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# LIQUEFACTION OF COAL

DP/POL/82/002

Technical Report*

Prepared for the Government of the Polish People's Republic
by the United Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme

Based on the work of Mr. J. A. Harrison,
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Vienna

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## ABSTRACT

LIQUEFACTION OF COAL

DP/POL/82/002/11-04/32.1.1
POLAND

This report describes my visit, as an Instrumentation Expert, to the Central Mining Institute (C.M.I.) Katowice and to the Institute for Carbochemistry, Tychy-Wyry, Poland in support of this project.

This visit is a follow up to my visit in October 1985, which has been fully reported. It covered a period from the 26th November - 9 December 1986. The objective was to further advise the project team on methods of measuring and controlling the basic parameters of the 80 kg/hr P.D.U. plant, the 5 kg/hr bench scale unit and on instrumentation matters generally.

The main items covered in the discussions were, an update to flow measurement and density measurement techniques in the light of developments and commercial acceptance during the past year, more detailed discussions and recommendations on the application of data acquisition and logging techniques to the 80 kg/hr P.D.U. plant, industrial chromatograph selection for establishing the gas compositon from the plant and the means of obtaining material balances on the plant. Other general items of instrumentation and techniques were also covered as they arose in the discussions.

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# INTRODUCTION

## LIQUEFACTION OF COAL
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## POLAND

The purpose of this project is to assist the Polish Government in their investigations of coal liquefaction processes with a view to utilizing their coal resources in order to meet the liquid fuel requirements of the country.

The immediate objectives are:-
To prepare for the start of a programme to test, at P.D.U. scale (80 kg/hr) the process parameters for the effective liquefaction of selected coals.

To carry out a programme of liquefaction R and D in a 5 kg/hr bench scale unit to define appropriate process operating parameters.

This report describes my visit, as an Instrumentation Expert, to the Central Mining Institute (C.M.I.) at Katowice, Poland and to the Institute for Carbochemistry at Tychy-Wyry, Poland, in support of this project. The visit covered a period from 26th November - 9th December 1986 and the objective was to advise the team at the Institute on methods for measuring and controlling the basic parameters in the P.D.U. and on instrumentation matters generally.

The discussions with the staff on the Institute covered a much wider range of topics than had been specified in the original job description remit, but I think that this was beneficial to all.

The major part of the mission consisted of daily discussion sessions with the staff associated with the project.

Many of the topics raised were returned to time and time again as earlier discussions were thought out further, raising other considerations.

Because of this the report has not been compiled as a daily chronicle of matters discussed, but on a subject basis, where discussions over a period of days have been collected together and are combined, together with the conclusions and recommendations, under the subject heading. This report has been compiled from rough notes that were made during the discussion period and which were written up each evening.

I wish to record my thanks and appreciation to Mr J. Maloszewaki, Director of the Central Mining Institute and to Mr A. Goszcz, Deputy Director of the Central Mining Institute for their kindness, consideration and the interest that they showed in my visit.

In the absence of Dr Matula, Director of the Institute of Carbochemistry (in the U.S.A.)., I wish to record my thanks and appreciation to Prof.M. Ihnatowicz, Deputy Director of the Institute and to her staff for their kindness, consideration and the co-operation that they showed during my visit.

I wish to record my special thanks to Prof. Y Kulozycka, U.N.I.D.O. Co-ordinator for the organising of my visit and all the details of my stay.

Finally, my thanks to Eng. Marian Krzyminski who acted as interpreter for me.

## RECOMMENDATIONS

The problem of making recommendations is a difficult one, especially in the light of discussions concerning the recommendations resulting from my previous visit, see page number 19, where the restraint of finance manifested itself as a real one.

In my opinion, the procurement and installation of some of the items of instrumentation equipment discussed on this visit, is vital to the success of this project. These include gas analysis equipment, equipment for ensuring that it is possible to carry out material balances, data logging equipment and flow measuring equipment.

I am not in a position to know whether or not satisfactory equipment is available in the Eastern Block Countries, to fulfil these requirements and if so. whether finance is available for their purchase, but if not, I think that it is crucial that all interested parties tackle the problem of how the equipment required can be purchased from the West.

## 1. INTRODUCTORY MEETINGS

### A. AT THE CENTRAL MINING INSTITUTE

This meeting at the Institute at which I was warmly received , was held part way through the mission. It has been reported in this order so as to maintain consistancy with my 1985 report.

Those present:

Mr J. Maloszewski - Director of the Institute.
Mr A. Goszcz - Deputy Director of the Institute.
Prof. M. Ihnatowicz - Deputy Director of the Institute of Carbochemistry
Prof. Y. Kulozycka - UNIDO Co-ordinator
Mr J.A. Harrison - UNIDO Instrumentation Expert
Eng. M Krzyminski - Acting Interpreter

I was asked to give my views on the 80 kg/hr P.D.U. and on the progress that had been made. I recalled that I had seen the unit about a year ago and at that time much work was still to be done on the construction of the unit, as outlined in my previous report. One year later the unit is built and has completed its' first run with material. The unit ran for a period of 5 days before it was shut down, as per schedule, while further coal was prepared for the next run. This next run is to be undertaken with a higher density of coal slurry.

The fact that this first material run had been completed successfully, without any major problems, is very encouraging and is a great credit to the team involved in all aspects of the unit. In my experience it is unusual for the first run of a pilot plant of this type to go so smoothly.

Discussions then turned to the Coal Industry and in general terms to the research and development activities of British Coal. The Director of the Institute mentioned that he hoped to visit Great Britain in the Spring, when he hoped to visit the British Coal Research Establishments.

## B. At The Institute of Carbochemistry

Those present:

Prof. M. Ihnatowicz - Deputy Director of the Institute
Prof. Y. Kullozycka - UNIDO Co-ordinator
Eng. J. Swiadrowski - Responsible for the P.D.U
Eng. M. Krzyminski - Interpreter
Mr J. A Harrison - UNIDO Instrumentation Expert

As the Director of the Institute was in the U.S.A. I was welcomed to the Institute by Prof. M. Ihnatowicz and a meeting was held where an up-to-date account of the progress on the 80 kg/hr P.D.U. was given to me. Coal conversion developments in the Western World were also discussed, as were recent developments in the Instrumentation and Control Engineering Fields.

Successful runs have been undertaken on the P.D.U. with oil, hydrogen and finally with coal based slurry. Slurry with a solids content of approximately 25% was used. The coal had previously been crushed and ground to achieve a size not greater than 0.3 mm. The unit ran for a total of 5 days and was then shut down as scheduled. Preparations are now in hand for the next run where a higher density slurry will be used. It is planned to have slurry with a solids content of 40%.

There were no major problems highlighted in these preliminary runs such as mechanical failure, blockages or coking, but leakage of slurry at the circulating pumps was a problem. Gland packing materials are being investigated.

Later discussions with the project team highlighted some minor problems that had arisen. These are reported later in discussions with the project team.

On the activities in the Western World, in coal conversion technology, I pointed out that I was not aware of any further major developments in the U.S.A. during the past year. As far as British Coal is concerned, in my opinion, little change in the level of activity has occurred in the past twelve months chiefly, I suspect, to the continuing low price of oil. The current price is now approximately 14 dollars a barrel and it has been considerably lower. The other factor is the general economic situation. These two factors highlight the present uncompetative nature of coal conversion technology and the resultant degree of activity in this field. I still consider that coal conversion technology will come into its' own as oil supplies run down.

In the British Coal Industry the chief activity in this field is the building of a pilot plant for coal conversion with a capacity of 2.5 tons/Day (approximately 100 kg/hr). This plant is being built at Point of Ayr colliery in North Wales. It is expected to be completed late 1987 and commissioning is expected to start early 1988.

The instrumentation cost for this plant is in the order of 30% of the capital cost of the plant. You will recall that I spoke of using this criteria when we discussed the adequacy of the instrumentation on the 80 kg/hr P.D.U. on my last visit.

The role of the Coal Research Establishment of British Coal in coal conversion technology appears to be a support function for this pilot plant and it is actively pursuing research and development in areas such as filtration, catalysts and computer control applications. Amongst other activities at C.R.E. more emphasis now appears to be in hand in furthering the Research and Development effort in the application of Fluidised Bed Technology, both atmospheric and pressurised, in boilers for industrial use and for power generation.

On the development of Instrumentation and Control equipment, one must appreciate that very little advance occurs in twelve months. This is particularly so in the field of coal consversion technology where the technical requirements of any new equipment is high in terms of operating demands and the commercial attractiveness in terms of market quantity is, as of now, low. These factors do not encourage instrument manufacturers to develop equipment for this market yet.

In the field of flow measurement, two comparitively new instruments have appeared and are gaining acceptance in slurry flow measurement. One equipment employs a non-intrusive technique, whereas the other employs an intrusive technique. I have brought data on these two developments for discussion at later meetings.

## 2. INSTRUMENTATION AND CONTROL DISCUSSIONS

### A. Introduction.

In the daily discussion sessions, discussions took place with the scientific and engineering staff associated with the P.D.U. A visit was also made to the unit.

The topics discussed were returned to time and time again as earlier discussions were further thought out. In the light of this, reporting of these discussion sessions has not been compiled as a daily chronicle of points discussed, but on a subject basis, where discussions over a period of days have been collected together and are presented under each subject heading.

### B. Visit to the 80 kg/hr P.D.U.

This was one of my first actions after my meeting with Prof. M. Ihnatowicz. It was interesting to compare the engineering with the situation on my last visit. The unit is a highly professional piece of engineering and on the Instrumentation and Control aspects of the unit is on a par with plants that I have previously been involved with. In my opinion the control room presentation, although functional, is limited by the availability of equipment that can be used. This is particularly noticable in the type of recorder used.

The problem of leaks, that had been mentioned in the earlier discussions, were evident.

### C. Flow Measurement

This was one of the main discussion areas, highlighting the importance of this measurement on the P.D.U. The main areas of interest were the flow measurement of coal slurry, hydrogen and recirculating gas.

I outlined two comparatively new instruments that were gaining acceptance.

1. One is a non-intrusive instrument developed in the U.S.A. I know of at least two American companies that manufacture equipment operating on the same principle. The operating range of pressure and temperature makes it attractive for coal conversion technology applications.

The principle of operation is based on the "Coriolis" effect, where if fluid or gas is passed through a U shaped tube, which is vibrated at its' natural frequency and at an amplitude of only a few m.m., this will cause the fluid or gas to take on a vertical movement relative to the direction of flow. This will apply a force to the tube which will be different at each end of the U tube. This differential movement is sensed and a signal proportional to mass flow is produced.

I tabled and left the following data relative to the equipment. Technical paper on the principle of operation, a list of applications that had been undertaken, general sales literature and a budgeting price (for guidance only). I also left information from the two companies in England acting as agents for the American companies. I had not been able to establish whether or not these American companies had representation in Poland or in any of the Eastern Block Coountries.

The team highlighted a problem that they had in accurately measuring gas flow because of changing density, so much so that they now extracted a sample to measure its' density. They then used the density measurement to apply a correction to the flow measurement. It was pointed out and agreed, that if the instrument just described could be applied to this flow measurement, this would overcome the problem.

2. The second type of flow measurement instrument is the "segmental Wedge". This is an intrusive device. the pipe section being formed into a wedge shape. The wedge section is coated with special materials to reduce wear. The pressure drop across the wedge as measured as with an orifice plate. It offers advantages over the orifice plate in terms of robustness and wear. It is being used successfully on many applications including coal slurry and tar sands. It offers cost advantages over the first instrument described but it does not give mass flow.

I tabled and left the following data, technical literature specifying the two types of configuration available i.e. Integral flow element with d/p cell. Wedge flow element with remote sensors and d/p cell.

A budget cost for each unit was given for guidance purposes, together with the name and address of the Company agent in Poland.

3. Flow measurement using Ultra Sonic techniques was raised and discussed as to whether or not they could be used for some of the more difficult measurements on the P.D.U.

These techniques do appear to be attractive but as I pointed out applications are limited by pressure and temperature. I described some of the applications that I had been involved in, some not very successfully.

I tabled technical information on an ultrasonic on/off level detector with a temperature limit of 250°C. A slurry, sludge and suspended solids system which is non-intrusive i.e. the sensor is clamped to the outside of the pipe. Its' temperature limit is 150°C. Information on a flow measurement system was also tabled.

I pointed out that the data tabled had been supplied to me by a company specialising in this field and they had many years of experience in applying this technique. I also provided them with the name and address of their agent in Poland.

## D. Density Measurement

As the subject of density measurement had been raised in our earlier discussions, I outlined a density measuring instrument that had been successfully used for many years for gas density measurement. Its' operating range limits its' use but on the right application it is very reliable.

This instrument is also non-intrusive and operates on the principle of vibrating a tube at its' natural frequency. If the density of the material passing through the tube changes, this will change the mechanical damping and hence change the natural frequency of the tube. This change in frequency is measured and is directly related to the density of the material.

I tabled and left technical literature on the specification for the equipment as well as a price list and the name and address of the Company agent for Poland.

## E. Temperature Control of Distallation Column

One of the problem areas on the 80 kg/hr P.D.U. is the temperature control of the Distallation Column, where the accuracy of control is not up to the requirements.

The temperature measurement is in a hazardous area and the only equipment that the team have available that is suitable for receiving the temperature signal is an explosion proof e/i convertor giving an output of 4-20 mA. This signal is then fed into a further convertor giving an output of 0-20 mA. This signal is in turn fed to a third convertor to finally produce a pneumatic signal of 0.2-1 Atmosphere which is then used as the input to the controller controlling the steam heating to the Distallation Column.

The accuracy of control suffers from the seriesing of the three convertors, as will the system response.

The barrier techniques discussed on my previous visit had been considered as an alternative to the existing system. Attempts had been made to feed the temperature signal via a barrier directly to a final convertor. The team were having difficulty in identifying equipment suitable for this approach.

I promised to follow this up on my return to England.

## F. Data Logging

Discussions were held with the staff involved in introducing a data logging and computing facility into the Institute. It appears that the requirements that they are considering covers two quite separate applications.

The first requirement is aimed towards a computer system that could be used for general engineering design, calculations and/or analysis of data from other areas of activity at the Institute.

The second requirement was to have extra facilities so that data could be received from the 80 kg/hr P.D.U., processed and then fed to the computer via a suitable interface. It was suggested by the team that by purchasing a locally produced system of I.C. boards to provide, for example, input ranging, sampling, A to D conversion and control, signals from the P.D.U. could be fed via this system of I.C. boards, to the computer to provide a data logging and acquisition facility.

It was further suggested by the team that the computer would be an "IBM copy" available from a Far East Country.

The main reason for this approach was financial, as if the I.C. boards were made locally no hard currency would be involved. The "copy" computer would be much cheaper than the real thing.

I stated that while recognising the financial aspects, I could not recommend this approach on several grounds as follows:-

i) They were in effect proposing to build a "special" and were going to proceed into the field of high technology electronic engineering. I pointed out the many areas where the established companies in this field had spent considerable design and developmment effort over a period of many years. These efforts covered areas such as A to D conversion, interference limiting techniques, switching and sampling, timing and synchronisation. To attempt the design and development in these areas would require a high level of technical involvement by the Institute and would be very time consuming.

ii) In the event of problems with the system, the problem of establishing responsibility due to the involvement of more than one company in the manufacture and supply, could be a serious one.

iii) Due to the above, it would be very difficult to get manufacturers support in maintaining the system, putting a further strain on the technical resources of the Institute.

iv) As this was their first venture into the field of data logging, I considered that their proposal was much too ambitious.

In my opinion a commercially available dedicated simple data logger should be considered for the P.D.U. As a first step the engineers and scientists involved in the P.D.U. project should meet and decide what data they required logging, how they required the data to be presented, what manipulation and calculation of the data was required. From this information a specification could be drawn up establishing the number of signals to be logged, their type and the expected range of the signals. With this specification consideration could be given to a commercial data logger system that could meet the requirements. I stressed that at the earliest stage possible, potential suppliers of any equipment should be invited for discussions.

I tabled information on a typical data logging system, together with tehcnical reports on various aspects of logging associated with the system. These covered, familiarisation, process control, scanning, A to D conversion, interference and 3 wire strain gauges. A price list and the company agent was also tabled.

I pointed out that there were many other companies who manufactured equipment that could be suitable, but I had tabled this information as I had been responsible for buying and installing various types of data logging equipment manufactured by this company over many years and they were leaders in this field.

At a further meeting, the team members responsible for the data logging aspects, tabled documents, for my consideration, showing the preliminary work that they had done on their "special system". I reiterated my previous views and stated that I could not support this approach and would not recommend it.

I raised the question of the Hewlett Packard approach that they had proposed on my previous visit. This consideration had now been discontinued as the unit was now approaching obsolescence and spares were becoming a problem.

## G. Material Balances

This is an important requirement for the project and was discussed at great length. I pointed out that it was essential that instrument measurements were made at the appropriate points on the P.D.U. such as slurry in, hydrogen in, recirculating gas etc. Accuracy of measurement achievable in these areas was discussed and accuracies over short term periods, in the order of 1% were hoped for. I expressed the view that in my opinion this was not achievable, particularly due to the pulsating nature of the flow in some areas due to the action of the appropriate pumps. I suggested that material balances should be considered over longer periods of time and the instrument readings integrated over this period of time to improve the accuracy.

## H. Chromatography

The on-line measurement of gas composition is a further requirement of the P.D.U. I pointed out that this was a highly specialised area of instrumentation and I tabled information on a process gas chromatograph that I was familiar with and which was used in liquefaction type plants.

The information supplied covered a range of equipment covering detectors, ovens and controllers. An application questionnaire was also included. A very important area is the design and engineering aspects of the sample system associated with the chromatograph and I tabled drawings of typical sample systems, both manual and automatic.

I recommended that they used the questionnaire to the full and discussed their requirements with this specialist company should they intend to proceed further.

I was questioned on the use of this equipment as a control media and I hastened to point out that it was not a controller in any form. I then explained its' method of operation and the time aspects in the making of the analysis, with particular reference to the column. This time element made it unsuitable for control purposes.

The problem of measuring the Hydrogen content in the recirculating gas was raised and it was suggested by one member of the team that by measuring the density of the gas he could directly establish the percentage Hydrogen in it. Although this might give a guide, I questioned the accuracy because of the other constituants in the gas and their concentration.

I promised to look into this requirement of measurement of Hydrogen in the circulating gas on my return to England. I did mention the use of N.M.R. for Hydrogen measurement, but pointed out that this was only available for laboratory use.

## J. Implementation of Recommendations from First Visit.

At my final meeting at the Institute, I questioned the Directorate and staff on what action had occurred with reference to the recommendations that I had made on my previous visit.

I was informed that they were under active consideration and in some cases, points that I had made had been followed up, such as in the use of "barriers". Difficulties had been experienced in applying this technique, as reported and I had already promised to supply them with further data to assist them.

Improvements to the level of staffing of the Instrumentation Department had also been undertaken, but only to a limited degree because of the problem of attracting staff.

Where the recommendations involved modifications to the P.D.U. this raised serious financial implications and delays which I fully understand and appreciated. I did point out that if my first visit had been undertaken when the P.D.U. was still in the design stage, the financial ramifications would have been greatly reduced. A simple example of this is in the case of accommodating duplex thermocouple wells in place of single wells, for data logging purposes. At the design stage this would have resulted in minimal cost increases. To implement this now meant modification to the plant resulting in higher costs and time delays.

In the case of the recommending of instruments, if these were not available in Eastern Block Countries, hard currency was required and this was a major problem.

## APPENDIX

Senior Members of staff met on visit.

CENTRAL MINING INSTITUTE

Mr J. Maloszewski - Director

Mr A. Goszcz - Deputy Director

INSTITUTE FOR CARBOCHEMISTRY

Prof. M Ihnatowicz - Deputy Director

Prof. Y Kulozycka - U.N.I.D.O. Co-ordinator

Eng. J. Swiadrowski - P.D.U.

Eng. T. Gabrys - Mech. Engineering

Eng. M. Krzyminski - Material Preparation

Eng. B. Kiecka - Design

Mr. W. Szczepanczyk - Instrumentation

Mr E. Jedrysik - Data Handling

Mr M. Pawlowski - Data Handling