OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

14834

RESTRICTED

April 1985
ENGLISH

India. COAL GASIFICATION .

DP/IND/80/004

INDIA

Technical Report *

Mission 8 to 22 February 1985

Prepared for the Government of India
by the United Nations Industrial Development Organization,
acting as executing agency for United Nations Development Programme

Based on the work of K.H. van Heek,
Chief Technical Adviser

United Nations Industrial Development Organization
Vienna

* This document has been reproduced without formal editing.

3505

CONTENTS:

Summary

From February 10 to 19, 1985 I have visited the Regional Research Laboratory in Hyderabad to act as Chief Technical Advisor of the UNDP funded coal gasification project. The main activities of my visit have been:

- Review of the pilot plant work, with special regard to the UNDP-provided instrumentation, assessment of the test runs performed.
- Discussion on status and further programme of the supporting work with special regard to the use of the UNDP funded laboratory devices.
- Assessment of the visits of the experts to the project and review of the training.
- Assistance in preparation of work specifications for the rest of the programme on experts and training.
- Assistance in planning further programmes of the project with special regard to the end of this phase by 1985.

The RRL gasification project has made good progress during the last year:

The pilot plant is fully operational and the UNDP provided analytical and electronic instruments are in use. It is especially satisfying that the mass spectrometer computer combination is hooked-up and functioning quite well. Further development of the computer software is recommended.

Five trial runs have been performed from January 1984 to February 1985. The assessment of the data with oxygen steam and different pressures show that the results achieved are very valuable and will be useful for the gasification characteristics of Indian coals and for gasifying modelling. Of special value are the results from the quenching experiments, which give an insight of the gasifier. It has provided data, which are not at all available in the literature and undoubtedly form a part of the know-how.

As to the supporting work, about 60 runs with an Indian coal have been performed with the thermogravimetrical analyser. The experiments are well performed whereby the instrument has worked perfectly. Minor problems have been solved by the Indian scientists with help of Bergbau-Forschung by written comments throughout the year. The next task is to come to a in-depth interpretation of the data and thereby to full use of the equipment. The Lytel-catalyst screening unit has been in use throughout the year and some 40 runs have been performed. The instrument in general showed a satisfying performance. Good progress has also been made in gasifier modelling. The visit of the experts and the training received have resulted in a working computer programme which is already installed on the RRL computer. This forms a sound basis for further activities of the modelling team, whereby especially kinetic data relevant for Indian coals have to be used.

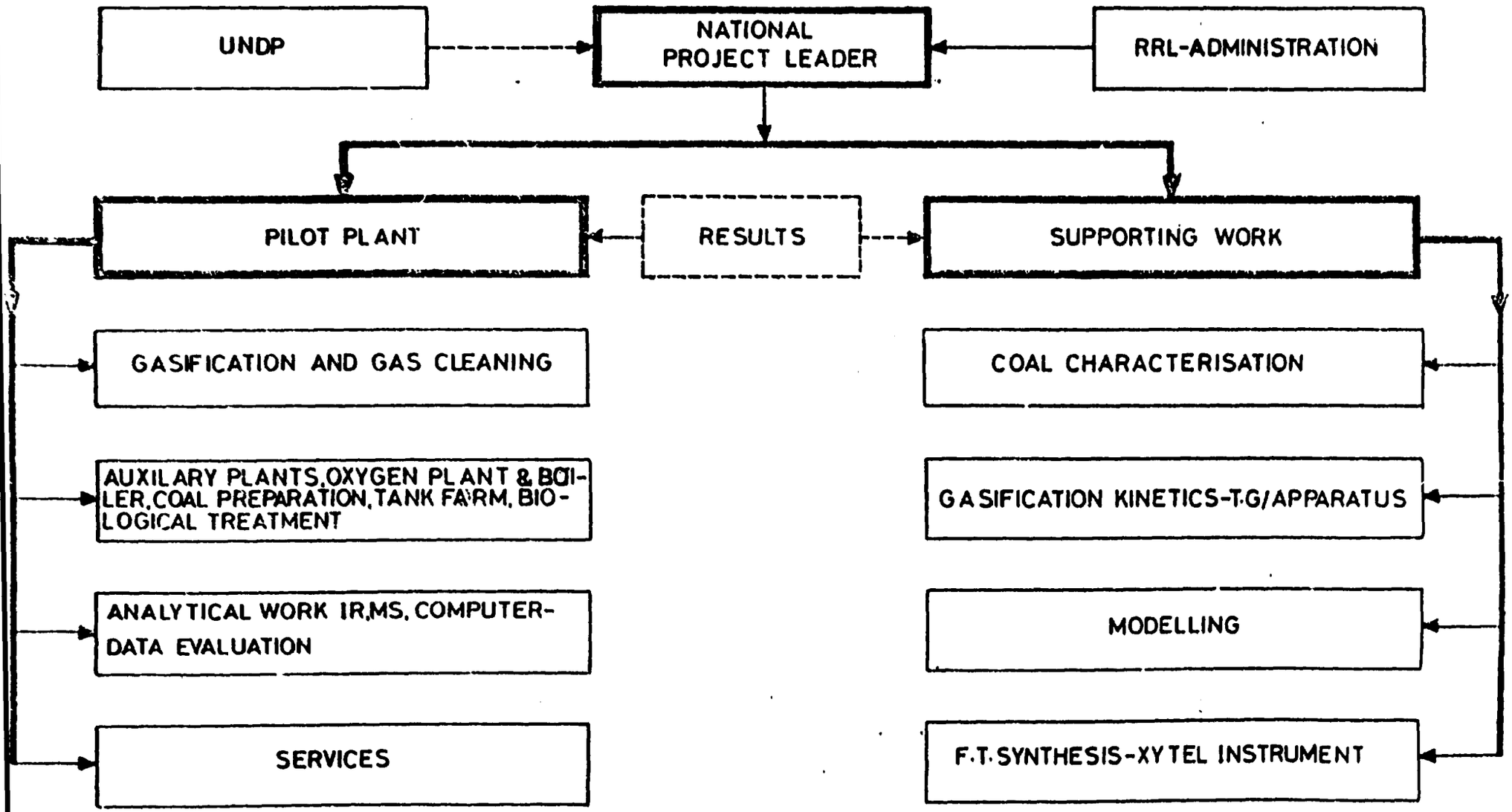
The review of the visits of experts and the training received showed that these measures have been very useful for the progress of the project. It was discussed and agreed that the rest of the experts and training programme should strenghthen the work on gasification kinetics.

With regard to the end of the project the mode of assessment of the project's results by UNDP, the final report and - most important - the possible continuation of the programme have been discussed.

I wish to express my sincere thanks to the director of RRL, the national project director and all colleagues of RRL for the open information and the free discussion on status, problems, organisation and future work of the project. The organisation of my visit was excellent and the friendly atmosphere, the kind hospitality and manifold assistance during my stay are very much appreciated.

STRUCTURE OF GASIFICATION PROJECT

DP/IND/80/004



Status of Feb. 1983

Time table of the mission

- February 1985 -

Date	Day	Action
8/9	Fri/Sat	Travel Essen-Bombay
10	Sun	Travel Bombay-Hyderabad First discussion with project management (Dr. Vaidyeswaran, T.S.R. Anjaneyulu, K.S. Rao)
11	Mon	morning: - Agreement on program of my visist (Dr. Vaidyeswaran) - Visit to TGA and 1st discussion on status (Prasad, Narasimhan) afternoon: - Visit to pilot plant (Anjaneyulu) - Status of MS+Computer (Dr. Ehsan, Premkumar)
12	Tue	morning: - Visit to TGA. review of RRL's performance report and further actions (Prasad) afternoon: - Review of runs performed at pilot plant (Dr. Vaidyeswaran, K.S. Rao, T.S.R. Anjaneyulu)
13	Wed	morning: - Discussion on further plant data evaluation using the MINC computer (Anjaneyulu) - Meeting with modelling group and discussion of status of modelling (M.M. Mallikarjunan, K.B.S. Prasad, K. Venkat Reddy) afternoon: - Discussion of plant operating, experts program and TGA operating (Anjaneyulu, Rao, Dr. Vaidyeswaran)

Date	Day	Action
14	Thu	morning: - Visit to the plant, final discussion about MS+Computer (Anjaneyulu, Rao, Ehsan, Premkumar) afternoon: - Discussion of experts and training programm for 1985 (Anjaneyulu, Vaidyeswaran)
15	Fri	morning: - Final meeting with modelling group (Mallikarjunan, Madhusudhan) - Meeting with the F.T. Group M. Janardana Rao, head, A. Satyanarayana, Xytel F.V.L.N. Prakash, minireactors, Xytel G. Muralidhar, prep. and characterisation of catalyst G.S. Salvapathy, G.C. analysis M.M. Mallikarjunan, kinetcis K. Venkateswarlo, minireactors, Xytel (Mrs.) V. Durgakumari, FT-Kinetics Sharad Shiraokar, Instrumentation afternoon: Discussion on experts and training for 1985 (Vaidyeswaran, Anjaneyulu, Rao)
16	Sat	morning: Review of results on TGA (Prasad, Mullikarjunan) afternoon: Final discussion on TGA performance and data evaluation (Prasad) Exchange of information on coal pyrolysis and supercritical extraction (Dr. Subbarao)
17	Sun	morning: Briefing with Mr. Anjaneyulu and Mr. K.S. Rao on further programme of my visist afternoon: Meeting with Dr. Gopalakrishnan, Gen. Manager of BHEL, R.&D. Corp.

Date	Day	Action
18	Mon	morning:
		Review of training received (Anjaneyulu, Mallikarjunan, Akmal, K.S. Rao)
		Review on the experts visiting in 1984 (Anjaneyulu, K.S. Rao)
		afternoon:
		Final discussion and assessment on pilot plant data
		Discussion on further programme at pilot plant (Anjaneyulu, Rao)
19	Tu	morning:
		Final meeting with the pilot plant staff
		afternoon:
		travel to Bombay
19/20	Tu/Wed	travel to Essen
21/22	Thu/Fri	writing of the report

1. Technical status of pilot plants

1.1 General

The coal preparation and screening, the high pressure boiler and the oxygen plant are fully operational to the designed capacities and they are operatable at short notices.

The gasification and the byproduct condensation are of the same status. The gas cleaning section was commissioned and operated during the trial runs with air-steam gasification and the CO_2 level in the pure gas was brought down to 1.8 %. Presently there is a leakage of a gasket in the middle section of the absorber. Its change requires dismantling and erection of the absorber again. Therefore this work has been postponed and the last trials carried out without gas cleaning. The tankfarm is fully operational and arrangements were made for collection of samples of tar, oil and gas liquor. Biological treatment of the effluents is nearing completion.

1.2 Control and instrumentation, including the UNDP-provided instruments

In general it can be stated, that all equipment is there and properly installed, to operate the plant. As described in previous reports, the pilot plant is sufficiently equipped and the instruments in use are obviously operating well. In particular the gas analysis is done by using Orsat- or Janak-techniques.

For a better and more efficient gas analysis UNDP has provided a Gas Chromatograph (GC) to sets of Infra red analysers (IR) - for the raw gas and the gas achieved after cleaning - and a mass spectrometer (MS), the latter combined with a computer for the calculation of the gas concentrations from the mass spectra and for collecting and evaluation of process data such as relevant temperatures, pressures and flows.

Following a suggestion of my previous visit the GC is used in the "supporting work" for the analysis of the products from the FT experiments (see chapter 4.2). The IR apparatus are not used very much, because of minor teething problems and some obstacles to do calibration. I have recommended to keep them operating during the runs of the plant, so that at least the tendencies of the different gas concentration can be followed-up even, when proper calibration values have yet not been established. Also a calibration of the IR by comparison with the outputs of the other instruments for the same gas to be analyzed is possible.

A lot of time in the visits to the plant was spent to discuss status, further needs and development of the MS computer combination as provided by Balzers. From March 5 to 30, 1984 Balzers engineer H. Gaug visited RRL mainly for the completion of the programming of the computer. Initially there were problems also with the MS itself to be solved, which had been done by him in contact with the mother company. On his leave the MS-computer combination showed the following functions:

- Calibration using the 4 cylinders of premixed gases controlled by computer software.
- Measurement of process gas concentrations (H_2, CO, CO_2, CH_4, C_2H_4, N_2, O_2).
- Aquisition of data on temperatures, pressures and flows.
- Display of process data on the screen and print out.

The Balzers engineer left with RRL a preliminary manual of the software. Full operation manual was received by RRL in Dec. 1984.

On restarting the instruments in May 1984 RRL had difficulties. The main reason had been a shift in the outlet peaks of the MS. This mistake was found and finally corrected by a long lasting correspondence between Balzers, Toshnival brothers (Balzers agent in Hyderabad) and RRL. Finally in January 1985 RRL engineers were

able to change the software on instruction of Balzers. After that calibration was possible using the 4 cylinders of premixed gases. To include also the air calibration the program had again to be changed slightly an advice of Balzers and this was achieved 6th February 1985.

Proper function of all the instruments has been demonstrated to me. Readings of gas composition, process temperatures, pressures and flows were displayed on the screen and could be printed out. During on pilot plant run with steam and oxygen on Febr. 14, 1985 I have checked these recordings with results of the other instruments.

The gas composition as given by the MS seems to be in order. The errors of the other instruments or methods have to be taken into account. As to the process data, the computer output and meter readings as they are collected in the controlroom are not at all the same. As an action check and calibration of the transmitters, thermocouple signals etc. as well as the software for conversion of them into flows, temperatures and pressures is necessary otherwise the computer outputs are not of use.

Another action to be taken concerns the MS-calibration which now totally relies on the cylinders of premixed gases. These are costly and not easy available. Therefore based on earlier discussion a provision has been made to use a gas mixing pump, which is already purchased by UNDP, and gases which are available at RRL. However, the software of the computer has to be developed so that this - and possibly other calibration modes - can easily be performed besides the standard mode.

An additional action concerns the computer assisted data evaluation, which should be done using the computer and the data stored during the runs. The calculations concern values like:

- total carbon conversion rate,
- steam decomposition,
- O_2, steam and coal consumption related to throughput.

All these could be given in well organized form like tables, or printer made surveys summarizing definite periods like days, hours of stable operations, shifts etc.

For the last two actions the project needs considerable assistance by a "software-man" which may be available at the computer center of RRL. Thus, I repeat my recommendation concerning a proper assistance in the programming of the computer.

2. Operation and trials performed

2.1 Overview

From 18.1.1984 to 18.2.1985 trials runs have been carried out as listed below:

Trial Run No	Duration	Coal	Gasification agent pressure
1	18.01. - 21.01.1984	Ramagundam	air steam 5 to 10 bar
2	02.03. - 30.03.1984	Ramagundam	air steam 5 to 10 bar
3	16.07. - 24.07.1984	Ramagundam	air steam 5 to 10 bar
4	20.08. - 04.09.1984	Ramagundam	oxygen steam 10, 15, 20, 21 bar
5	06.02. - 18.02.1985	Monuguru	oxygen steam 10, 15, 20, 24 bar

The runs 1 to 3 were more to gain operational experience to prepare for the oxygen-steam operation in 4 and 5.

Run 1 discontinued because of voltage fluctuations and power restrictions. During run 2 the gas purification section was commissioned and operated fully satisfactory. In this run the mass spectrometer and the computer were hooked up for the first time with the plant, however was not working well as mentioned. Run 3 was meant for testing the systems before the plant should be changed over to operation with steam. Run 4 covered a full trial at different pressures with throughputs between 60 to 95 % of the designed capacity of the different pressure levels. During this run the operational data were collected and samples of coal, ash, tar oil and gas liquor were taken. At the end of the run, the gasifier was quenched and after a complete cooling sequential layers of the solid contents of the gasifier were withdrawn as samples. Each came to about 100 kg. Run 5 was performed during my stay at RRL under the same conditions as in run No 4 however with a new Indian coal including the quenching experiment.

2.2 Analyses coal and products

Gas samples were analysed during the operation of the plant as described in chapter 1.2. Representative samples were collected every shift for coal, ash, tar, oil and gas liquor. Overall samples for the day were also prepared. Following analysis were carried out:

Coal:

- screen analysis
- bulk density
- proximate and ultimate analysis
- ash fusion characteristics
- chemical composition of ash

Asch:

- screen analysis
- bulk density
- combustibles

Tar and oil:

- specific gravimetry
- destillation characteristics
- tar acid content
- benzene insolubles
- elementary analyses
- calorific value

Gas liquor:

- pH
- specific gravimetry
- NH_3 and phenol content
- BOD and COD

With the sequential layer samples collected after quenching the gasifier following analyses were done:

- size analysis
- bulk density
- true density
- average particle size
- minimum fluidization velocity
- proximate and ultimate analysis
- Gray King assay.

2.3 Data evaluation and assessment

From the operational data collected at intervals of half hour average data were computed and specific consumptions of coal, oxygen and steam per unit volume of gas produced were evaluated. Also the crude gas yield and its calorific value, gasifier load and coal - to - gas-efficiency were calculated.

The data of runs 4 and 5 are summarized in lists for each period of the runs, which I have inspected. The formation gathered during

the runs are very valuable and will be useful for the gasification characteristics of the Indian coals and for gasifier modelling. Of special value are the results from the quenching experiment as it gives an insight into the gasifier with special reference to the extent of the different zones - combustion, gasification, pyrolysis and drying, for which quantitative data are established. These are not at all available in the literature and undoubtedly form a part of the know-how.

3. Further working programme of the pilot plant

As it has been already agreed at the last Tripartite meeting tests shall be carried out with some more Indian coals from different other regions. As far as the steam-O_2 gasification is concerned, these runs can follow the procedures and conditions as applied in runs 4 and 5. Additional flow meters for high pressure water and steam will be installed to come to a more precise mass balance. Also minor constituents of the outlet gas - being of importance for the selection and design of purification processes - should be analyzed on selected samples.

As to steam-air gasification the steam flow measurement is not accurate in the range of operation and the pipeline not sufficient to carry the desired quantity of air. Steps have been taken for procurement and installation.

4. Supporting work

4.1 Kinetics of gasification (TGA)

The thermo gravimetrical analyzer (TGA) working at high pressures up to 100 bar under gas atmospheres relevant to gasification such as H_2O, CO_2, H_2 and mixtures enables the RRL project team to support the pilot plant work by evaluation of the gasification kinetics. This subject is completely new in the laboratory and on

its implementation both the sophisticated instrument and the numerical and theoretical evaluation of the data needs experiences which only can be achieved after some time.

On the TGA, which had been installed in late 1983, I had received a performance record before my visit. It summarises the major operating problems which had to be faced during first years' operation and is asking for advices for data evaluation. The instrumental problems concern mainly minor but time consuming things like electronic failures, leakages, blockages of indicators etc. The record has been handed over to BF, which has supplied the instrument. I have received the comments and advices, which I have give the RRL staff on this visit. It should be mentioned and appreciated, that most of the failures have been detected and cleared away by RRL scientists on the basis of the training received at BF, the instruction by the UNDP expert Mr. Sulimma and by support e.g. from the instrumentation group of RRL. Also assistance has been required in one case from the Indian representative of Sartorius, the balance supplier. Moreover BF has given help by written comments throughout the year. To sum up, as to the performance I am fully convinced that future operating or apparatus troubles which may arise can be handled by the Indian colleagues in the same way than in other similar laboratories.

Even in spite of this time consumption by maintenance about 60 runs were made on char from Godavari coal, which was also used in the first runs of the pilot plant. The char was made in the Gray-King assay (1 h at 700 °C). From these runs 5 were done with steam (non-isothermal, 10 to 30 bar) and all others with CO_2 (isothermal, non-isothermal, 5 to 30 bar). I have reviewed the results in detail with the scientist in charge, Mr. Prasad.

First of all the experiments are well performed and during these runs the instrument has worked perfectly both as the high pressure balance and the computerized data collection and evaluation are concerned. The original data found are basically sound. However, there are still difficulties in understanding the procedure of

further evaluation, which is necessary for a proper comparison of the results in reproducibility tests and comparing different gasifying agents and pressures. Although I have given some advice for a modified display, checking of the data, kinetic laws etc., I feel that further assistance is most desirable in order to come quicker in-depth evaluation of data and thereby to full use of the equipment. Thus I would like to recommend that the expert and training provisions that are still in the project for 1985 shall be devoted to this subject (see section 5.3).

We also have agreed on a number of selected experiments with the Godavari char to be carried out at BF with the similar TGA for comparison.

Also the programme of the coming period has been discussed, whereby my general recommendation is, that it should meet the requirements of the gasifier modelling as close as possible. In particular the following types of runs have been considered:

- Continuation of the experiments with Gray-King assay coke under the conditions of the gasifier concerning pressure and for comparison with the BF trials as mentioned before.
- Kinetic studies on samples from the pilot plant quenching experiment looking for the nearest simulation of the layer in the gasifier from which this sample has been taken. Thereby in a first approach simulating the composition of the gas by a mixture of H_2O and H_2 (possibly also of CO_2).
- Kinetic studies on char from other coals under gasifier conditions.

This programme should be performed and possibly changed in close connection and permanent discussion with the modelling group, the members of which should also take part in the data evaluation of the TGA. A more detailed programme could be worked out in consultation with the expert as proposed in 5.3.

4.2 Gas conversion

The supporting group working on the conversion of the gases produced by coal gasification is mainly concerned with the synthesis of chemical feedstocks such as olefines which are used in polymer production. The instruments provided by UNDP funds - XYTEL testing unit and GC - have been fitted into the ongoing programme, which consists of

- preparation of catalysts,
- screening tests in "minireactors" (g-scale),
- tests in larger scale (Xytel),
- analysis of the products achieved (GC).

On the Xytel testing unit some 40 runs have been performed during the last year. The instrument in general showed a satisfying performance, is highly dependent on the computer, however. Therefore it could be considered to install provision for manual operation, if this can be done by RRL's instrumentation group. As a minor failure it was noted, that the graphic display was not working. Xytel has been asked for assistance.

The products of the FT-experiments are analyzed using GC's. Thereby the UNDP-provided one is used for the gaseous effluents and an Indian made one for the liquid ones. The UNDP provided GC had some failures due to voltage fluidisations in the power supply, which has been solved in the meantime.

4.3 Gasifier modelling

Based on the visits of Prof. Denn as UNDP expert in Jan. 1984 and Dec. 1984 and the training received by Mr. Mallikarjunan in July 1984 good progress has been made in reactor modelling. It can be regarded as extremely helpful that in the meantime two complete computer programmes of Denn's model are available at

RRL based on the knowledge achieved during the experts visit and the trainee's stay at Berkeley:

1) one - dimensional, neglecting the radial effects

2) two - dimensional, including also the heat flux from the gasifier axis to the jacket.

Programme 1 already has been installed on the RRL computer and runs have been implemented. Programme 2 is in progress to be installed. However its performance needs a bigger computer, which is available at the Computer Maintenance Corporation (CMC), Hyderabad, and will be used by RRL.

The results of the runs performed using No. 1 on the basis of Dann's data on kinetics, heat transfer etc. have been compared with the plant data and major differences in the gas composition mainly with respect to CH_4 and H_2 and the completeness of the gasification being much higher than predicted as indicated by the very low carbon content in the ash. This is by no means surprising as the input data of the model especially those on the kinetics do not represent all the reactions occurring in general and do not take into account the gasification properties of the Indian coals used.

Further improvement and development of the model has been discussed resulting in the following actions to be taken by the modelling group in close cooperation with the colleagues evaluating the data of the pilot plant and the TGA:

- Performance of additional computer runs with the unchanged model however using the latest data of the plant as input.
- Improvement of the kinetic basis using rate equations and data as published in literature for high volatile bituminous coal similar to the Indian coals e.g. by IGT, Chicago (Johnson, Babu), BF, Essen (Mühlen).
- Including kinetic data on pyrolysis based on data published e.g. by BF, Essen.

- Utilisation of results from the quenching experiment of the pilot plant by making use of the measured course of the C-consumption in vertical direction. This can be used for matching of the oxidation zone and estimation of the true gasification rate, for the latter taking into account results of the residence-time studies which are underway.
- Input of data of the results at TGA available for gasification kinetics of char and lateron of coal pyrolysis.

My advice is that this all should first be done using programme 1, lateron it may be extended to 2.

During this visit to RRL Prof. Klose - UNDP expert - has introduced to the RRL modelling team a more sophisticated model, which also reflects the temperature differences between solids and gases (heterogenous model). An ALGOL programme was received, which has already been interpreted and changed into FORTRAN, but still has to be tested. - The model is more practically orientated and needs a lot of inputs of experimental results, which will be available at RRL after sufficient kinetic studies of the different reactions occurring at and interacting with gasification have been performed.

Thus one aim of the gasifier modelling at RRL should be to analyze the validity of the models available - under implementation of the inputs concerning kinetics as mentioned above -in the light of the results of the pilot plant and possibly go an intermediate and thereby own way between the two approaches by combining useful elements of each.

The modelling group is well organized, consisting of engineers and scientists who understand the process and have good experience in computer programming. Moreover, and this being most important, a plant engineer is collaborating in direct supplying the pilot plant data needed. This personnel is competent to perform the further development of the programme.

5. Experts and training programme

5.1 Assessment of the experts visits

Dr. B. Konrad	18th April, 1984	- 29th April, 1984
Prof. E. Klose	18th March, 1984	- 2nd April, 1984
Mr. B. Locke	24th Aug., 1984	- 2nd Sept., 1984
Prof. M.M. Denn	9th Jan., 1984	- 20th Jan., 1984

I have solicitated a discussion with the project leaders about the degree of usefulness of the experts, who have visited RRL during 1984/85. The main reason for this was to compare our joint expectations when proposing the subject and the expert with the outcome of the visit. However, the experts' reports were not available and therefore are not regarded in this assessment. Thus it reflects more the impressions of the project leaders.

The two visits of Prof. M.M. Denn, Berkely, Cal., are regarded to be very useful for the modelling activities. He has given lectures and was having a series of discussions with the group. His suggestions and explanations of his model have really formed good foundation from which the RRL modelling group could start.

Prof. Klose, Bergakademie Freiberg/GDR, has visited RRL for 3 weeks in May 1984. He has explained his model in detail, has discussed with the engineers engaged in modelling and with the plant engineers. He also has given lectures on the topic "modelling on experimental basis" and "gasifiers in FRG".

Only on the basis of these visits and the follow-up training received in connection with these two experts by RRL engineers (see 5.2) the progress achieved in gasifier modelling has been possible. Thus the visits have to be regarded as very useful and they have fully met the expectations of the RRL project leaders and of myself.

Dr. B. Konrad, Inst. of Fuel Technology, Prague, came in April 1984 for 2 weeks. He discussed with RRL staff such subjects as planning of experiments on gasification, test programmes, plant data acqui-

sition, sample collection, establishment of energy and mass balances etc. Moreover lectures were given on "gas industry in CSSR" and "Prospects of gasification". His visit fully met the expectations.

In August 1984 Mr. B. Locke, UK, was visiting for 2 weeks. His advice was mostly in plant operation and economic evaluation of the process. Also the temperature profile measurements in the gasifier have been discussed. He gave lectures on "F.T. synthesis" and "Evaluation of gasification processes". Overall the visit generally has been useful even though it was felt that some of the areas could have been treated better.

5.2 Review meeting with the trainees

A review meeting was held with the members of the RRL gasification project team T.S.R. Anjaneyulu, M.M. Mallikargunan, K. Akmal, who have been to Europe and the USA for training. As in my previous visits I wanted to discuss experiences whereby also such items as daily schedule, language problems, personal expectations and disappointments and of course the benefit of the knowledge received for the project were covered. On the whole I am convinced that the training measures have been of great value for the progress in project work and for personal development and motivation. In detail the following items should be mentioned:

Mr. T.S.R. Anjaneyulu, member of the project leaders team, was on a 5 weeks study tour on coal gasification in March/April 1984 to gas works and research facilities in UK, FRG, CSSR and USA.

In the UK he has visisted the Coal Research Establishment of NCB in Stoke Orchard for 5 working days. The information received on gas clean-up experiments and especially on the detection of trace elements in the gas produced by gasification are directly relevant to the projects aim, if fuel gas possibly in connection with gas turbines is concerned.

At Bergbau-Forschung, Essen; FRG, Mr. Anjaneyulu received during a 5 days stay informations on pilot plant instrumentation. Especially contacts have been made to suppliers of spares to be ordered for the pilot plant. In addition he was intimated with the various models of data evaluation as performed in BF's pilot plant and he could clarify some open questions with respect to the TGA as supplied by BF to RRL.

In the CSSR he stayed 8 working days at the Vresova gas works, a commercial plant operating 26 fixed bed gasifiers for conversion of coal into town gas. The aim subjects in which he has been introduced were, plant operation including on-load, off-load operation, trouble shooting, load variations etc. Thereby the hosts were more interested in discussion on the table than in the field. Also same reluctance was noticed in giving information e.g. very short visits were allowed to the control room and the computer center. This is to some extent understandable as it touches the sensible know-how of this industry. Also some language problems had to be faced. On the whole, the visit has to be regarded useful for the project, even if a little bit more information had been expected.

At Morgantown Energy Technology Center Mr. Anjaneyulu spent 5 working days. He was introduced to the fixed bed gasifier system and the sophisticated instrumentation hooked-up including all computer installations and outputs. Also gas clean-up problems could be studied. Moreover the documents and reports of US gasification projects have been made available to him. I feel that the information received are fully useful for the project.

Mr. M.M. Mallikarjunan has been 6 weeks in the USA, whereby he spent about 4 weeks at Berkeley, Cal., working in Prof. Denn's group. Under continuous assistance of one of Denn's students he has been introduced into the gasifier models and worked practically with the computer system installed there. The benefits of his visit have already mentioned in chapter 5.2 and 4.3 of this report. In addition he attended the "4th Advanced Gasification

Projects Contractors Meeting" in Morgantown for 3 days, which was useful as it has given the latest information about the status of US-projects. Also he paid a 4 days visit to Prof. Berty's group at Akron University, where a very elaborated experimental technique has been developed for laboratory studies on F.T. synthesis and experiments on kinetics of gasification are done.

Mr. Khaleel Akmal has received an about 3 weeks training at the Bergakademie, Freiberg, mainly on modelling. Prof. Klose, who had just finished his visit as RRL as an UNDP expert and his co-worker have given him a more depth knowledge of the gasifier model developed (see chapter 4.3). Also the many experimental set-ups which are in use in connection with the model have been demonstrated to him. The usefulness of this part of the training is evident. In addition Mr. Akmal was able to visit the gas works "Schwarze Pumpe" for 5 days in which 24 fixed bed gasifier are used for the conversion of lignite into town gas. He was systematically introduced into the single units of a commercial gasification plant. At both places of his visit there were no language problems. Communication was done in English, at Schwarze Pumpe, with the help of an interpreter.

On another occassion I have also talked to Mr. K. Ventkateswarlu who was in Oct./Nov. 1984 4 weeks in the FRG visiting places well-known for their F.T. work. He has visited the Technische Hochschule Aachen (Prof. Hammer), the Technische Universität Karlsruhe (Prof. Schulz) for a short time. About three weeks were spent with Prof. Deckwer and his group in Oldenburg University. He got acquainted with the different types of reactors and with recent methods of product analysis. These information are directly linked to the supporting work of the project.

Mr. Anjaneyulu and the trainees have made daily notes about their findings and learnings and the final reports I have received are excellent.

Mr. Anjaneyulu and the three scientists have expressed their sincere thanks for the unique opportunity provided by the UNDP funds. They are especially grateful to their hosts for all the information received and their kind hospitality.

5.3 Experts and training programme, study tours

In the programme there is still provided a provision for one expert to come to RRL and for one trainee to go abroad. Reviewing the different possibilities relevant for the project I feel that the supporting work should be strengthened in such a way that utmost use can be made from the equipment provided by UNDP funds. From my experience of this visit and as mentioned earlier the highest need seems to be to support the research work on the kinetics of char gasification and coal pyrolysis and in agreement with the project leaders I propose that the expert and the trainee should be devoted to this subject.

As to the expert, provision exists in the project for one on mass spectrometer, computer, data logging etc. His service was to be obtained during 1984. However, it appears that no suitable person could be found. Under the aforesaid aspects it is now proposed that the job requirements for the expert should be redefined as follows:

- Advise the RRL project team on theory and methods of coal gasification kinetics;
- provide assistance and advice in evaluation of the kinetic data obtained in the TGA;
- provide expert guidance in preparation of software and further evaluation of the data.

It was also felt that to provide such expertise, Dr. H.J. Mühlen from BF GmbH, Essen, is the right person. He has wide experience in the use of TGA and development of software programmes. His dissertation work has also been on gasification kinetics.

As to the training provision exists in the field of modelling of gasifier for about 4 weeks as discussed in the last meeting of the TPR. This was to have taken place in November 1984 but was postponed. As mentioned before it will be more useful for the project if a member of the team undertakes training on studies on the kinetics of the gasification and pyrolysis and also development of software computer programming for evaluation of the data on kinetics. He should also get acquainted with the latest application of the TGA. A suitable place for this training is the laboratories of BF GmbH, Essen.

Further provision exists in the project for two visits by project members during 1984-1985 for attending international conferences. However during 1984 no one from the project attended any conference. During 1985 the following two conferences are taking place:

(a) Conference on Coal Gasification to be held in the second half of May 1985 in Portugal.

(b) International Coal Science Conference to be held in the last week of October 1985 in Australia.

Participation in the above two conferences will be very useful for the project and it is my proposal that one scientist may be deputed to each of these conferences.

6. Matters with regard to the end of the project

The running phase of the project will - so far as UNDP support is concerned - be ending by the year 1985. Therefore I have discussed with the project director and the project leaders the as-

sessment of the projects's results, the Final report and some aspects for the possible continuation of the work.

As to the assessment I have been informed that UNIDO will appoint an expert to evaluate the projects' results in comparison with the aims of the original proposal. The question is to what extent this would be a technical discussion and how detailed the information has to be given. Under the aspect that the project has been jointly financed by UNDP (ca. 25 %) and RRL (ca. 75 %) I think it is fair not to insist in giving all information at least not in written documents especially if this expert should be selected from an engineering company active in coal gasification, which is not desirable. In any case I am prepared to help UNIDO in finding an expert. Also I could be available for a detailed discussion of the work and scope of the project, if desired.

Similar aspects should be regarded for the Final Report, whereby I propose that the main results can be made clear enough by giving relevant examples.

As to the time after Jan. 1, 1986 one should consider that the tests on 8 Indian coals - as proposed to the last Tripartite Meeting and agreed - hardly can be performed by the end of 1985 Under the aspect, that the plant and all the costly equipment is full operational and that in the meantime the operating team is trained and motivated if would be wise at least to plan a prolongation of the project by 9 to 12 months, which also could be defined as a new project phase. This would require funds just for same spares and - if at all possible - for 1 expert and 1 trainee to make an utmost use of the UNDP funded sophisticated instruments. I think that especially experts and training are necessary in order to assure continuity.

Also after the implementation of these tests continuation of the work should be considered. By the high effort of RRL and Indian Government and with the support of UNDP a research facility has been built up which so far as fixed bed gasification is concerned

is unique in the world. This combination of pilot plant, experimental laboratory work concerning coal analysis, kinetics of gasification and pyrolysis and reactor modelling will be in future of high value for the use of Indian coal. Thereby it should be considered that just most of the Indian coals because of theier high ash contents and non-caking quality are ideally suitable to be gasified in fixed bed reactors.

Thus in prolongation of the work the following items for a future working programme could be considered:

- Use of the facilities at RRL - pilot plant, laboratory work and modelling - for testing coals to be fixed bed gasified. Thereby besides the Indian coals also other solid feedstock especially also from developing countries can be taken into account.
- Use of gas produced in the pilot plant for experiments and testing of different new processes of gas cleaning and conversion. This also could be done in smaller units using a by-pass stream of the gas as already proposed by RRL earlier and could cover as well the aspects of the production of fuel gas for turbines and of the production of chemical feedstocks or liquid fuel by syntheses of F.T. type.
- Further fixed bed gasifier development and a engineering and feasibility studies, together with partners from the Indian industry.

The support from UNDP for such as programme would cover limited funds for spares and international exchange (experts, training and study tours).