

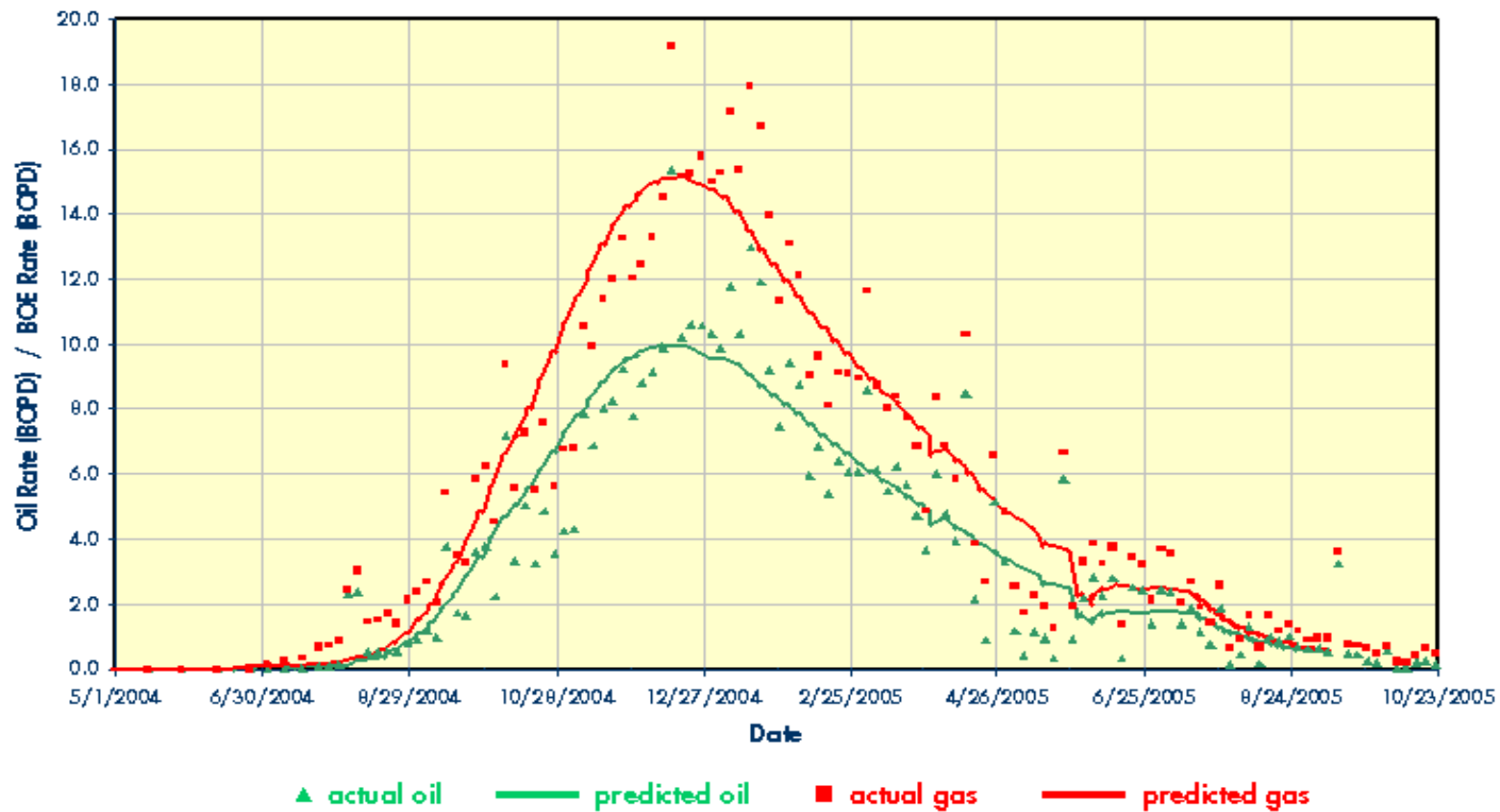
Shell ICP – Shale Oil Refining

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Basis for ICP Shale Oil Refining Assessment – MDP[s] Field Pilot Production

Research demonstrates In situ Conversion Process works technically on a small scale – what remains is to prove it works commercially



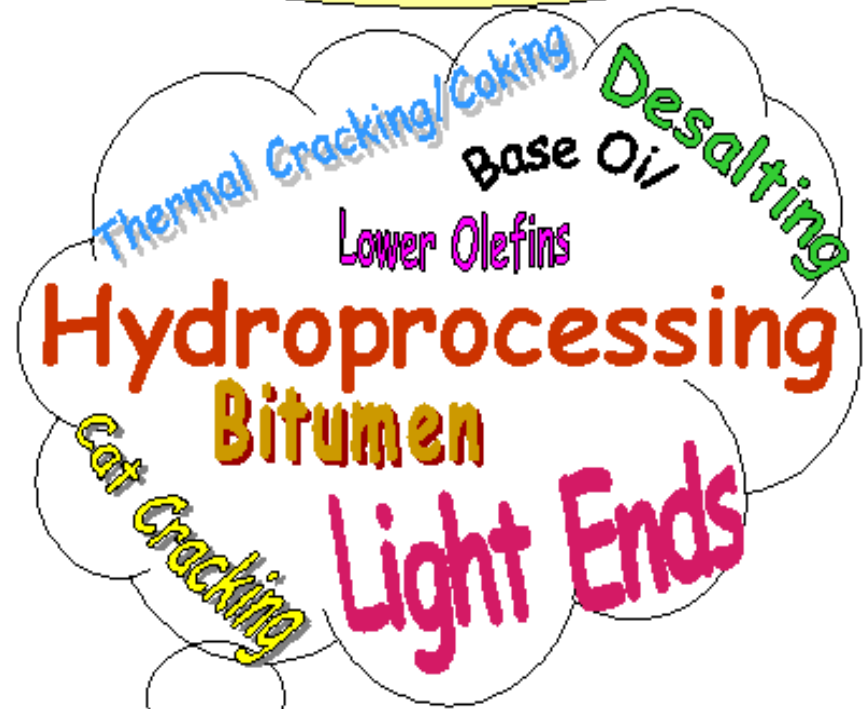
Source: MDP South test (2004/05)

ICP Shale Oil Assessment Program

Characteristics

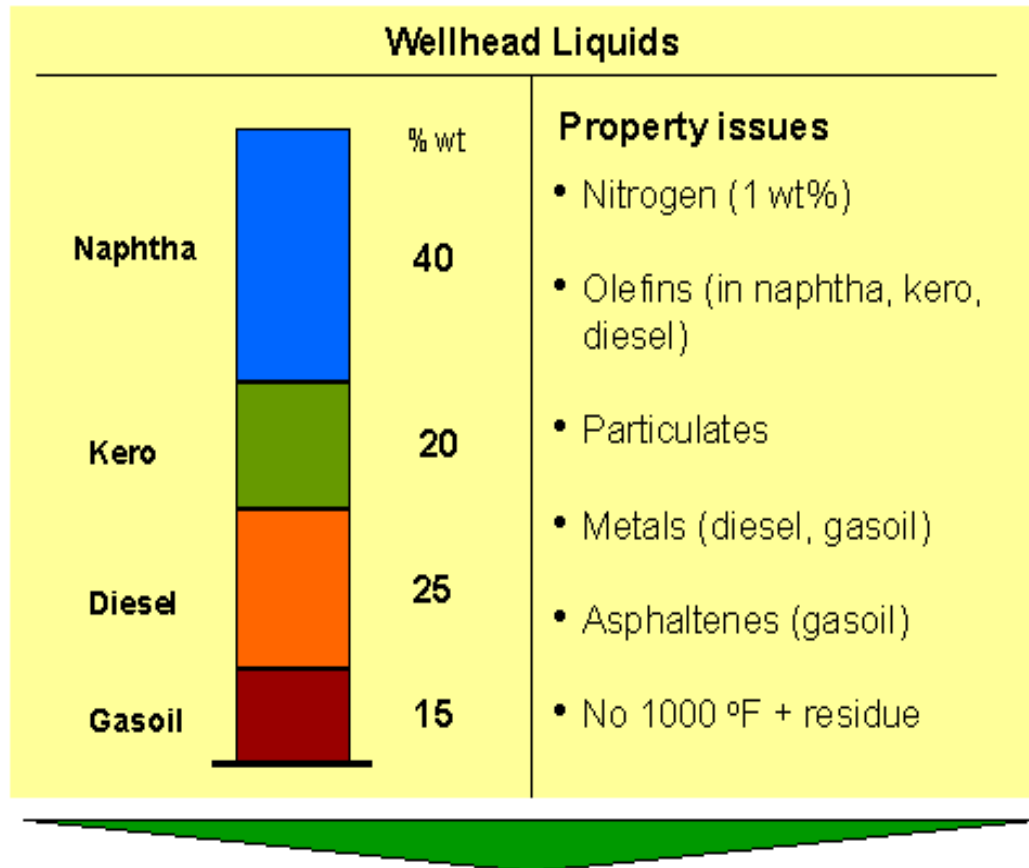


Processes/Products



ICP Shale Oil - Characteristics

MDP[s] DATA

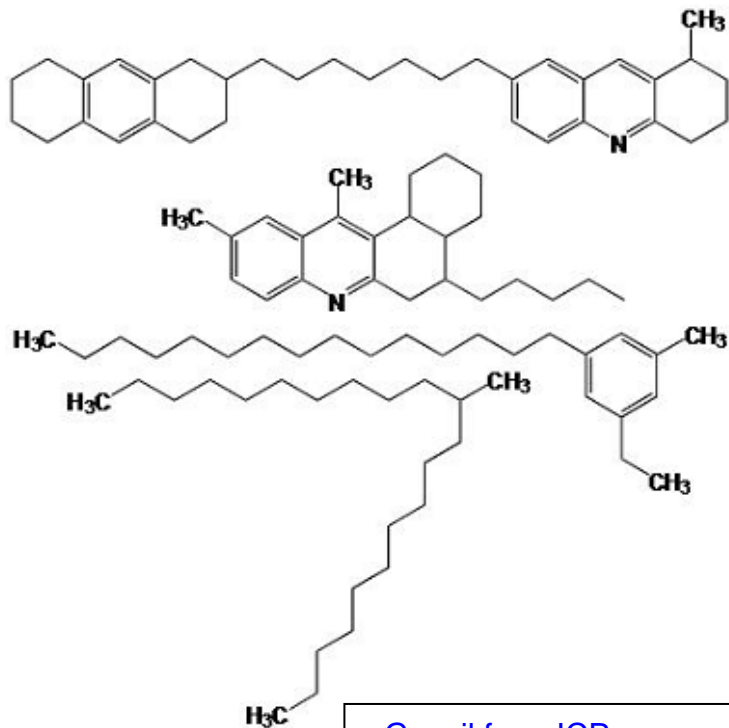


Pilot plant testing and analytical characterization used to understand the properties of shale oil and assess processability

ICP Shale Oil - Characteristics

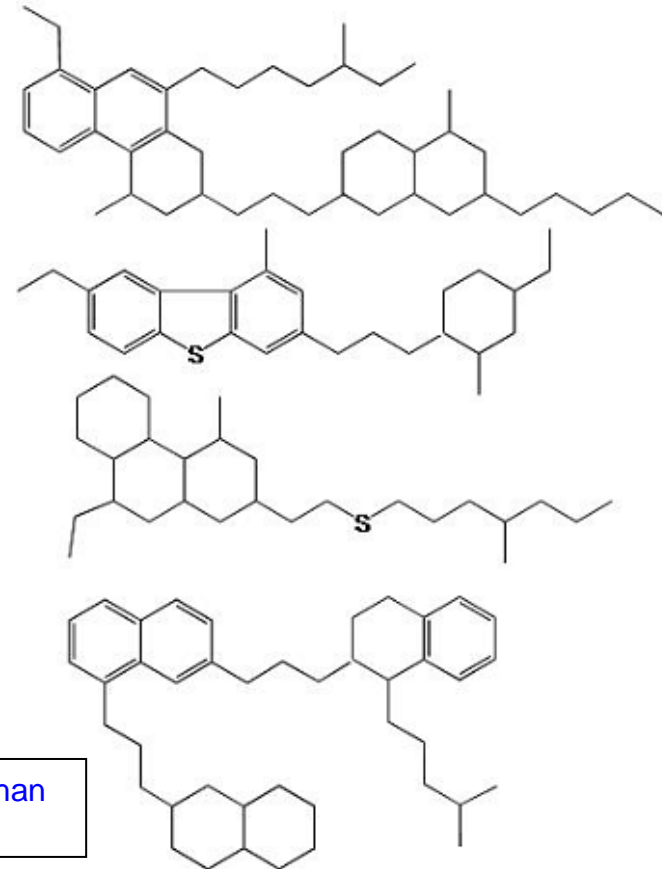
Typical Molecular Representation

ICP Shale Oil Gasoil



Gasoil from ICP more paraffinic than from bitumen

Athabasca Gasoil

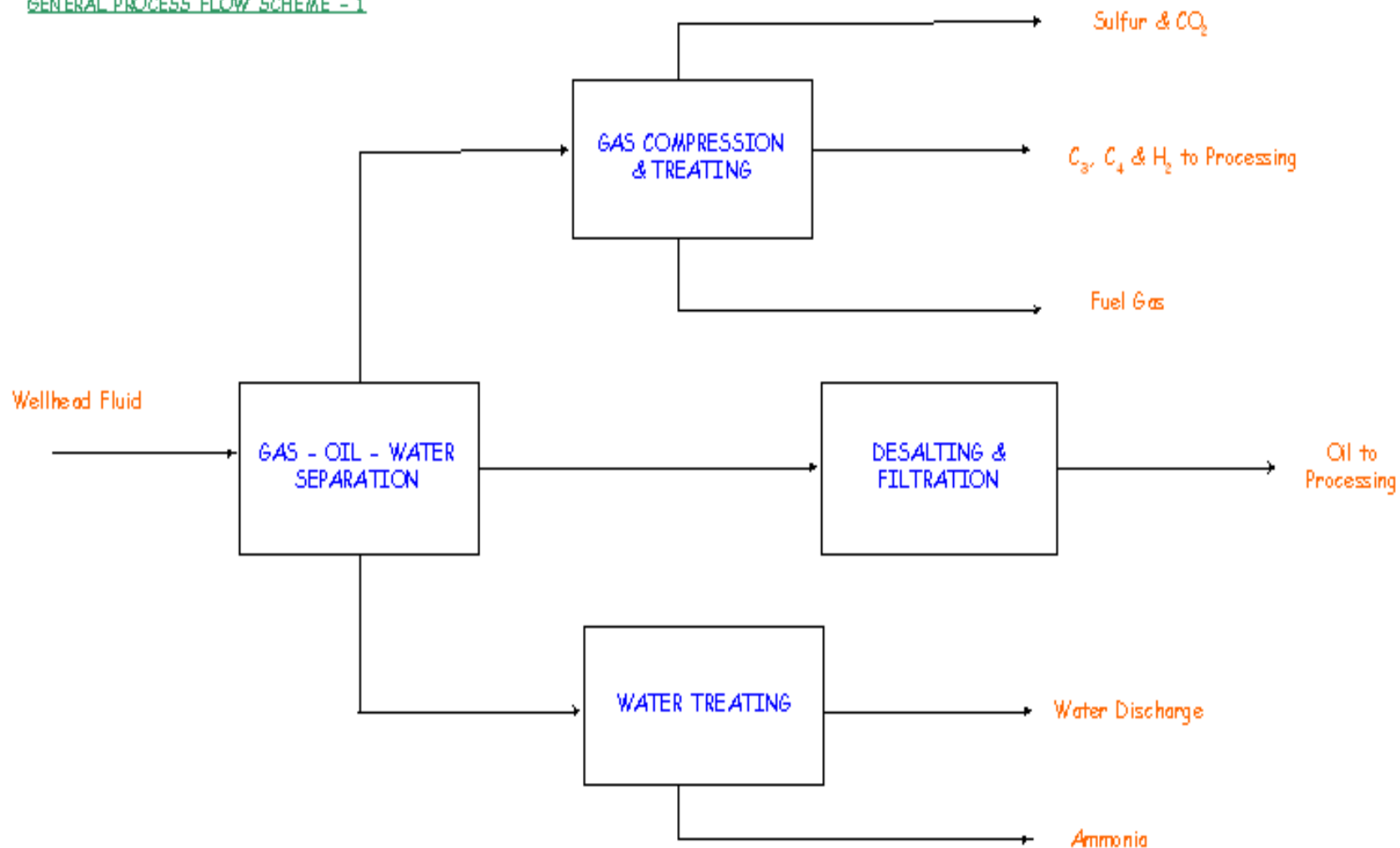


ICP Sour Gas & Water - Processing

- Water washing of ICP Gas to remove/dilute corrosive salts
- Sour water contains H_2S , CO_2 and NH_3
 - 2-stage sour water stripping
- Treatment of stripped water to discharge
 - Removal of contaminants (metals, phenols, salts)

ICP Shale Oil Processing – General Flowscheme 1

SHELL TOP SHALE OIL REFINING
GENERAL PROCESS FLOW SCHEME - 1

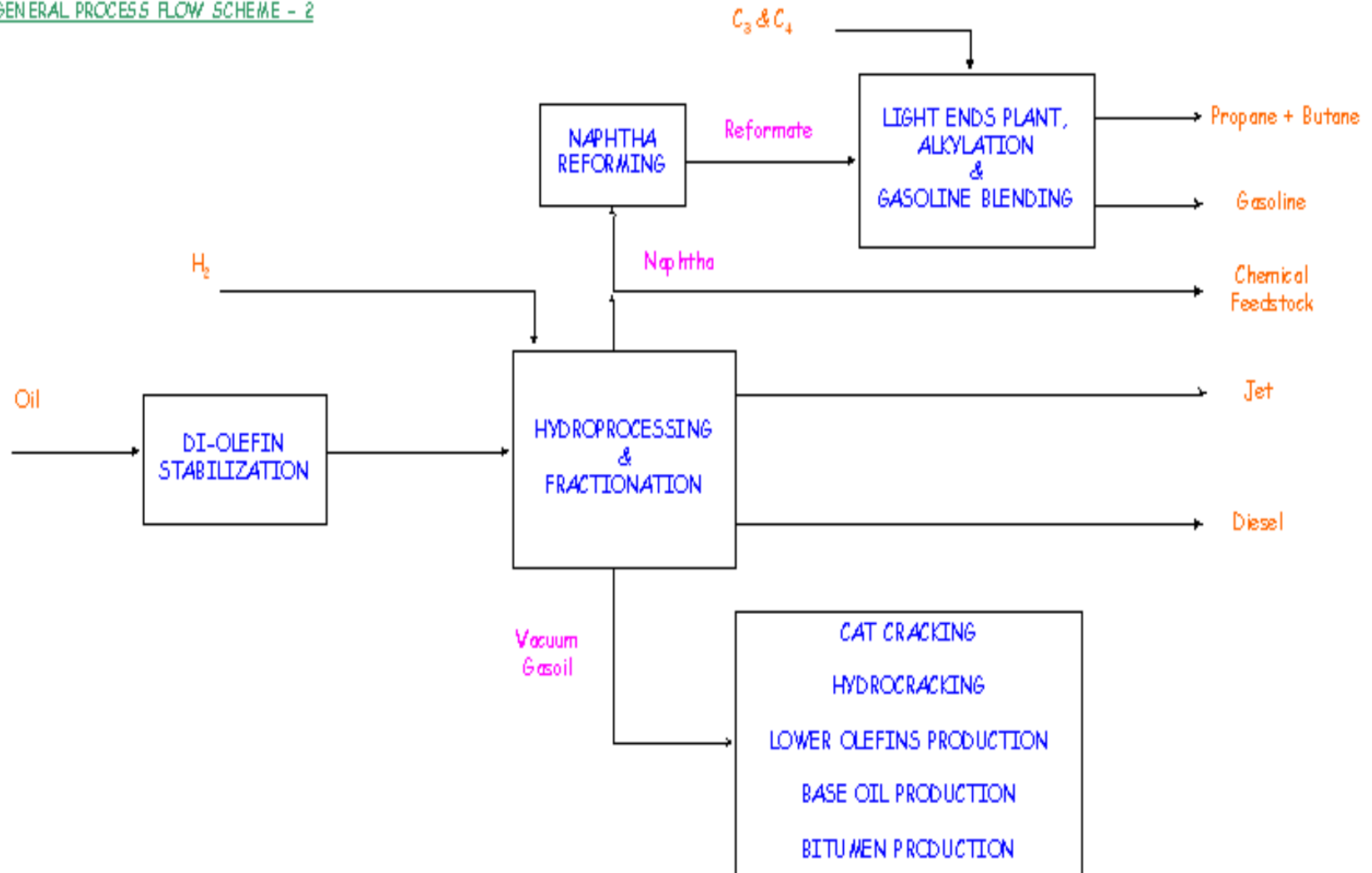


ICP Shale Oil - Processing

- Raw shale oil has a tendency to foul because of particulates and di-olefinic species
- C_3 & C_4 olefins from ICP shale gas can be alkylated to produce high octane gasoline
- Paraffinic shale oil naphtha can produce low octane reformat or be used as chemical feedstock after hydrotreating
- H_2 in ICP shale gas can be recovered for hydroprocessing demand
- Paraffinic shale oil Middle Distillates make excellent jet & diesel
- Paraffinic shale oil vacuum gasoil can be subjected to various conversion processes, e.g. Cat Cracking, Hydrocracking, or used for the production of Lower Olefins or Base Oil/Bitumen

ICP Shale Oil Processing – General Flowscheme 2

SHELL ICP SHALE OIL REFINING
GENERAL PROCESS FLOW SCHEME - 2



Shale Oil Product - JP-8 Jet Fuel

Specification Test	Shell ICP Shale Oil JP8 2007	Shale Oil JP5 1974	Paraho Shale Oil JP5 1978	GTL JP8	Petroleum JP-8
Total Acid Number, mg KOH/g	0.002		0.001	0.004	0.005
Aromatics, vol %	3.2	25.95	24.0	0.0	20.3
Olefins %	0.7	2.29	1.6	0.0	0.6
Mercaptan Sulfur, % mass	0.000		0.01	0.000	0.000
Total Sulfur, % mass	0.00	0.05	0.04	0.00	0.07
Distillation:					
IBP, °C	146	171	186	144	160
10% recovered, °C	166	191	193	167	177
20% recovered, °C	171	199	196	177	183
50% recovered, °C	186	219	207	206	200
90% recovered, °C	219	254	232	256	237
EP, °C	245	282	253	275	255
Residue, % vol	1.3	1.0	1.2	1.5	1.2
Loss, % vol	0.5	1.2	0.2	0.9	0.7
Flash point, °C	44	65.5	66	45	52
Cetane Index (calculated)	52.4	49.5	44.6	66.0	45.1
Freeze Point, °C	-53	-22.5	-46	-51	-49

Courtesy of DoD

Shale Oil Product - JP-8 Jet Fuel

Specification Test	Shell ICP Shale Oil JP8 2007	Shale Oil JP5 1974 (at -18°C)	Paraho Shale Oil JP5 1978	GTL JP8	Petroleum JP-8
Viscosity @ -20°C, cSt	3.7	5.1 (at -18°C)		4.9	4.2
Viscosity @ -40°C, cSt	6.7		7.99 (at -34°C)	9.5	8.3
Heat of Combustion (measured), BTU/lb	18740	18532	18561	18870	18470
Hydrogen Content, % mass	14.7	13.7	13.7	15.4	13.8
Smoke Point, mm	40	22	21	42	23
Copper Strip Corrosion	1a	1a	3b	1a	1a
Thermal Stability @ 260°C:					
Tube Deposit Rating	0	Fail	0	1	1
Change in Pressure, mm Hg	0		0	0	1
Existent Gum, mg/100mL	0.2	81.7	0	0.6	0.2
Particulate Matter, mg/mL	0.1	164.2	0.6	1.0	NR
Filtration Time, minutes	3			10	NR
Water Reaction	1			1	1
Specific Gravity @ 15°C	0.778	0.8058	0.807	0.756	0.798
Nitrogen, ppm	0	895	1.0	0	

Courtesy of DoD

Shale Oil Product - ULSD

Test Description	ICP Shale Oil	Conventional No.2 Diesel	GTL
Aromatics, % vol (D1319)	8.2	24.4	1.0
Olefins, % vol	1.4	1.8	1.0
Saturates, % vol	90.4	73.8	98.0
H/C Ratio	1.96	1.94	2.13
Ash Content, mass% (D482)	<0.001	<0.001	<0.001
Total Aromatics, mass%, (D5186)	9.7	28.2	1.4
Mononuclear Aromatics, mass %	8.6	23.6	1.4
Polynuclear Aromatics, mass %	1.2	4.6	<0.1
Sulfur, ppm	1.0	4.5	-
Nitrogen, ppm (D4629)	<1.0	-	-
LHV, BTU/lb (D240)	18,581	-	18,878
HHV, BTU/lb (D240)	19,865	-	20,246
Particulate Contamination, mg/L (D6217)	0.6	-	-

Conclusion

Conventional refining, with some modifications,
can upgrade ICP Shale Oil to Marketable
Products

