approach
CFD







Internals
CFD



Reactor internals
3D printing

Catalyst fluidisation
Cold mock-up

H-Oil Pilot test

Since 1996 : over 45,000 hours of operating data

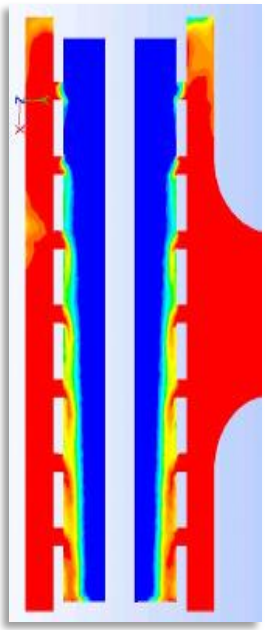
- **Feedstocks tested**
  - Vacuum Residue, Atmospheric Residue, DeAsphalted Oil, Vacuum Gas Oil, Whole crude, Whole bitumen, HCGO, hydrotreated VGO, ...
- **Origin of the crudes**
  - Canadian (Athabasca mined, Athabasca SAGD, Athabasca PFT, Lloydminster, Cold Lake, ...)
  - Middle East (Safaniya, Buzurgan, Arabian Heavy, ...)
  - South-American (Zuata, Morichal, Cerro Negro, Boscan, Chichimene, ...)
  - Russian (Ural, Siberian, ...)
  - Chinese (Tahe)……

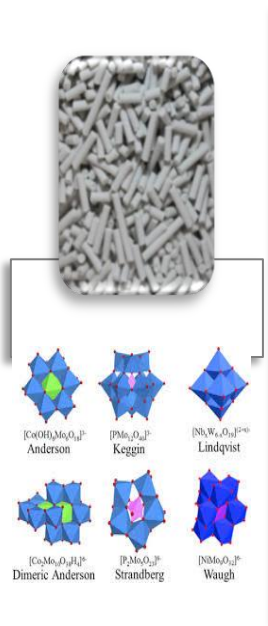
  ➡ Metals: 0 to 1500 ppm, S: 0.2 to 6wt%, CCR: 0.1 to 35wt%, N: 10 to 8000 ppm
- **Large range of operating conditions (T, P, LHSV,…)**

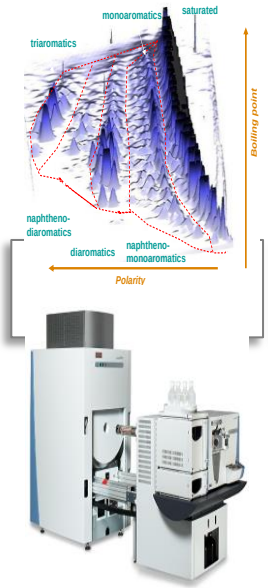
FROM INITIAL IDEAS TO INDUSTRIAL APPLICATION

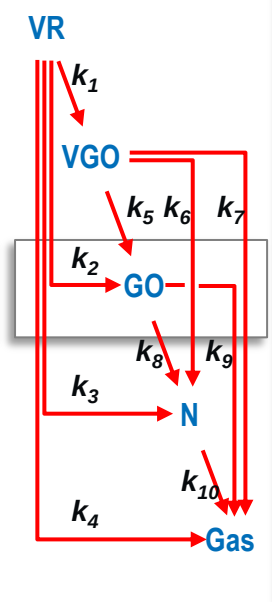
Cutting-edge research and development of new and improved processes and technologies for the industry

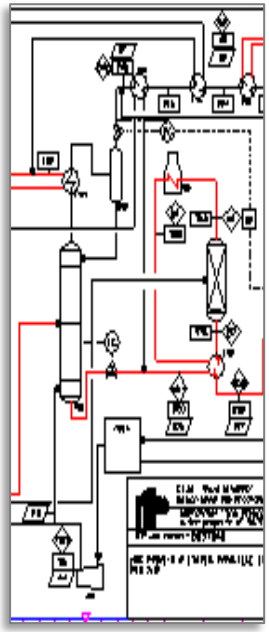
Cold Flow Mock-Ups | **CFD Flow Modeling** | **Catalyst Development** | **Pilot Plant Units** | **Analytical Tools** | **Kinetic Models** | **Process Models**





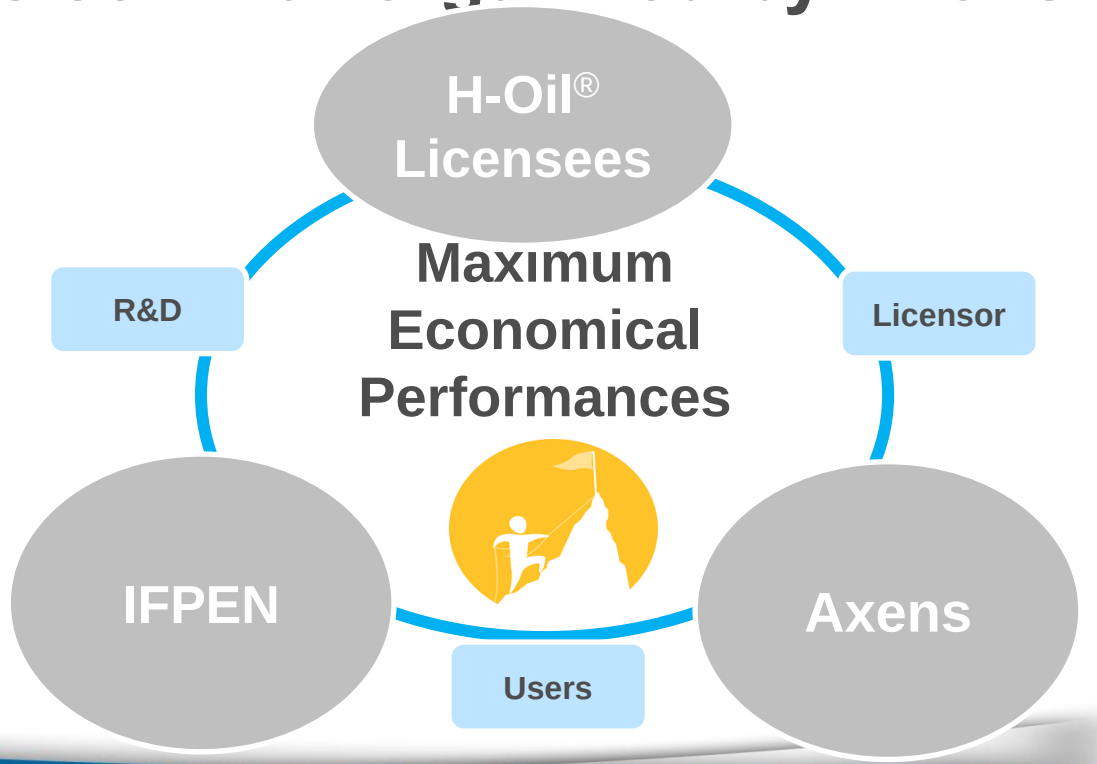






H-Oil community

- 10 Companies around the world
- Site visit possible
  - › For discussion with independent operators (none H-Oil unit is a captive unit)
  - › For operators training
- On regular basis : User's seminar organized by Axens
  - › Last one : October 2017



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