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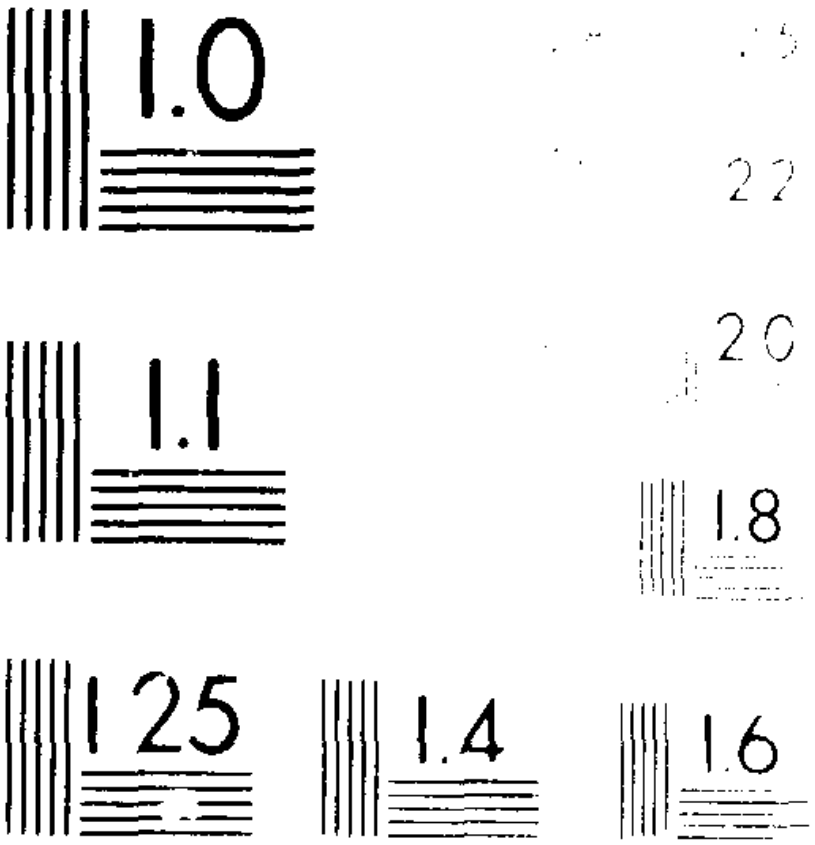
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July 1984
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COAL GASIFICATION

DP/IND/80/004

INDIA

Technical Report[x]

(Mission 15 March - 5 April 1984)

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

Based on the work of E. Klose,

Consultant in Modelling of Coal Gasification Reactions

United Nations Industrial Development Organization

Vienna

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1. Summary

1.1. Survey

The main point of the visit was to strengthen the capabilities of the Regional Research Laboratory in Hyderabad for R + D on Coal Gasification specially for Modelling of Coal Gasification Reactions.

Therefore, the relevant laboratoties and pilot plants were visited and all problems were discussed very intensively. Besides other activities, such as briquetting, coal pyrolysis, upgrading of coaltar and -oil and activated carbon manufacture were reviewed.

The following lectures were given and intensively discussed:

I **Mathematical model for the gasification of coal under pressure**

II **Energy supply problems in G.D.R. and importance of coal**

A list of our publications related to those lectures is given in part 3.

1.2. Time table

15.3.	Travel form Freiberg to Vienna
16.3.	Briefing in Vienna
17. - 18.3.	Travel from Vienna via Bombay to Hyderabad
19.3.	Introduction in the R+D-Project of Coal Gasification (Dr. Vaidyeswaran; K.S. Rao)
	Visit to coal gasification pilot plant
20.3.	Visit to Thermogravimetric Analysis Apparatus (TAA) and acquainting with this arrangement
	Lecture I
21.3.	Discussion with modelling group
22.3.	Discussion with modelling group
23.3.	Discussion with modelling group
	Discussion about working programme of the TAA
26.3.	Discussion with modelling group
-	Visit to Department of Simulation, Optimazion

	and Control
	(Dr. A. Husain)
	Lecture II
27.3.	Discussion with coal group
28.3.	Discussion in pilot plant
	Discussion with modelling group
29.3.	Discussion in pilot plant
	Visit to semitechnical plants of activated carbon manufacture and discussion on activated carbon
30.3.	Discussion with modelling group
	Final discussion with Dr. Vaidyeswaran and K.S. Rao
1. - 2.4.	Travel from Hyderabad via Bombay to Vienna
3.4.	Debriefing in Vienna
4. - 5.4.	Travel from Vienna to Freiberg
6.4.	Preparation of report

1.3. Main partners of scientific discussions:

Dr. R. Vaidyeswaran
K. Seshagiri Rao
M. M. Mallikarjunan
K. Venkat Reddy
B. Madhusudhan
M. A. K. Akmal
S. Narayan Reddy

A meeting took place with

- Dr. G. S. Sidhu, Director General, CSIR, New Delhi, by a visit to Hyderabad
- Dr. G. Thyagarajan, Director RRLH.

1.4. Conclusions and recommendations

During the visit the gasification programme was reviewed and discussed intensively on the following main points:

- Application of mathematical models for coal gasification under pressure in a fixed bed.
- Interpretation of results of the trials with the pilot plant.
- Proposition for coal and product analysis from pilot plant (gas, tar, oil, waste water, ash).
- Working programme for the determination of kinetic parameters of coal with the Thermogravimetric Analysis Apparatus.

Additional problems related to coal conversion were also discussed:

- Briquetting of coal and char with and without binders.
- Pyrolysis of non caking coals.
- Production of pitchcoke from coaltars.
- Activated carbon manufacture.

For the visit of M. A. K. Akmal to G.D.R. the fellowing programme was discussed:

- 2 weeks stay at Bergakademie Freiberg to study the scientific methods of kinetic measurements for coal and coke.
- 2 weeks stay in VEB Gaskombinat Schwarze Pumpe to study the problems of large scale operation to convert brown coal into town gas.
- For tests he will bring along a coal sample to Freiberg.

The main aim of the pilot plant programme will be to achieve stable continuous operations over longer periods.

Variable parameters:

- steam/oxygen ratio,
- coal throughput,
- variation of particle size distribution,
- air-steam operation.

The pilot plant is suitable for examining the gasification of different Indian coals as well as foreign coals. Measurement of temperatures and gas composition inside the gasifier

is not necessary, and it will be very difficult. With this reactor and the present coal the installation of movable coal distribution system is not necessary.

A new work programme will have to be prepared, when results of the present trials have been reviewed

The prerequisites to coal gasification modeling are encouraging. The scientists of the modelling group have conscientiously made necessary peparations for this task.

With the TAA unit tests were made with char prepared from coal used in the gasifier. The performance of trials according to the work programme (sec. 2.2.) is possible. It is recommended to make comparison tests with the apparatus in Freiberg.

2. Detailed Report

2.1. Modelling of the fixed bed pressure gasification

After lecture I discussions with the scientists of modelling group took place. This was the reason for the stay in Hyderabad and covered half of the time.

Participants of these discussions were:

M. M. Mallikarjunan
K. Venkat Reddy — Specialists of modelling

They had been involved in catalytic process modelling before.

B. Madhusudhan
M. A. K. Akmal
S. Narayan Reddy — Specialists of coal gasification

The following topics were discussed extensively:

- fundamental structure of programme for modelling. This may be divided into two parts.
  - preheating, drying, degasification
  - reduction and oxidation processes

- specification of the various steps of fixed bed pressure gasification
- equations and diagrams for heat transfer, chemical reactions, mass balance and heat balance
- necessary values for characterization of the solid
  - . ultimate analysis,
  - . course of drying
  - . course and products of degasification
  - . values of chemical reactions,
  - . change of particle size during degasification and gasification,
  - . explanation of the input values for computer,
  - . possibilities of thermodynamic equilibrium calculation for different gasification processes.

With respect to the conditions of pilot plant and Indian coals some points of the existing programme must be changed

- for drying and degasification the particles have also the form of spheres.
- process of drying must be determined experimentally.
- height of ash zone must be reduced.

The scientists have good knowledge about basic mathematical modelling and setting up a computer programme appears possible. The department of simulation, optimization and control (Dr. A. Husain) has a great number of basic programmes and a highly experienced staff.

2.2. Studies of kinetic of gasification reactions

The TAA unit received from Bergbau-Forschung is installed and test were made with char prepared from the coal used in the pilot plant. In the near future , systematic tests will be possible.

K. S. Rao
K. H. V. Prasad (T. G. Apparatus)
K. L. Narasimhan (Coal characterisation)
M. M. Mallikarjunan
M. A. K. Akmal

A test programme was discussed with the above scientists:

- preparation of samples for trials,
- variable parameters:
  - temperature
  - kind and mixtures of gases
  - pressure
- interpretation of the test results.

The TAA unit will be useful for kinetic studies of different carbonaceous materials. The calculated kinetic values are necessary for the computer modelling of the gasifier. Furtheron the results can be used for the determination of reactivity of the coal and help with interpretation of results of the pilot plant.

For comparison, tests with Indian coals are recommended with the apparatus in Freiberg. In case of positive results an offer will be made for an extensive work programme in Freiberg.

2.3. Pilot plant for the fixed bed pressure gasification

The plant was operated in trials. Two intensive inspections of the pilot plant has been made including the auxiliary plants and the analytical works (under K. S. Rao). During discussions advise has been given for many problems:

- Evaluation of trials from coal gasification pilot plant. For interpretation of the test results it is necessary to calculate several balances:
  - C-balance for gas yield,

. H-balance for steam decomposition,
. heat balance for thermal efficiency.

With the present values from measurement and product quality the balance can be calculated and hence developing a computer programme for such computation becomes possible.

- Necessary characterization of the input coal and the output ash as supplement to the usual chemical analysis:

. abraison test from the input coal,
. abraison test from char prepared from the input coal,
. size analysis from the ash by sieving,
. gas streaming through an ash bed.

- Technical problems of the pilot plant:

. shut down of the plant and conservation by stoppages,
. separation of liquor drops behind the after cooler,
. measurement of steam quantity by different steam temperatures.

Participants of the discussions:

Dr. Vaidyeswaran; K.S. Rao; S.N. Reddy; B. Madhusudhan, M.A.K. Akmal and other scientists of the pilot plant.

The pilot plant is suitable for examining the gasification of different Indian coals as well as foreign coals. In the first phase the experimental tests should begin with runs of 5 - 8 days duration with one coal, including utilisation of gas cleaning unit:

. for training of personnel,
. stabilising plant operation under steady conditions,
. collection of data,
. interpretation the results with computer.

The variable parameters are:

. steam/oxygen ratio,
. coal throughput,
. variation of particle size distribution,
. air-steam operation.

The final aim is to get results for

- gas yield and coal consumption
- gas quality,
- steam and oxygen consumption for gasification,
- steam decomposition,
- carbon conversion to gas components, to tar and oil and carbon residue in ash,
- thermal efficiency.

A new work programme should be made after interpretation of the results from the present programme.

2.4. Exchange of information about other problems of coal conversion

After lecture II discussions with the scientists of the coal group took place.

Participants of these discussions:

Dr. Vaidyeswaran; K.S. Rao; D.P. Agraval; Y.V. Subbarao; K.L. Narasimhan; Dr. E.R. Saxena and other scientists of coal group.

- Discussion about problems of coal conversion:
  - briquetting of coal and char with and without binders,
  - pyrolysis of non caking coals,
  - production and quality of formed coke.
  - conditions for pitch coke manufacture from coal tar.

- Discussion about activated carbon

  Discussion of fundamentals of activated carbon manufacture from wood, coalchar and coconut shells:

  - characterization of raw materials and activated carbon,
  - influence of activation conditions (temperature, residence time, gas atmosphere and gas composition),
  - mechanism of pore formation during activation

  The two semitechnical plants of activated carbon manufacture were visited.

2.5. Visiting programme in G.D.R. for M.A.K. Akmal

For the visit of M.A.K. Akmal in G.D.R. the work programme was discussed with Dr. Vaidyeswaran and K.S. Rao:

- 2 weeks stay at Bergakademie Freiberg to study the scientific methods of kinetic measurements for coal and coke and to discuss still existing questions about modelling of coal gasification.
- 2 weeks stay in VEB Gaskombinat Schwarze Pumpe to study the problems of large scale operation to convert brown coal into town gas, the equipment for measurement and the interpretation of trials with production plants.
- For kinetic studies he will bring along a coal sample to Freiberg.

2.6. Acknowledgement

I wish to express my sincere thanks to the management, the scientists and the staff of RRL for the good organization of my stay and the free and open information exchange and the stimulating discussions.

3. List of our publications about coal gasification

3.1. Problems of fixbed pressure coal gasification

- Richter, G.; Scholz, G.; Wuntschoff, T.; Klose, E.
  Neue Erkenntnisse und Erfahrungen bei der Verfahrenstechnik der Druckvergasung
  Energietechnik (Leipzig) 27 (1977) 9, S. 368 - 372.

- Scholz, G.; Kanuth, B.; Klose, E.
  Ergebnisse der Entwicklungsarbeiten zur Kohledruckvergasung
  Energietechnik (Leipzig) 31 (1981) 10, S. 364 - 369.

- Wuntschoff, T. u. a.
  Einige Ergebnisse von groß- und kleintechnischen Untersuchungen zur Optimierung des Prozesses der Kohledruckvergasung
  Freib. Forsch. Hefte [x] A 666 (1982), S. 99 - 112.

- Knauth, B.; Klose, E.
  Technische Fortschritte auf dem Gebiet der thermisch-chemischen Kohleveredlung in der DDR
  Energietechnik (Leipzig) 32 (1982) 5, S. 167 - 172.

3.2. Modelling of coal gasification

- Biba, V.; Klose, E.; Malecha, J.; Macak, J.
  Mathematisches Modell zur Kohlevergasung unter Druck
  Teil I : Energietechnik (Leipzig) 26 (1976) 1, S. 28 - 32
  Teil II: Energietechnik (Leipzig) 26 (1976) 2, S. 71 - 75.

- Klose, E.; Toufar, W.
  Mathematische Modellierung der Festbett-Druckvergasung
  Energietechnik (Leipzig) 26 (1976) 12, S. 546 - 555.

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Mathematische Modellierung der Festbett-Druckvergasung - Diskussion von Parametern und Resultaten
Energietechnik (Leipzig) 28 (1978) 1, S. 26 - 30.

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Modellierung der Festbettvergasung als Beispiel für die mathematische Beschreibung von Schachtofenprozessen
Erdöl und Kohle-Erdgas-Petrochemie 33 (1980) 7, S. 331.

- Toufar, W.; Klose, E.
Festbettvergasung als Schachtofenprozeß - Aussagen der mathematischen Modellierung des Prozesses
Energietechnik (Leipzig) 30 (1980) 8, S. 298 - 302.

3.3. Gasification kinetics

- Althapp, A.; Klose, E.; Köpsel, R.
Bedeutung und Inhalt reaktionskinetischer Untersuchungen, insbesondere bei der Vergasung kohlenstoffhaltiger Materialien
Freib. Forsch. Hefte A 591 (1978) S. 7 - 23.

- Köpsel, R.; Althapp, A.
Die Bestimmung der Reaktionsfähigkeit von Kohlenstoffwerkstoffen aus der Sicht der chemischen Kinetik
Freib. Forsch. Hefte A 618 (1980) S. 125 - 134.

- Althapp, A.; Born, M.; Klose, E.; Stöffgen, F.
Einfache Apparaturen zur thermogravimetrischen Analyse von Proben im Bereich von 10 mg bis 500 g.
Freib. Forsch. Hefte A 625 (1980) S. 69 - 81.

- Köpsel, R.; Althapp, A.
Differential-Kreislaufapparatur mit Thermowaage zur Ermittlung der chemischen Kinetik von Kohlen und Koksen mit CO_2
Freib. Forsch. Hefte A 636 (1980) S. 83 - 92.

- Althapp, A.; Müller, G.; Klose, E.
Weiterentwicklung der Apparatur zur Bestimmung der Reaktionsfähigkeit von Kohlenstoffmaterialien
Freib. Forsch. Hefte A 647 (1981) S. 69 - 75.

- Born, M.; Klose, E.
Calculation of the limit pore ranges of the reaction of porous carbon materials with CO_2
FUEL 62 (1983) April, p 482 - 484.

- Köpsel, R.; Klose, E.
Verbrennungskinetik von Brennstoffpartikeln - gegenwärtiger Wissensstand
Energietechnik (Leipzig) 33 (1983) 4, S. 149 - 152.

- Köpsel, R.; Geyer, J.; Althapp, A.
Experimentelle Untersuchung der Vergasungsgeschwindigkeit von Braunkohlen
Freib. Forsch. Hefte A 672 (1983) S. 4 - 19.

- Geyer, J.; Althapp, A.; Köpsel, R.
Experimentelle Ergebnisse der Xylit-Vergasung
Freib. Forsch. Hefte A 672 (1983) S. 20 - 36.

3.4. Coal conversion

- Krug, H.; Naundorf, W.; Klose, E.
Herstellung von hochwertigen Pyrolysebriketts aus nichtbackenden Steinkohlen
Neue Bergbautechnik (Leipzig) 10 (1980) 12, S. 699 - 703.

- Klose, E.; Toufar, W.
Vergleichende Betrachtungen zur Entgasung mit unterschiedlichen Aufheizgeschwindigkeiten
Freib. Forsch. Hefte A 647 (1981) S. 33 - 44.

- Klose, E.; Toufar, W.
Aufarbeitung der Flüssigprodukte aus der klassischen Kohleveredlung durch Destillation und Hydrierung
Freib. Forsch. Hefte A 656 (1982) S. 91 - 105.

- Klose, E.; Toufar, W.
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Untersuchungen zur Reaktionskinetik der Gasaktivierung kohlenstoffhaltiger Materialien in einem Laborwirbelschicht-Versuchsreaktor
Freib. Forsch. Hefte A 672 (1983) S. 101 - 113.