सीएचटी
ISO 9001:2015

उच्च प्रौद्योगिकी केन्द्र
(पेट्रोलियम एवं प्राकृतिक गैस मंत्रालय), भारत सरकार
Centre for High Technology
(Ministry of Petroleum & Natural Gas), Govt. of India

सीएचटी/एसएसी-89/ 2509
CHT/SAC-89/

28 सितंबर 2020
28th September 2020

सेवा में/ To,

पेट्रोलियम और प्राकृतिक गैस मंत्रालय की हाइड्रोकार्बन पर वैज्ञानिक सलाहकार समिति के अध्यक्ष, सदस्यगण व स्थायी अतिथिगण।
(संलग्न सूची के अनुसार)
Chairman, Members & Permanent Invitees of Scientific Advisory Committee (SAC) on Hydrocarbons of MoP&NG
(as per list attached)

विषय: पेट्रोलियम और प्राकृतिक गैस मंत्रालय की हाइड्रोकार्बन पर वैज्ञानिक सलाहकार समिति (SAC) की 89वीं बैठक का कार्यवृत्त

Sub: Minutes of 89th Meeting of the Scientific Advisory Committee (SAC) on Hydrocarbons of Ministry of Petroleum & Natural Gas

प्रिय महोदय/महोदया / Dear Sir/Madam,

दिनांक 17 सितंबर 2020 को वीडियो कॉन्फ्रेंसिंग द्वारा सम्पन्न, पेट्रोलियम और प्राकृतिक गैस मंत्रालय की हाइड्रोकार्बन पर वैज्ञानिक सलाहकार समिति की 89वीं बैठक के कार्यवृत्त की प्रतिलिपि आपकी सूचना एवं आवश्यक कार्यवाही हेतु संलग्न की जा रही है।

Enclosed please find a copy of the Minutes of 89th Meeting of the SAC on Hydrocarbons of Ministry of Petroleum & Natural Gas held on 17th September 2020 through video conferencing for your information and necessary action.

सादर,
With kind regards,

भवदीय,
Yours sincerely,

(के.के. जैन)
कार्यकारी निदेशक
(K.K. Jain)
Executive Director

Copy for information to:

- **Secretary, P&NG**
- **Chairman IOCL**
- **CMD BPCL / HPCL / EIL**
- **MD MRPL / CPCL / NRL**

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List of Members for 89th meeting of SAC

S. N.	Name, S/Shri	Designation	Organisation
		CHAIRMAN	
1.	Dr. Anil Kakodkar	Former Chairman, Atomic Energy Commission	BARC
		MEMBERS	
2.	Prof. R. Kumar	Professor Emeritus	IISc, Bangaluru
3.	Prof. J. B. Joshi	Professor Emeritus	HBNI
4.	Dr. M. O. Garg	President – Refining and Petchem R&D	RIL
5.	Prof. A. B. Pandit	Vice Chancellor	ICT, Mumbai
6.	Dr. Shashi Kant	Technical Advisor	Universal Group, Vadodara
7.	Prof. Shankar Narasimhan	Professor	IIT, Chennai
8.	Dr. R. K. Malhotra	Director General	FIPI
		EX-OFFICIO MEMBERS	
9.	Shri S.M. Vaidya	Chairman & Director (Refineries)	IOCL
10.	Shri Arun Kumar Singh	Director (Refineries)	BPCL
11.	Shri V. S. Shenoy	Director (Refineries)	HPCL
12.	Dr. S.S.V. Ramakumar	Director (R&D)	IOCL
13.	Ms Vartika Shukla	Director (Technical)	EIL
14.	Dr. Sanjeev S. Katti	Director General	ONGC Energy Centre
15.	Shri Manoj Jain	CMD & Director (BD)	GAIL
16.	Shri Niranjan Kumar Singh	Secretary	OIDB
17.	Shri Niranjan Kumar Singh	Executive Director	PCRA
18.	Shri N.V. Marathe	Officiating Director	ARAI
19.	Dr. Anjan Ray	Director	CSIR-IIP
20.	Shri S.C.L. Das	Director General	DGH
		MEMBER SECRETARY	
21.	Shri K.K. Jain	Executive Director	CHT
		PERMANENT INVITEE	
22.	Shri Sunil Kumar	Joint Secretary (Refineries)	MoP&NG
23.	Shri Sanjay Bhargava	Executive Director (R&D)	BPCL
24.	Shri S. Bharathan	Head (R&D)	HPCL
25.	Shri R. Srikanthan	Director (Technical)	CPCL
26.	Shri S.C. Gupta	Head (R&D)	EIL
27.	Shri D.V. Shastry	Executive Director (R&D)	GAIL

September 28, 2020

Minutes of 89th Meeting of Scientific Advisory Committee (SAC) on Hydrocarbons of MoP&NG

1. The 89th Meeting of SAC was held on 17th Sept'20 through Video Conferencing. The meeting was chaired by Dr. Anil Kakodkar, Chairman, SAC.

   The list of participants is enclosed as **Annexure-I**.

2. ED (CHT) welcomed the Chair, JS (R), permanent invitees & other members of SAC.

3. **PRADHANMANTRI JI - VAN YOJANA**

3.1 Discussion on proposal from SAIL

CHT mentioned that a letter dated 14th Sept'20 has been received from Chairman SAIL enquiring about eligibility and quantum of VGF for their proposed Bio-ethanol production facility utilising Surplus CO rich gases at Ferro Alloy Unit, Chandrapur under PM JI-VAN Yojana. Subsequently CHT has gathered following additional information from LanzaTech and SMTRI, Ministry of Steel;

- Quantity of off gases: 15000 nm^3 with 50-60% CO having potential of 10-11 KTA ethanol (~12.5 lakhs Litre per Annum)
- Gas is being flared.
- SAIL is finalising project report with MECON and report with $\pm$25% cost is expected by Nov'20.
- Anticipated Cost: Rs 250 – 300 crores as per LanzaTech
- SAIL proposes to carry DFR in next 3-4 months and would like to consider VGF for financial evaluation.

SAC deliberated extensively and observed that as per Gazette / RFS, industrial and municipal wastes are covered under the definition of biomass for ethanol production. However, the waste itself is also defined as under;

"**Waste** is any substance or object which the holder discards or intends or is required to discard. Raw materials that have been intentionally modified to count as waste (by adding waste material to a material that was not waste) shall not be considered as qualifying under this Scheme."

Going by the above definition, the gases cannot be considered as wastes, if it can be utilised for other useful application.

CHT was advised to get details of other options that are available to SAIL for utilisation of the gases for further deliberations.

3.2 Status of RFS for remaining projects under Phase-1 of PM JI-VAN Yojana

CHT mentioned that as advised by Steering Committee, CHT has issued RFS on 17th June'20 for remaining projects (2 commercial and 4 demonstration) under phase-I with the same terms and conditions. The Information about the RFS was also sent to following for soliciting wider participation:

- Oil companies (PSU as well as Private)
- Licensors including Shell, UOP, LanzaTech, etc.
- Research institutes and Academia
- International oil and petrochemical companies

As no proposal was received till cut-off date of 16th Sept'20, RFS has been extended by 1 month till 15th Oct'20. JS (R) informed that MoP&NG is considering modifications advised by SAC in the PM JIVAN Yojana and no further extension is advised.

JS (R) sought clarification to earlier recommendation of SAC for considering "Bolt On" project under the scope of PM JI-VAN Yojana and not "Brownfield Projects". CH SAC mentioned that strictly speaking, there is no clear-cut definition. In "Bolt On" projects, we attach additional process technology elements / features building-on/sharing some of the existing process technology elements / features. On the other hand, "Brown field" projects do not entail use of existing process / technology elements except use of available assets/infrastructure/services/utilities etc. and therefore fall under capacity expansions/infrastructure utilization etc. JS(R) mentioned that brown field projects, where land is available, may benefit from lower capex and help in quickly expanding the production of biofuels. SAC was of the view that the purpose of the scheme is to provide VGF to projects based on new technologies which are risky and not viable. The objective of expanding bio fuel production by way of expansion can be achieved through different policies. If we mix the two, the new technology development will be at disadvantage which is definitely not the objective of PM-JIVAN Yojana.

SAC advised that further RFS for remaining projects of Phase-1 and Phase-II, may be started after consideration of various changes in the scheme, as recommended by SAC.

4. Review of ongoing R&D Projects

4.1 Coal to Liquid (CTL) Technology: EIL/BPCL/Thermax

Objective:

- To carryout research work in the area of gasification, syn gas clean up and synthesis of liquid fuels from syn gas through Fischer-Tropsch process for addressing various design aspects of units involved in CTL process and preparation of basic design package for demonstration plant.

Physical Progress

MOU Date	Start Date	End Date	Extension	Physical Progress
Mar 2009	July 2009	July 2013	July 2020	90%

Financial Progress (All figures in Rs, lakh)

Agency	Contribution	Expenditure till date	2020-21		
			BE	RBE	Expenditure
CHT	#1483.95	*1289.16	60.00	--	--
EIL	1073.58	860.58	60.00		
BPCL	421.10	421.10	--		
Thermax	332.00	349.63	5.50		
Total	3310.63	2920.47	125.50		

(EIL: Rs 1062.88 lakh; BPCL: Rs 421.07 lakh) revised as per approval of SAC in its 81st & 86th meeting.

*(EIL: Rs 868.09 lakh; BPCL: Rs 421.07 lakh)

Status

The Project constituted of four major steps of coal gasification, Syn gas clean up, Synthesis of FT liquid, and preparation of BDEP for demo plant. BPCL/ EIL has shared results of technology and compared with M/s Sasol for operating condition and yield. Yield per pass of 50% obtained vs 52% (Sasol). Operating conditions were also better.

Gasifier was developed for 30 bar operation with M/s Thermax and installed in Jan'15. Many issues were faced during operation with gasifier. SAC in its 87th Meeting on 13th Dec'19, concurred the recommendation of expert group regarding repair / maintenance / modification of the plant and extended the project till 31st July'20. SAC advised EIL to establish operation at 6 bar and scale it up further as problems may go away at larger scale. Simplified model may be used to see whether current problems can be addressed. SAC also advised to use CFD model to study pressure effect in Gasifier operation and to aim for Gasifier operation at design pressure. BPCL was advised to evaluate cost of production of drop in fuel through FT route.

Oxy blown operation, was tried in Jan'20 but there were issues with boiler operation, electrical air heater failure, and commissioning of ASU. After partial rectification of the previous issues, EIL informed that subsequent to completion of maintenance related work including replacement / testing of Xomox-type plug valves, gasifier was operated during 1st week of Jan'20 in combustion mode for ~24 hrs. However, oxy-blown gasification campaign could not be conducted due to following operational issues:

a. Wet steam generation: Due to substantial formation and accumulation of condensate in steam line & subsequent carry-over from separator drum to super-heater section,

desired process steam temperature needed for gasifier operation was hampered. The boiler was shifted near to gasifier and condensate separator was replaced with large size one. These modifications were completed on 27th Feb'20 and the issue was resolved.

b. Electrical air heater failure: After rectification of boiler circuit, operation for oxy-blown gasification was started. During the heating stage, electrical air heater which raises the air temperature up to 500°C (crucial for operation) failed. 7 out of 12 heating coils were found damaged. Procurement & replacement of coil assembly got delayed due to COVID-19 lockdown. PO was placed on 18th Jun'20, with expected delivery of 3 weeks.

c. Commissioning of Air Separation Unit (ASU): Commissioning activities of ASU got delayed due to COVID-19 pandemic as ASU vendor, based in Maharashtra, expressed inability to take up balance commissioning activities on immediate basis.

The required modifications were completed (except ASU, O2 cylinders being used) and one gasification trial was attempted in Aug'20 third week. After 16 hrs of heating and combustion, the operation was switched to oxy-blown gasification mode, though it could be sustained for only 4 hrs. Run was stopped due to fluctuations in steam flow from boiler leading to temperature spikes in gasifier. Part of coils in boiler was found damaged. Spares for boiler elements are being procured. One boiler chamber has been made operational for carrying out gasification run.

EIL informed that after repair of coils in one boiler, Plant was again run during 6-10th Sept for 45 hours (13 hours in heating mode, followed by 6 hours of combustion mode and for 26 hours in air steam gasification mode). The operation was steady and carried out at 5 bar and 860°C under auto control, but had to be terminated due to CO spillage in the flare area (external to the gasifier). High ash coal with 43% ash was used and feed rate maintained at around 60 Kg/hr. The material balance shall be worked out after evaluation of various solid and gas samples for composition. Under the guidance of the Expert Group, further attempts shall be made to optimise the operations and maximise pressure after repair of 2nd boiler coils, which is expected to be completed in 3 weeks' time. Based on difficulty in oxy-blown operation, guidance of Expert Group will be sought to conduct two runs with air before switching over to oxygen to check system integrity and get confidence on operation. Hence, the air blown / oxy blown operation is planned by end Oct, 2020 after commissioning of ASU. EIL requested for project extension up to 31st Jan'21.

SAC expressed happiness over the developments and observed that some positive results have been reported albeit after a long wait. Although there are limitations due to small size of the unit and what can be achievable on real front, it is advisable to collect maximum amount of data and improve our understanding including through CFD work to the extent presently feasible.

SAC opined that one more size expansion aided by CFD model may be needed before full scale commercial unit, therefore there is a need to operate the plant to collect sufficient data for modelling, for which separate project is already undertaken and the progress will be discussed subsequently.

SAC deliberated extensively and advised following;

i. In addition to mass balance, energy balance also needs to be done
ii. Bottom ash and cyclone separator ash content needs to be quantified. Unburnt coal which goes with ash also needs to be assessed.
iii. Project on modelling of CFD should be used for comparison
iv. Check condition of refractory.

SAC advised that the results of operation with material balance should be shared and discussed in Expert Group led by Prof. R. Kumar to benefit from learnings from operations and finalise parameters & path forward for subsequent operating runs.

SAC approved project extension till Jan'21.

4.2 Development of 3D CFD Model of Fluidised Bed Coal Gasifier: EIL

Objective:

To develop integrated model for complete fluidized bed coal gasification system using a combination of phenomenological models and state-of-the-art CFD modelling for:

a. Credible scale-up of CTL technology
b. Enabling design of a demonstration unit and subsequently designing / offering commercial unit
c. Identifying problem areas in CTL technology development which shall help in overcoming problems in CTL pilot plant running.

Physical Progress:

MOU Date	Start Date	End Date	Physical Progress
Sept 2019	Nov 2019	Feb 2022	25%

Financial progress (All figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2020-21		
			BE	RBE	Expenditure till Aug'20
CHT	213.00	63.59	120.00	101.50	-
EIL	213.00	46.63	110.00	101.90	-
BPCL	213.00	63.59	100.00	101.60	-
Total	639.00	173.81	330.00	305.00	-

Overall Status:

Cold Flow Experimental set up and CFD Software /Hardware upgradation:

- Orders placed for Hoppers, Feeder system, Compressor, Instrumentation work. Tenders floated for Structural works and Bag filter and order expected by Oct'20. EIL will expedite procurement for cold flow experimental set up and material supply at site as per schedule of Feb 2021.

- CFD software upgradation completed in Nov'19. Order placed for hardware on 20th July'20. Delivery of hardware is expected by Sept'20.

Expert Consultancy and Technical Support

- Order for Expert Consultancy placed to IIT Madras on 5th Feb'20. Order for special Technical Consultancy was also placed to Ansys Software Pvt Ltd. on 14th Feb'20. Advanced ANSYS Training on Multiphase Simulations and User Defined Functions (UDF) completed in July'20.

Advanced Training and CFD Modelling

- Training activities were completed through online sessions (due to COVID pandemic) instead of originally planned onsite training for advanced simulation techniques using ANSYS CFD software.

- Literature Survey was carried out for CFD simulation work on coal gasification, population balance model application for predicting coal PSD due to attrition.

- EIL explained that to address the hydrodynamics of fluidization, reactions, heat transfers and other complex physics involved, a multipronged approach is being adopted. Three different teams are working in parallel on the three main components of the gasifier viz. the bubbling bed, the freeboard & the cyclones with the recycle loop and taking help from IIT Madras as well as ANSYS.

- Multiphase modelling familiarization is being carried out by simulating case studies from the literature on bubbling fluidized bed and cyclones in ANSYS CFD.

- One team is working on developing a fine-grained model for the bubbling phase (fluidized) in lower half of gasifier. A second group is working on modelling the entrainment / elutriation occurring in the freeboard. The third group is concentrating on the cyclones and the loop seal in the return leg along with other phenomenological models for processes such as thermal fragmentation and attrition in the bed. Fine grained CFD modelling of bubbling bed, free board and cyclone is expected to be completed by Oct 2020.

  Different types of material namely (sand, coarse char and fine char) have been considered while modelling bubbling fluidized regime having volume fraction of solids of about 3% (Coal) and inert (Sand) of about 55% in line with the packing limit of about 58% seen in commercial gasifiers. The volume fraction contours of the dominant phase (sand) could clearly capture the stable bubbling regime within the fluidized bed. The model will next be extended to multiple sizes of solids and other phenomena like

thermal fragmentation. Actual geometry of CTL gasifier at R&D was considered for the set up.

- For understanding the effect of particle size and density on the entrainment and elutriation from the freeboard to the cyclone system, results of the fine-grained simulations of the freeboard were presented.

  For Cyclone modelling, the idea is to have an empirical correlation which can then feed into CFD simulation through a User Defined Function (UDF) in ANSYS, since explicit modelling of the multiple cyclones with particle tracking will greatly increase the mesh size and computational time. The idea is therefore to obtain grade efficiency curves / correlations for the cyclones which can be fitted into an UDF in ANSYS for simulating the entire system of gasifier, cyclones and the recycle loop.

- At the moment, only cold flow model is considered with no physical effects (Heat) or kinetics taken into consideration. A few published models for coal fragmentation during devolatilization have been studied and work is underway for developing a phenomenological model for thermal fragmentation of coal that can be implemented using User Defined Functions in the CFD simulations of the gasifier. Model development for Thermal fragmentation of coal is expected to be completed by Nov 2020. Literature shall be looked into for the study of agglomeration impacting the particle size distribution within the bed.

- At gasifier inlet, feed will be modelled considering the actual PSD and including mixing effects, but as of now only batch fluidised bed hydrodynamic simulations are being validated against literature.

EIL has indicated that schedule of some of the initial milestones of this project have been impacted by 6 - 8 weeks due to COVID-19 pandemic. Three teams of 3-4 persons are working in parallel and EIL is putting all efforts to make up for lost time and target to complete the project within the overall schedule.

SAC advised to involve both CTL operation group and the group involved in hydrodynamic & kinetic studies during discussions and development.

4.3 Biomass Hydro-pyrolysis for production of fuel grade Hydrocarbons: HPCL/ CSIR-IIP

CHT mentioned that the project was undertaken with Role of IIP to develop catalyst & optimize operating conditions for a single step hydro pyrolysis process for the conversion of lignocellulosic biomass to value added hydrocarbons in 500 g/h unit. The role of HPCL in the project is for demonstrate the process in 5 kg/h unit.

SAC in its 84th meeting on 22nd Apr'19, advised to consider both MNRE & CHT funded projects together, as the scope of work pertaining to IIP was same. SAC in its 87th meeting on 13th Dec'19, extended the project till Nov'22. CHT presented the progress as under;

Physical Progress:

	MOU Date	Start Date	End Date	Extension	Physical Progress
MNRE funded	31st Jan'12	31st Jan'12	31st Jan'15	Apr'19	20%
CHT funded	Sept 2016	Nov 2016	Nov 2019	Nov 2022	

Combined Cost of both Projects and contributions of all Agencies (Figures in Rs, lakh):

Participating/Funding Agencies	MNRE Project (IIP)		CHT Project (IIP / HPCL)		
	MNRE	CHT/OIDB		HPCL	Total
IIP	232.19	39.49	640	-	**911.68**
HPCL	-	-	800	966.9	**1766.90**
Total	232.19	39.49	1440	966.9	**2678.58**

Total Expenditure by MNRE, CHT & HPCL in both Projects (Figures in Rs, lakh):

Participating/Funding Agency	MNRE	CHT/OIDB	HPCL	Total
IIP	232.19	562.64	-	794.83
HPCL	-	-	465.00	465.00
Total	**232.19**	**562.64**	**465.00**	**1259.83**

Overall Status

- Expert group under the chairmanship of Prof. R. Kumar has reviewed the project 5 times on 4th Nov'18, 16th Feb'19, 25th Jun'19, 21st Jan'20 & 13th Jul'20.
- During recent Expert Group (EG) meeting held on 13th Jul'20, IIP informed that several experiments were performed by using catalyst in fluidized bed reactor in the presence of HPCL team, but could not succeed to complete the runs due to limitations of the 100 g/hr unit. Therefore, so far the catalyst was used for hydrodeoxygenation of biomass pyrolyzed vapours in the fixed bed reactor. The best results are as under:

Feed	Pressure Bar	Temp, °C	Fixed Bed Catalyst	Product Yields, wt%				Organic Liquid Composition wt%
				Organic Liquid	Aqeous Liquid	Char	Gas	
Rice Straw	15	550/500	Pt-Re/Al_2O_3	3.6	18.2	34.7	43.5	HC: 90 Oxy: 10
Deashed Rice Straw	15	500/500	NiMo/Al_2O_3	4.7	21.8	29.0	44.5	HC: 86 Oxy: 14
Pinewood	15	500/450	NiMo/Al_2O_3	7.9	30.7	27.4	33.9	HC: 99.6 Oxy: 0.4
Pinewood	15	500/400	NiMo/Al_2O_3	10.5	27.2	23.4	38.9	HC:86.1 Oxy: 13.9

- IIP is exploring the option of using other reactors available at IIP.
- During the review by the expert group earlier, Prof. Kumar showed concern on the inferior results obtained till date compared with the best results published in the literature. His observations and suggestions are summarized below:

  a) IIP has so far carried out thermal pyrolysis at higher temperature (500 °C) without using any catalyst in the fluidized bed reactor followed by removal of oxygenates in the subsequent fixed bed reactor. This approach may not produce drop in fuel to match with published best results (yield and oxygenates).

  b) Very few experiments were carried out in the fluidized bed reactor by IIP using catalyst and H2 and the same were discontinued due to clinker formation. IIP has been advised to carry out more experiments in fluidized bed reactor before reaching to a conclusion. It was advised to analyse all possible reasons of clinker formation like catalyst particle size, density, reaction temperature, possibility of volatisation at the entry itself, etc. As per IIP, the gas flow has been maintained in the feeder section to ensure the distribution of feed particles and also provided the water circulation for the feeder line to avoid the high temperature in the feeder line. The effect of sand particle size and Biomass size should be analysed.

  c) Because of high temperature operation, ash melting occurs which is leading to bed agglomeration. Biomass should be in dispersed form and if too many solid particles are allowed at higher temperature, it will lead to clinker formation. Higher surface area for biomass devolatilization can be ensured by using smaller sand and biomass particles and higher amount of sand in the pyrolysis reactor.

  d) Organic liquid yield is too low (5-8%) and gas yield is very high (40-50%). Pyrolysis should be conducted at lower temperatures (350-400°C).

  e) The properties of developed catalyst are not suitable for fluidized bed reactor.

  f) The operating conditions for maximizing the liquid yield have not been finalized. Hydropyrolysis experiments should be performed at lower temperature.

  g) Suitable catalyst needs to be developed and used in the fluidized bed reactor for simultaneous devolatilization of biomass and upgrading of pyrolysis vapours. CSIR-IIP informed the limitations of the unit to use the catalyst in fluidized bed reactor.

  h) IIP has agreed to implement the above-mentioned suggestions and conduct experiments accordingly in next 6 months to improve the results.

SAC deliberated extensively and observed as under;

a. IIP was advised to develop catalyst expeditiously.
b. Use of easier feed: Pine leaf has only 1% ash and has yielded better results than rice straw which has very high silica ash and low softening point.

c. Sufficient experiments work has been done on co-pyrolysis of biomass and plastics by IIT madras and TERI

SAC advised that new work plan may be prepared in discussions with Prof. R Kumar and Prof. JB Joshi.

4.4 Development of catalyst and process for Slurry phase Residue Hydro-cracking: IIP/ BPCL/ HPCL/ EIL

Major Activities:

- Catalyst development by HPCL, BPCL & IIP
- Trial of catalysts at IIP & HPCL reactor
- Process Design for demo plant by EIL using the best catalyst

Physical Progress:

MOU Date	Start Date	End Date	Extension	Physical Progress
June 2015	July 2015	July 2018	July 2020	75%

Financial Progress (All figures in Rs, lakh)

Agency	Contribution	Expenditure till date	2020-21		
			BE	RBE	Expenditure
CHT	#1366.00	*1361.27	-	4.73	-
HPCL	776.00	776.00	-	-	-
CSIR-IIP	93.00	93.00	-	-	-
Total	2235.00	2230.27	-	4.73	-

(CSIR-IIP: Rs 516 lakh, HPCL: Rs 850 lakh)

* (CSIR-IIP: Rs 511.27 lakh including interest of Rs 2.45 lakh, HPCL: Rs 850 lakh)

Status:

- IIP, BPCL and HPCL each have prepared 3 catalyst formulations and shortlisted their best performing catalyst
- Catalyst performance data with their best catalysts has been generated by IIP & HPCL for selection of final catalyst for reactor model development by EIL.
- Comparison of data from pilot study was done by EIL on basis of following parameter namely Residence time, catalyst used (% of feed), gas, liquid yields, Coke yields and residue conversion. CHT mentioned that results are very close and prima facie the catalyst of BPCL has been found better, however, the performance data with recycling of pitch is not available.
- EIL pointed out that Pitch needs to be recycled back for more than 95% conversion. As catalyst performance depends upon slurry recycle. Asphaltenes are difficult to crack and objective is to keeping them in solution while recycling. This aspect needs to be studied

further for need for elimination of any sedimentation of asphaltenes with combined feed. ED CHT mentioned that few months back in a joint meeting with EIL and CHT, HPCL, IIP, BPCL have mutually agreed that BPCL catalyst is performing better and can be taken forward for kinetic modelling. The Protocol for evaluation was decided by HPCL, BPCL IIP, and pitch recycle was not pointed. HPCL mentioned that pitch recycling is not part of the project as the same is not feasible at pilot level due to its inherent flow properties. Therefore, Kinetic data generation has to be carried out for the best selected catalyst for completing and validating the kinetic model. EIL stated this aspect may be examined at the time of setting up of demo package.

Based on the above discussions, it was decided that for this project kinetic modeling shall be done with BPCL catalyst and the kinetic & reactor modeling will be done on once- through basis. The Scale up may be done with recycling.

- EIL will require 6 months for kinetic model, reactor simulation and modeling after receiving complete kinetic data. Participating agencies requested for project extension till July'21.

SAC approved project extension till July'21

4.5 Renewable crude and liquid Hydrocarbon fuels from Algae: CPCL / ICGEB/ABAN

The project was recommended by SAC under 2 phases (The current project is for Phase-1 only).

Phase-1: Cultivation of algal consortium in open pond and scale up studies in larger ponds (4000 m^2) to assess biomass productivity (with a target yield of 25 $g/m^2/day$) with GM algal strains to enhance the yield by 20-30%.

Phase-2: Process to handle 110 kg algal slurry / day

Physical Progress:

MOU Date	Start Date	End Date	Extension	Physical Progress
Dec 2016	Mar 2017	Mar 2019	Aug 2020	91%

Financial Progress (All figures in Rs, lakh):

Agency	Contribution	Fund released till date	2020-21		
			BE	RBE	Fund released till Aug'20
CHT	#434.52	*400.06	32.45	34.47	-

(CPCL: Rs 386.34 lakh; ICGEB: Rs 48.18 lakh); * (CPCL: Rs 351.88 lakh; ICGEB: Rs 48.18 lakh)

Status:

CPCL shared the major progress and learnings, as under;

- Biomass productivity of 16 gm/ m2/day has been achieved, which is comparable to reported value globally. Marginal variation in productivity is seen with respect to seasons or Pond size.

- ICGEB could achieve increase of 30-40 % in lab in photo bioreactor with Genetic modification (GM). However, GM could not be tried due to limitations in open pond and difficult approval process for the same in open pond.
- CPCL shared that help was taken from Reliance on issue of contamination due to sea water and we came out successfully. To enhance productivity a paddle wheel was introduced.
- In CPCL R&D, hydrothermal liquefaction of Bio crude has yielded ~ 24.5% yield. The biocrude was distilled with Petro crude and concerns were observed due to high salt content and also due to high N, O and S in the products.
- Life cycle analysis is also made available by IIT
- The cost of bio crude is estimated to be ~ 200 USD per bbl. The same is not considered commercially viable considering current low crude oil price scenario, which is expected to continue in future also. In terms of energy content chosen, it seems difficult to match crude oil price.
- In view of above, CPCL requested to foreclose the project.

SAC observed that at the time of initiating the project, this scenario was visualized. The economics was visualized only with higher yields with intervention of GM and that is how ICGEB was brought into picture. With the restriction of GM, the viability looks impossible at this stage. IOC R&D supplemented their similar experience with joint project with NTPC. In fact, they are looking at potential benefit in high value protein rich product or fatty acids rather than synthetic crude oil.

SAC recommended foreclosure of the project and advised CPCL to submit the Closure report documenting the objectives, technical data, experiences, major insights and learnings during the execution of the project for future reference.

4.6 Synthetic Aviation Lubricants (SAL) - Phase 2: CSIR-IICT, HPCL & CEMILAC

Project is an extension of SAL Phase-1, wherein 2 synthetic lubricants (SVS-11 and SVS-21) were developed.

Objective:

- To prepare 500 kg each of the base oils for SVS-11 and SVS-21 lubricants at CSIR-IICT and carryout preliminary testing.
- Formulation of the SVS-11 & SVS-21 lubricants and their physico-chemical testing at HPCL - R&D.
- Testing of both the lubricants for compatibility with elastomers at 3BRD/ HPCL/ IICT and for ground test in Aero engines on test bed in comparison with reference oils and In-flight by IAF with CEMILAC participation.

The testing was planned in TV-2 aero engine of MI-8 helicopter supplied by 3BRD. Subsequently, as TV-2 aero engine is under phase out, it was decided to try these lubricants in TV-3 aero engine of MI-17 helicopter.

Only SVS-11 has been found compatible while carrying out rubber seal compatibility study & tribology testing. Therefore, its testing in TV-3 aero engine & also in-flight tests (MI-17 helicopter) is to be done.

Physical Progress:

MOU Date	Start Date	End Date	Extension	Physical Progress
Mar 2016	Apr 2016	Sept 2017	Dec 2020	60%

Financial Progress (All figures in Rs, lakh):

Agency	Contribution		Expenditure till date
	Original	Revised*	
#CHT	97.02	139.02	139.02
HPCL	118.00	169.10	91.90
CSIR-IICT	30.00	43.00	43.00
CEMILAC	5.00	7.16	--
Total	250.02	358.28	273.92

Only to IICT

Status of SVS-11

- The formulation, lubricant properties and Elastomer compatibility test of SVS-11 lubricant against commercial oil OX-27 completed during June - July 2019 and SVS-11 exhibited the required properties on par with proven oil OX-27.
- HPCL shared the Elastomer compatibility test results of SVS-11 oil to 3BRD during Aug'19.
- HPCL submitted the test results of SVS-11 oil duly vetted by DGAQA to CEMILAC during Nov'19 & thereafter CEMILAC approved the clearance for SVS-11 lubricant oil for carrying out ground engine tests & in-flight test at 3BRD during Dec'19. HPCL supplied 490 Kg of SVS-11 oil to 3BRD during Jan'20.
- On 24th Feb'20, 3BRD informed IICT that due to production pressures no engine has been allotted for engine test and the same is expected after March'20.
- Due to above reason IICT has requested for project extension till Dec'20 for;
  - Ground testing of SVS-11 lubricant in TV-3 engine test bed at 3BRD (Apr-Jul 2020). As per latest update, 3BRD has finalized the testing schedule, engine (TV-3 aero engine) availability and other related aspects. Engine to be used for testing is under build up. Testing is expected to be completed by Oct'20.
  - Test schedule finalization with Air HQ to facilitate flight trails after ground tests of SVS-11 at 3BRD and in-flight testing of SVS-11 (after Oct'20)
  - Compilation of the data from participating organizations & submission of final report by CSIR-IICT (Nov-Dec 2020)

- Alternate applications of Lubricants as explored by HPCL
  - Rolling oils (component)
  - Synthetic automotive engine oils (component)
  - Synthetic industrial gear oils (component)
  - Hydraulic oils as seal swell agents
  - New EV vehicle transmission oil formulations (component)

During the meeting, IICT requested for extension up to March'21, in view of prevailing border situation with China. SAC considered and accorded extension of the project till Dec, 2020 and advised IICT put up request with reasons.

4.7 Improving (Speedy) Leak Detection Time in Pipelines by Deployment of Real Time Ethernet Protocols: HPCL-VSPL/ECIL

Objective:

- The Current SCADA Protocols viz. DNP and IEC 101/104 are able to acquire the Data related to Pipeline variations enabling Lead detection systems in the order of 10 to 15 sec. The objective of the project is to design, engineer and develop an "Electronic system Design and Manufacturing (ESDM)" and field test with Real time Deterministic Ethernet Protocols based "DATA ACQUISITION MODULE (DAQ module)" which will reduce the time of acquisition up to 10 to 20 milli sec.
- Field trial of developed DAQ Electronic system, by deploying along 200 Kms section of HPCL's Vishaka – Vijayawada – Secundrabad Pipeline, or significant part of that section of pipeline
- To study improvement in Leak detection performance along with Leak Detection Software vendor (Energy Solution International, Emerson Group company, who has installed their Leak detection software in HPCL's Cross country Pipelines).
- The Enhanced Leak Detection time could be in the order 2 to 5 Minutes with location accuracy of ± 200 to 350 metres as compared to 10 to 15 minutes with location accuracy of ± 2 Kms

Physical Progress:

MOU Date	Start Date	End Date	Physical Progress
Sept 2018	Nov 2018	Apr 2020	89%

Financial Progress (All figures in Rs, lakh):

Agency	Contribution	Expenditure till date
CHT	#55.20	55.20
HPCL	61.84	61.83
Total	117.04	117.03

CHT's contribution to HPCL

Overall Status:

- ESDM was developed with 2 PCBs. Its field validation has been done, where in, data acquisition time was in the range of 10-20 milli sec as defined in the objective.
- Further, trial of ESDM along with leak detection software was taken by deploying two DAQ systems (one in upstream and one in downstream of live leak simulation spot). 3 leaks were simulated in pipeline shut off condition and 6 were simulated in pipeline operation mode. Out of total 9 cases, in 3 cases, combined system reported leak detection instantaneously; however the location accuracy was within 1 km. For improvement in the results, Emerson has advised to deploy minimum 4 DAQ systems (two in upstream and two in downstream). HPCL shall deploy 14 DAQ systems over 200 km pipeline (from Vizag to Rajamundary) in the final phase of the project, which shall comply with Emerson's suggestion.
- Based on field validation outcome, HPCL has finalized design of ESDM using single PCB. Trial production of 4 ESDM has been done. After its QA/QC tests, the same will be delivered to ECIL by 1st week of Sept'20. Trial will be started with 4 ESDM from Sept'20 third week.
- HPCL mentioned that there is delay in activities due to in procurement of components from China, Germany and U.S due to COVID-19 pandemic. There was also delay in offline analysis of data by Emerson and release of software, due to Work-from-Home scenarios. Electronic component sourcing, PCB manufacturing, testing & field deployment also got delayed, again due to COVID-19. The actual progress against the approved milestones is given below.

Activities as per MOU	Completion Schedule		Status
	Plan	Actual / Revised	
Phase-1: System Architecture	Feb 2019	04th Feb'19	Completed
Ph-2.1: ESDM Development	Nov 2019	30th Jan'20	Completed
Ph-2.2: Field Validation	Dec 2019	11th Feb'20	Completed
Ph-2.3: Finalized Design of ESDM from Field Investigation Results	Feb 2020	21st Mar'20	Completed
Ph-3: Final and Full-Scale Trial in VVSPL, Vizag – Rajamundry Section	Apr 2020	Nov'20	
Final Report Submission	May 2020	Nov'2020	

HPCL requested to extend the project from Apr'20 till Nov'20

SAC considered and extended the project till Nov, 2020

4.8 Production of lower olefins (Ethylene and Propylene) from Syngas: IICT/BPCL

Objective:

- Preparation, characterization and testing of catalysts for direct production of lower olefins from syngas, for establishing proof of concept.
- Development of process know-how in fixed-bed reactor (4 cc cat vol)

BPCL shall join after proof of concept.

Physical Progress:

MOU Date	Start Date	End Date	Physical Progress
Feb 2019	Mar 2019	Sept 2020	65%

Financial Progress (All figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2020-21		
			BE	RBE	Expenditure till Aug'20
CHT	#84.044	41.80	34.04	42.00	-
CSIR-IICT	154.176	154.18	-	-	-
Total	238.22	195.98	34.04	42.00	-

CHT's contribution to CSIR-IICT

Overall Status:

- Automatic gas adsorption unit for characterization of catalyst for BET SA, PV, PSD procured through CHT fund and commissioned on 29/07/2020 and working satisfactorily. Procurement of said equipment got delayed by 11 months.
- Dual high pressure fixed bed reactor unit with refinery gas analyzer under CSIR-IICT funds is expected to be delivered by Sept'20 end against earlier plan of Aug'20 end and commissioning by Oct'20 first week. IICT shall complete the experimental work within 4 months subsequent to commissioning of reactor.
- CSIR-IICT has informed that about 20 nos. of catalyst recipes were prepared at 10 g level and will be screened in the above dual fixed-bed reactor unit. Another series of 20 nos. of catalyst recipes prepared for both FTO and Oxide - Zeolite approaches. Physico-chemical characterization of catalyst recipes in progress.
- These recipes will be thoroughly characterized and tested for single step production of lower olefins from syngas.

- A makeshift FBR has been assembled in lab with a catalyst loading volume of 2-4 CC maximum in the month of February 2020 and it is being used for screening of various catalyst recipes, till automated dual HP FBR reactor is delivered. It has 3 MFCs for CO, H_2 and N_2 gas infection, can operate at 30 bar max pressure and 500^0C temperature. 5 no. of catalyst recipes prepared for loading in makeshift FBR. The actual progress against the approved milestones is given below:

Milestones as per MoU	Completion/ Rescheduled date	Current Status
State-of-art report & procurement of HP FB	Jun 2019	Completed

MRU unit and Automatic gas physisorption unit & schedules of experiments		Literature review on SynOlefins has been prepared. The POs for supply of HPFBMRU and AGAU issued to qualified vendors on 02/03/2020 and 19/4/2020.
Preparation and physico-chemical characterization of catalyst recipes for fixed bed reactor	Sept 2019	Partially completed About 20 nos of catalyst recipes were prepared for both FTO and Ox-Zeo approaches. 10 nos samples were characterized. Another lot of 20 nos recipes under preparation will be completed by Dec2020
Supply, installation, commissioning of HP FB MRU, Automatic gas physisorption unit	Nov 2019	Partially completed The AGAU was installed and commissioned on 28/07/20 and characterization of textural properties of synthesized catalysts is under progress. This equipment was procured from the grants of CHT Rs 41,99,911/- HPFBMRU will be reaching to CSIR-IICT in the last week of Aug and installation by 1st week of Sept 2020
Screening of catalyst recipes in fixed bed reactor, fine tuning of catalyst preparation, identification of promising catalysts	Apr 2020/ Dec 2020	Screening of catalysts initiated in recently assembled medium pressure FBR in July 2020, could not completed due to mal function of check valves, CO gas MFC. Now it is repaired and will be used till the HPFBR reaches. This activity will be continued till Dec2020.
Process optimization studies on most promising catalysts and scale up of catalysts to 500 g level	Jun 2020/ Jan,2021	Optimization studies will be conducted over HPFBR in Jan 2021.
Catalyst life test, regenerability, catalyst & feed poisoning studies on most promising catalysts	Aug 2020/ Feb,2021	Catalyst cycle length and regenerability will be conducted in Feb 2021.
Submission of final report after approval of draft report	Sept 2020/ March,2021	Final draft report will be submitted in March 2021.

Due to delay in procurement of equipment, IICT requested for project extension till Mar'21.

SAC considered and agreed for extension of the Project up to March, 2021.

4.9 Development of Superior Absorbents for CO_2 Separation from Biogas: ICT-Mumbai/IOC

Objective:

Biogas is required to have 90% min CH_4 & 3.5% max N_2+CO_2 for use as CNG. CO_2 capture is a crucial step in upgrading biogas. The objective is to develop a novel, hindered amine-based solvent for CO_2 separation from biogas and test its performance in a closed-loop absorber-desorber system in a bench-scale setup and pilot-plant. The separation efficiency and regeneration features of this solvent will be superior to that of the traditional MDEA-based solvent.

Properties of aqueous solvents	MDEA	MEA	AMP	AHPD	Polyamine
CO_2 loading capacity, mol CO_2 / mol amine	0.07 – 1.1	0.15 – 0.69	0.25 – 1	Not known	0.5 – 1.8
Heat of reaction, MJ/kg CO_2	50 – 65	70 – 85	50 – 75	Not known	66 – 78
Kinetic rate constants @ T=30 ^{0}C for the reaction with CO_2, LM^{-1} s^{-1}	15	7000	900	150	55000
Price, Rs./Litre	1300	950	4500	3400 Rs/kg	800 Rs/kg
Corrosive or not?	No	Yes	No	Not known	Yes
Regeneration energy, MJ/kg of CO_2	2	4.3	3.9	Not known	4.1

Major Activities

- Batch experiments for CO_2 absorption and desorption separately to measure the efficiency of absorption and desorption: ICT
- Continuous experiments in a lab-scale, closed loop absorber-desorber setup to measure the CO_2 absorption efficiency and regeneration energy: ICT
- Experiments in a VLE setup to measure the CO_2 solubility and stirred cell to measure absorption rates and investigate absorption kinetics: ICT
- Continuous experiments in a pilot plant to investigate the performance and energy requirements: IOC R&D

Physical Progress:

MOU Date	Start Date	End Date	Physical Progress
March 2019	March 2019	March 2022	33%

Financial Progress (All figures in Rs, lakh)

Agency	Contribution	Expenditure till date	2020-21		
			BE	RBE	Expenditure till Aug'20
CHT	#85.57	42.79	17.00	20.00	-
IOCL	87.97	-	-	-	-
Total	173.54	42.79	17.00	20.00	-

CHT's contribution to ICT-Mumbai

Overall Status:

- The capital equipment (viz. high-pressure vapour-liquid equilibrium setup) was installed in March 2020. Demonstration by vendor is pending due to COVID-19 pandemic. Ambient temperature VLE trials completed.

The actual progress against the approved milestones for the 6 proposed solvent formulations is given below.

Milestones as per MOU	Completion Schedule	Status
Investigation on AMP/EG/PrOH & AHPD/EG/PrOH	Mar 2020	**Completed** - Absorption; Kinetics; Low-temperature VLE trials **Ongoing** - Regeneration;Study in bench-scale absorber-desorber setup (Will be completed by Dec'20)
Investigation on AMP/EGMEE/H_2O & AHPD/EGMEE/H_2O	Mar 2021	**Completed** - Absorption; Kinetics **Remaining** - VLE; Regeneration; Study in bench-scale absorber-desorber setup
Investigation on Polyamine/EtOH	Mar 2022	To begin in April 2021
Investigation on Amine/Glycerol/H_2O	Mar 2022	To begin in April 2021
Performance in pilot plant	Mar 2022	To begin in October 2021

Abbreviations: AMP: 2-amino-2-methyl-1-propanol; EG: Ethylene Glycol; PrOH: 1-Propanol; EGMEE: Ethylene Glycol mono-Ethyl Ether; AHPD: 2-amino-2-hydroxymethyl-1,3-propanediol; EtOH: Ethanol

SAC noted the Progress.

4.10 Stabilization and up gradation of biomass derived oils in a dual stage catalytic reactor: TERI/IOC

The project is an extension of MNRE sponsored non-catalytic pyrolysis project which was originally sanctioned by MNRE and later transferred to CHT, MoP&NG in July'18. The major

objective of the project is catalytic up gradation of bio oil vapours over indigenously made novel catalysts for further improving bio oil characteristics especially in terms of Oxygen content (<5%) and H:C ratio. This upgraded oil is intended to be co-processed in refinery or could find possible direct applications as alternate transport fuels.

Physical progress:

Sanction Date	End Date	Extension	Physical Progress
Sept 2013	Sept 2016	Aug 2020	90%

Financial progress (All figures in Rs, lakh):

Agency	Contribution	Expenditure till date
CHT	44.07	44.07
MNRE	120.00	120.00
Total	164.07	164.07

Overall Status:

- Fixed Bed Catalytic Cracking Upgradation Unit was delivered in Sept'19 against May'19 and their integration with existing pyrolyser and commissioning completed in Jan'20. This activity got delayed by 4-5 weeks due to unavailability of service engineer from Fabricator's side along with unforeseen technical issues in the Mass Flow Controller (MFC) attached to the H2 gas line in the reactor assembly.
- The catalysts for both the stages for two stage vapor cracking and upgrading have been prepared and thoroughly characterized.

Phase I Catalyst (made indigenously)	Phase II Upgradation Catalyst
Mg/Al-HT (BET surface area: 55 m^2g-1)	Zeolite Y (BET surface area: 925 m^2g-1)
Ni/Mg/Al-HT (BET: 90 m^2g-1)	Zeolite beta (BET: 680 m^2g-1)
Ni/Co/Al-HT (BET: 50 m^2g-1)	ZSM-5 (BET: 425 m^2g-1)
Ni/Cu/Al-HT (BET: 63 m^2g-1)	MCM-41 (BET: 63 m^2g-1)
Co/Fe-HT (BET: 67 m^2g-1)	

- Experiments done for three selected biomass derived bio oils in stage-I. In stage-II, 3 sets of catalysts so far tried on bio-oil vapours coming from stage I. 2nd stage trial with MCM41 will be completed by Sept'20.

Biomass	Calorific value (MJ/Kg) of Bio oils			Overall % increase
	feed oil	After Stage-I	after Stage-I + Stage-II	
Rice Straw	21	26	28	33 %

Cotton Stalk	19	24.3	25.2	33%
Cashew Nut Shell	34	35.1	40-41	21%

- Chemical and Physical characterization of all the stage I and Stage II upgraded oils including CHNO analysis, Moisture content & GC/MS are under progress in parallel for the three biomass oil so far upgraded with both Stage I & Stage II catalysts.
- Project progress got delayed by 2 months due to COVID-19 pandemic. Due to overall delay of Reactor delivery and commissioning by 6 months, TERI requested for project extension by 5 months to complete the following:
  a. Experiments with combined catalysts of Phase I and Phase II
  b. Detailed Characterization and evaluation of fuel properties of upgraded bio-oil
  c. Complete interpretation of results and techno-economic analysis of the overall process developed.
  d. Project report submission

SAC considered the above and agreed for project extension up to Jan'21.

4.11 Design and development of Fiber Optic Gas Sensors and System for Petroleum Industry: CSIR-CSIO /BPCL

Reliable sensing of explosive, toxic gases like methane, carbon monoxide, ammonia, hydrogen sulphide, etc. are essential in many industrial and environmental applications. Currently available catalytic, acoustic, FTIR and chromatography based gas analyzer and sensors are bulky, highly sensitive to humidity, operates at higher temperature and also their sensitivity deteriorates with time.

Optical fiber based gas sensing is gaining popularity because it offers several advantages such as immunity to electromagnetic interference, low cross sensitivity, small size and the possibility for distributed gas sensing. In recent years, wavelength modulated near infrared Tunable Diode Laser Overtone Absorption Spectroscopy (WMS-TDLAS) based gas sensing has begun to play an important role in gas sensing techniques based on spectroscopy and its research has been widely spread.

SAC in its 83rd meeting on 17th Nov'18, recommended the Project as under:

Phase-1: Proof of concept for CO & H_2S gases (12 months) at Project cost of Rs 75.83 lakh

Phase-2: Development of prototype & field testing along with BPCL (12 months)

Phase-3: Commercialization by identified manufacturing partner

BPCL shall join as commercial partner after proof of concept in Phase-1.

Objective:

To demonstrate functional laboratory level proof of concept of fibre optic gas sensor and system for gas composition analysis of mixture of hydrogen sulphide and carbon monoxide gas at laboratory level (CSIR-CSIO) for its application in Petroleum Industry.

Target specifications:

Response time: ≤ 100s (dependent on the diffusion time of gas in the gas cell i.e. flow dependent).

Detection range: 0 – 50 ppm for H_2S and 0 – 1000 ppm for CO

Detection limit: 10 ppm for H_2S & 40 ppm for CO (depends on optical path length of gas flow cell).

Physical Progress:

MOU Date	Start Date	End Date	Physical Progress
Dec'19	Jan'20	Jan'21	30%

Financial progress (All figures in Rs, lakh):

Agency	Contribution	Fund released till date	2020-21		
			BE	RBE	Fund released till Aug'20
CHT	75.83	37.30	33.20	50.17	11.63

Overall Status:

- Three Project Assistant recruited w.e.f. 20th Jan'20. Consultant recruitment is expected by Oct'20.
- The critical items like laser diode for H_2S gas detection, Fiber coupled gas flow cell, Standard reference gas cell for calibration are received. Another laser for CO gas detection is expected to be delivered by Sept'20. Out of 13 critical items required for the project, 66% items have been received and 34 % items will be delivered by Nov'20.
- The integration and testing of received items (like fiber coupled gas flow cell and standard reference gas cell with CO & H_2S gas and balance nitrogen) is in progress.
- CSIO is working on the absorbance, transmittance and test other parameters using a broadband light source, NIR spectrometer, Optical Spectrum Analyzer available in their laboratory.
- PO for 3 major critical items will be placed as soon as CSIO receives permission from CSIR HQ for import permission. Meanwhile alternate arrangement like arranging instrument from other labs/using different instrument if possible is also planned to meet the project objectives in case of inadvertent delay in obtaining import permission.

- The status and summary of literature survey and compilation on available commercial gas sensors, gas detector & gas analysers is as follows:

Gas	Commercially available products	Scientific papers on different technologies
Benzene	80	18
Hydrogen	196	27
Hydrocarbon	24	initiated

- The design concept of Gas mixing system for mixing different concentration of CO, H_2S & N_2 gas has been finalised after discussion with BPCL and the tender was released accordingly. Technical and commercial evaluation of bidders for the same is completed. CSIO has informed that there is delay in project execution due to COVID-19 and revised guidelines for import. Accordingly, the schedule is revised as under:

	Milestones as per MoA	Completion Schedule	Revised Completion Schedule	Status
1.	Interaction with BPCL & Recruitment of manpower	Jun'20	Sept'20	Consultant recruitment is expected by Oct'20.
2.	Procurement	Jun'20	Nov'20	All procurement shall be completed by Nov'20.
3.	Preparation of experimental set up & testing.	Jul'20	Dec'20	In progress
4.	H_2S gas detection and concentration validation	Oct'20	Feb'21	Future activity
5.	CO gas detection and concentration validation	Dec'20	Mar'21	Future activity
6.	H_2S and CO gas detection from known composition of gas and concentration validation	Jan'21	May'21	Future activity
7.	Gas sensor overall performance evaluation & documentation	Jan'21	May'21	Future activity

Due to delay in Recruitment of consultant and prevailing situation of COVID, CSIO requested to extend the project till May'21.

SAC considered the above and extended the project up to May'21.

5.0 Review of ongoing Projects under HCF

5.1 Scale-up studies and process development for Hydrogen Production by Catalytic Decomposition of Natural Gas: HPCL-R&D, CeNS and IIT Delhi

Background

- In an earlier project, funded under HCF, HPCL & IITD developed a technology at lab scale to produce H_2 & CNT by catalytic decomposition of methane.

- The most promising catalyst (60% Ni- 5% Cu- 5% Zn on Al2O3 support) was developed and operating conditions were optimised (750°C and 0.25 atm. partial pressure of methane).
- Methane conversion was 93% (91% H_2 yield) in Fixed bed reactor (1 gm catalyst) and 82% in Fluidised bed reactor (5 gm catalyst).
- Deactivated catalyst regenerated at 750°C up to 4 cycles. Reduction in methane conversion was minimal from 93% to 85% in fixed bed.
- The carbon yield (mass of carbon/g metal) in fixed bed was 991%. High purity bamboo shaped structure of CNTs (OD: 35-40 nm; ID: 10-15 nm and Length: 2-3 μm) were produced

Objective and roles under the current project

The project aims scale-up studies and process development for production of hydrogen and carbon nanotubes by catalytic decomposition of natural gas at a feed rate of 1 Kg/hr. The project is envisaged in under two phases, however, the current project is for Phase-1 only, as under;

Phase-I: design and setting-up pilot plant facilities and conducting experiments at HPCL R&D for scale up studies and process development, separation, purification of carbonaceous by-products and its value addition.

Phase-II: preparation of basic engineering package (BEP) for demo unit

- Role of IITD: H_2 & CNT production in 25 gm catalyst fluidized bed reactor (FBR) and to determine the hydrodynamic stability of catalyst in the FBR as well as the time required for optimum CNT deposition.
- Role of CeNS: Develop a protocol for CNT separation from deactivated catalyst. Regenerated catalyst shall be used again in the process. Further, CeNS shall find suitable applications of CNTs for techno-economic viability.
- Role of HPCL: Design and set up a pilot plant of 1 kg/h feed rate by using data from IITD & CeNS. The pilot plant's outcomes shall be used for the development of basic engineering package for a demonstration unit.

Physical Progress:

MOU Date	Start Date	End Date	Physical Progress
Feb 2017	Mar 2017	Mar 2021	15%

Financial Progress (Figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2020-21		
			BE	RBE	Expenditure till Aug'20

CHT	#1692.10	*118.54	218.50	-	5.98
HPCL	1253.60	611.20	150.00	-	15.00
Total	2945.70	729.74	368.50	-	20.98

(HPCL: 1489.80; IIT-D: 102.30; CeNS: 100.00); *(IIT-D: 72.03; CeNS: 46.51)

Overall Status:

- IITD procured & installed fluidised bed reactor (FBR) during Oct'19 and commissioned the same in Mar'20.
- The catalyst developed in earlier project (60% Ni- 5% Cu- 5% Zn on Al2O3 support) tried in FBR, and produced >80 vol% hydrogen in product gas for 6 h run time at reaction temperature of 750 deg C with 4.3 kg CNTs/ kg of active metal (i.e. 716 g CNT produced per hour per kg of active metal). The produced CNTs dimensions are: 60-100 nm (OD); 25-30 nm (ID) and 1.5 to 3 microns length.
- So far, the best reported yield of CNT is 17 kg CNT/kg active metal (3.4 Kg CNT/Kg Catalyst) with 20% Ni 1.6% Cu 1.6% Zn/ Al_2O_3. However, with this catalyst formulation methane conversion reduced from 70 Vol% to 20 Vol% in 3 h time.

	Earlier	**2019**	**Mar'20**	**Aug'20 trial #**
Reactor type	Fixed Bed	Fluidized Bed	Fluidized Bed	Fluidized Bed
Catalyst	60%Ni-5%Cu-5%Zn	60%Ni-5%Cu-5%Zn	20%Ni-1.6%Cu-1.6%Zn	60%Ni-5%Cu-5%Zn
Support	Al_2O_3	Al_2O_3	Al_2O_3	Al_2O_3
Temp, deg C	750	750	750	750-900
pCH4, atm	0.25	0.25	0.25	1
Reaction time, h	10	6	3	60
Methane conversion	93%	> 80	70 ---20	> 85 - 30
gm of C / gm of metal	9.91	4.3	17	30
CNT OD, nm	35-40	60-80	60-80	
CNT ID, nm	10-15	25-30	25-30	
Length, micron	2-3	1.5 - 3	1.5 - 3	
Shape	bamboo	bamboo	bamboo	

# Time, h	**0**	**10**	**10**	**20**	**20**	**30**	**60**
Temp, Deg C	750	750	800	800	900	900	900
Methane Conversion, %	> 85	40	60	20	30	30	30

- CeNS has conducted a detailed characterization of value-added CNT and their potential applications in polymer-CNT composites, conductive inks and electrodes have been completed. The properties and parameters associated with the above applications have also been estimated and compared with the sources available presently. A separate process for the recovery of catalyst and CNT from spent catalyst based on ultra-sonication in presence of a surfactant and centrifugation was devised. With the current separation protocol, 63% CNT can be recovered from spent catalyst in 3.5 h.

- So far seven meetings of the Expert Group have been held (17th May'18, 9th Oct'18, 4th Nov'18, 16th Feb'19, 25th Jun'19, 21st Jan'20 & 13th Jul'20) under the Chairmanship of Prof. R. Kumar. The current catalyst formulation has limitation in terms of achieving desired CNT quality and yield. Current yield of CNT is 17 Kg/ Kg active metal (3.4 Kg C/ Kg Cat- Methane conversion drops from 75 to 10 vol% in 3 h).The Expert Group in its last meeting on 13th Jul'20 made following suggestions:

  a. Catalyst development based on different supports like MgO, carbon-based supports etc. for improving the yield and quality of CNT

  b. Catalyst development for higher yield of CNT so that catalyst can be used as once through and CNT separation can be avoided. Effect of Ni particle size on CNT quality and yield also need to be investigated.

  c. Cost of catalyst production and price of CNT produced are to be evaluated for finalizing the approach viz. catalyst regeneration and recycle, once through use of catalyst with only recovery of metal or without recovery of metal, etc.

  d. Experiments with ferrocene within an objective to use it as catalyst not as raw material for CNT synthesis and operating window to be established.

  e. Submit an approach and way forward after internal meeting among HPCL, IIT Delhi and CeNS.

- As per suggestion of the Expert Group in its first meeting on 17th May'18, decision on pilot plant is under hold till catalyst finalization. Previously, HPCL has synthesized 500g of IITD developed catalyst composition and completed generation of 500 g spent catalyst deposited with CNT. CNT was separated and residual catalyst recyclability studies were conducted. It was observed that recycled catalyst is not able to produce the same quality and yield of CNT as fresh catalyst.

- IITD has proposed 6 months' time frame to complete the experimental studies as suggested by Expert Group. Progress against the approved milestones is listed below.

Milestones as per MoU	**Date**	**Current Status**
Design & Setting up of pilot plant	Oct 2018	HPCL: Design of reactor was changed to bubbling mode. Process Flow Scheme and reactor design completed. Pilot plan

		procurement is on hold till catalyst finalization
Pilot Plant installation & Commissioning activities	Jan 2019	No Progress
Setting up Catalyst scale up facilities	Mar 2018	HPCL: 1 kg catalyst prepared and spent catalyst generated for application evaluation
Catalyst design, screening and scale-up	Sep 2019	IITD: Catalysts are prepared with varying active metal concentration. Currently working with Ferrocene as catalyst. Expert group suggested to develop a catalyst for better CNT quality and yield.
Pilot Plant Experiments & IPR Filing	Sep 2020	No progress
Identification, separation, purification and evaluation of CNT	Sep 2020	HPCL: 500g spent catalyst generated. CNT separation completed. Residual catalyst recycle tests completed CeNS: Developed the CNT separation method with 63% CNT recovery
Value addition from purified CNT	Dec 2020	CeNS: Mechanical properties of separated CNTs-polymer composite have been studied. Electrical conductivity of spray dried films of separated CNTs have been studied for conductive ink applications. Separated CNT was applied for super capacitor and Zn-Air battery applications
Data Generation for demo unit	Mar 2021	-
Technical Report	Mar 2021	-

- HPCL has expressed that the current catalyst formulation is expensive as it contains 70% expensive metals as active component. To have economically feasible process cost effective catalyst formulation to be worked out. Further, Current catalyst formulation does not yield constant vol% of H_2 in product gas. Operating window should be established in such a way that constant yield of H_2 can be achieved at constant operating pressure and GHSV.
- To identify large scale applications of produced quality CNT, HPCL will have meeting with BARC and DRDO

The design and procurement of pilot plant by HPCL shall be taken up subsequent to satisfactory development of catalyst system.

SAC noted the above.

5.2 Creation of Solar based Hydrogen Production system and dispensing station for refuelling Hydrogen Fuel Cell vehicles: IOC

Objectives:

1. Solar Energy Studies
    a. Seasonal variation effect on plant operation
    b. Reduce the green-house gases and reduce emission by efficiency improvement
2. Green Hydrogen generation & refuelling Infrastructure
    a. Comparison of different types of electrolyses, storage system etc.
    b. Experience of safer handling of Hydrogen and refuelling
    c. Utilization of hydrogen for transportation and power generation application
    d. Hydrogen refuelling facility for trials of Hydrogen vehicle at Delhi NCR
    e. Familiarization with safer hydrogen handling on-board vehicle and hydrogen refilling site
    f. Testing, Monitoring and Evaluation of individual sub-systems and the entire value chain

Physical Progress:

MOU Date	Start Date	End Date	Physical Progress
20th March'20	April'20	April'25	7 %

Financial Progress (Figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2020-21		
			BE	RBE	Expenditure till Aug'20
CHT	2500.00	-	2400.00*	-	-
IOCL	4016.00	-	-	-	-
Total	6516.00	-	2400.00	-	-

*IOCL has indicated that no demand will be raised in FY 2020-21.

Overall Status:

- Administrative and Financial approval received by IOC R&D for setting up of the process.
- Technical specification finalized for the facility.
- Activities related to floating of tender for procurement completed during Jul'20. However, due to recent restriction on global tenders below Rs 200 crore, floating of National tender is being undertaken and is expected by Sept'20.
- Definition of similar item for tender and probable vendor list creation in progress.

SAC noted the above.

5.3 Setting-up of single step compact reformer unit of 4 TPD capacity to produce Hydrogen blended CNG (H-CNG) and associated facilities in Delhi bus depot for demonstration in commercial CNG vehicles: IOC-R&D

Objective:

- Setting-up of compact reformer unit of 4 TPD capacity to produce H-CNG
- Setting-up of associated infrastructures for compression, storage, and dispensing of H-CNG in Delhi bus depot
- Demonstration trial of H-CNG fuel in a fleet of 50 BS IV compliant commercial CNG vehicles
- Continuous Operation & Maintenance of the H-CNG plant during the trial period.
- To carry out performance & emission tests & monitoring of vehicles during the trial

Physical Progress:

MOU Date	Start Date	End Date	Physical Progress
Feb 2020	Mar 2020	Aug 2020	72%

Financial Progress (Figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2020-21		
			BE		
CHT	#920.00	763.58	-	CHT	#920.00
IOCL	919.00	919+@283	-	IOCL	919.00
*TM, GoD	1500.00	1500	-	*TM, GoD	1500.00
Total	3339.00	2282.58+@283	-	Total	3339.00

#CHT's contribution to IOCL *Transport Ministry, Govt. of Delhi

@Additional expenditure incurred for compliance to Delhi Fire Service.

Overall Status:

- HCNG plant and its associated infrastructure for compression, storage and dispensing of HCNG & Gas Generator set have been installed at Rajghat and pre-commissioning activities have been completed. 'Consent to operate' approval from PESO (application filed in Dec'19) received in start of Aug'20.

- M/S Ashok Leyland has completed adjustments required in 50 buses for conversion from CNG to HCNG fuel. Baseline vehicle emission & fuel consumption studies completed.

- HAZOP analysis of plant completed. Fire & Safety System installation in progress as recommended by Delhi Fire Service. DPCC approval for consent to operate, which was valid till 31st Jul'20 has been renewed till 31st Mar'21.

- Approval for dispenser is awaited from PESO.

- SOP procedures laid down, training of personnel done, Standard plant start-up has been done, and catalyst has been loaded. However, the plant can only be operated once all approvals are in place as storage capacity is small.

- After resumption of public transport in Delhi post lockdown, the bus trial can commence from Sept'20.

- Dr SSV Ramakumar, Dir (R&D), IOCL explained that patented Compact Single Step Reforming Process is being employed in the project for production of HCNG. Technip, India is the engineering partner in this. This project will run for six months on Delhi NCR route and as per direction of Hon'ble Supreme Court & as per the protocol, Emissions data will be collected. He informed that lab study on emission with ARAI has established reduction in HC and CO level with HCNG compared to CNG. He informed that even the NOX level, which increases with HCNG can be kept at the same BS-IV level with catalytic converter. The catalyst converter will be placed in 10 busses out of 50 buses.

- Normally CNG engines requires special lubricants and HCNG requires still different Lubricant for Thermal stability. Lube formulation, specially formulated for HCNG will also undergo trial.

- As per the agreement with IGL, the plant will be handed over to them for operation, If project is successful. IOCL is also planning to scale up at 100 MT /day capacity and engineering work is being done with M/S Technip. The further way forward shall depend upon final view and directions from the Hon'ble Supreme Court.

- IOC R&D sought extension of the project up to March'21 to undertake the demonstration trial for a period of 6 months.

SAC considered the above and agreed for project extension till March'21.

5.4 Development & Demonstration of commercially viable Fuel Cell buses based on Hydrogen produced from Multiple Pathways: IOCL/IISc/OEM

Broad Objectives

a. A comprehensive pilot study to develop and demonstrate clean transportation solution through hydrogen fuel cell technology based on various indigenously designed hydrogen production pathways / indigenously available resources.

b. To indigenously develop and commercialize fuel cell stack / system for heavy-duty buses.

c. Understanding the performance and durability of fuel cell buses under Indian operating conditions

d. To develop and scale up / explore commercially viable hydrogen production pathways from 4 different routes (namely: Biomass gasification, biomethanation to H_2, solar

electrolysis based on three different electrolyzer technologies, and natural gas reforming

e. Evaluate the technology by executing the field trials on 15 fuel cell buses in Delhi NCR region for a running distance of 20,000 kms and undertaking the techno-commercial evaluation for providing end to end solution for heavy duty buses including cost effective and environmentally friendly production pathways.

f. Developing an understanding of the complexities of hydrogen refuelling station especially in terms of addressing the requirements of heavy duty fleet.

Hydrogen Infrastructure

a. Indigenization of hydrogen production technologies to reduce the generation / purification cost

b. Development of 4 different pathways to establish techno-economic viability for production of 10 Kg/ Hr hydrogen with each pathway;

   i. To design and develop Bio oxy-gasifier in collaboration with Indian Institute of Science (IISc), Bangalore.

   ii. To setup biomethanation plant based on agro residue with low cost purification system for fuel cell grade hydrogen production.

   iii. To install & commission 110 Nm^3/hr solar based electrolyzer plant. The plant includes PEM, SOEC and Alkaline electrolyzers.

   iv. To setup small scale (minimal footprint) NG reformer with low cost purification system for fuel cell grade hydrogen with capability of integration with CCUS system at a commercial scale

c. Understanding the operational efficacy, performance and reliability of production plants at scaled up capacities

d. Understanding the system complexities and safety protocols for handling hydrogen and its dispensing at high pressures

Fuel Cell Stack Technology / Buses

a. Indigenization of fuel cell stack – which is the heart of the system and the costliest component involved in the technology development.
b. Scale up of stack to cater to heavy duty bus applications - 15 no. of liquid cooled PEM FC stacks (metallic) for buses
c. Fuel cell system development and critical BoP components for 15 no. of buses.
d. Automotive system development, drive-train optimization and deployment.
e. Integration and optimization of hybrid solution customized for Indian driving conditions for heavy duty applications.

f. Cutting edge fuel cell Catalyst / GDL materials for improved efficiency, efficacy and innovative in-situ pathways for handling refinery feed for fuel cells to reduce the OpEx significantly.

Wide Scale Trials in Delhi NCR

a. Demonstration of the fuel cell technology in 15 buses to be refuelled through above mentioned hydrogen production pilot plants.
b. Undertaking the wide scale trials to establish the efficacy and durability of the systems under Indian operating conditions.

Emission Quantification / TCO Assessment / Safety Requirements

a. Quantification of emission reduction benefits especially with respect to CO_2, NO_x & PM and the positive impact thereof on ambient air quality compared to conventional fuels and battery buses.
b. The hydrogen based fuel cell bus technology will be assessed in reference to Total Cost of Ownership (TCO) vis-a-vis conventional diesel buses and battery buses (at equal scale).
c. Enabling safety standards, regulations & legislations for hydrogen & fuel cell technology in India while addressing social issues related to waste management and agro disposal.

- The Project has been approved by GC of CHT in its 39th meeting on 16th Jul'20 with partial funding from CHT. The Signing of MoA with CHT is to be completed.
- IOC explained that out of the items to be procured, Storage, compressor and dispenser are available locally except electrolysers. SAC has asked all three types electrolysers- PEM, alkaline and SOFC. IOC informed that Two stage procurement process has been followed. 5 out of the 10 vendors, who responded against EOI, are with in the country, but they do not have full integration capability and 90% of components are procured from overseas principals. The specifications have been firmed up, budgetary Quotes obtained and national tender will be floated in a weeks' time.
- Dir(R&D), IOCL informed that the Proposal has been put up for approval of IOC Board and IOCL is trying to get more funding from alternate sources like MNRE and Invest India. Busses will be procured with grant from HCF, but before procuring in the tender itself, the fuel cell stack developer and OEM has to supply a prototype and will be tested in fuel cell lab as per predetermined criteria and same is incorporated in Tender. Against EOI, many OEMs have responded for joint development and supply of 15 buses in staggered manner over period of 18 months. The tender is expected by Oct'20. IOCL is parallelly working on land and biomass supply arrangements.

SAC noted the above.

6. CH SAC mentioned that Commercialization of completed projects /Process needs to be given thrust and suggested to keep it as an agenda point in the next meeting.

EIL informed that BPCL and EIL is going for commercialization of De-salter technology, which has been developed under one of the CHT funded project at Kochi refinery to revamp existing desalters.

Dir (T), EIL raised the issue of not being able to offer jointly developed technologies by EIL with others in projects where EIL acts as PMC due to conflict of interest. This hampers commercialization of indigenously developed technologies. CHT mentioned that the subject has been discussed in the past in various forums including SAC, EC of CHT and Working Group on Refineries headed by JS(R) and the recommendations for change of policy are documented. EIL was advised to pursue the matter with concerned authorities through MoP&NG.

7. Shri S. Bhargava ED (CRDC), BPCL shall cease to be the member of SAC due to his superannuation in September 2020. While acknowledging his technical contribution, SAC bid him farewell and wished him success in his new inning post retirement. Shri Bhargava thanked all members for the cooperation.

The meeting ended with thanks to the Chair and the participants.

Annexure-1

89th Meeting of Scientific Advisory Committee (SAC) on Hydrocarbons of MoP&NG held on 17th September, 2020 through Video Conference

List of Participants

	Name	Designation	Organization
1	Dr. Anil Kakodkar	Chairman - SAC	BARC
2	Sh. Sunil Kumar	Joint Secretary (Refineries)	MoP&NG
3	Prof. R. Kumar	Professor Emeritus	IISc
4	Prof. J.B. Joshi	Professor Emeritus	HBNI
5	Prof. A.B. Pandit	Vice-Chancellor	ICT
6	Dr. Shashi Kant	Scientist Emeritus	IOCL
7	Dr. M.O. Garg	President (R&D)	RIL
8	Prof. Shankar Narasimhan	Professor	IIT Madras
9	Dr. S.S.V. Ramakumar	Director (R&D)	IOCL
10	Ms Vartika Shukla	Director (T)	EIL
11	Dr. Anjan Ray	Director	IIP
12	Sh. K.K. Jain	ED	CHT
13	Sh. Manoj Sharma	ED (O)	IOCL
14	Sh. Sanjay Bhargava	ED (R&D)	BPCL
15	Sh. D.V. Shastry	ED (Trg. R&D and Start-up)	GAIL
16	Sh. R. Srikanthan	Director (T)	CPCL
17	Sh. S. Bharathan	Head (R&D)	HPCL
18	Sh. S.C. Gupta	Head (R&D)	EIL
19	Sh. Sanjeev Katti	DG	OEC
20	Sh. P. Raman	Director	CHT
21	Dr. Ravikumar V.	CGM (R&D)	BPCL
22	Sh. Alok Sharma	CGM (AE)	IOCL
23	Sh. S.B. Lahkar	CGM (T)	IOCL
24	Dr R.N. Maiti	GM (R&D)	EIL
25	Sh. A.S. Pathak	GM (R&D)	EIL
26	Dr. D. K. Rajeev Nambiar	GM (R&D)	EIL
27	Dr. Bharat L. Newalkar	GM (R&D)	BPCL
28	Prof. K.K. Pant	Professor	IIT-D
29	Dr. S. S. Thipse	Sr. Dy. Director	ARAI
30	Dr. A.K. Jain	CGM (R&D)	HPCL
31	Dr. G. Valavarasu	DGM (R&D)	HPCL
32	Sh. Pramod Kumar	DGM (R&D)	HPCL
33	Dr. M. Lavanya	DGM (R&D)	CPCL

	Name	Designation	Organization
34	Dr. B.L.A. Prabhavathi Devi	Senior Principal Scientist	IICT
35	Dr. Thallada Bhaskar	Senior Principal Scientist	IIP
36	Dr. S.K. Maity	Senior Principal Scientist	IIP
37	Prof. P.D. Vaidya	Professor	ICT
38	Dr. Chanchal Samanta	CM (R&D)	BPCL
39	Ms Piyali Das	Sr. Fellow	TERI
40	Dr. Mahesh Kasture	CM (R&D)	BPCL
41	Dr. Tushar S. Thorat	CM (R&D)	BPCL
42	Dr. K.N. Raja	CM (R&D)	HPCL
43	Sh. N.V.S.N. Raju	CM	HPCL
44	Sh. Surjit Kaman	Scientist	CSIO
45	Sh. Kaushal Parmar	Research Scholar	IIT-D
46	Sh. Brijesh Kumar	Advisor (T)	CHT
47	Sh. Manas Banerjee	Advisor (T)	CHT
48	Sh. S.K. Varshney	Jt. Director	CHT
49	Sh. Manoj Thomas Varghese	Jt. Director	CHT
50	Sh. Anoop Kumar Gupta	Dy. Director	CHT