

# CHEMICALS & LIQUID FUELS

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## Liquid Fuels from Coal and Biomass (Part-I)

### VISION & GOAL:

Basic & applied research related to the catalyst and process development for synthetic oils & chemicals production from syngas generated from coal/natural gas/biomass feed stocks. Diversification from fossil to renewable energy research and demonstration.

Development of catalyst and process for Fischer-Tropsch synthesis reaction, studies on reaction kinetics, effect of type and size of reactors on yield and selectivity pattern of hydrocarbon production. R&D has also been focused to some allied areas like hydrocarbon reforming, environmental catalyst, shift catalyst etc.

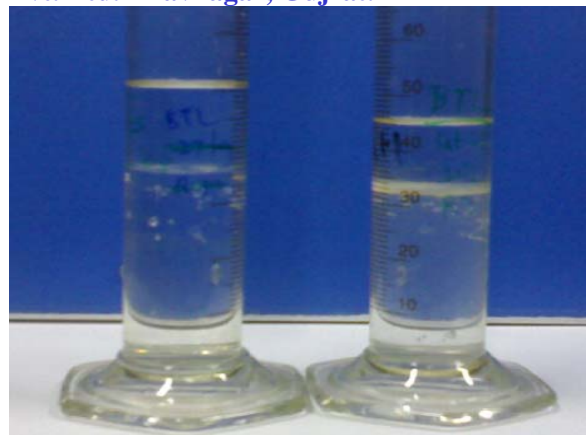
### CORE COMPETANCE & ACTIVITIES:

- Catalysis and catalyst development.
- Lab and bench scale process data generation.
- Environmental pollution reduction catalyst for modern catalytic converters.
- Scale up studies of developed process.

### PROCESS DEVELOPED:

- Catalyst & process for wax production (Laboratory Scale, Capacity: 100 ml)
- Catalyst & Process for Pre-Reforming of Naphtha, (Laboratory Scale, Capacity: 100 ml)
- Catalyst & process for Gas to Liquid Technology (GTL) via FT route. (Laboratory Scale, Capacity: 100 ml)

- Catalyst for DeNO<sub>x</sub> for Diesel for Euro IV/V Compliance (Laboratory Scale, Capacity: 10 ml)
- Catalyst & technology Biomass-to-Liquid Technology (BTL) for synthesis of gasoline & Middle Distillate by FT route from Biomass Gasifier derived syngas, (Laboratory Scale, Capacity: 100 mL). **Scale-up under progress in collaboration with M/s Garg Casteel Pvt. Ltd. Bhavnagar, Gujrat.**



**BTL Liquid product**



**GTL Liquid/wax product**

### **CURRENT RESEARCH AREAS:**

- Development of heterogeneous catalyst for synthetic oil via FTS route.
- Environmental pollution reduction catalysts.
- Nano-catalyst and support development.
- Hydrogen energy production technologies.

### **INFRASTRUCTURE FACILITIES:**

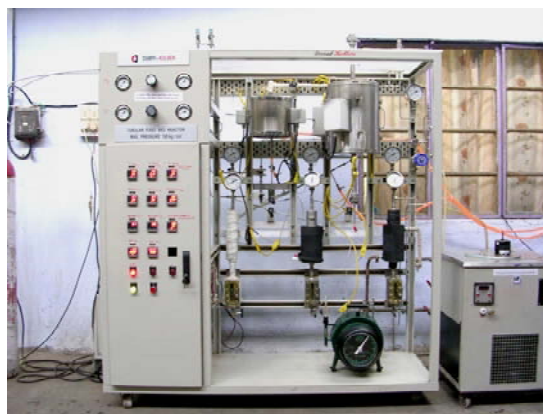
#### **Reactors:**

- **High Pressure Fixed Bed Tubular Reactor (100 mL)**
- **Multi-tubular high pressure fixed bed reactor (Process Development Unit Capacity: 3.5 L)**
- **Continuous stirred tank reactor (1.0L)**
- **LPG-Steam reformer for syngas production**
- **High Pressure Reformer reactor (100 mL)**

- **Fixed Bed Tubular Reactor ( 2 mL)**

#### **Instruments**

- **Gas chromatograph (TCD & FID),**
- **GC-MS & AAS**
- **TPD/TPR/Pulse chemisorption unit,**
- **UV-Vis Spectroscopie,**



**High pressure single tube reactor**



**GC-MS**

## Liquid Fuels from Coal, Petroleum Waste Materials & Biomass (Part-II)

### Core –Competence

1. Basic and applied research related to the development of process & catalyst for synthetic fuel from coal by direct route
2. Upgradation of petroleum waste materials to value added products .
3. Direct liquefaction of biomass to liquid fuels.

### Processes Developed

1. Multi stage hydrogenation of Coal to liquid fuels (Batch Scale Process)
2. Reconstituted coal-water emulsion as clean coal technology for power generation (Lab Scale, Capacity - 1.5 kg/h)
3. Process & Catalyst for upgradation of petroleum heavy residue to value added product (Lab scale, Capacity –1 kg/h)
4. Process for Petroleum heavy residue—water emulsion as substitute for fuel oil for power generation (Lab Scale, Capacity – 1 kg/h)

### Ongoing Research Activities

1. Generation of basic data in the area of “Aqua conversion process of upgradation of VTB, FCC Resid and Asphalt”
2. Development of process for the upgradation of VTB, FCC Resid and Asphalt in a 100 kg/h continuous reactor System.

### Forthcoming Research Activities

1. Development of process for liquefaction of biomass to liquid fuels.
2. Scale up studies on coal water emulsion.

### *Technical enquiry*

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## Organic Fine Chemicals of Coal Tar Origin

### Capability

CFRI is extensively involved in carrying out R&D work in the area of catalytic synthesis of organic fine chemicals of coal tar origin. These include development of lab scale processes for pyridine, picolines, cyanopyridines, nicotinamide, INH, beta-naphthol, resorcinol, 9:10-phenanthra-quinone, diphenic acid, etc. Studies have also been done on the development of novel catalysts and optimization of process parameters for maximum yield and selectivity of the product.

Pyridine, picolines and their derivatives such as cyanopyridines, amides and hydrazides are very important compounds of great commercial value in pharmaceuticals, agro-chemicals, rubber chemicals and textile sectors. Nicotinamide is an ingredient of vitamin-B Complex and isonicotinamide is an intermediate for production of isonicotinic acid hydrazide (INH), a potent anti-tuberculosis drug.

Technology developed in lab scale:

- i) [Synthesis of picolines from acetaldehyde and ammonia](#) - A process for synthesis of pyridine and picolines has been developed by cyclocondensation reaction of acetaldehyde, formaldehyde and ammonia in vapour phase using 10 g catalyst in a fixed bed reactor. The maximum yield achieved at optimum reaction conditions are 57 %. (PCT Patent No. WO 2004/063389)
- ii) [Ammoxidation of methyl pyridines to cyanopyridines](#) - The process has been developed upto lab-scale with 10 g catalyst by ammoxidation of methyl pyridines in a fixed bed reactor and 86 % yield of cyanopyridines has been obtained under optimum reaction conditions. (PCT Patent No: WO 2004/087310)
- iii) [Synthesis of nicotinamide from 3-Cyanopyridine](#) - Process for the synthesis of nicotinamide has been developed by catalytic hydration of 3-cyanopyridine in liquid phase upto the scale of 100 g per batch and 98 % yield of nicotinamide has been obtained. PCT Patent No. WO 2004/056776; US patent No. 7,345,176 (2008)
- iv) [Synthesis of isonicotinic acid hydrazide \(INH\) from 4-Cyano-pyridine](#) - Process for the synthesis of INH has been developed by hydrazinolysis of isonicotinamide in liquid phase upto 40 g per batch and 98 % yield has been achieved. This is a single step reaction with 100 % recovery of the product at the end of the reaction. PCT Patent No. WO 2004/056778, US Patent No. 6,734,309 (2004)

v) **Process for diphenicacid from phenanthrene** - The process has been developed for the oxidation of phenanthrene to diphenicacid on 25 g/batch. The maximum yield of 68% has been achieved with 99% purity. It is used in heat resistance resins, engineering plastics, LCD, pharmaceuticals and agrochemicals. (PCT patent No. WO 2004/056739)

**Technology commercialized:**

Process for 9:10-phenanthra-quinone from phenanthrene - Process has been licensed to M/s Castron technologies Ltd, Dhanbad.

**Facilities:**

1. Particle size analyzer (0.1-1250 $\mu$ m).
2. Surface area analyzer (Single BET).
3. Gas chromatograph (Chemito) with TCD & FID.
4. Catalyst testing unit of 15 ml catalyst volume, Pressure 20kg/cm<sup>2</sup>, Temperature- 500<sup>o</sup>C.

*Technical enquiry*

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## RESIDUE – WATER EMULSION

Comparison of combustion and other properties of Residue-Water emulsion, Fuel Oil and Orimulsion.

Properties	Fuel oil (No.6)	Orimulsion *	Residue-Water Emulsion**
<b>GCV(kcal/kg)</b>	<b>10140</b>	<b>7500</b>	<b>8200</b>
<b>Ignition temp. (°C)</b>	<b>743</b>	<b>663</b>	<b>300</b>
<b>Air : Fuel</b>	<b>15 : 1</b>	<b>11 : 1</b>	<b>12 : 1</b>
<b>Water content(%)</b>	<b>0.3 – 0.5</b>	<b>30</b>	<b>25</b>
<b>C (%)</b>	<b>86.0</b>	<b>60.0</b>	<b>86.4</b>
<b>H (%)</b>	<b>11.0</b>	<b>7.0</b>	<b>11.72</b>
<b>N (%)</b>	<b>0.3 – 0.5</b>	<b>0.4 – 0.6</b>	<b>0.35</b>
<b>S (%)</b>	<b>2.5 – 3.0</b>	<b>2.6 – 2.7</b>	<b>0.19</b>
<b>Asphaltene (%)</b>	<b>5.0 -10.0</b>	<b>7.0 – 8.0</b>	<b>Traces</b>

**\* Emulsion of Venezuelan bitumen and water with nonyl - phenyl ethoxylate as surfactant.**

**\*\*Emulsion of Petroleum Heavy Residue and water- (Developed by CIMFR)**

## COAL-WATER EMULSION

### Comparison of Properties OF Coal-Water Emulsion with other fuels

Property	FUEL OIL (NO. 6)	ORIMULSION*	COAL-WATER EMULSION **(30%)
GCV (kcal/kg)	10140	7500	8200
AIR : FUEL	15:1	11:1	4:1
H <sub>2</sub> O CONTENT(%)	1.0	30.0	7.2
C (%)	86.0	60.0	81.26
H (%)	11.0	7.0	6.65
N (%)	0.3 - 0.5	0.4 - 0.6	1.14
S (%)	2.0 - 4.5	2.6 - 2.7	0.287
Flash Pt. °C	66-76	-	77.00
ASPHALTENE (%)	5 - 10	7.0 - 8.0	Traces

\* Emulsion of Venezuelan bitumen and water with NPE( Nonyl Phenyl Ethoxylate) as surfactant.

\*\* Coal-Water Emulsion developed by CIMFR