PSA/2005/4

Development of the Integrated Gasification Combined Cycle (IGCC) Technology as suited to Power Generation using Indian Coals

Office of the Principal Scientific Adviser to the Government of India

December, 2005

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Office of the Principal Scientific Adviser
to the Government of India
Vigyan Bhawan Annexe
Maulana Azad Road
New Delhi-110 011

December, 2005

C O N T E N T S

SECTION - I

A Brief Report on the S&T Work Done to Establish the First (~100 MWE) IGCC Demonstration Plant in the Country

A BRIEF REPORT ON THE S&T WORK DONE TO ESTABLISH THE FIRST (~100 MWe) IGCC DEMONSTRATION PLANT IN THE COUNTRY – OFFICE OF THE PRINCIPAL SCIENTIFIC ADVISER TO THE GOVERNMENT OF INDIA.

- In November, 2002**,** the Prime Minister's Office (PMO) suggested to the Principal Scientific Adviser (PSA) that synergy between BHEL and NTPC should be established for the indigenous development of the IGCC technology and for the subsequent setting-up of the first IGCC (~100 MWe) demonstration plant in India.

- To oversee this, the PSA's Office set-up an R&D Committee on IGCC under the chairmanship of the Scientific Secretary. Please see ***Annexure-1*** for the composition and the terms of reference of the Committee and ***Annexures- II to V*** for the minutes of its four meetings held thusfar.

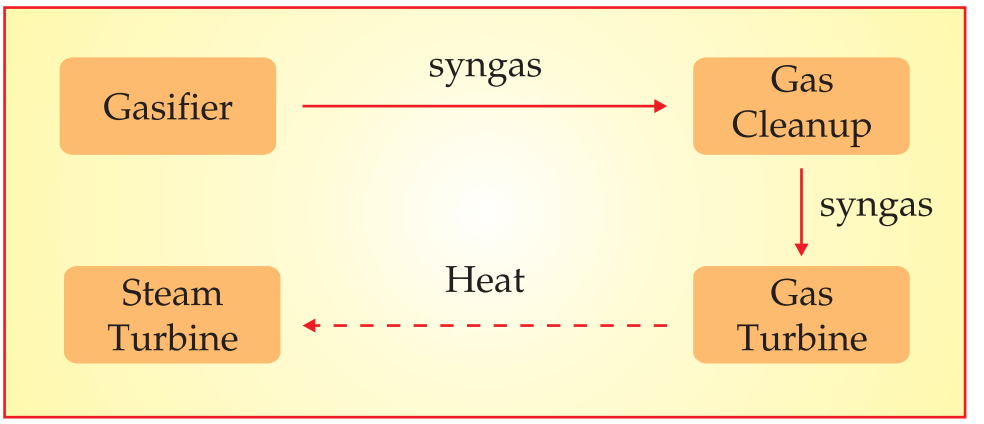
- The R&D Committee noted that the IGCC plant, based on the Pressurized Fluidized Bed (PFB) concept, was ideally suited for the high ash (35% to 45%) Indian coal. However, there was not much international experience available with PFB. BHEL had already set-up three R&D plants based on PFB [200 mm diameter Advanced Pressurized Fluidized Bed Gasifier (APFBG) (coal feed: 1.2 T/day); 450 mm diameter Performance Evaluation and Demonstration Unit (PEDU) (18 T/ day) and 1.1m diameter Combined Cycle Demonstration Plant (CCDP) (150 T/day, 6.2 MWe)]. Therefore, by using these BHEL plants, operating at different regimes of coal and air/ steam flow ***(see Table-1),*** there was a unique opportunity to carry-out experiments and their simulations. These simulations could then be reliably used for arriving at the design of the ~100 MWe plant.

Table 1: Some operating conditions for BHEL Plants

	APFBG	PEDU	CCDP
Coal (kg/hr)	33	131	4287
Air (kg/hr)	69	303	8064
Steam (kg/hr)	6.1	20	775
Operating pressure (bar)	1.28	5	8

- As is well known, an IGCC plant has three islands: a gasifier and allied coal/ash handling equipment, a gas clean-up system and the two turbines (one gas turbine and one steam turbine) ***(see fig.1)***.

Fig.1: Coal Gasification within the IGCC Concept



Since a gas clean-up system was already available in the CCDP, and also as its cost was a small fraction of the total (~ 5%), the Committee decided to concentrate on the gasifier part first. BHEL had already made a design for a 100 MWe plant. This was the upgraded version of their 6.2 MWe plant based on a similarity principal. However, NTPC had some technical reservations on this.

- Therefore, for carrying-out design validation of the BHEL's 100 MWe plant, a Working Group was constituted by the R&D Committee. This was headed by Dr. R.R. Sonde (then at the Heavy Water Board, Department of Atomic Energy), with representation from both BHEL and NTPC.

- The following performance parameters were selected for this 100 MWe plant:

  i) Carbon conversion efficiency ~85%

  ii) Cold gas efficiency ~71%

  iii) Gross efficiency ~ 39%

  iv) Gas Calorific Value (LCV) ~ 1000-1100 Kcal / Nm^3

  v) Broad operating range with a good availability factor, long term operation, etc.

- The Working Group has carried-out the following work, inter alia, during the last three years:

  i) A large number of experiments on APFBG and PEDU (the CCDP became available for experiments in March, 2004) to optimize the external parameters like air to steam ratio, air to coal ratio, coal size, etc. and internal parameters like temperature, residence time distribution, superficial velocity, etc.

  ii) Residence time distribution for determination of coal particles through radio tracer techniques, using La^{140} produced in the Dhruva reactor at Bhabha Atomic Research Centre (BARC).

iii) X-ray radiography studies for bubble hydrodynamics. For this a special gadget was designed and fabricated. The measurements were done at BARC.

iv) Intermediate gas composition measurements.

v) Gas contaminant analysis by neutron activation techniques.

vi) Porosity and moisture content measurements.

vii) Reviewed the past data on BHEL's R&D plants.

viii) Developed Artificial Neural Network (ANN) and phenomenological models to interpret the data (The PSA's Office had sanctioned a project to the National Chemical Laboratory, Pune, for the development of this for fluidized bed coal gasifiers. The project has recently been completed). Typical simulation results for some runs on the CCDP are displayed in ***Table-2***.

Table 2: Analysis of experimental data using the models developed (CCDP)

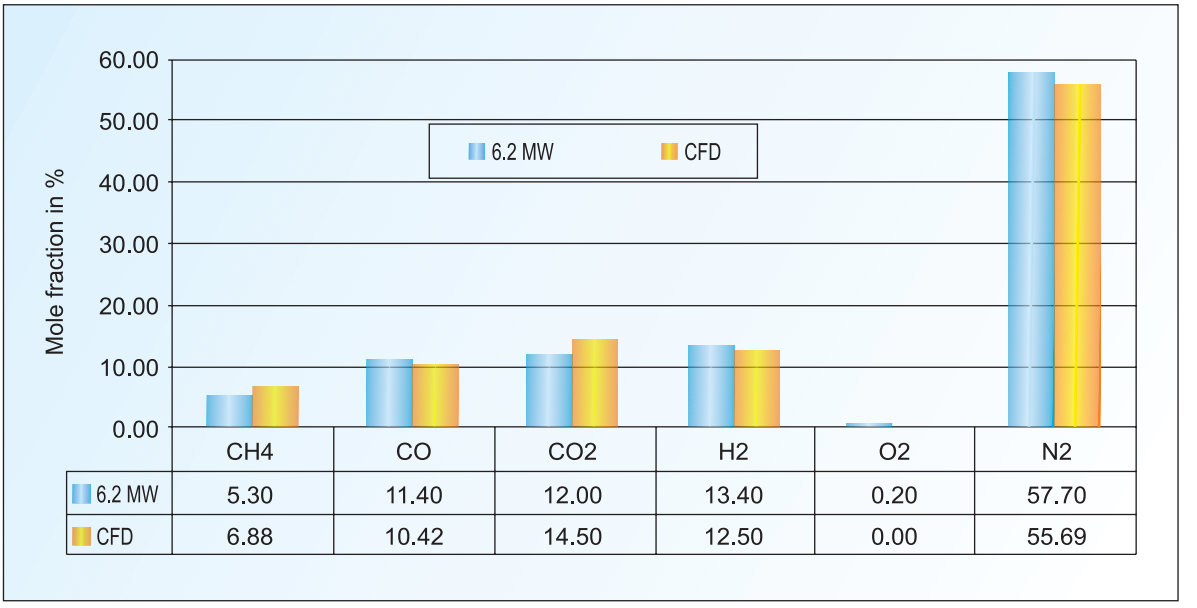
	20.7.05, 5 bar, 950°C			21.7.05, 8 bar, 1025 °C		
Parameter	**Expt**	**NFM**	**PFM**	**Expt**	**NFM**	**PFM**
Carbon Conversion (%)	80.44	78.59	80.4	89.2	91.93	93.35
Dry Gas Composition (Vol %)						
CO	14.40	11.8	13.12	16.90	17.92	18.88
CO2	13.9	15.9	15.05	11.7	12.08	11.48
CH4	1.20	1.3	1.37	1.30	1.02	1.16
H2	15	16.21	15.91	15.1	14.95	14.43
N2	55	54.8	54.56	54.5	54.03	54.05
Cold Gas Efficiency (HCV)	54.13	53.8	56.12	66.5	66.09	67.62

Expt: Experimental Result
NFM: Net Flow Model
PFM: Plug Flow Model

The agreement is very encouraging. In addition to this project, BHEL had commissioned an independent study in the Indian Institute of Technology, Madras, for the Computational Fluid Dynamics (CFD) analysis of the fluidized bed gasifier in IGCC plants. The CFD model was

validated using the data obtained from the CCDP ***(see fig.2)***. The model also predicts the performance of the 125 MWe gasifier.

Fig.2:Comparison between Experimental and CFD data for CCDP Plant



	CH4	CO	CO2	H2	O2	N2
6.2 MW	5.30	11.40	12.00	13.40	0.20	57.70
CFD	6.88	10.42	14.50	12.50	0.00	55.69

- Conduct of some of the above work required modifications in the R&D plants of BHEL. These were carried-out by BHEL. A vast amount of data were generated from the experiments done on the APFBG and the PEDU. The Working Group concluded from these experiments that carbon conversion efficiency and cold gas efficiency are not a strong function of coal quality (i.e. its source or its exact ash content). The efficiency figures obtained for the APFBG and the PEDU were lower than expected, possibly due to the high heat loss in small rigs or operation of rigs at lower pressures or bubble formation in the gasifier.

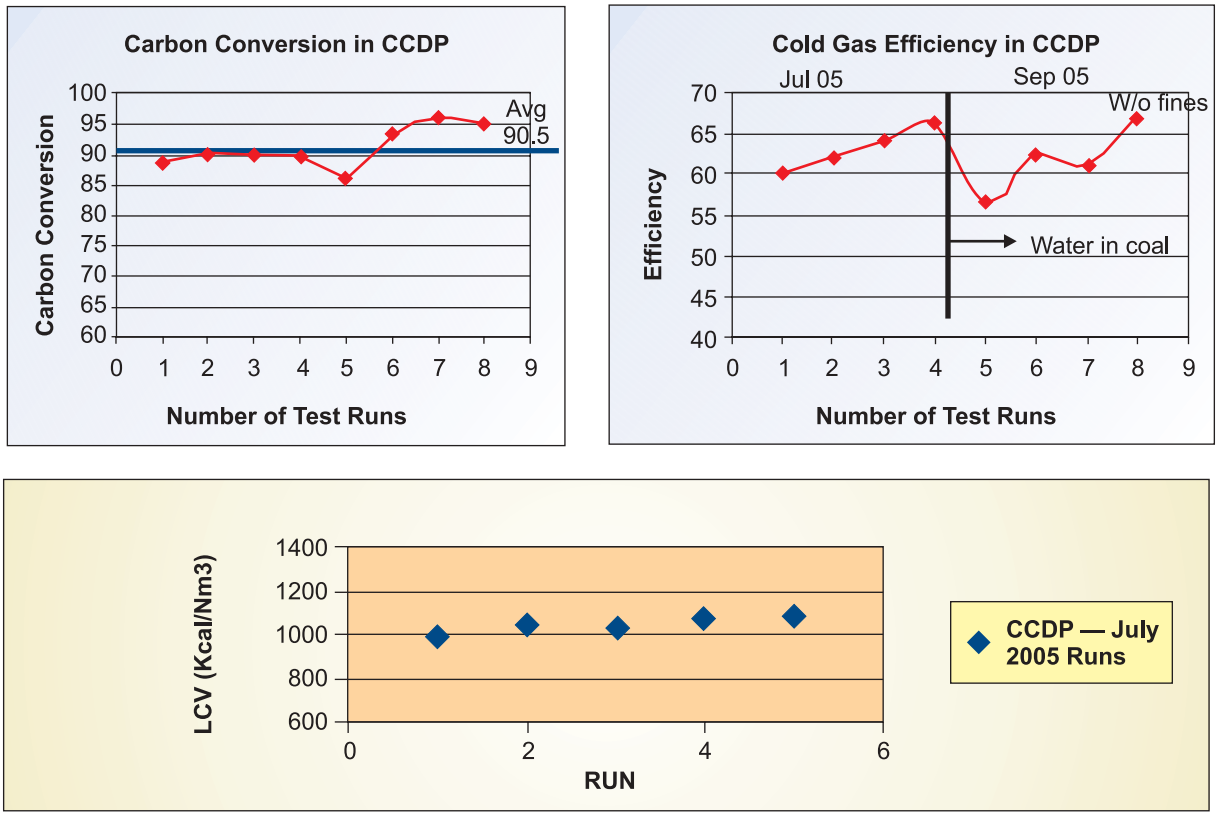
- The scale-up strategy, emerging from the studies done on the APFBG and the PEDU, pointed to:-

  - the need for operating the 100 MWe plant at a pressure of about 30 bar (maximum operating pressures of APFBG, PEDU and CCDP are 1, 5 and 8 bars, respectively). Therefore, to evaluate the pressure effects, further experiments were proposed on the CCDP, operating at higher pressures.

- During July 20-21, 2005, 5 sets of experiments were done by the Working Group on the CCDP at pressures varying from 5 bar to 8 bar and temperatures varying from 950°C to 1050°C. The results of these tests were to the satisfaction of the Working Group. The good performance of the CCDP was, primarily, due to substantial modifications done in that rig by BHEL during September, 2003 to March, 2004. A major modification was the addition of a flat plate distributor. This improved the uniformity of the fluidization and the bed temperature, leading, in turn, to the operation of the CCDP at temperatures as high as 1050°C and consequent improvement in the overall gasifier performance.

- Results of the experiments done on the CCDP have shown that at a temperature of 1050°C, the carbon conversion efficiency in the CCDP was 88-89%, while the cold gas efficiency was 68.8%. The LCV was ~ 1100 Kcal / Nm^3 ***(see fig.3).*** These are quite close to the set values. The results of September, 2005 experiments were on the lower side as the coal (of finer size and having higher water content) conditions were changed and thus not acceptable.

Fig.3: Carbon Conversion & Efficiencies for the CCDP



- The model predictions, using the NCL developed models, for the 125 MWe plant operating at 30 bar are given in the ***Table-3*** for two different types of coal and temperature conditions.

Table 3. Model predictions for the 125 MWe plant at 30 bar

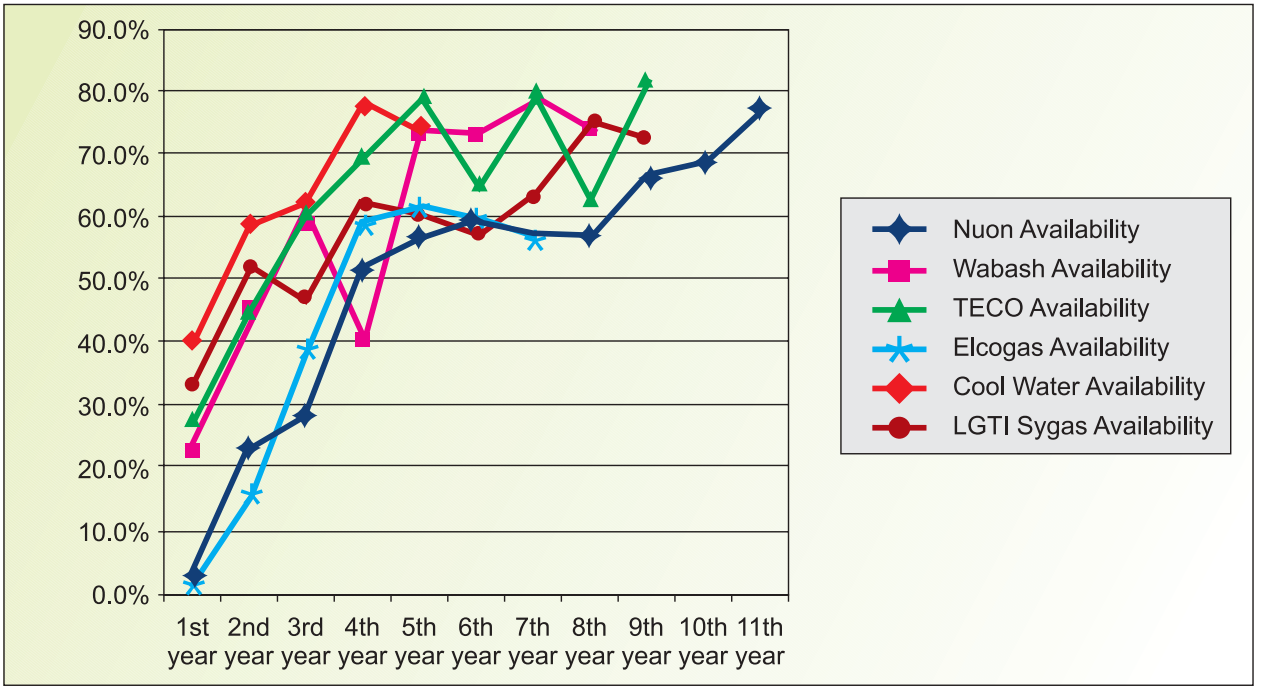
Carbon Conversion (%)	93.21	92.3	93.74
Dry Gas Composition (Vol %)			
CO	20.75	20.83	24.7
CO2	10.6	10.47	8.58
CH4	2.17	2.1	2.01
H2	15.1	14.93	15.42
N2	51.38	51.67	49.28
Cold Gas Efficiency (HCV)	72.62	71.64	71.41

These show that one may go ahead in setting-up the 100 MWe IGCC Plant.

- **Now that the technical feasibility of upgrading the 6.2 MWe CCDP of the BHEL to 100 MWe has been satisfactorily established, a detailed project report may be prepared jointly by the BHEL and the NTPC for setting-up the first 100 MWe IGCC demonstration plant in the country with financial support from the Government of India.** It is also suggested that BHEL and NTPC should continue to do more experiments and simulations on the 6.3 MWe plant.

- According to O. Maurstad (LFEE 2005-002 WP), low availability is still an issue with IGCC plants world over ***(see Fig. 4)***. It can be seen that most of the plants were able to reach the 70-80% availability after a number of years. It is hoped that newer plants will do so in a shorter span of time as solutions like adding a spare gasifier etc. exist. It is suggested that we can gather this experience on the proposed 100 MWe demonstration plant.

Fig. 4 IGCC availability history (from LFEE 2005-002 WP)



- In a meeting of the Inter-ministerial Steering Group on IGCC chaired by the Secretary (Power) on the 15th of December, 2005, it was decided that the BHEL and the NTPC should come-out with a detailed project report, positively by the 15th of January, 2006. It was pointed-out that the cost of the 100 MWe demonstration plant would be around Rs. 800.00 crores. The Secretary (Power) gave the following decision on the funding of the proposed plant:

  - Rs. 4.00 crores per MW to be contributed by NTPC.
  - The remaining cost to be met partly by BHEL and partly by the Planning Commission as grants-in-aid.

SECTION - II

Annexures

Annexure-I

F.No.: Prn.SA/IGCC/2002
GOVERNMENT OF INDIA
OFFICE OF THE PRINCIPAL SCIENTIFIC ADVISER
TO THE GOVERNMENT OF INDIA

326, Vigyan Bhawan Annexe
Maulana Azad Road
New Delhi-110011
Tel. No. :011-23022091
011-23022008
Telefax No. : 011-23022009

Dated : 7th of January, 2003

OFFICE MEMORANDUM

Subject: Constitution of an R&D Committee for the development of Integrated Gasification Combined Cycle technology, as suited to Coal Gasification based Power Generation in India.

The undersigned has been directed to convey the decision of the Government of India to constitute an R&D Committee for the development of Integrated Gasification Combined Cycle (IGCC) technology, as suited to Coal Gasification based Power Generation in India, with a view to ensure, amongst other things, that the R&D, that has already been done in India on IGCC technologies and related areas, is fully utilized.

2. The following shall be the Composition and the Terms of Reference of the said Committee:

2.1 Composition:

S.No	Name, Designation & Organization	Status
i.	**Dr. S.K. Sikka**, Scientific Secretary to the Principal Scientific Adviser to the Government of India, 324-A, Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi – 110 011	Chairman
ii.	**Shri S.L. Kapur**, Director (Technical), National Thermal Power Corporation Ltd., NTPC Bhawan, Scope Complex, 7 Institutional Area, Lodi Road New Delhi – 110 003	Member
iii.	**Shri Virendra Kumar**, Director (Engg. R& D), Bharat Heavy Electricals Limited, BHEL House, Siri Fort, New Delhi - 110 049	Member

iv.	**Dr. (Smt.) Malti Goel**, Scientist 'G', Department of Science and Technology, Technology Bhawan, New Mehrauli Road, New Delhi – 110 016	Member
v.	**Shri Chandan Roy**, Executive Director (Engg.), National Thermal Power Corporation Ltd., NTPC Bhawan, Scope Complex, 7 Institutional Area, Lodi Road, New Delhi – 110 003	Member
vi.	**Shri S. Balagurunathan**, Executive Director, Bharat Heavy Electricals Limited, Corporate Research and Development, Vikasnagar Hyderabad – 500 093	Member
vii.	**Dr. O.P. Rao**, Scientist 'F', Council of Scientific and Industrial Research, Room No. 201, Anusandhan Bhawan, Rafi Ahmed Kidwai Marg, New Delhi – 110 001	Member
viii.	**Dr. R.R. Sonde**, Chief Engineer (Process), Heavy Water Board, Department of Atomic Energy, 5th Floor, Vikram Sarabhai Bhavan, Anushaktinagar, Mumbai – 400 094	Member
ix.	**Shri P.R. Mohanty**, Production Manager, Heavy Water Plant, Talcher, Department of Atomic Energy, P.O. Vikrampur, District Angul, Orissa – 759 106	Member
x.	**Shri Neeraj Sinha**, Scientist 'E', Office of the Principal Scientific Adviser to the Government of India, 326, Vigyan Bhavan Annexe Maulana Azad Road, New Delhi – 110 011	Member-Secretary

2.2 Terms of Reference

The following shall be the Terms of Reference of the Committee:-

i. The Committee shall ensure that the R&D done, so far, on IGCC technologies and related areas by various Indian Organizations, is fully utilized for the construction and commissioning of commercially viable Coal Gasification based IGCC power plants in the country.

ii. As a modest beginning, the Committee will facilitate, in every conceivable and feasible way, the setting-up and commissioning of a 100 MWe Coal Gasification based IGCC demonstration plant in the country.

iii. The Committee shall have the power to take, on payment of appropriate remuneration, the services of senior experts, as and when required, for discharging its duties.

iv. The Committee will also execute any other task that is assigned to it, from time-to-time, by the Office of the Principal Scientific Adviser to the Government of India.

v. Initially, the tenure of the Committee will be two years from the date of issue of this Office Memorandum. The tenure can be extended beyond the said period, if deemed fit by the Government of India.

vi. The Committee will meet atleast once every four months during its entire tenure.

vii. The Chairman of the Committee shall have the authority to co-opt members as and when required, and shall also have the authority to call for emergency meetings of the Committee, even when they are not due.

viii. Special invitees can be invited to attend meetings of the Committee, with prior consent of the Chairman.

ix. The travelling and daily allowances will be payable, as per the existing rules of the Government of India, to the non-official constituents, if any, of the Committee.

3. This issues with the approval of the Scientific Secretary to the Principal Scientific Adviser to the Government of India.

Sd/-
(NEERAJ SINHA)
SCIENTIST 'E'

Encl.: As stated above.

To

i. Shri S.L. Kapur, Director (Technical), National Thermal Power Corporation Ltd., NTPC Bhawan, Scope Complex, 7 Institutional Area, Lodi Road, New Delhi – 110 003.

ii. Shri Virendra Kumar, Director (Engg. R&D), Bharat Heavy Electricals Limited, BHEL House, Siri Fort, New Delhi- 110 049.

iii. Shri Chandan Roy, Executive Director (Engg.), National Thermal Power Corporation Ltd., NTPC Bhawan, Scope Complex, 7 Institutional Area, Lodi Road, New Delhi – 110 003.

iv. Dr. (Smt.) Malti Goel, Scientist 'G', Department of Science and Technology, Technology Bhawan, New Mehrauli Road, New Delhi – 110 016.

v. Shri S. Balagurunathan, Executive Director, Bharat Heavy Electricals Limited, Corporate Research and Development, Vikasnagar, Hyderabad – 500 093.

vi. Dr. O.P. Rao, Scientist 'F', Council of Scientific and Industrial Research, Room No. 201, Anusandhan Bhawan, Rafi Ahmed Kidwai Marg, New Delhi – 110 001.

vii. Dr. R.R. Sonde, Chief Engineer (Process), Heavy Water Board, Department of Atomic Energy, 5th Floor, Vikram Sarabhai Bhavan, Anushaktinagar, Mumbai – 400 094.

viii. Shri P.R. Mohanty, Production Manager, Heavy Water Plant, Talcher, Department of Atomic Energy, P.O. Vikrampur, District Angul, Orissa – 759 106.

Copy, for information, to:

i. Prof. V.S. Ramamurthy, Secretary, Department of Science and Technology, Technology Bhawan, New Mehrauli Road, New Delhi – 110 016.

ii. Dr. R.A. Mashelkar, Secretary, Department of Scientific and Industrial Research and Director General, Council of Scientific and Industrial Research, Anusandhan Bhawan, Rafi Ahmed Kidwai Marg, New Delhi – 110 001.

iii. Shri C.P. Jain, Chairman and Managing Director, National Thermal Power Corporation Ltd., Scope Complex, Lodi Road, New Delhi – 110 003.

iv. Shri K.G. Ramachandran, Chairman and Managing Director, Bharat Heavy Electricals Limited, BHEL House, Siri Fort, New Delhi- 110 049.

v. Dr. P.C. Hiremath, Chief Executive, Heavy Water Board, Department of Atomic Energy, 5th Floor, Vikram Sarabhai Bhavan, Anushaktinagar, Mumbai – 400 094.

Copy also to:

i. Dr. R. Chidambaram, Principal Scientific Adviser to the Government of India, 318, Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi – 110 011.

ii. Dr. S.K. Sikka, Scientific Secretary to the Principal Scientific Adviser to the Government of India, 324-A, Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi – 110 011.

Sd/-
(NEERAJ SINHA)

Annexure-II

MINUTES OF THE FIRST MEETING OF THE R&D COMMITTEE FOR THE DEVELOPMENT OF INTEGRATED GASIFICATION COMBINED CYCLE TECHNOLOGY, AS SUITED TO COAL GASIFICATION BASED POWER GENERATION IN INDIA.

The first meeting of the R&D Committee for the development of Integrated Gasification Combined Cycle (IGCC) technology, as suited to Coal Gasification based Power Generation in India, was chaired by Dr. S.K. Sikka, Scientific Secretary to the Principal Scientific Adviser to the Government of India, in the Tiruchirapalli unit of M/s Bharat Heavy Electricals Limited (BHEL) on Wednesday, the 26th of February, 2003 at 1030 hr.

2. The list of participants is annexed. Leave of absence was granted to the following members of the Committee, who were not able to attend the meeting owing to their pre-scheduled commitments:

i) Shri S.L. Kapur, Director (Technical), National Thermal Power Corporation Limited (NTPC), New Delhi.

ii) Dr. K. V. Raghavan, Director, Indian Institute of Chemical Technology (IICT), Hyderabad.

iii) Dr. O.P. Rao, Scientist 'F', Council of Scientific and Industrial Research (CSIR), New Delhi.

In the absence of Dr. Raghavan and Dr. Rao, the CSIR was represented in the meeting by Dr. K.B.S. Prasad, Scientist 'F', IICT, Hyderabad.

3. The meeting was commenced with a visit to the Combined Cycle Demonstration Plant (CCDP) of the BHEL located in its Tiruchirapalli unit. The Committee was taken-around the power house as well as the Pressurized Fluidized Bed Gasifier (PFBG) of the CCDP.

4. The Committee then assembled in the Main Conference Room of the Tiruchirapalli unit of the BHEL for conducting the remaining part of the meeting, with Agenda 8 having been taken care of already with a visit of the CCDP.

5. Immediately after assembling in the Main Conference Room, the Committee was welcomed to the Tiruchirapalli unit by its Head, viz. Shri A.K. Mathur, Executive Director, BHEL. The Member-Secretary then informed the Members about the co-opting of Dr. K.V. Raghavan, Director, IICT, Hyderabad, as a Member of the Committee, subsequent to its constitution. He then requested the Chairman to conduct the meeting as per the Agenda.

Agenda Item No. 1: Welcome address by the Chairman of the Committee.

6. The Chairman, after welcoming the participants to the meeting, recalled the deliberations held in two earlier meetings chaired by the Principal Scientific Adviser to the Government of India on the 5th and the 9th of December, 2002, wherein a unanimous conclusion was reached on the PFBG

being best suited for the high ash containing Indian coals. He, however, opined that further studies were required to be done on issues such as operational flexibility with load fluctuation, coal conversion efficiency, etc., for scaling-up the 6.2 MWe IGCC Plant of the BHEL to 100 MWe.

Agenda Item No. 2: Presentation by Dr. O. P. Rao, Scientist 'F', Council of Scientific and Industrial Research, New Delhi on "Coal Gasification/ IGCC: Perspective and Requirements".

7. Since, as stated above, Dr. O.P. Rao, Scientist 'F', CSIR, New Delhi, was not able to attend the meeting due to unforeseen circumstances, Dr. K.B.S. Prasad, Scientist 'F', IICT, Hyderabad, made a presentation on his behalf, albeit on a related topic. Dr. Prasad's presentation focused on Moving Bed Gasification of Coal for the Indian Power and Energy Sector.

8. He presented the work done by the IICT on moving bed gasifiers and hot gas clean-up system. He was of the view that the environmental issues associated with moving bed gasifiers could be addressed. However, since a decision to go ahead with the PFBG technology had already been taken, the IICT would support any indigenous effort in the development of the 100 MWe IGCC Demonstration Plant.

9. He also informed the Committee that the IICT was, currently, implementing a project (funded by the Ministry of Coal) on warm gas clean-up system. The Committee felt that with a view to absorb the technology as and when it is developed, the NTPC and the BHEL could keep themselves informed about the progress in the Project's implementation. A hard copy of Dr Rao's presentation was also distributed to all the participants.

Agenda Item No. 3: Presentation by Dr. (Mrs.) Malti Goel, Scientist 'G', Department of Science & Technology (DST), New Delhi, on "Promoting R&D in partnership in socio-economic Ministries: DST initiative in Clean Coal Technology".

10. The second presentation was made by Dr. Malti Goel, Scientist 'G', Department of Science and Technology (DST), New Delhi. In this presentation, the R&D programmes funded by the DST and the active role played by the DST in promoting Clean Coal Technology were highlighted.

Agenda Item No. 4: Presentation by Shri S. L. Kapur, Director (Technical), National Thermal Power Corporation (NTPC), New Delhi, and his colleagues on "The world-wide scenario of IGCC Technology".

11. The third presentation was made by Shri Chandan Roy, Executive Director (Engg.), NTPC and his colleague Shri D.K. Dubey, Deputy General Manager (PE-Mech). The presentation highlighted the need for coal based IGCC Plant in view of its superiority compared to other competing technologies, particularly with respect to its potential for achieving much higher efficiencies and better environmental performance. The global scenario on IGCC was also presented. The presentation also brought-out that foreign experience on moving bed gasifiers was mostly for non-power operations, and that on fluidized bed gasifiers was limited. The presentation also reiterated that the PFBG technology is best

suited for the high ash containing Indian coals. The presentation further brought-out that commercial IGCC plants could be a reality by the year 2015, and could reach efficiency levels of the order of 65% by the year 2025 in view of continuous developments in gas turbine technology. The presentation also brought-out that IGCC Plants worldwide were not a bench-mark for India, and, therefore, home grown IGCC technology would have to be developed based on a collaborative approach by players within the country.

Agenda Item No. 5:Presentation by Shri Virendra Kumar, Director (Engg. R&D), M/s Bharat Heavy Electricals Limited (BHEL), New Delhi, and his colleagues on the experience of M/s BHEL in "Using IGCC technology for coal gasification based power generation".

12. The BHEL Presentation was made by Shri N.V.S. Ramani, Additional General Manager, BHEL, Hyderabad which covered the BHEL's experience with both moving bed, as well as fluidized bed gasifiers, and their integration with the 6.2 MWe CCDP; experimental results of the 18 tonnes per day and 168 tonnes per day PFBG Plants in Hyderabad and Tiruchirapalli, respectively; the further work being undertaken; etc. For the proposed 100 MWe IGCC plant to be set-up using a collaborative approach, the BHEL presented the major parameters and selection criteria based on conceptual design, cold gas clean-up system, etc. The BHEL also requested that the decision on site selection may be taken on priority to enable the preparation of site specific feasibility studies.

13. Shri Virendra Kumar, Director (Engg. R&D), BHEL, suggested that the Committee may now facilitate, in the first phase, the setting-up of the 100 MWe IGCC Demonstration Plant with PFBG, the gas turbines available (with current levels of efficiencies suitable for low caloric value coal gas) and the cold gas clean-up system (which is well established). Parallely, development work may proceed for hot / warm gas clean-up system, which could be retrofitted in the 100 MWe plant in due course.

Agenda Item No. 6: A presentation on "Evaluation of thermo-dynamic efficiency and computer simulation of the combined cycle" by Dr. R.R. Sonde, Additional General Manager (RP/TD), Heavy Water Board, Department of Atomic Energy, Mumbai.

14. The next presentation was made by Dr. R.R. Sonde, Additional General Manager (RP/TD), Heavy Water Board, Department of Atomic Energy, Mumbai. He highlighted that complete system analysis of IGCC plant was required to be done for achieving the desired efficiency. R&D requirement and the development needs for sub-systems was also highlighted. The use of Tomography and CFD in understanding the gasifier in greater detail was also highlighted. He also mentioned the potential of membrane technology for oxygen enrichment in air blown PFBG systems.

Agenda Item No. 7: A discussion on the minutes of the meeting of the Inter-Ministerial Steering Group, held in New Delhi on the 23rd of January, 2003 under the chairmanship of the Secretary, Ministry of Power, to over-see the IGCC Demonstration Project.

15. With reference to the minutes of the said meeting, the NTPC informed that in order that the it may commit funds for setting-up a 100 MWe IGCC Demonstration Plant, the following steps need to be taken by the BHEL:

- Preparation of pre- feasibility report based on site selection;
- Clearances from various statutory bodies;
- Preparation of detailed project report, etc.

Accordingly, the Chairman advised that the BHEL and the NTPC may interact on this issue directly with each other and take necessary action, under intimation to the Member-Secretary.

16. After detailed deliberation on the presentations and the related topics, the Chairman suggested the following action plan for the setting-up of the proposed 100 MWe IGCC Demonstration Plant:

- A Working Group, led by Dr. R.R. Sonde, Additional General Manager (RP / TD), Heavy Water Board, Department of Atomic Energy, Mumbai, along with S / Shri P.R. Mohanty, Manager (O&M), Heavy Water Plant, Talcher, Department of Atomic Energy, Orissa, N.V.S. Ramani, Additional General Manager, BHEL, Corporate R&D, Hyderabad and Shri D.K. Dubey, Deputy General Manager (PE-Mech), NTPC, Noida, was requested to evaluate the data generated by the existing facilities of the BHEL, i.e. the PFBG rig in Hyderabad and the 6.2 MWe CCDP in Tiruchirapalli, for up-scaling to 100 MWe. Towards this end, the BHEL would carry out any experiment suggested by this Working Group.
- The Working Group was further requested to submit its report to the Committee by the 31st of May, 2003.
- Membrane technology is a possible development area for oxygen enrichment in air blown PFBG systems. Dr. R.R. Sonde was requested to apprise the members of the Committee on the available literature and status of technology.

17. The meeting then ended with a Vote of Thanks to the Chair and all present.

Annexure to the minutes of the first meeting of the R&D committee for the development of Integrated Gasification Combined Cycle technology, as suited to Coal Gasification based Power Generation in India

DATE : 26th of February, 2003

TIME : 1030 hr

VENUE : Tiruchirapalli unit of M/s Bharat Heavy Electricals Limited

List of Participants

S.No.	Name, Designation & Organization	Status
1.	**Dr. S.K. Sikka**, Scientific Secretary to the Principal Scientific Adviser to the Government of India, 324-A, Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi – 110 011	Chairman
2.	**Shri Virendra Kumar**, Director (Engg. R& D), Bharat Heavy Electricals Limited BHEL House, Siri Fort, New Delhi- 110 049.	Member
3.	**Dr. (Smt.) Malti Goel**, Scientist 'G', Department of Science and Technology, Technology Bhawan, New Mehrauli Road New Delhi – 110 016.	Member
4.	**Shri Chandan Roy**, Executive Director (Engg.), National Thermal Power Corporation Ltd., Engineering Office Complex, Plot No. A-8A Sector 24, Post Box No. 13, Noida – 201 301.	Member
5.	**Shri S. Balagurunathan**, Executive Director Bharat Heavy Electricals Limited, Corporate Research and Development, Vikasnagar, Hyderabad – 500 093.	Member
6.	**Dr. R.R. Sonde**, Additional General Manager (RP /TD), Heavy Water Board, Department of Atomic Energy, 5th Floor, Vikram Sarabhai BhavanAnushaktinagarMumbai – 400 094.	Member
7.	**Shri P.R. Mohanty**, Manager (O&M), Heavy Water Plant, Talcher Department of Atomic Energy, P.O. Vikrampur, District Angul Orissa – 759 106.	Member
8.	**Er. Neeraj Sinha**, Scientist 'E', Office of the Principal Scientific Adviserto the Government of India, 326, Vigyan Bhavan Annexe, Maulana Azad Road, New Delhi – 110 011.	Member -Secretary
9.	**Shri A.K. Mathur**, Executive Director, Bharat Heavy Electricals Limited, Tiruchirapalli – 620 014.	Special Invitee

10.	**Dr. K.B.S. Prasad**, Scientist 'F', Indian Institute of Chemical Technology, Uppal Road, Hyderabad - 500 007.	Special Invitee
11.	**Shri A.K. Ghosh**, Chief (Power Systems Engineering), Bharat Heavy Electricals Limited, BHEL House, Siri FortNew Delhi- 110 049.	Special Invitee
12.	**Shri K. Thirumalai**, Chief, Combined Cycle Demonstration Plant Bharat Heavy Electricals Limited, Tiruchirapalli – 620 014.	Special Invitee
13.	**Shri N.V.S. Ramani**, Additional General Manager, Bharat Heavy Electricals Limited, Corporate Research and Development Vikasnagar, Hyderabad – 500 093.	Special Invitee
14.	**Shri C.R. Ramanathan**, Senior Deputy General Manager, Combined Cycle Demonstration Plant, Bharat Heavy Electricals Limited, Tiruchirapalli – 620 014.	Special Invitee
15.	**Shri D.K. Dubey**, Deputy General Manager (PE-Mech), National Thermal Power Corporation Ltd., Engineering Office Complex, Plot No. A-8A, Sector 24, Post Box No. 13, Noida – 201 301.	Special Invitee

Annexure-III

MINUTES OF THE SECOND MEETING OF THE R&D COMMITTEE FOR THE DEVELOPMENT OF INTEGRATED GASIFICATION COMBINED CYCLE TECHNOLOGY, AS SUITED TO COAL GASIFICATION BASED POWER GENERATION IN INDIA.

The second meeting of the R&D Committee for the development of Integrated Gasification Combined Cycle (IGCC) technology, as suited to Coal Gasification based Power Generation in India, was chaired by Dr. S.K. Sikka, Scientific Secretary to the Principal Scientific Adviser to the Government of India, in the Committee Room 'A' of the Vigyan Bhawan Annexe on Thursday, the 31st of July, 2003, at 1100 hr.

2. The list of participants is annexed. Leave of absence was granted to the following member of the Committee, who was not able to attend the meeting owing to pre-scheduled commitments:

i) Dr. K. V. Raghavan, Director, Indian Institute of Chemical Technology, Hyderabad.

3. The Chairman welcomed the participants to the meeting and gave them a brief over-view of the developments that had taken place since the first meeting of the Committee held in the Tiruchirapalli Unit of the Bharat Heavy Electricals Limited (BHEL) on the 26th of February, 2003. He then invited comments from the members present.

4. Shri S.L. Kapur, Director (Technical), National Thermal Power Corporation Limited (NTPC), New Delhi, responded by thanking the Office of the Principal Scientific Adviser to the Government of India for having taken this initiative to evaluate the IGCC technology in the country, with the ultimate aim of setting-up a 100 MWe IGCC demonstration project. He expressed complete satisfaction with the functioning of the Working Group, constituted by the Committee in its 1st meeting. He also opined that the country can now look forward, confidently, to the setting-up of its first 100 MWe IGCC demonstration project. He, however, added that further work was required to be done on the "Hot Gas Clean-up" system. He also referred to the deliberations held in the first and second meetings of the Inter-departmental Committee chaired by the Secretary, Ministry of Power, wherein it had been decided that the most suitable location for the said 100 MWe IGCC demonstration project would be the NTPC's site in Auriya.

5. Shri Virendra Kumar, Director (Engg. R&D), BHEL, New Delhi, also commended the Working Group for the work it had done thus far. He also informed the Committee that the BHEL was renovating its 6.2 MWe Combined Cycle Demonstration Plant (CCDP) located in its Tiruchirapalli Unit, and that the renovation work was likely to be completed by October, 2003. He further opined that the mandate given by the said Inter-departmental Committee – of setting-up the country's first 100 MWe IGCC demonstration project at the NTPC's site in Auriya – and this Committee's deliberations could progress in tandem.

6. After the above comments from Shri Kapur and Shri Kumar, the Chairman took up the agenda items one-by-one for discussion.

Agenda Item No. 1: Confirmation of the minutes of the first meeting of the Committee, held in the Tiruchirapalli Unit of the Bharat Heavy Electricals Limited on the 26th of February, 2003.

7. The minutes of the first meeting of the Committee were confirmed.

Agenda Item No. 2: A presentation on the work done so far by the Working Group constituted by the Committee – presentation to be made by the Leader of the Working Group.

8. Dr. R. R. Sonde, Additional General Manager (RP/TD), Heavy Water Board, Department of Atomic Energy, Mumbai, made a power-point presentation on the work done, so far, by the Working Group. The presentation was very well received by the Committee. To a query of the Chairman, Dr. Sonde responded by saying that the Working Group was aiming to submit its full report to the Committee by the end of October, 2003. He gave copies of the interim report of the Working Group to the Member-Secretary to the Committee for being circulated to all concerned. The following are the highlights of the work done by the Working Group thus far :

- Evaluation of the past data from the indigenous R&D gasifiers of the BHEL and comparison with their design intent.
- Non-invasive experiments on solid tracer for evaluating critical parameters and hydrodynamic evaluation of the gasifier through gamma ray radiography.
- Development of Artificial Neural Network Modelling for the gasifiers and optimization of the operating parameters.
- Development of phenomenological models and system model for the entire cycle.
- Programme for gas characterization for design of the gas clean-up system.
- The main conclusion, so far, has been that the exact ash content of the coal does not seem to effect the process.

9. During the discussion that ensued, Shri Chandan Roy, Executive Director (NCR), NTPC, Noida, suggested that the Committee may also look at the fuel-feed system and the Instrumentation & Control of the proposed 100 MWe IGCC demonstration project.

10. It was decided, after discussion, that the problem of Sulphur removal need not be looked at by the Working Group, at this juncture.

11. Shri P. K. Modi, Additional General Manager, NTPC, Noida, suggested that the refractory lining of the gasifier needs attention for optimal performance of the gasifier and, hence, the full system. To this, Shri N.V.S. Ramani, Additional General Manager, Corporate Research and Development, BHEL, Hyderabad, responded by saying that the BHEL was seized of the issue and would keep the NTPC informed of the steps taken for improving the quality of the gasifier's refractory lining.

Agenda Item No.3: Discussion on the course of action, once the Working Group submits its report to the Committee.

12. It was decided that discussion on the future course of action would be held in the Committee's next meeting, after the Working Group has submitted its full report. It was decided to schedule the next meeting of the Committee tentatively for the end of October / beginning of November, 2003.

Agenda Item No.4: Any other point with the permission of the Chair.

13. No other point was raised by any of the members present.

14. The meeting then ended with a Vote of Thanks to the Chair.

Annexure to the minutes of the second meeting of the R&D committee for the development of Integrated Gasification Combined Cycle technology, as suited to Coal Gasification based Power Generation in India

DATE : 31st July, 2003

TIME : 1100 hr

VENUE : Committee Room "A", Office of the Principal Scientific Adviser to the Government of India, Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi – 110 011.

List of Participants

S.No.	Name, Designation & Organization	Status
1.	**Dr. S.K. Sikka**, Scientific Secretary to the Principal Scientific Adviser to the Government of India, 324-A, Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi – 110 011	Chairman
2.	**Shri S.L. Kapur**, Director (Technical), National Thermal Power Corporation Ltd., NTPC Bhawan, SCOPE Complex, 7, Institutional Area, Lodi Road, New Delhi – 110 003.	Member
3.	**Shri Virendra Kumar**, Director (Engg. R& D), Bharat Heavy Electricals Limited, BHEL House, Siri Fort, New Delhi- 110 049.	Member
4.	**Dr. (Smt.) Malti Goel**, Scientist 'G', Department of Science and Technology, Technology Bhawan, New Mehrauli Road, New Delhi – 110 016.	Member
5.	**Shri Chandan Roy**, Executive Director (NCR), National Thermal Power Corporation Ltd., Engineering Office Complex, Plot No. A-8A, Sector 24, Post Box No. 13, Noida – 201 301.	Member
6.	**Shri S. Balagurunathan**, Executive Director, Bharat Heavy Electricals Limited, Corporate Research and Development Vikasnagar, Hyderabad – 500 093.	Member
7.	**Dr. O.P. Rao**, Scientist 'F', Council of Scientific and Industrial Research, Room No. 201, Anusandhan Bhawan, Rafi Ahmed Kidwai Marg, New Delhi – 110 001.	Member
8.	**Dr. R.R. Sonde**, Additional General Manager (RP / TD), Heavy Water Board, Department of Atomic Energy, 5th Floor, Vikram Sarabhai Bhavan, Anushaktinagar, Mumbai – 400 094.	Member

9.	**Shri P.R. Mohanty**, Manager (O&M), Heavy Water Plant, Talcher, Department of Atomic Energy, P.O. Vikrampur, District Angul, Orissa – 759 106.	Member
10.	**Shri Neeraj Sinha**, Scientist 'E'Office of the Principal Scientific Adviser to the Government of India326, Vigyan Bhavan Annexe Maulana Azad Road, New Delhi – 110 011.	Member Secretary
11.	**Shri A.K. Ghosh**, Chief (Power Systems Engineering), Bharat Heavy Electricals Limited, BHEL House, Siri Fort, New Delhi- 110 049.	Special Invitee
12.	**Shri P.K. Modi**, Additional General Manager (PE-Mech.), National Thermal Power Corporation Ltd., Engineering Office Complex, Plot No. A-8A, Sector 24, Post Box No. 13, Noida- 201 301.	Special Invitee
13.	**Shri N.V.S. Ramani**, Additional General Manager, Bharat Heavy Electricals Limited, Corporate Research and Development, Vikasnagar, Hyderabad – 500 093.	Special Invitee
14.	**Shri D.K. Dubey**, Deputy General Manager (PE-Mech), National Thermal Power Corporation Ltd., Engineering Office Complex, Plot No. A-8A, Sector 24, Post Box No. 13, Noida – 201 301.	Special Invitee

Annexure-IV

Minutes of the third meeting of the R&D Committee for the development of Integrated Gasification Combined Cycle technology, as suited to Coal Gasification based Power Generation in India.

The 3rd meeting of the R&D Committee for the development of Integrated Gasification Combined Cycle (IGCC) technology, as suited to coal gasification based power generation in India, was held in the Committee Room-C, Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi, on Friday, the 30th of July, 2004 at 1030 hr.

2. The meeting was chaired by Dr. S.K. Sikka, Scientific Secretary to the Principal Scientific Adviser to the Government of India.

3. The list of participants is annexed **(Annexure-A)**. The Indian Institute of Chemical Technology (IICT), Hyderabad, was not represented in the meeting despite the Director, IICT, having telephonically confirmed his, or his representative's participation in the meeting. Leave of absence was granted to Shri P.R. Mohanty, Manager (O&M), Heavy Water Plant, Department of Atomic Energy, Talcher, who was not able to attend the meeting owing to pre-scheduled commitments.

4. The Member-Secretary welcomed all the participants to the meeting and gave them a brief over-view of the related developments that had taken place since the last meeting of the Committee held on the 31st of July, 2003. He then requested the Chairman to conduct the meeting as per the agenda **(Annexure-B)**.

5. Before commencing the meeting formally, the Chairman took note of, and thereafter approved, the following changes in the composition of the Committee: -

i) Shri Ramji Rai will now represent the Bharat Heavy Electricals Limited (BHEL) as its Director (Engineering, R&D), in place of Shri Virendra Kumar, who superannuated from service on the 31st of January, 2004.

ii) Shri Chandan Roy would continue to represent the National Thermal Power Corporation Limited (NTPC) in the Committee as a Member, even after taking over as the Director (Operations) w.e.f. the 1st of January, 2004.

iii) Dr. R.R.Sonde would continue to remain a Member of the Committee, even after taking over as Executive Director (Energy Technologies) in the NTPC w.e.f. the 1st of June, 2004.

6. In his opening remarks, the Chairman made the following observations: -

i) The over-all efficiency of the proposed 100 MW IGCC power plant would have to be increased from less than 30%, that had been arrived-at by the Working Group in its final report, to more than 39%.

ii) The differences on technical issues between the Members of the Working Group will have to be resolved quickly.

iii) All the involved parties would have to continue working together for making the dream of setting-up the first 100MW IGCC power plant in the country come true.

7. The Chairman then took-up the agenda items one-by-one for discussion.

8. The minutes of the 2nd meeting of the Committee, held in New Delhi on the 31st of July, 2003, were confirmed.

9. The Chairman then invited the Leader of the Working Group, i.e. Dr. R.R. Sonde, to present the Working Group's report to the Committee. Dr. Sonde gave a detailed presentation on all aspects of the Working Group's final report, copies of which were made available to all the Committee Members. His presentation highlighted the experimental work that still remains to be done ***before a feasibility report or a detailed project report (DPR), on the setting-up of the said 100 MW IGCC power plant, can be prepared.***

10. Dr. Sonde's presentation was followed by a presentation by Shri N.V.S. Ramani, Additional General Manager, Corporate R&D, BHEL, Hyderabad, on the BHEL's view-point on the design of the said 100 MW IGCC power plant.

11. After both the presentations were made, a detailed discussion took place on the adoption of the future course of action. The Committee then converged on the following decision points: -

i) The work carried-out by the Working Group has revealed that in the present form of the fluidized bed gasifier and the optimized operating conditions of the system, the overall maximum carbon conversion and cold gas efficiencies workout to about 82% and 62%, respectively, which deliver an overall efficiency of less than 30%. It was felt that in order to deliver an overall efficiency of 39.5% for the proposed 100MW IGCC plant, efforts should be made to optimally design the Gas Turbine (GT) and the gasifier islands in an integrated manner.

ii) The Working Group will carryout whatever additional efforts required to meet the above objective and evaluate the individual efficiency figures to yield an overall efficiency of 39.5%. It will then work out the efficiencies required to be delivered from the gasifier for a given configuration of GT (currently to be based on the established frame 6F).

iii) The Working Group will finalize all modifications that are required to be done in the basic design of the gasifier for enhancing its efficiency. It will workout a revised experimental programme for demonstrating the efficiency parameters.

iv) It was also decided that the BHEL and the NTPC may jointly develop this technology. An MoU could be entered into by both of them for a complete demonstration of this new technology.

v) Detailed discussions were held on the pressure effects and it was revealed that there are several un-resolved issues, including the impact of pressure on swelling properties for non-coking coal, attrition and fragmentation behaviour, methane conversion, gas diffusion characteristics

and hydrodynamics. There are several impacts of these parameters on the overall performance and it is difficult to quantify the overall impact of these. It was, therefore, felt that experiments shall be conducted at high pressures for fully understanding the sensitivities of each of the said parameters.

vi) The pressure of operation is currently limited to 11 bar in the Combined Cycle Demonstration Plant (CCDP) of the BHEL, Tiruchirapally and about 6 bar in the PEDU of the Corporate R&D, BHEL, Hyderabad. Since the final design has to be carried-out at 30 bar, it was felt that high pressure operations may be carried-out through a new high pressure rig (30 bar / 100mm) to be set-up jointly by the BHEL and the NTPC. If required, the setting-up of such a new rig could be part financed by the Office of the Principal Scientific Adviser to the Government of India. Alternately, some kinetics and coal swelling tests can be conducted at high pressures in a reaction calorimeter and the data thus generated can be used in the model for prediction at high pressures.

(Two technical papers on these were circulated to all the Members, by the Leader of the Working Group).

vii) It was decided to dwell on the impact of heat loss on efficiency by conducting experiments in the 200mm rig and the PEDU (of the BHEL) for similar conditions for finding out the effect of heat loss due to the geometry and also conduct experiments on those rigs at different conditions for a constant heat loss. The Working Group indicated that the past experience of operation at reduced loads in the 200mm rig and the PEDU did not reveal large impact of heat loss on the overall performance.

viii) The corrections to Horio's correlations, by using the extrapolation within the same region, was discussed and it was agreed to follow this strategy carefully.

ix) The scale-up strategy indicated that either a two reactor configuration of 2.28 m diameter each or a single reactor of 3.6 m diameter could be used for establishing the technology. This would also be useful when the proposed 100 MW IGCC power plant may have to operate on oxygen (oxy fuel) instead of air.

x) Particle size and its distribution in the gasifier is also indicated to be a complex phenomenon, together with its impact on gasification in terms of bubble size formation and elutriation. It was decided that a detailed study on this may be carried-out to fully understand the phenomenon.

xi) It was felt that all the above studies, including the gas tracer experiments and the cold model studies in the Bhabha Atomic Research Centre (using X-ray radiography) must be conducted expeditiously by the Working Group.

xii) For doing all the above-listed work, the Working Group was given time until the end of the October, 2004.

xiii) The said 100 MW IGCC power plant would, definitely, have to be set-up using indigenous technology; however, as of now, it was pre-mature to talk of commencing work on the setting-up of the country's 1st 100 MW IGCC power plant. This was so because the findings of the Working Group have pointed-out that there were several more experiments that were required to be conducted on the IGCC rigs of the BHEL [i.e. the CCDP in Tiruchirapally and the PEDU in the Corporate R&D, Hyderabad], before one could even think of preparing the DPR.

xiv) In addition to its 4 existing Members, the Working Group would also include, with immediate effect, the following as members: -

- Dr. O.P. Rao, Scientist 'F', Council of Scientific and Industrial Research, New Delhi.
- Shri N. Sundararajan, General Manager, Corporate Research & Development, BHEL, Hyderabad.
- Shri P.K. Modi (Project Engineering), Engineering Office Complex, NTPC, Noida.

xv) All the constituents of the Committee, as well as those of the Working Group, would ensure complete confidentiality of information being exchanged. No information would be passed-on, at any cost, to any outside agency, be it National or International. If required, the lead players, i.e. the BHEL and the NTPC, may enter into a formal agreement on this issue.

12. The meeting then ended with a Vote of Thanks to the Chair, and to all the Members and Special Invitees present, by the Member-Secretary.

Annexure-A to the minutes of the third meeting of the R&D Committee for the development of Integrated Gasification Combined Cycle technology, as suited to Coal Gasification based Power Generation in India.

DATE : 30th July, 2004

TIME : 1030 hr

VENUE : Committee Room 'C', Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi-110 011.

List of Participants

S.No.	Name, Organization's name and address	Status
1.	**Dr. S.K. Sikka**, Scientific Secretary to the Principal Scientific Adviser to the Government of India, 324-A, Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi – 110 011	Chairman
2.	**Shri S.L. Kapur**, Director (Technical), National Thermal Power Corporation Ltd., NTPC Bhawan, Scope Complex, 7, Institutional Area, Lodi Road, New Delhi – 110 003.	Member
3.	**Shri Ramji Rai**, Director (Engg. R&D), Bharat Heavy Electricals Limited, BHEL House, Siri Fort, New Delhi – 110 049.	Member
4.	**Shri Chandan Roy**, Director (Operations), National Thermal Power Corporation Ltd., NTPC Bhawan, Scope Complex, 7, Institutional Area, Lodi Road, New Delhi – 110 003.	Member
5.	**Dr. (Smt.) Malti Goel**, Scientist 'G', Department of Science and Technology, Technology Bhawan, New Mehrauli Road, New Delhi – 110 016.	Member
6.	**Shri S. Balagurunathan**, Executive Director, Bharat Heavy Electricals Limited, Corporate Research and Development Vikasnagar, Hyderabad – 500 093.	Member
7.	**Dr. R.R. Sonde**, Executive Director (Energy Technologies), National Thermal Power Corporation Limited, NTPC Bhawan, Scope Complex, 7 Institutional Area, Lodi Road, New Delhi – 110 003.	Member
8.	**Dr. O.P. Rao**, Scientist 'F', Council of Scientific and Industrial Research, Room No. 201, Anusandhan Bhawan, Rafi Ahmed Kidwai Marg, New Delhi – 110 001.	Member

9.	**Shri Neeraj Sinha**, Scientist 'E', Office of the Principal Scientific Adviser to the Government of India, 324-A, Vigyan Bhavan Annexe Maulana Azad Road, New Delhi – 110 011.	Member Secretary
10.	**Shri A.K. Ghosh**, General Manager, Bharat Heavy Electricals Limited, BHEL House, Siri Fort, New Delhi- 110 049.	Special Invitee
11.	**Shri N. Sundararajan,** General Manager, Bharat Heavy Electricals Limited, Corporate Research and Development, Vikasnagar, Hyderabad - 500 093.	Special Invitee
12.	**Shri P.K. Modi**, General Manager (Project Engg.), National Thermal Power Corporation Limited, Engineering Office Complex, 4th Floor, Plot No. A-8A, Sector 24, Noida 201 301.	Special Invitee
13.	**Shri N.V.S. Ramani**, Additional General Manager, Bharat Heavy Electricals Limited, Corporate Research and Development, Vikasnagar, Hyderabad - 500 093.	Special Invitee
14.	**Shri D. K. Dubey**, Deputy General Manager (Project Engineering), National Thermal Power Corporation Limited, Engineering Office Complex, 4th Floor, Plot No. A-8A, Sector 24, Noida 201 301.	Special Invitee
15.	**Dr. B.D. Kulkarni**, Deputy Director and Head, CEPD Division, National Chemical Laboratory, Council of Scientific & Industrial Research, Pune- 411 008.	Special Invitee

Annexure-B to the minutes of the third meeting of the R&D Committee for the development of Integrated Gasification Combined Cycle technology, as suited to Coal Gasification based Power Generation in India.

DATE : 30th July, 2004

TIME : 1030 hr

VENUE : Committee Room 'C', Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi-110 011.

AGENDA

1) Welcome address by the Member-Secretary to the Committee.

2) Opening remarks by the Chairman of the Committee.

3) Confirmation of the minutes of the 2nd meeting of the Committee, held in New Delhi on the 31st of July, 2003.

4) A presentation by the Working Group on its report that has been recently submitted to the Chairman – presentation to be done by the Leader of the Group.

5) Discussion on the future course of action to be adopted for the setting-up of the first 100 MW IGCC plant in the country.

6) Any other point with the permission of the Chair.

7) Vote of Thanks by the Member-Secretary to the Committee.

Annexure-V

Minutes of the fourth meeting of the R&D Committee for the development of Integrated Gasification Combined Cycle technology, as suited to coal gasification based power generation in India.

The 4th meeting of the R&D Committee for the development of Integrated Gasification Combined Cycle (IGCC) technology, as suited to coal gasification based power generation in India, was chaired by Dr. S.K. Sikka, Scientific Secretary to the Principal Scientific Adviser to the Government of India in New Delhi on Friday, the 14th of October, 2005 at 1430 hr.

2. The list of participants is annexed. Leave of absence was granted to Shri Chandan Roy, Director (Operations), National Thermal Power Corporation Limited (NTPC), New Delhi; Dr. J.S. Yadav, Director, Indian Institute of Chemical Technology, Hyderabad and Shri P.R. Mohanty, General Manager, Heavy Water Plant, Department of Atomic Energy, Talcher, who were not able to attend the meeting owing to pre-scheduled commitments.

3. The Chairman welcomed all the participants to the meeting and gave a power point presentation highlighting some important data from a recent report on the Power Systems Development Facility (PSDF) – a circulating fluidized bed reactor set-up in Wilsonville, Alabama, U.S.A. He also noted that experiments have now been done on the Combined Cycle Demonstration Plant (CCDP) of the Bharat Heavy Electricals Limited (BHEL) and simulation capabilities have been validated against these. He then requested the Leader of the Working Group to present the Working Group's final report to the Committee. The main findings of the experiments done on the CCDP at a temperature of 1050°C and a pressure of 8 bar were presented by the Working Group as follows: -

a. Carbon Conversion Efficiency : 88% to 89%

b. Cold Gas Efficiency : 68.8%

c. Lower Calorific Value (LCV) of the Gas : 1050 kcal / Nm^3

4. These were very close to the stipulated values for the ~100 MWe plant. The Leader of the Working Group also highlighted the following remaining technical issues:

i) Minimum acceptable LCV of the Gas for optimum operation of the Frame 6FA GE make Gas Turbine (GT) $\simeq$ 1100 kcal / Nm^3.

ii) Reduction in the unburnt carbon in the bottom and fly ash from the 6% and 15% (respectively) in the CCDP to acceptable levels so that the ash can then be disposed-off.

5. As regards (i) above, Shri N.K. Nair, Director, Central Electricity Authority (CEA) – who attended the meeting as a special invitee – felt that even an LCV of 1050 kcal / Nm^3 was sufficient for firing the gas turbine. Further, the members felt that the "gas blending" option (viz. blending the syngas with upto 5% of natural gas) could also be tried to increase the LCV of the syngas, if required.

6. As regards (ii) above, the Chairman opined that the "Loop Seal" method used in the PSDF facility in Wilsonville, USA, could be tried as an experiment on the CCDP to reduce the unburnt carbon in the bottom and fly ash to acceptable limits. The BHEL representatives informed the Committee that disposing the fine coal particles containing ash was not a problem.

7. Also, as regards (ii) above, Dr. B.D. Kulkarni, Deputy Director and Head, CEPD Division, National Chemical Laboratory (NCL), Pune – a Special Invitee to the meeting – remarked that the Free Board Region (FBR) of the gasifier could be designed in such a way so that the un-burnt carbon in the bottom and fly ash could be reduced to acceptable levels. To this, Dr. V. Gopalakrishnan, Executive Director, BHEL, Trichy Complex, reacted by saying that the BHEL could simulate the FBR design of the gasifier and the results of the simulation could be used by Dr. Kulkarni in the phenomenological model already developed by the NCL for validating this concept.

8. The Chairman suggested to the representative of the CEA (Shri N.K. Nair, Director) that the Ministry of Power (MoP) could fund R&D projects on IGCC to address the remaining technical issues. Shri Nair said that he would convey this view of the Chairman to the MoP.

9. After further detailed deliberations in the meeting, the Committee decided as follows:

- Now that the technical feasibility of upgrading the 6.2 MWe CCDP of the BHEL, Tiruchirapalli, to ~100 MWe had been established, the BHEL and the NTPC should immediately start the joint preparation of the Detailed Project Report (DPR) for the ~100 MWe plant.
- The DPR preparation could be done by a two-member committee comprising of Dr. V. Gopalakrishnan, Executive Director, BHEL, Trichy Complex and Dr. R.R. Sonde, Executive Director (Energy Technologies), NTPC, Noida.
- The DPR may be prepared and submitted to the concerned authority by this two-member committee within three months.
- Notwithstanding the DPR preparation work, all further experimental work, required to be done on the CCDP for addressing the remaining technical issues, should be continued by the Working Group.
- Given its low ash content of about 28%, Assam coal could be experimented upon by the NTPC and the BHEL for its utility as the fuel to be gasified for the proposed ~100 MWe IGCC demonstration plant.

10. The meeting then ended with a Vote of Thanks to the Chair, and to all the Members and Special Invitees present, by the Member-Secretary.

Annexure to the minutes of the fourth meeting of the R&D Committee for the development of Integrated Gasification Combined Cycle technology, as suited to coal gasification based power generation in India.

DATE : 14th October, 2005

TIME : 1430 hr

VENUE : Committee Room 'C', Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi-110 011.

List of Participants

S.No.	Name, Organization's name and address	Status
1.	**Dr. S.K. Sikka**, Scientific Secretary to the Principal Scientific Adviser to the Government of India, 324-A, Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi – 110 011	Chairman
2.	**Shri Ramji Rai**, Director (Engg. R&D), Bharat Heavy Electricals Limited, BHEL House, Siri Fort, New Delhi – 110 049.	Member
3.	**Dr. (Smt.) Malti Goel**, Scientist 'G', Department of Science and Technology, Technology Bhawan, New Mehrauli Road, New Delhi – 110 016.	Member
4.	**Dr. R.R. Sonde**, Executive Director (Energy Technologies), National Thermal Power Corporation Ltd., Engineering Office Complex, Plot No.A-8A, Sector 24, Noida-201 301.	Member
5.	**Shri Neeraj Sinha**, Scientist 'E', Office of the Principal Scientific Adviser to the Government of India, 324-A, Vigyan Bhavan Annexe Maulana Azad Road, New Delhi – 110 011.	Member Secretary
6.	**Dr. V. Gopalakrishnan**, Executive Director, Trichy Complex, Bharat Heavy Electricals Limited, Tiruchirapalli-620 014.	Special Invitee
7.	**Dr. B.D. Kulkarni**, Deputy Director and Head, CEPD Division, National Chemical Laboratory, Council of Scientific & Industrial Research, Pune- 411 008.	Special Invitee
8.	**Shri N.K. Nair,** Director, Central Electricity Authority, Sewa Bhawan, R.K. Puram, New Delhi – 110 066.	Special Invitee
9.	**Shri A. K. Ghosh,** General Manager (CEPD), Bharat Heavy Electricals Limited, BHEL House, Siri Fort, New Delhi- 110 049.	Special Invitee

10.	**Shri S.K. Goyal,** General Manager (R&D), Bharat Heavy Electricals Limited, Corporate Research and Development, Vikasnagar, Hyderabad - 500 093.	Special Invitee
11.	**Shri M. Karunakara Reddy,** General Manager, Coal Research, Combined Cycle Demonstration Plant, Bharat Heavy Electricals Limited, Tiruchirapalli-620 014.	Special Invitee
12.	**Shri P.K. Modi**, General Manager (Project Engg.), National Thermal Power Corporation Limited, Engineering Office Complex, 4th Floor, Plot No. A-8A, Sector 24, Noida 201 301.	Special Invitee
13.	**Shri G. Viswanathan,** Additional General Manager, Combined Cycle Demonstration Plant, Bharat Heavy Electricals Limited, Tiruchirapalli-620 014.	Special Invitee
14.	**Shri N.V.S. Ramani**, Additional General Manager, Bharat Heavy Electricals Limited, Corporate Research and Development, Vikasnagar, Hyderabad - 500 093.	Special Invitee
15.	**Dr. K. Nandakumar,** Additional General Manager (CEPD), Bharat Heavy Electricals Limited, BHEL House, Siri Fort, New Delhi- 110 049.	Special Invitee
16.	**Shri D. K. Dubey**, Deputy General Manager (Project Engineering), National Thermal Power Corporation Limited, Engineering Office Complex, 4th Floor, Plot No. A-8A, Sector 24, Noida 201 301.	Special Invitee
17.	**Shri Sujay Karmakar,** Manager (Energy Technologies), National Thermal Power Corporation Limited, Engineering Office Complex, Plot No.A-8A, Sector 24, Noida-201 301.	Special Invitee