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January 1986

RESTRICTED 15415 ENGLISH

Republic of Korea.

DEVELOPMENT OF

FLUIDIZED BED COMBUSTION BOILER,

DP/ROK/82/029

REPUBLIC OF KOREA

Technical Report *

Mission 23 December 1985 - end January 1986

Prepared for the Government of the Republic of Korea

by the United Nations Industrial Development Organization

acting as executing agency for the United Nations Development Programme

Based the work of Brian Locke,

expert in coal p: ssing and new energy technologies,

such as fluidized bed combustion and gasification

United Nations Industrial Development Organization

Vienna

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I EXPLANATORY NOTES

During the mission the Won stood at approximately

1300 to £1

885 to $1

Technical Abbreviations and typical meanings

FBC or fbc	- fluidized bed combustion
CV or cv	- calorific value of coal
PFBC or pfbc	- pressurized fluidized bed combustion
high rank (coal)	- anthracites - may be high or low grade
low rank (coal)	- lignites - may be high or low grade
high grade(coal)	- low ash (and moisture) content
low grade (coal)	- high ash (and moisture) content
bed	- the bed of burning coal (grate or fbc)
mbc	- multi bed combustion

Acronyms

KIER - Korea Institute of Energy and Resources

CSL - Combustion Systems Ltd - licensor of fluidized bed combustion technology from UK to the Huyundia Company in Korea

NCB - National Coal Board, UK, organizer of much fluidized bed combustion work

CRE - Coal Research Establishment of the National Coal Board UK

Unfamiliar Units

tph - tons per hour - for steam, or coal, may generally include long tons, short tons, metric tons unless specific accuracy is required

Btu/lb - for calorific values ≏ 0.55 kg Cal/Kgm

Language

English was used throughout the mission. Accordingly, although all the staff in discussions did well as English-speakers, and the author is accustomed to adapting from translated words, nevertheless it is possible that errors of fact or interpretation may have arisen. If any are pointed out they can be corrected.

II ABSTRACT

Title - Development of fluidized-bed combustion boiler.

Number - DP/ROK/82/029/11-53/32.1.I.

Objective - To assist in the development of a fluidized-bed combustion boiler for utilizing low-grade Korean anthracite.

Duration - One month overall.

Main conclusions and recommendations

1. The programme is worthwhile, and its results should be of value to Korea's continuing industrialization.

2. The particular purpose - to develop technology to burn one of the most difficult of all fuels (Korean high-ash anthracite) - should also, when realized, be of value economically to the nation as well as commercially to industry and for export.

3. The programme should be encouraged to develop along the lines recommended as regards overcoming the technical problems that had caused concern (e.g. coal feeding) - and also for all the other components of a development programme to provide designs and services for industry.

4. The Institute should work closely with industry, and also maintain its staff's valuable connexions abroad.

5. The work can be of use for other and imported coals, too, and need not be restricted to the originally-intended fuel.

6. A further assignment in perhaps a year's time would enable progress to be encouraged and the programme to be further developed.

C.1

III TABLE OF CONTENTS

		Page
I	Explanatory notes	2
II	Abstract	3
III	Table of contents	4
	Introduction	6
	Summary of Recommendations	8
IV	Activities and output	10
	A - Objectives, duties and job description	10
	B - The work	13
	C - Findings, observations and results of the activities	14
V	Seminar notes - UK fbc work	15
	- UK coal utilization developments	16
	- Energy conservation and management	18
	- Coal processing (with addenda on lignites, 10MWe cogeneration and 20 tph boiler)	20
VI	Programme Considerations	25
VII	Recommendations - preliminary	30
	- specific	31
	- process	32
	- system	33
	- components of a development programme	34
	- general	36
VIII	Conclusions	37

TABLE OF CONTENTS (Continued)

ANNEXES

1. People met

2. The KIER establishment

3. Chronology of the mission

4. The KIER fbc work

5. Photographs of the pilot plant

6. Fbc slides for seminar

7. National Coal Board films (16mm sound): Sheffield University fbc film (VHS video cassette)

8. Current papers describing the present coal utilization and fbc position in Britain - used in seminars and left with KIER

9. Papers outlining the background to fbc and its bases - a brief selection - used in seminars and left with KIER

10. Papers by Brian Locke on recent aspects of gasification - used in seminars and left with KIER

11. Energy conservation and management (notes by Brian Locke)

12. Outline of coal pelleting tests by the National Coal Board and the California Pellet Mill Co. of UK

13. Dust separators for flue gas - discussed in seminars

14. Papers by Brian Locke on innovation and process development - a selection

15. Huyundai Heavy Engineering Co Ltd (visit notes)

INTRODUCTION

Energy bought from abroad costs nearly 6 billion $ p.a., and represents a quarter of all import costs. These figures will probably rise as the economy catches up again with the growth planned for it. Of the total energy usage, Korean anthracite represents perhaps a third, today, and from mines that are becoming ever deeper (and more costly) in the search for workable seams. Less than a third of Korean coal output is mechanized, and the government hopes to raise this to 36% during 1986, 57% by 1991 and 69% by AD2000. (By comparison 94% of UK output is mechanized). The more Korean coal used, the better for the Korean economy, as import costs tend to rise, more energy is needed, and rising productivity generally reduces the labour force.

The four developments to aid the nation's energy expansion are in nuclear power development and in oil (and liquefied natural gas) importation, and two concern coal. The government plans to double the use of coal for power generation, to 19% in 1991, and also to provide for a considerable increase in the use of briquettes for domestic use. Then, as the fourth development, there is fluidized bed combustion that is perhaps the only, and certainly the best, technology for the use of Korean anthracite for industrial and power purposes.

About a third of Korea's anthracite production is of low-grade material - below 6,300 Btu/lb, and with ash contents up to the 70's%. Such material is almost impossible to burn economically in conventional boiler plant, but it can be burnt in specially developed fluidized bed combustion boilers, furnaces, and dryers. Boilers come first. Of course, better grades of coal (also oil, and gases) can also be burnt at high efficiency in fluidized bed combustion (fbc) plant.

KIER have a development programme to derive practical working design data for the fbc usage of this high ash low grade material. They have made a good beginning from its origins four years ago. In parallel, Huyundai Heavy Industries Ltd have two foreign licences for fbc plant from Ahlstrom, with which they have built a boiler at Inchon for low-ash imported bituminous coal (that is relatively easy to burn), and from Combustion Systems Ltd (CSL) that they will be using in their programme to burn Korean anthracite as well as imported coals. It will be important for the KIER researchers and the Huyundai licensees to work closely together, and also to visit Britain (and other countries as well) to see the very wide range of types, sizes, configuratic s and applications for fbc to industrial steam-raising and processing needs.

The present mission has been concerned partly with technology transfer in fbc; but also, and equally important, with inculcating some philosophy concerning the practicalities of process development and industrial application. In addition, KIER have been interested in other coal technologies (such as solvent extraction, briquetting, atmospheric pollution reduction, and ash utilization) as well as energy conservation and energy management in industry and in the nation. Assistance has been given on these topics as well as with fbc. The mission objectives were achieved, and, indeed, extended.

This has been a difficult time of year for the KIER personnel: they have been heavily committed by their obligation to produce end-of-year reports. Accordingly the author has adapted the timetable of his mission entirely to suit the KIER personnel. Examination of the pilot plant, the laboratories, and the establishment have all been fitted in with the needs of the KIER personnel, along with seminars on both general topics and detail issues, and with discussions with individual members of the staff who have wanted to discuss problems. Films and slides have been shown illustrating British work currently on fbc, coal utilization, and coal handling: and much literature has been left at KIER (appropriately annotated and collated) to cover the background and present position of the technologies in which they are interested.

Finally, as well as the four directions of energy development mentioned above, the KIER interest in energy management and conservation, and in reduction of atmospheric pollution, are worthy of government action and support in the national interest.

The KIER programme is well conceived and the author is glad to have the opportunity to assist in its development.

SUMMARY OF RECOMMENDATIONS

Recommendations were made under six headings:

1. Preliminary - concerning the engineering, operation, maintenance, development and recording of the plant.

2. Specific - concerning coal feeding problems, equipment drives, and start-up.

3. Process - including freeboard height and gas velocity, cooling tubes, baffles, ash sensible heat recovery, fines recycling, tube metallurgy and layouts.

4. System - including distributor plate configurations for preventing stone build-up, multiple beds, circulating beds, feed classification, combustion chamber shapes, and gas cleaning.

5. Components of a development programme for fbc - a logical approach to a comprehensive programme aimed at providing design and test data for boiler and power plant for different coals, markets and applications, and environmental issues.

6. General - covering economics, relations with industry, laboratory equipment and other facilities, and information concerning work elsewhere in the world - including foreign visits to stimulate progress at KIER, and a visit to KIER in 1987.

The recommendations naturally overlap: they are laid out in detail in the body of the report.

There is no hard and fast "order of priority" for the recommendations, they are presented here in a logical order starting from the plant itself and proceeding through the principles of the work, to its overall purpose and related issues.

The results of the whole programme should, and it will take time, be realized in the form of design data available to, and services provided for, Korea's boiler-making industry. In parallel both coal mining and coal-using industry should benefit from the improvements in the technology of using the difficult fuel concerned (high ash anthracite) and also other imported coals. It will be important for KIER to continue to work closely with industry.

IV ACTIVITIES AND OUTPUT

A. Objectives, duties and job description

Basically

The long-term objective of the project is to reduce the dependence of the Republic of Korea on foreign supplies of energy (oil and natural gas) through scientific research and experimentation into combustion techniques of lower grades of anthracite coal, a natural resource found in abundance on the Korean peninsula.

The immediate objectives of the project are:

1. To further KIER's technical capability by introducing its staff to the most recent scientific advances and techniques in properties analysis and utilization of coal.
2. To establish the economic feasibility of the various coal technologies either singly or in combination with one another and/or other energy sources,with special consideration of the Korean pattern of energy use.
3. To associate KIER's research results more closely with the coal and other related industries to encourage commercial application, and thereby benefit both producers and consumers.

The expert was assigned to Korea Institute of Energy and Resources (KIER), Ministry of Energy and Resources, and, in consultation with the Korean authorities he will be expected to assist in the development of a fluidized-bed combistion boiler for utilizing low-grade Korean anthracite.

Specifically he performed the following tasks:

1. Reviewed the coal and ash handling systems of a fluidized bed combustor (1 ton/hr steam generation) and recommended modifications, where necessary, for improvement of the system.

2. Checked the two coal feeding methods used in the KIER fluidized bed combustor: over-bed gravity feeding and under-bed pneumatic feeding. Recommended modifications for the KIER coal feeding methods.

3. Introduced modern techniques for the pneumatic coal transportation and advised on appropriate pneumatic transportation method for the Korean anthracite coal.

The expert submitted a brief report on his findings during the assignment at KIER and on recommendations for activities to be carried out at KIER after his departure.

Additions

It was also requested by telex that the following items be covered:

"a) The status of research activity of the National Coal Board, the British Coal Utilization Research Association, and Combustion Systems Ltd.

b) Basic design of a 20 ton/h steam generating fluidized bed boiler, particularly for fuel of high-ash anthracite (60-70%).

c) System design of small power-generating cycles with fluidized bed combustion boiler - around 10 MWe."

Then, on discussion with those concerned, and as outlined in KIER technical papers about their equipment, the following specific matters were of concern:

d) Whether to feed coal from above the bed, or into it from the side or below.

e) Whether to recycle fine carry-over material, and, if so, how and where.

f) How to reduce elutriation and carry-over.

g) How to reduce accumulations of stone on the distributor plate.

h) How to reduce the amount of fines in the coal, or reduce their effects.

i) How to prevent condensation in the coal feed screw conveyor.

j) How to prevent gas flow outwards during ash removal from the bed - and the consequent upsetting of fluidization and of bed conditions.

Also, it appeared that, as well as in-section discussions and seminars on the plant, its problems and the programme for the way ahead, three more general seminars were desired.

k) U.K. coal utilization developments.

l) Energy conservation and management.

m) What to do with coals generally whether low ash bituminous (imported) or high ash anthracite (indigenous) - gasification, briquetting, smokeless fuels, chemical syntheses &c - including the implications of importing lignite or other coals from Indonesia and Pakistan, and how best to use them.

B. The Work

People met are listed as Annex 1.

The Establishment is summarized as Annex 2.

The cnronology of the mission is shown as Annex 3.

The past work and the pilot plant are described in papers (Annex 4) that were read and discussed with the staff.

The pilot plant was visited frequently - and indeed other sections of the KIER work were also seen. The pilot plant was also seen operating: and photographs of it, and of the damaged star valve coal feeder form Annex 5.

Discussions were held with individual members of the staff, and with groups - to elucidate problems, their causes, and means to their solution, on fluidized bed combustion and other matters too. These discussions and section seminars covered items b) - k) on p.11 & 12.

Seminars were held on the topics requested (see p.11 & 12) and their outlines follow. These covered items a), k), l) and m) on p.11 & 12.

Annexes 6 and 7 list the visual aid material.

To back up the mission discussions, technical papers and other background material were left at KIER, including papers in the following categories:

1. The present coal utilization and fbc position in U.K.
2. The background to fbc and its bases.
3. Recent aspects of gasification.
4. Energy conservation and management.
5. Outline of coal pelleting tests in the U.K.
6. Dust separators for flue gas.
7. Innovation and process development.

These constitute Annexes 8 to 14.

The Huyundai Heavy Engineering Co. was visited. The visit notes constitute Annex 15.

C. Findings, observations and results of the activities

1. The pilot plant is of sensible initial design, and competently built.

2. The development staff is of good quality and they are learning to work together as a professional operating/development team.

3. The purpose of the work is well chosen to contribute to the energy development needs of Korea.

4. The background facilities - laboratories, workshops, literature from around the world, and general experience of current work in other countries - are all good.

5. Observations concerning details of the pilot plant, its operation, and on its programme of experiment and adaptation, constitute the sections on Programme Considerations and on Recommendations (q.v.).

6. The pilot plant was built using some of the know-how and experience deriving from work in Britain, within the general ambit of Combustion Systems Ltd and the National Coal Board. In Britain there are over one hundred commercial projects in fluidized bed combustion, comprising installations with a total thermal rating of some 900 MW.

   It would be useful for persons from the directorate, and the project leader and some of the staff, to visit Britain to see some of the present activities and discuss future developments. The author would be very happy to make appropriate arrangements.

7. High ash anthracite is one of the most difficult fuels to burn effectively and fluidized bed combustion is certainly the best industrial technique to use such fuels. Even so, there will be much work to do, both in KIER and jointly in conjunction with boiler-makers and plant users. The programme is worthy of encouragement from the top.

8. The staff have gained valuable experience by having been able to present papers at foreign international conferences. It would be useful for them to be encouraged to continue this practice.

V SEMINAR NOTES

SEMINAR NOTES - UK fbc work (7 December)

UK work on fbc began in the 1960's, following on from a variety of initial approaches for different purposes in the previous decade. The first operating boiler was set to work in 1969 and was used for experimentation (and rearrangement of components) as well as providing steam for the establishment (the British Coal Utilization Research Association).

The slides listed in Appendix 6 were used to illustrate different lines of development of shell, water-tube, and hybrid boilers. Dryers, incinerators and calcinders were also described, along with the differences of design and system that different applications indicated.

Most UK industrial coals are washed and graded, and the implications of rank, grade, size consist and other characteristics of coal, upon fbc design and operation, were discussed - as also turn-down, load following and controls, ash discharge, stone removal, and feeding systems.

The implications of Korean coals were discussed.

SEMINAR NOTES - UK Coal Utilization Developments (17 December)

Output - some 110.10^6tpa deep mined - plus open-cast: plus small amounts from licensed mines and recovery from dumps.

Domestic and Industrial coal - washed and graded. High rank for domestic use. Special pricing systems.

Power Station coal - higher ash - special (different) negotiated prices.

Financial inducements for conversion to coal firing.

Coal Ranking System - high rank through to low rank.

Delivery - special systems - merry-go-round trains to power stations. Tipper, and conveyor, and pneumatic trucks.

Stock piles and bunkers/silos at customer sites.

Handling on site - vehicle systems, gantries, surface-charged filled by trucks, pneumatic handling (dense phase; lean phase according to need) to service hoppers and bunkers. Elevators, conveyors, vibrators.

Usage on site
- boilers - shell, water-tube, sectional, magazine
- pulverized fuel - for boilers - or octopus for kilns
- stokers - chain, spreader, coking, overhead (Vekos), underfeed, gravity
- fluidized bed combustors - for most types of boiler, dryers, kilns (clay, grass, stone), air heaters. - a total of 900 MW plant installed and on order.

Ash handling - pneumatic, conveyors, skips, water systems (conveyor draglink), vibrators, also cleaning by vacuum systems

Technical advice - from architects' manuals to on-site visits.

Research & development - Fludized bed combustion - continuing work on all the types and systems, including pyrolizer and multisolids (of interest for anthracite) for both boilers and furnaces in UK and abroad. Much work on high ash content materials, grit refiring, flow disruptors, and nozzles. Also fluidized gasifier systems, 12 tpd.

- Conventional combustion - different de-ashing systems, vibrators.
- Coal/water mixtures - 2 tph.
- Many domestic boiler systems for simpler and cleaner operation.
- PFBC - power - combined systems.
- Pollution issues, use of ash (cement, brick), chemicals, cokes, solvent extraction (2.5 tpd) pyrolysis, catalysis.

Most of this work is done and managed by the National Coal Board, in its own establishments or by contract (often joint) elsewhere. The NCB now incorporates the British Coal Utilisation Research Association.

Dec. 1985

SEMINAR NOTES - Energy Conservation and Management (18 December)

Five components 1 - realizing the need e.g. the very existence of KIER
2 - stopping waste - short term measures
3 - process rearrangement - medium and long term
4 - designing new plants and processes
5 - policy and government leadership

1. In Korea the lack of oil and natural gas and bituminous coal, the need to develop nuclear power and uses for high-ash anthracite, all while developing industry and society, show the need for ever-improved efficiency. Importing energy costs money - it is bad to waste it. KIER is basic in the campaign. Energy Managers are another component.

2. Lights left on, doors left open, heating or air conditioning unnecessarily used - all waste money. Why tear up 10,000 Won bills? One may be accustomed to cold corridors in laboratories, for example, but they are paths for leakage of heat expensively provided inside the rooms, and by the systems using solar heat. Steam, power, water, compressed air - are all energy: and leaking steam traps, broken lagging, dribbling valves - all waste it.

3. Energy audits can show where the paid-for energy goes in a works, or hospital or laboratory, or workshop or hotel. Each section can then be tackled. Approaches can include - adjust each plant item to work at optimum efficiency; recycle hot air, waste waters, hot-product via heat exchange systems to heat incoming cold materials; improve the vacuum in power plant condensers; use back pressure turbines instead of reducing valves in steam systems; reduce the percentage of waste product by improved quality control; incinerate (or digest) garbage and the (irreducible minimum of) waste products to recover the energy.

4. On newly designing a system there are many opportunities - reconciling production efficiency of plant items with mechanical and thermal efficiency: designing for energy recycling so as to minimize energy inputs and outputs even though the instantaneous energy inventory may be high; lay out buildings and production lines, along with power loads, for "energy flow" including zoning, load factor

optimization, computerized control; "designing out" components liable to misuse (compressed air especially); matching market potential fluctuations to capacity of sections of plant. Use new processes, e.g. fbc. Integrate the system design for energy use.

5. Statistics, services, education, publicity, publications, Energy Manager stimulation, targetting, monitoring, incentives, legislation, lists of equipment makers.

6. "The Energy User's Data Book" (edited by this author) containing practical data for energy utilization and efficiency surveys and audits (especially in industry) was copied in its entirety, by KIER.

SEMINAR NOTES - Coal Processing (gasification, briquetting, smokeless fuels &c) (18 December)

In combustion the aim is simple - to burn the burnable material in the easiest way for the characteristics of the coal concerned - rank, moisture, ash &c, in the cheapest plant, with minimal environmental damage.

In coal processing the aim is to separate the hydrocarbons from the ash and the moisture, and either to separate one hydrocarbon from another, or to react the hydrocarbons suitably to produce quite different products - e.g. plastics.

In briquetting and smokeless-fuel-making, the processing is simpler - aiming at a lump product.

Gasification can be in fixed bed, fluidized, and in suspension: and reacting below, or above, ash fusion temperature: and with air alone, air and steam, or oxygen and steam; and large scale or small scale - according to the use for the products - furnace gas, power, synthesis for CH_4 or synthesis for chemical feedstocks - CH_3OH, NH_3, H_2, or Fischer Tropsch. The aim is a $CO+H_2$ mixture, purified for further processing or power use.

Other process routes include hydrogenation (Bergius) - work done in Korea, amongst many other countries - and solvent refining - with many scores of different process arrangements and combinations. Much recent laboratory work has been done over the last 15 years, but there are no large real prospects immediately in view today. NCB(UK) has a 0.5 tpd solvent refining rig now well characterised for operation and products and is building a 2.5 tpd plant at a colliery - for transport fuels notionally.

Briquetting starts as the simplest processing techniques - binderless or with binder (pitch, bitumen, sulphite lye, starches) with various types of press making discrete or continuous product. Some briquettes can be "desmoked" - in hot air - e.g. fluidized sand: or carbonized in retorts - e.g. Phurnacite for very special domestic usage

Fluidized carbonisation is used to "desmoke" coal particles in a low partial pressure of oxygen: thereafter they may be briquetted either as they stand, or mixed with a "binder" coal, to make very reactive briquettes for smokeless domestic use.

Pelleting is a more modern term, involving agricultural livestock feed processing machines, generally with lower pressures than for briquetting - multiple extrusions through a perforated (sometimes rotating) ring. This should be cheaper; and the product is smaller in cross section than briquettes. (Some samples available for demonstration - and left at KIER).

Ash content implies two basic types of processes - low ash (well under 20%, say) and the developments in Europe and USA all apply: high ash, and ash considerations may dominate the process and the product. An example is the Yontan briquette where the high ash residue is solid and the same size, shape and configuration as the original briquette - compared with other briquettes or pellets where the ash is a low-volume powder.

Imported coals may impose or offer additional process aspects - bituminous coal is of higher reactivity, easier to burn; by products are a possibility in processing. Pyrophoric tendencies may suggest processing at the mine. Sulphur content will require limestone for combustion to minimize atmospheric pollution.

Addendum - Pakistan or Indonesian Lignites - briquetting or combustion

a) Briquetting

- a) Many lignites can be briquetted without a binder, which saves costs.

b) Lignite briquettes will not require holes through them for combustion surface, as do Korean anthracite briquettes, as the coal is sufficiently reactive.

c) Some lignites, e.g. some of those in Pakistan, contain sulphur. That sulphur cannot cheaply be removed from the fuel, so it may be possible to retain it by adding limestone. (See below).

d) Some lignites, e.g. some in Indonesia, are pyrophoric, and would cause fires in ships. So it will probably be best to process them at the mine - and to allow time for sufficient surface oxidation to reduce the likelihood of fires.

e) Lignites will need a properly designed stove to burn smokelessly. Alternatively the material, or the briquettes, may be "desmoked" (see above) but this adds to costs.

Note on Sulphur. If there were, say, 4% S and no calcium oxide (or hydroxide or carbonate) in the ash, and using a Ca/S ratio of, say, 2 then $4 \times 2 \times 40/32 \simeq$ 10% limestone calcium, or 25% limestone addition, on coal weight. Experiments would be required on briquetting and on burning. That figure should be a worst case.

b) Combustion - raw - a) Lignites should burn easily on most sorts of combustion equipment, allowance being made for their reactivity and friability.

b) If the lignite contains sulphur then ordinary combustion will usually require SO_2 "washing" (which might be dry, e.g.NIRO) in most countries today.

c) It would be cheaper to use fluidized combustion with limestone addition to the bed.

c) Power Plant 10MWe - There is much operating experience with single water tube and coil-type boiler units at 100,000 lb/h steam. This will produce some 10 MWe; with the option of back pressure process steam as well, in a cogeneration system, for lower power output.

d) Cogeneration 10MWe- With steam at 600 p.s.i.g. 700°F (c.200 deg F superheat) some 25 lb/h would be needed per 1 kW turbogenerator output, if the back pressure were 50 p s.i.g. for industrial process use or for district heating. (No condenser would be involved). So 3 x 85,000 lb/h boilers would be needed. This is well within the range of long-term operating experience of fluidized bed combustion boilers of the water tube or coil-types. Lignite could be used directly: for anthracites adaptation would be required - no problem.

f) 20 ton per hour boiler - A 20 tph boiler for lignites could be supplied "from the catalogues" of a number of existing boiler manufacturers.

For high ash anthracites, a system would need to be derived - because it is really ash that is handled, from which a small amount of coal is burnt off: whereas with most coals, it is the coal that is handled, from which a small amount of ash is deposited.

In view of the burn-out time likely to be needed, (and this will almost certainly require recycling or circulation for the finer particles) the system will probably end up as a circulating system (e.g.multi-solids such as Foster Wheeler UK develop); or else multi-bed system where fines carried up from one bed can be caught for burn-off in the second (upper) bed (e.g. the system that ASEA/Stal develop). There are other directions for design, such as the rotating fluidized-bed combustor, or the cyclone furnace, but these would require departure from the line of development so far (and rightly) followed by KIER.

The proportion of burn-out in the different components of such systems as suggested, will depend on the likely range of size consist for Korean anthracites in the foreseeable future. The intention to mechanise more faces in the future should be taken into account in forecastin

Cooperation with boiler-makers will be desirable.

The author will provide general flowsheets for the 10MWe and 20 ton/h systems of interest.

VI PROGRAMME CONSIDERATIONS

Initially

The programme has begun well, and can usefully become the experimental counterpart of the Huyundai activity on a practical boiler-making scale, operating under the CSL (and possibly other) licence(s). The 0.1 tph steam, and 1.0 tph steam units followed successively from laboratory bench scale and rig work. The staff have attended international conferences (except in Britain) and have presented papers on their work. There has been some contact with Leeds University in Britain - but apparently not with other Universities pre-eminent in fluidization and fluidized bed combustion, such as Aston, Birmingham, Cambridge, London (University College, Imperial College), or Sheffield. There has been wide reading and a good collection of relevant literature.

The 0.1 tph and 1.0 tph units were designed for different types of investigation and are complementary: the former has in-bed cooling, and the latter has water wall cooling, and both can recycle fines. A cold model is at present being constructed, that will allow investigation of circulating systems.

In the work so far the aim has been to reach the maximum overall combustion efficiency by recycling fines in the 0.1 tph plant. Fines have built up to such an extent that the total solids inventory has been up to 3.5 times that designed, based on the coal feed (i.e. the recycle rate was up to 2.5 times the coal feed rate). Under these circumstances the plant has really been a form of circulating system, with a very high freeboard dust loading. This experience will be useful in conjunction with the cold model results.

In addition to studying variables during build-up conditions, it will also be desirable to study one variable at a time, keeping others basically constant (or relatively constant). These matters appear under the heading "Recommendations".

At present there are a number of general points that were apparent about the pilot plant, its maintenance and condition, and its operation - and these have been discussed in detail with the staff and they appear in the chapter on Recommendations, under sub-headings Preliminary and Specific. As just one example, the operating run begun on 4 December had to be shut down when a coal feeding star valve seized and the drive shaft sheared. On dismantling, a 30mm piece of stone was found jammed inside, and also the cast iron outer casing of the valve had been ruptured. Actually this breakdown merely confirmed the need to implement one of the recommendations that had already been made earlier that day, concerning overload protection.

In discussions with the staff the point has been made that the recommendations should also help in enabling minor repairs to be made rapidly during a run, so that the plant will not so frequently have to be shut down when detail problems occur. Costs will be saved too. There is no point in going into minutiae in this report - the points have all been discussed and well taken by the staff, with sketches and descriptions of what is needed.

<u>In future</u>

As regards the development of fluidized bed combustion, there will need to be experiments in many different directions so as to build up a body of corporate operating experience, know-how and "feel" for the plant and its characteristics and potential. It is unlikely that the plant itself will remain unchanged, and merely be used for study of operating variables in its present state and configuration. Indeed an operating boiler would not be a scale-up directly of either the 0.1 tph or the 1.0 tph rigs. The plant is an experimental rig and will be expected to develop as experience is gained.

There are two aspects of experimentation related to what may be called the process and the system.

(i) As regards <u>the process</u> there will be a number of lines of experiment aimed at improving performance of the plant in its present basic configuration. These include varying gas velocity, freeboard height, and also adding baffles (or tubes) in the bed and in the freeboard, to reduce the amount of bed material deposited directly into the boiler fire-tubes as large bubbles rise up unopposed. As one concomitant, the boiler water level, and, of course, the combustion chamber pressures, both fluctuated violently during the run that was seen. Control of combustion chamber draught (balanced or slightly negative) would lead to more stable conditions throughout the plant and improve the accuracy of use of instrument readings.

The carbon in cyclone dust represents perhaps a quarter to a third (w/w) of the carbon in the coal feed as the cyclone dust contains 30+%C. It will be important to make use of this calorific content. The first approach will be to recycle the fines, and this can conveniently be done using the under-bed injection point intended originally for coal feeding. Indeed it will be worth experimenting with separating the coal feed into two fractions (perhaps over, and under, 2mm) and feeding the larger at the side as now, and the smaller, along with cyclone dust, from below (which is also a matter for consideration under the heading "System").

Also, with such high proportions of ash (c 70%) it will be desirable to recover heat from it. At present it seems that the carbon content of ash discharged is about 1%, making that amount of carbon perhaps 2% (w/w) of the carbon content of the feed coal. This is less important as a system-loss than that of carbon in cyclone fines. Also the bag house dust (5% of coal fed w/w) at 14-18% carbon represents only some 2% of carbon fed as fuel. These smaller losses can all be considered in due course, and the ash sensible heat loss can be relatively easily recovered. A fluidized hopper could be used, with air destined for combustion - which would be preheated, with some provision for possible final burn-out of carbon. Alternatively there could be water cooling tubes for preheating water destined for the boiler. These issues have all been discussed.

Matters such as these should be tried out on a bench scale first, before making changes to the plant. For example the residence time/temperature/O_2% relationships can be determined for recycle dusts, ash &c. Related to all this is the need to experiment, first on a bench scale and then on the plant, with different alloys for cooling tubes, nozzles &c.

(ii) As regards the system there will be different types and shapes of distributor plate to try out, so as to reduce the problems of build up of stone particles. The ash content being high, stone will accumulate,and will not be removed down the ash drain - except for a small area around it. Some slope will be required, and various configurations were discussed and sketches were shown.

Then there is the whole matter of fine material, and both circulating systems (e.g. "multisolids") and multiple beds (e.g. "mbc") will need to be considered along with the concept of having two fractions of feed coal - fines and "ordinary" coal fired in different beds, or even different boilers, and different gas cleaning equipment. The matter of combustion chamber shape will also need consideration when the previous matters have been thought out. All these issues have been introduced, but going through their implications will take time.

(iii) Most important is the development programme. Design and operating variables will need to be investigated on the plant as it stands (modified as to practicalities as recommended) - and the variables will include fluidizing velocity, excess air, combustion temperature, coal size distribution, burning rate, bed height, recycle rate and coal feeding point location. Relationships will need to be established for one chosen coal; then for other coals that could usefully include imported bituminous coals.

The plant will need to be modified in the light of experience as time goes on, and according to factors that may be introduced such as economics, or coal supply changes.

A basic purpose of such a plant is to derive design data, and these are in general terms, and to answer specific questions such as may be asked by a boiler manufacturer, e.g. Huyundai. It will be desirable to work closely with the Huyundai developers and designers in two-way communications - each side can help the other to the common good. It will be useful too to visit and work on fbc plants installed in industry. These issues figure in Recommendations, and have all been discussed.

Finally there are two matters

a) Economics. This programme is important in that energy imports represent a quarter of all Korean imports and cost over six billion $ per annum. By contrast indigenous coal output is perhaps a thirdof the total energy use. Development of uses for the anthracites under consideration should have economic effect out of all proportion to the cost of the work.

It would be useful to set up a small high-level group to study the economics of fbc plant; not only the background economics in Korea, but the whole technico/economics of the programme, the plants, and their effects.

There are many facets of useful work in this field: one, as an example, is the uses for ash, and the related matters of transport and the siting of plant. More ash is being processed than coal.

b) Facilities. Morefacilities will be required - extra laboratory equipment, more plant instrumentation, more visits by staff to international conferences and fellowships to foreign companies and universities. Perhaps there may be UN help with funding. The programme is important, and could lead to boiler exports too; so it would be bad for it to be short of the necessary facilities.

VII RECOMMENDATIONS

1. Preliminary

a) Set up safety procedures - both principles and practice. Prohibit smoking on the plant. Frame rules. Allocate responsibility. (Examples of the need were pointed out).

b) Set up maintenance procedures - both as a schedule of planned maintenance, and also as need arises. Allocate responsibility. (Examples of the need were pointed out).

c) Install steps at places where pipe cladding is now used for stepping on - and repair the damaged insulation and cladding.

d) Colour-code all lines, so that pipes can be easily distinguished - air, water, steam, exhaust gas, instrument air &c, so that the possibility of mistakes will be reduced.

e) Make rigid all the instrumentation lines wherever possible, and, preferably colour-code them too. Mixing plastic tube with rigid piping is not good practice.

f) Wherever changes are made to the plant, make them in such a way that further changes can be easily made. Replaceable sections, withdrawable tubes, adjustable mountings, interchangeable instrumentation and standardized flanges are just some of the points to bear in mind. An experimental plant is likely to require many changes.

g) Make sure that good records are kept of both maintenance and changes (including the reasons for the changes, and what happened). In due course, records of wear, corrosion and erosion &c will be needed too.

2. Specific

a) Install an initial screen for the hand-feeding of the first belt conveyor. That should help in removing unwanted material - first stage. This will prevent most oversize material from entering the system.

b) Install a magnetic collector* above the first belt just after the hand feeding screen (a). This will catch ferrous material that could do damage.

c) Install a small rotating trommel screen instead of the fixed attitude vibrating screen at the discharge of the coal elevator. This would be much less likely to blind than the present arrangement.

d) Install a magnetic collector* over the feed point from the elevator to the trommel (c). This will be a second stage protection from damage by ferrous material.

e) Install a coal hopper before the screw feed to the combustor and below the weighed hopper. Then the coal weighing can be more accurate; and also smooth out delivery to the screw feeder.

f) Wherever possible on high-load drives, install shear pins or shear keys: these can be replaced more cheaply and more quickly after overload than shafts or castings.

g) Systematize the start-up supplying of bituminous coal. Opening the top of the screw feeder to pour in small quantities of coal by hand upsets the draught and interferes with the smooth running of the system.

* Note - A proper purpose-made electromagnet collector - not just a small bar magnet.

3. Process

a) Experiment with increasing the freeboard height - at present bed material passes over the baffle into the boiler fire-tubes. The freeboard height is, of course, related to gas velocity and particle size.

b) At some stage experiment with cooling tubes in the bed (instead of some of the water wall surface) - and also with baffles in the bed, to break up the large bubbles now produced in the unobstructed bed. Note – the boiler water level fluctuates widely.

c) Experiment with baffles in the freeboard to help knock back carry-over and prevent it going upwards.

d) Experiment with a cooled ash hopper or collector - e.g. fluidized, and recovering heat in air destined for combustion, or via immersed water tubes (boiler preheat) or both.

e) Experiment with injecting cyclone fines below the bed through the entry originally intended for pneumatic coal feeding.

f) Experiment with control of draught in the system: a small negative pressure in the combustor would reduce the passage of combustion gas outward through the screw coal feeder. In the same way gas out-flow during ash removal, from the bed, would be reduced.

g) Experiment with (i) different tube materials as regards basic metallurgy and corrosion and erosion.

(ii) different layouts of tubes and other components liable to wear and erosion.

4. <u>System</u>

a) Experiment with different configurations of distributor plate and nozzle arrangement along the lines discussed as having been successful elsewhere. It will be important to prevent accumulations of stone from building up - and desirable to remove stone and ash continually in any working plant.

b) Experiment with multiple beds where fines carried up from a lower bed can burn-out more fully in an upper bed.

c) Experiment with circulating beds so that larger material can burn out in the fluidized bed, and fines can burn out in the circulation system.

d) Experiment with size-separating (classifying) the feed coal, and feeding larger material into the bed from side or top, and fines from below.

e) Experiment with the concept of two different boilers - one for larger material, and the other for fines.

f) Experiment with different shapes of combustion chamber - e.g. with a cross sectional area increasing with height.

g) Consider and test different types of gas-cleaning equipment, e.g. the Paladon.

5. Components of a development programme

(i) With existing equipment

a) with one chosen coal - ranges of operating variables - e.g. fluidizing velocity, bed temperature, recycle techniques, investigating, e.g. freeboard combustion and plant efficiency; heat transfer rates; sources of heat loss; elutriation and carry over; carbon also ash balances; sulphur retention, NO_x, heavy metals, dust and grit emission; signs of corrosion and erosion and any wear of refractories; effect of size consist of coal
- deriving relationships and optima.

b) with different coals - the above, and the effects of e.g. ash content, rank, size consist as they all interconnect
- also deriving relationships and optima.

c) modifying the plant - in the light of experience - e.g. altering combustion chamber geometry (perhaps as regards carry-over), adding baffles, extent and distribution of heat transfer surface (particularly as regards different ash contents), ash removal from the bed (and heat recovery), and better cyclones
- also deriving relationships and optima.

d) <u>deriving design data</u> - preferably in conjunction with boiler makers - studying problems they have in design, or operation, e.g. for scale up - e.g. location of coal feed points, disposition of heat transfer surface, recycle, ash removal
- market requirements, particularly for sales outside Korea
- check all inputs to control system design.

(ii) <u>With new equipment</u> - deriving from the above.

(iii) <u>On industrial plant</u> - deriving from the above.

(iv) <u>Other fuels, different purposes</u> (e.g. incineration, or power generation) other needs (e.g. dryers)

- according to requirement.

(v) <u>Variables for trials</u>, i.e. for virtually any stage of the programme where it is the actual fluidized bed combustion under examination (as distinct from ancillary issues), e.g.

a) gas velocity in the fluidized bed
b) combustion temperature
c) excess air
d) coal size distribution
e) load - i.e. burning rate
f) bed height
g) recycle rate
h) feeding point location

(vi) <u>In due course</u>

a) Uses and applications of ash should be considered and the related matters of transport and siting of plant
b) environmental requirements for exhaust gas should increasingly be studied.

6. General

a) Set up a technico/eonomics study group.

b) Co-operate closely with Huyundai Heavy Industries Ltd.

c) Visit,and work upon, industrial fbc plant.

d) Be prepared to provide additional laboratory equipment and plant instrumentation as the programme evolves; and particularly bench-scale rigs for particular purposes.

e) Continue to participate in international fbc conferences.

f) Encourage visits abroad to companies and research bodies and fellowships to Universiti to ensure full information and awareness of progress made elsewhere.

g) Consider export requirements for boilers - coals and environmental issues especially.

Note - many of the recommendations have been illustrated by reference to the literature left with KIER, and listed in the annexes.

Practical points have been demonstrated on the plant.

VIII CONCLUSIONS

1. There has been a good interchange of views, technology, and philosophies of fbc development with KIER.

2. It was useful to visit Huyundai Heavy Industries Ltd., who have licences to develop fbc.

3. The KIER development programme needs to be encouraged. It is a good programme; the present mission has added useful components; it is of value to Korean industry; it ought to run in conjunction with the Huyundai progress; and it should be of value to Korean energy, Korean industry, and Korean exports.

4. Recommendations made concerning the pilot plant, and its future programme and development work, have been welcomed by the staff.

5. KIER representation abroad so far has been valuable. It is important that it be continued, and especially KIER (and Huyundai) people should visit Britain, where fbc initiatives began, and where there is the widest range of research and developing fbc technologies in the world.

6. The KIER interests in other aspects of coal processing and in energy conservation and management, should be taken further - into government action, and industrial application.

7. The author is glad to be able to contribute experience and initiative to this mission, and will be happy to help further with its aims, purposes and results.

8. There should be a follow-up assignment in perhaps a year - to review progress and take further the programme planning.

ANNEXES

1. People met
2. The KIER establishment
3. Chronology of the mission
4. The KIER fbc work
5. Photographs of the pilot plant
6. Fbc slides for seminars
7. National Coal Board films (16mm sound): Sheffield University fbc film (VHS video cassette)
8. Current papers describing the present coal utilization and fbc position in Britain - used in seminars and left with KIER
9. Papers outlining the background to fbc and its bases - a brief selection - used in seminars and left with KIER
10. Papers by Brian Locke on recent aspects of gasification - used in seminars and left with KIER
11. Energy conservation and management (notes by Brian Locke)
12. Outline of coal pelleting tests by the National Coal Board and the California Pellet Mill Co. of UK
13. Dust separators for flue gas - discussed in seminars
14. Papers by Brian Locke on innovation and process development - a section
15. Huyundai Heavy Engineering Co Ltd (visit notes)

PEOPLE MET

Post Title	Name of Incumbent
KIER people	
President KIER	Keung-Shik Park
Vice President of Energy	Jee D. Kim
National Project Director	Won-Hoon Park
Principal Researcher	Jae-Ek Son
Principal Research	Dong Chan Kim
Senior Researcher	Hun S. Chung
Senior Researcher	Kyun Young Park
Senior Researcher	Sung Kyu Kang
Senior Researcher	Sung Keun Son
Senior Researcher	Suk Whan Park
Researcher	Yeong-Seong Park
Researcher	Jeong-Hoo Choi
Senior Administrator	Chief of the Multilateral Cooperation Division, MOST
Senior Administrator	Chief of the International Cooperation Division, KIER
International Coordination	T.H. Chu
Associate Professor, Engineering College, Inha University	Jae-on Chae
Head of Coal Utilization	Eung K. Shon
Director, Thermal Process Division	T.J. Park
Senior Research Engineer, Energy Laboratory	Young Sung Ghim

And a number of others whose names were not noted

Post Title	Name of Incumbent
Huyundai people	
	S K Lee
	Cho Jai Soo
	Lyn Han Ho
	Mr Kim

THE KIER ESTABLISHMENT

The Korea Institute of Energy and Resources is both in Seoul and in a section of Yousoung (part of Taejeon) called Daedok Science City along with a dozen other research institutes, and a university It began in 1918 with geological survey, and from 1946 onwards added geological-mine. .logical research, energy conservation (1977), and energy research (1980), taking its present name in 1981. Three sections handle resources, energy and policy, under a President who has the support of advisory committees on research and activities, and reports to a Board of Trustees. There are 812 staff, including 132 graduates and PhDs. Work, and income, come from government, the electricity industry, and industry. There is much international contact, both as technical alliances with official research bodies overseas, and as two-way traffic of staff going abroad and of foreigners visiting KIER.

Subjects of work include paleontology and geological mapping; applied geology and remote sensing research; research and exploration for mineral resources; marine exploration; geophysical survey and research; mining and technology; research on mineral utilization; residential and commercial energy conservation; industrial energy conservation; new and renewable energytechnology; fossil fuel utilization technology; energy policy, resources policy and economics; and research supporting activities. The KIER description follows.

Energy

"In energy, KIER's responsibilities include:

- Research and development on new and renewable sources of energy and other alternative energy sources

- Research and development on energy conservation technology

- Research and development of fossil energy, especially in coal conservation and utilization

- Selection, assessment and adjustment of energy research and development projects and establishment of assessment criteria

- Test and inspection of energy equipment and facilities

In resource development, KIER's responsibilities include:

- Geological research on land and at sea
- Exploration, development and optimum utilization of mineral and fuel resources
- Research and development of resources policy analysis
- Consultation and training as requested by the Government, end-users, etc.

The Energy Laboratory at KIER is divided into the seven departments of Energy Conservation, Energy Conversion, Energy Equipment, Solar Energy, Energy Policy Analysis, Research Coordination, and Administration. It has 302 staff members, 267 of whom are considered technical and 35 of whom are considered non-technical. The Resources Laboratory is divided into the eight departments of Geology, Economic Geology, Resources Exploration, Resources Development, Resources Utilization, Coordination and Technology, Research Planning, and Administration. It has 354 staff members, 319 of whom are technical staff, 35 of whom are non-technical. An organization chart is attached."

The assignment was to assist the fossil fuel utilization technology work, in particular as regard fluidized bed combustion of low grade coals and the associated feeding problems. The Institute was also interested in coal/water mixtures, briquetting, gasification, energy conservation, and the general situation on coal utilization research, development, and industrial activity in Britain.

As well as the fluidized bed combustion work, the following equipment was also seen briefly:

Solar work
- water panels glass covered
- water panels apparently opaque covered
- silicon panels of different sorts
- also passive solar systems
- the above are partly incorporated into the working buildings and partly separate experiments

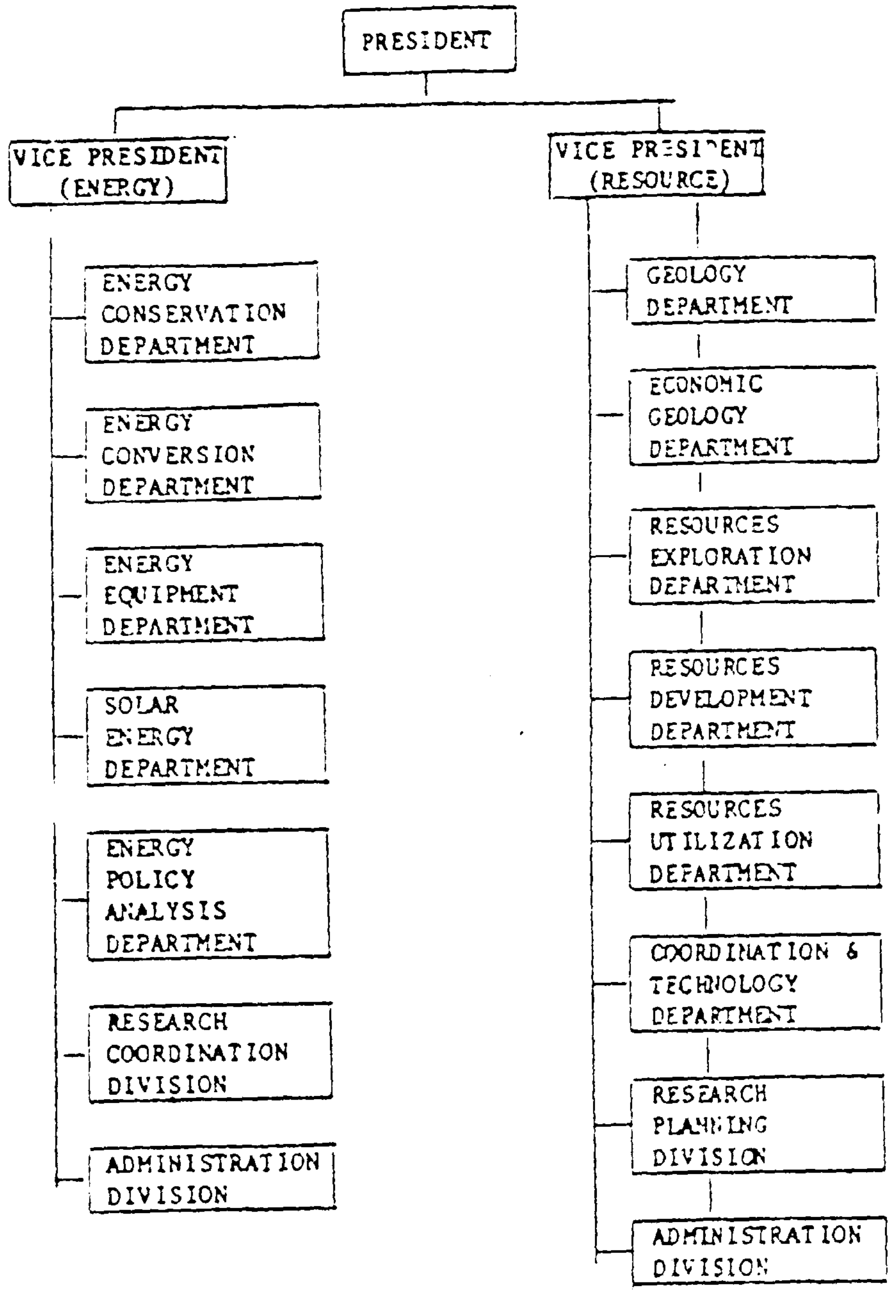
Wind work
- 10 kW three bladed aerofoil
- smaller machine with "marine-type" blades

Boiler work - coal/oil/water/slurry - two ball mills and mixing tanks - small water tube boiler

- cold oil burnertesting rig - with burner and sample tubes movable within spray cone
- hot burner test boiler, c1½m combustion tube in shell boiler
- hot burner test boiler, c1m combustion tube in shell boiler

ORGANIZATION AND PERSONNEL OF THE KOREA INSTITUTE OF ENERGY AND RESOURCES

ORGANIZATION



b. PERSONNEL

	ENERGY LAB.	RESOURCES LAB.
TOTAL	302	354
TECHNICAL	267	319
NON-TECHNICAL	35	35

CHRONOLOGY OF THE MISSION

30 November 1985	Arrival in Seoul as requested. Met by KIER representative and installed.
2 December 1985	Taken by KIER representative to UNDP office for formalities, to British Embassy, and to Daejon. Introduced to KIER people there.
3 December 1985 (until 18 December)	At the Daejon establishment of KIER. The activities described in the report under the heading "The Work" were begun. National Coal Board (UK) films especially borrowed (in response to the request for a description of coal utilization and fbc work in Britain) had not arrived despite their despatch in London on 13 November. Telexes were sent on 3 December (and also on 9 December) to UNIDO Vienna and UNIC UK by UNDP Seoul. A video cassette on fbc from Sheffield University was tried but seemed to be incompatible with available equipment. Visited the pilot plant many times, witnessed part of a run. Visited the laboratories and other parts of the establishments. Helped over individual problems with load control, dust separation, and furnace characterisation, and discussed oxygen separation.
7 December 1985	Held seminar on fbc plant in Britain.
13/14 December 1985	Visited Huyundai Heavy Engineering Ltd, Ulsan, (arranged by KIER) and saw facilities and discussed their approach to, and problems concerning fbc (under CSL licence).
16 December 1985	National Coal Board films arrived safely. Telexes were sent thanking those who had expedited them. The films were run through so as to select from them those appropriate to particular seminars.
17 December 1985	Held seminar on UK coal utilization developments.

18 December 1985	Held seminar on Energy Conservation and Management, and on Coal Processing (gasification, briquetting, smokeless fuels &c) extending in to the use of Pakistan and Indonesian lignites. Assignment dinner arranged by KIER. Drafts for written report and other material copied and left with KIER.
19 December 1985	Taken to Seoul by KIER representative. Visited UNDP office to report orally on conclusions and recommendations.
20 December 1985	Departure from Seoul for London via Hong Kong.
22 December 1985	Departure from Hong Kong.
23 December 1985	Arrival in London.
23 December 1985 until end of January 1986	Typing, compilation and reproduction of report, including processing of photographs &c. Return of NCB films and Sheffield University video tape to their owners. Despatch of typed drafts to KIER and to UNDP Seoul. Despatch of final report and accompanying material to UNIDO Vienna (original plus copy) and to UNDP Seoul (original plus two copies at their request).

THE KIER FBC WORK

The pilot plants are described in the papers:

1. Utilization of low-grade Korean anthracite in a fluidized bed boiler" - Jae-Ek Son, Jeong-Hoo Choi, Yeong-Seong Park, Young-Oh Park, Won-Hoon Park - at the Eighth International Fluidized Bed Combustion Conference, Houston, Texas, March 1985, USA.

2. "Particulate entrainment in a coal-fired fluidized bed combustor" - Jae-Ek Son, Won-Hoon Park - First Korea Japan Seminar on Powder Technology, Seoul, August 1985, Korea.

3. "Operational experiences of KIER FBC pilot plant" - Jae-Ek Son, Jeong-Hoo Choi, Yeong-Seong Park, Young-Oh Park - in a Joint Workshop on Coal Utilization Technology, KIER-PETC, October 1985, Korea.

The work was begun in 1982, with Korean funding. Huyundai, who built the plants, have a licence from Combustion Systems Ltd (CSL) in UK. The KIER aim is to research around relevant aspects of the technology, and to derive designs for a 20 tph (steam) boiler and a 10 MWe power cycle. In detail there are problems of feeding coal and recycling fly ash, which are the original subject of this mission, other aspects of energy technology having been added, in the course of time.

The papers are not reproduced here - there are copies at KIER.

The KIER work scope and work schedule follow, then diagrams of the facilities.

"Fluidized bed combustion

a. Work scope

1) To establish the appropriate operating conditions for fluidized bed combustion of low-grade Korean anthracite

2) To identify any difficulties in operation under these conditions

3) To investigate the preparation, handling and feeding characteristics of the fuel

b. Elements of the test plan

In this study, bench scale and pilot scale combustion tests will be carried out. In the bench scale tests, the effects of a number of parameters on combustion efficiency will be extensively investigated because it is relatively simple to implement single parametric combustion test for each parameter in such lab.-scale combustor. There are, however, some limitations of pilot scale combustor on the experimentation in a wide range of operating conditions. Therefore, the scope of pilot scale tests will be focused for the interpretation of the major effects which will be made clear from the results of bench scale combustion tests. Items to be tested are :

1) Combustion efficiency

2) Entrainment

3) Fly-ash reinjection

4) Heat transfer

5) Material problem

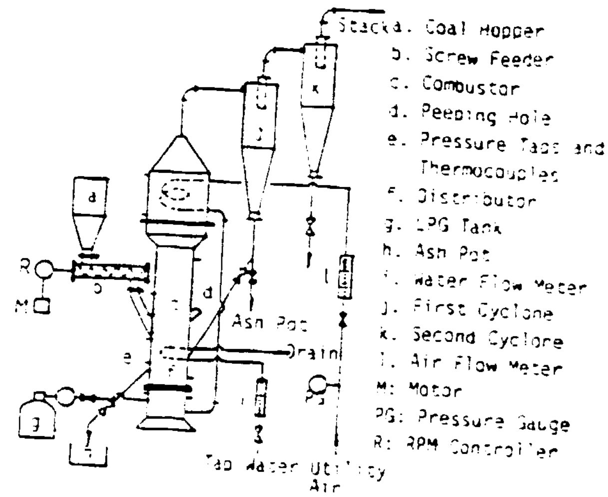
C. Facilities

1) Lab-scale combustor : 6inch diameter fluidized bed combustor. Flow diagram is shown-1

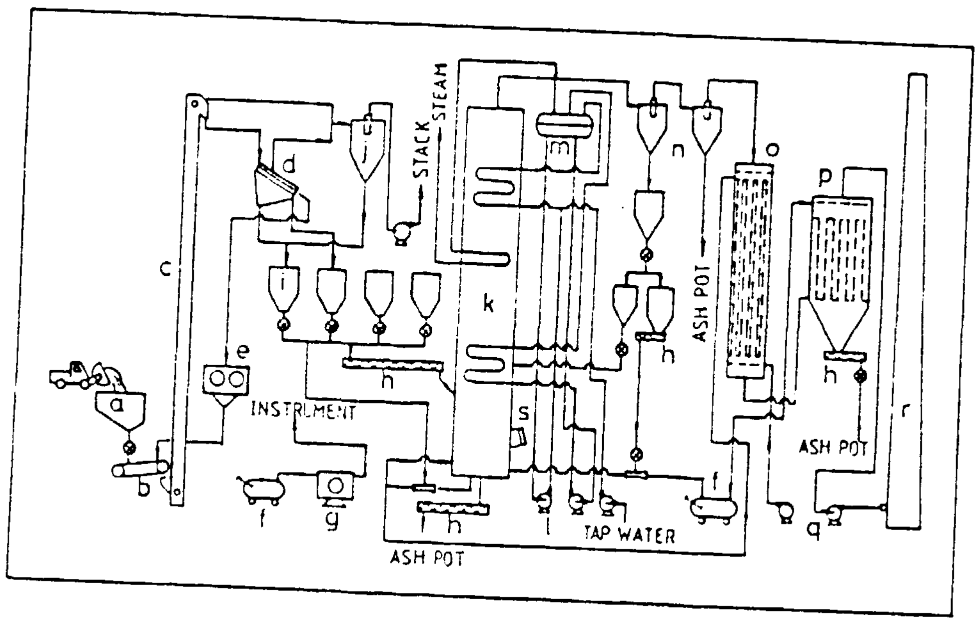
2) Pilot plant : Specification and flow diagram are shown-2"

Work Schedule

Item	1984	1985	1986
1. Preparation of experimentation and test operation	—		
2. Lab-scale test			
- Combustion characteristics		—	
3. Lab-scale test			
- Heat transfer		—	
4. Pilot plant test			
- Combustion Characteristics			—
- Entrainment			—
- Fly-ash reinjection			—
- Heat transfer			—
- Material problem			—
5. Final Report preparation			—
- Coal Feeding			



1 Bench Scale Fluidized Bed Combustion System.



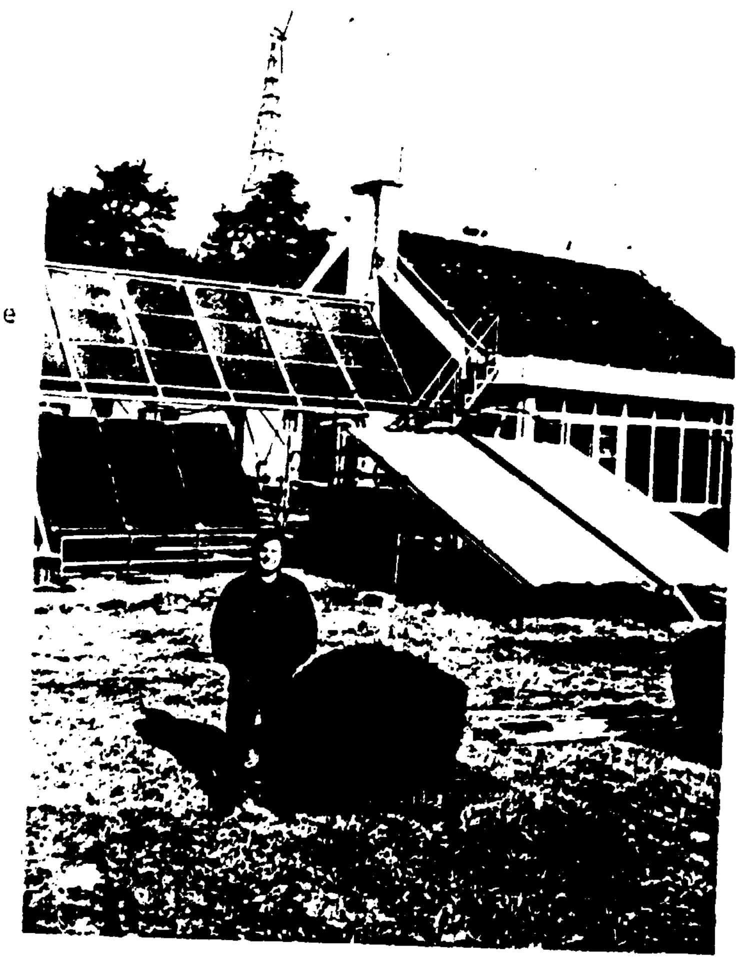
a. Coal Storage Bin	b. Conveyor	c. Elevator	d. Screen
e. Crusher	f. Compressor	g. Dryer	h. Screw Conveyor
i. Coal Bins	j. Dust Cyclone	k. Combustor	l. Pumps
m. Steam Drum	n. Cyclones	o. Air Preheater	p. Baghouse
q. Fans	r. Stack	s. Start-up Burner	

2 KIER Pilot Plant Flow Diagram.

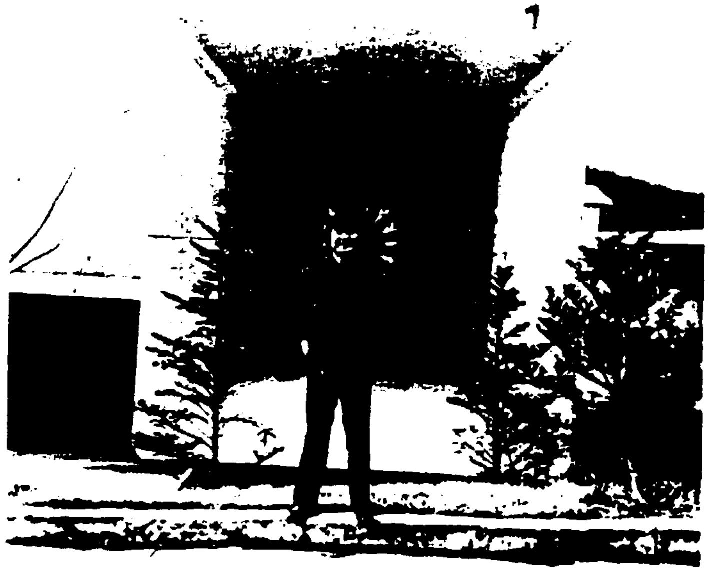
PHOTOGRAPHS OF THE PILOT PLANT

Laboratories and administration blocks

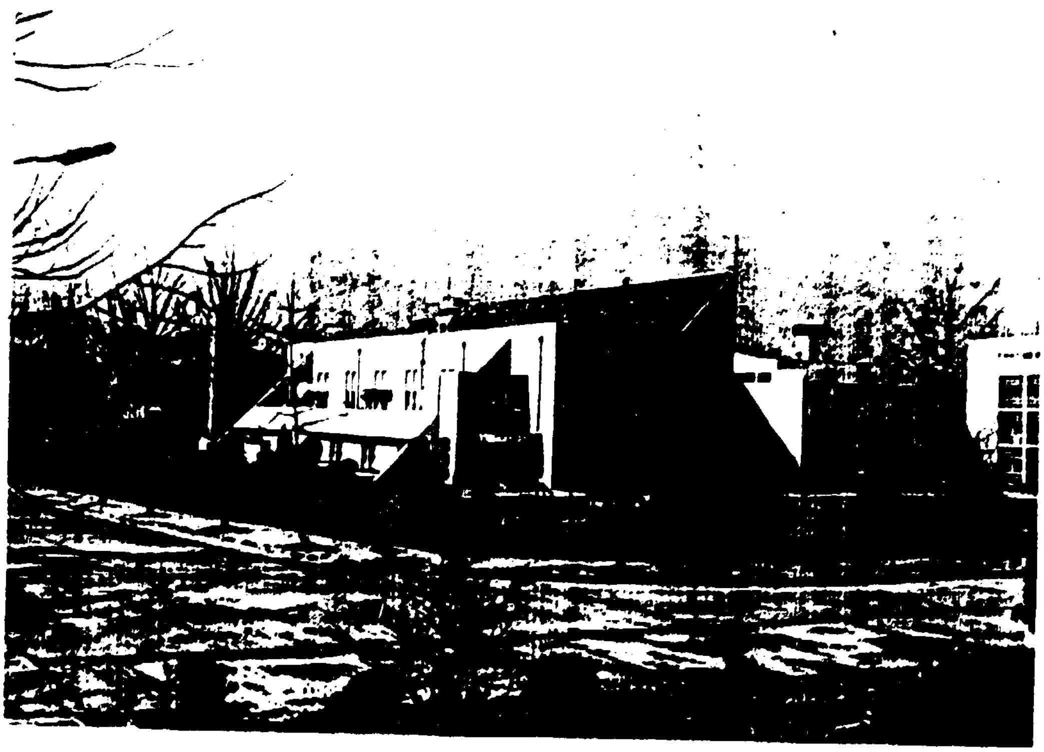
Some of the solar equipment



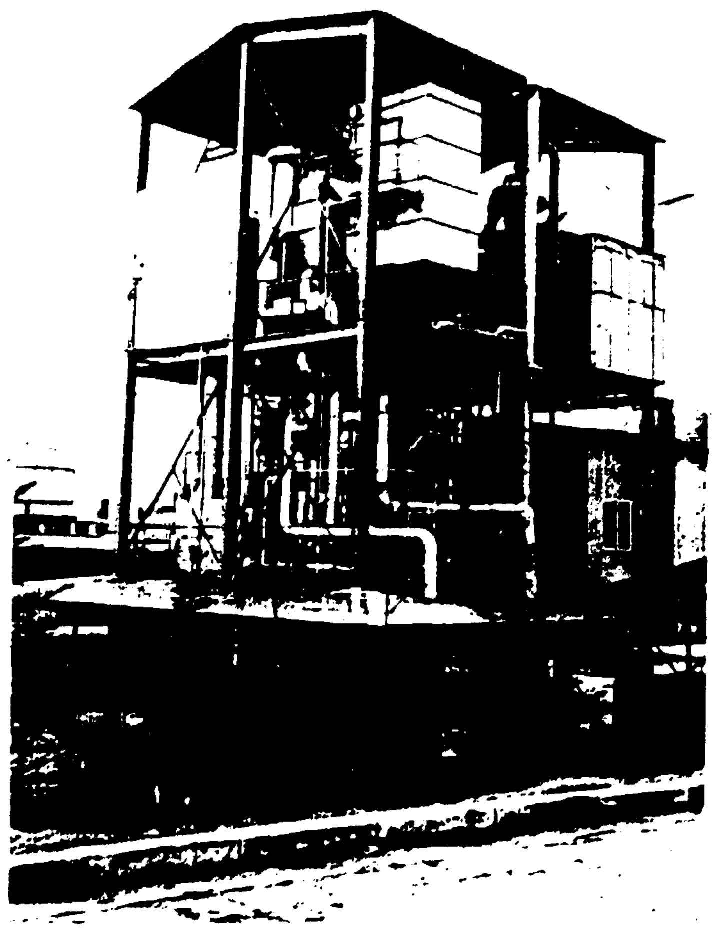
Wind
tunnel



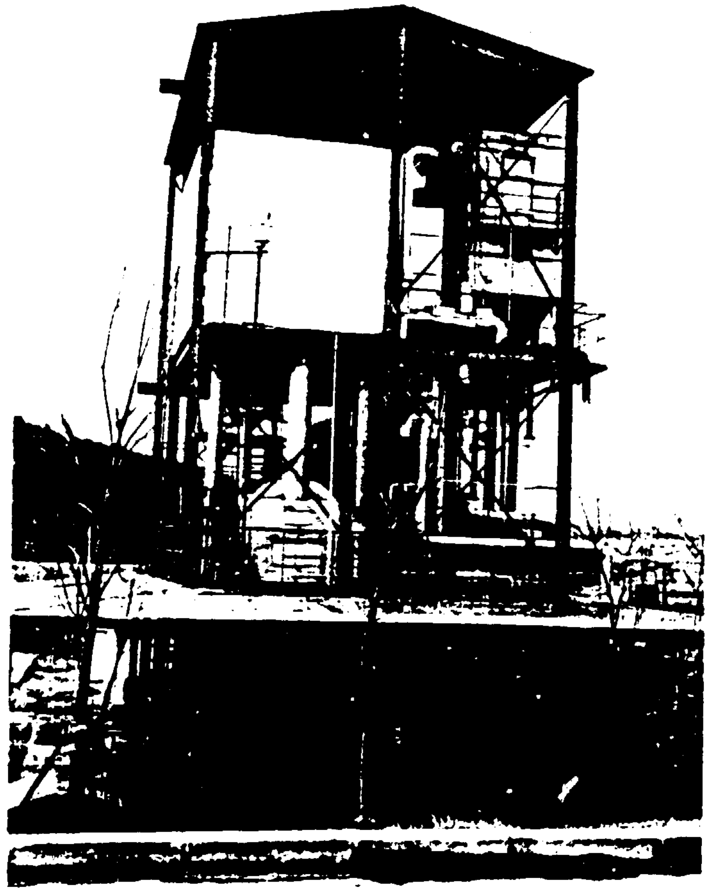
Workshop building



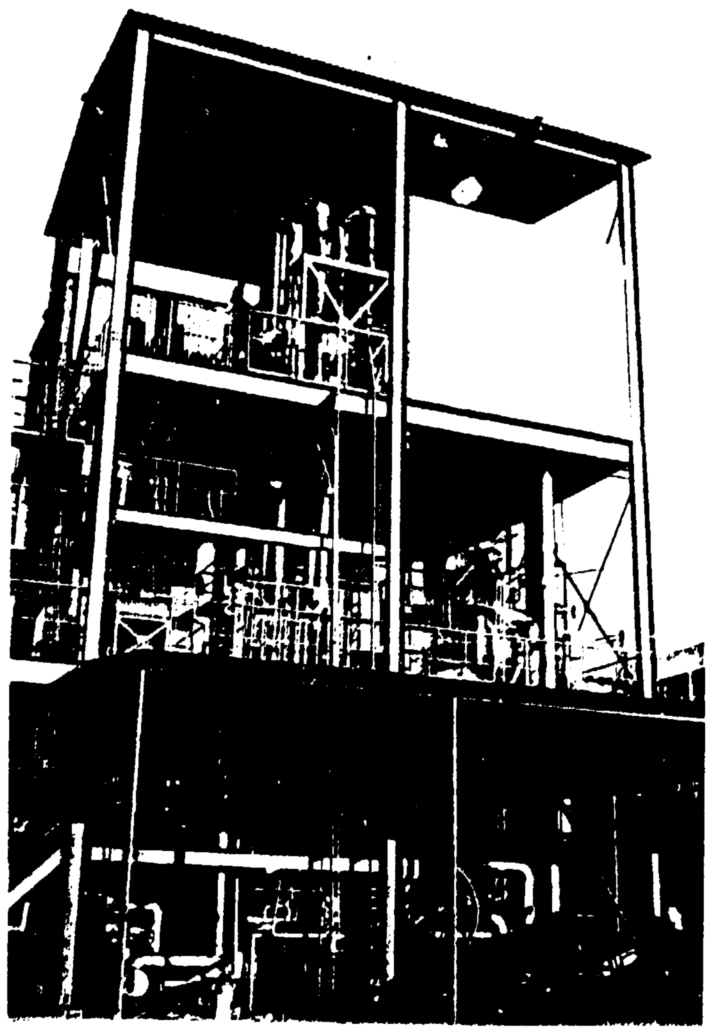
Coal-water mixture equipment



FBC pilot plant from the North East. 1 tph boiler components to the left



Pilot plant
from the East.
1 tph fire tube
convection heat
exchange boiler
middle left



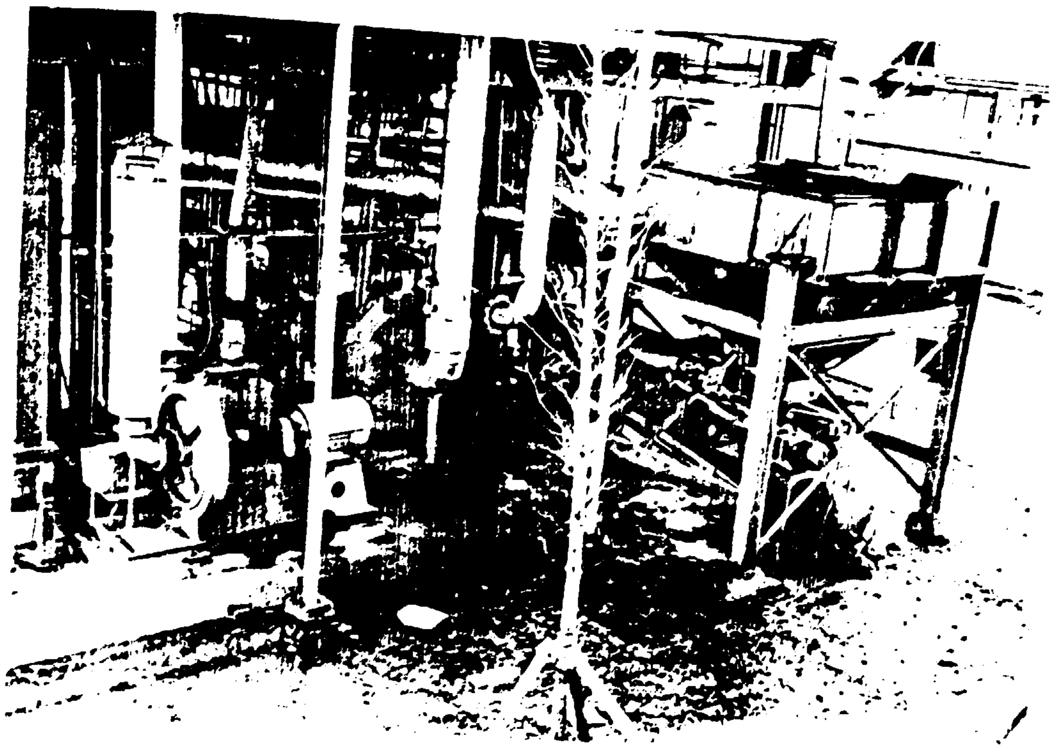
FBC Pilot plant
from the South.
0.1 tph fbc
boiler on left.
1.0 tph fbc
boiler on right

Coal supply

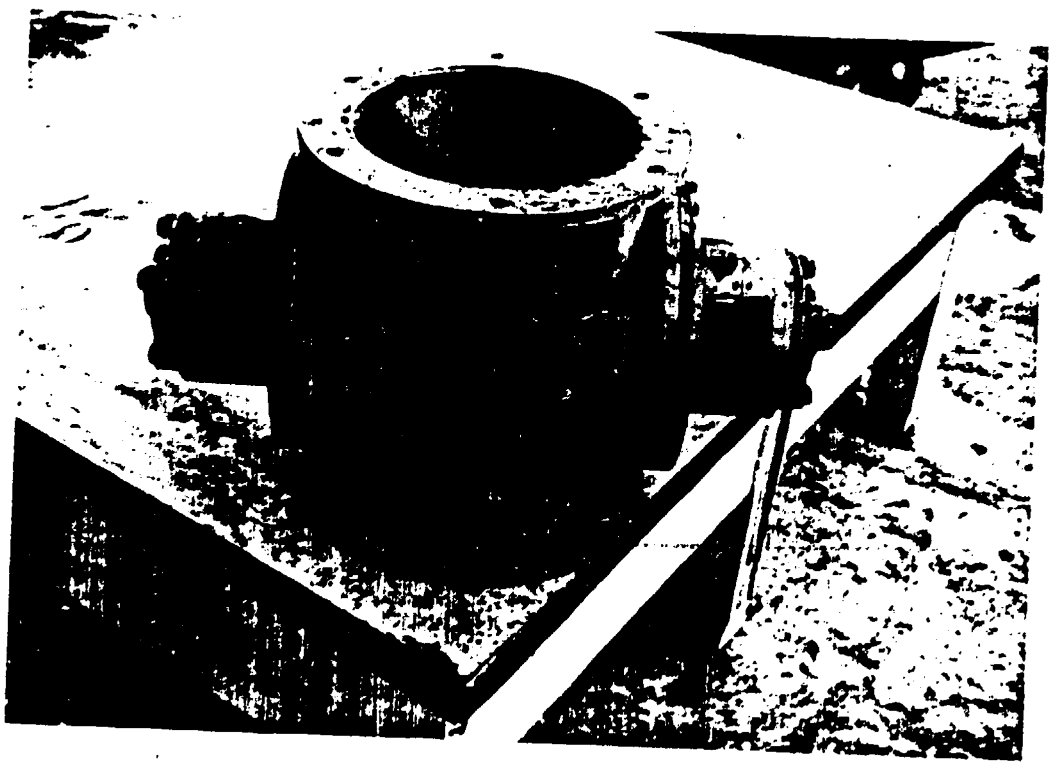
Stone in coal

First coal feed
hopper and
belt conveyor

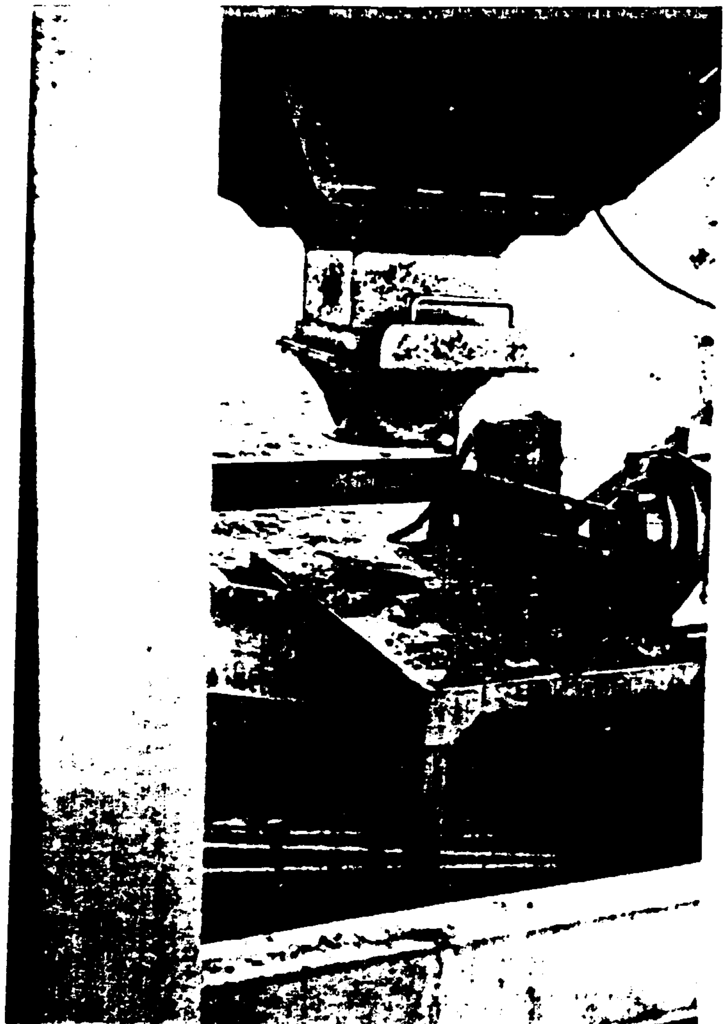
Coal service bunker
on right



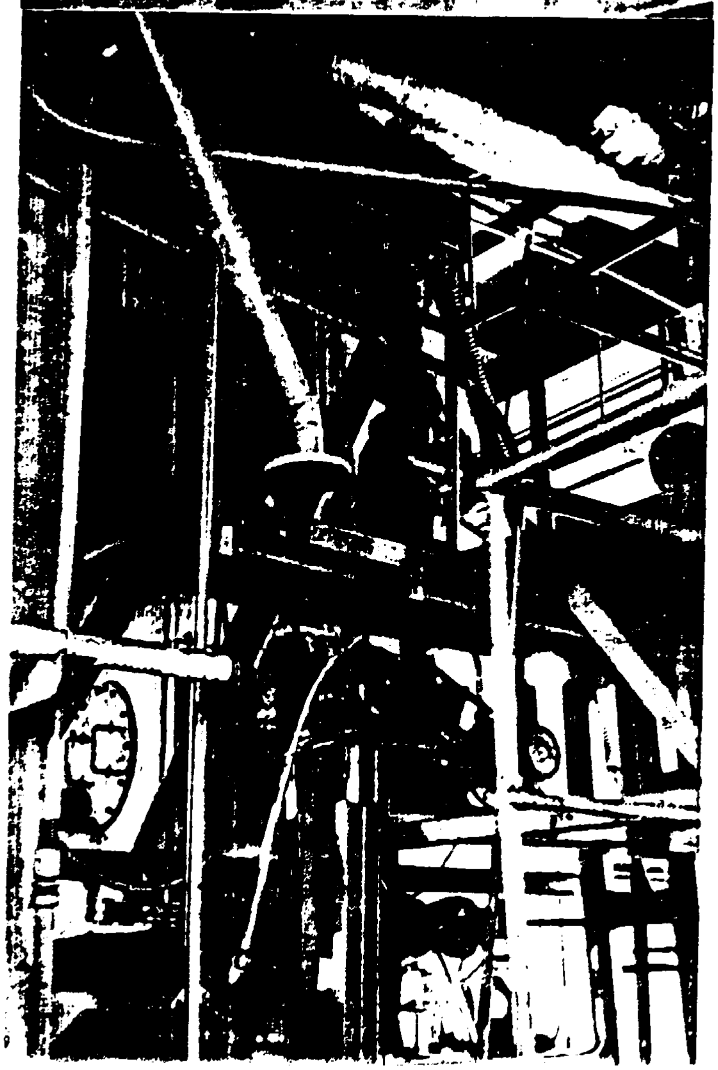
Star feeder rotary valve below service
bunker - sheared shaft and ruptured
body

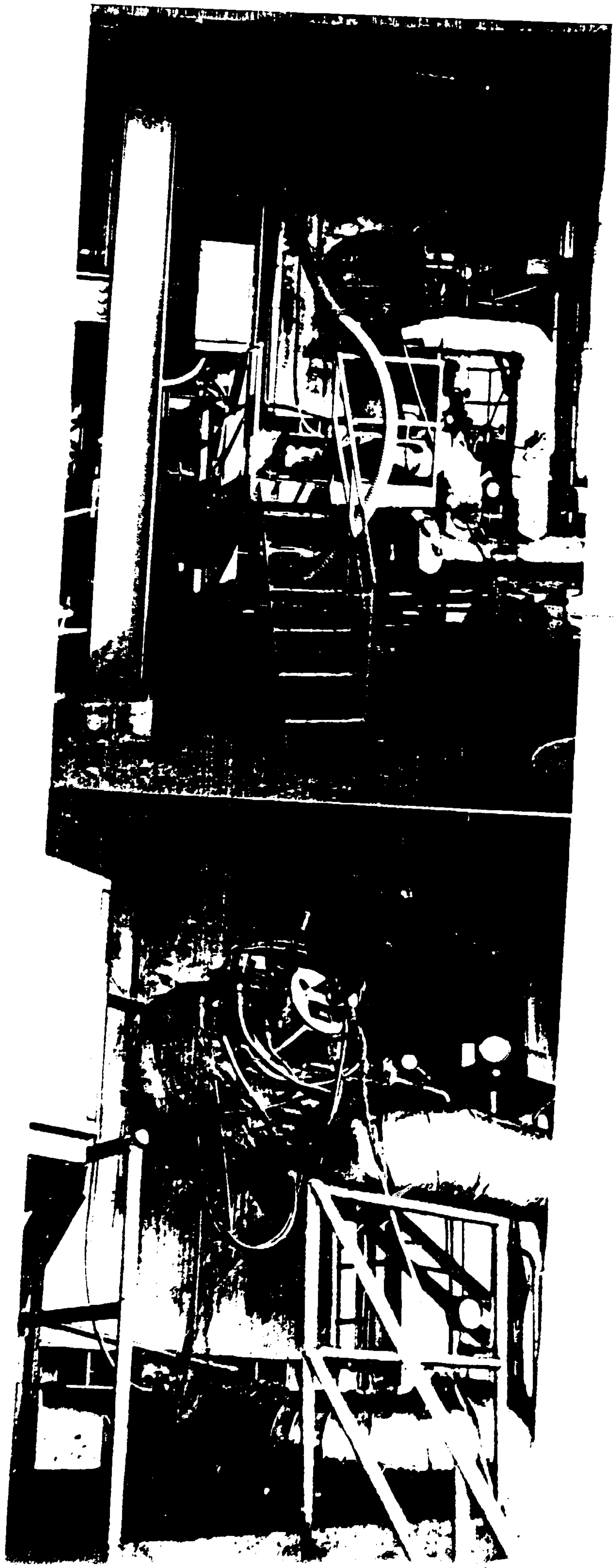


Position for
service
bunker star
feeder rotary valve



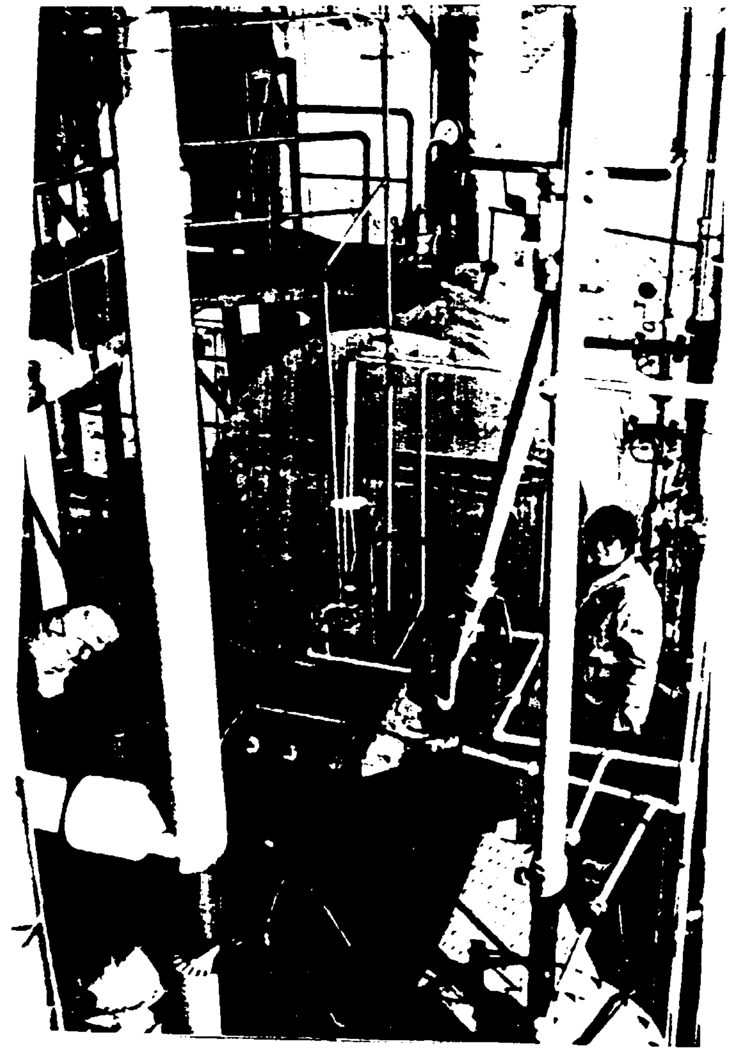
Coal feeding
components
for the 1 tph
boiler



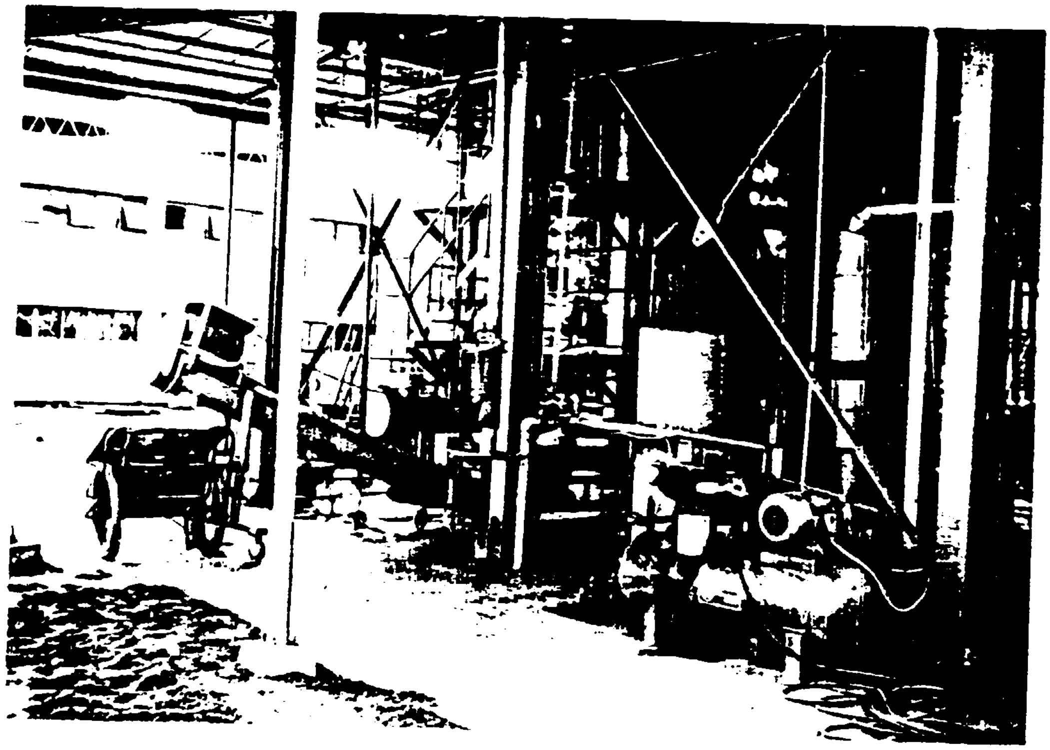


Lighting up burner (gas/diesel oil), 1 tph boiler

1 tph fire tube convection heat exchanger

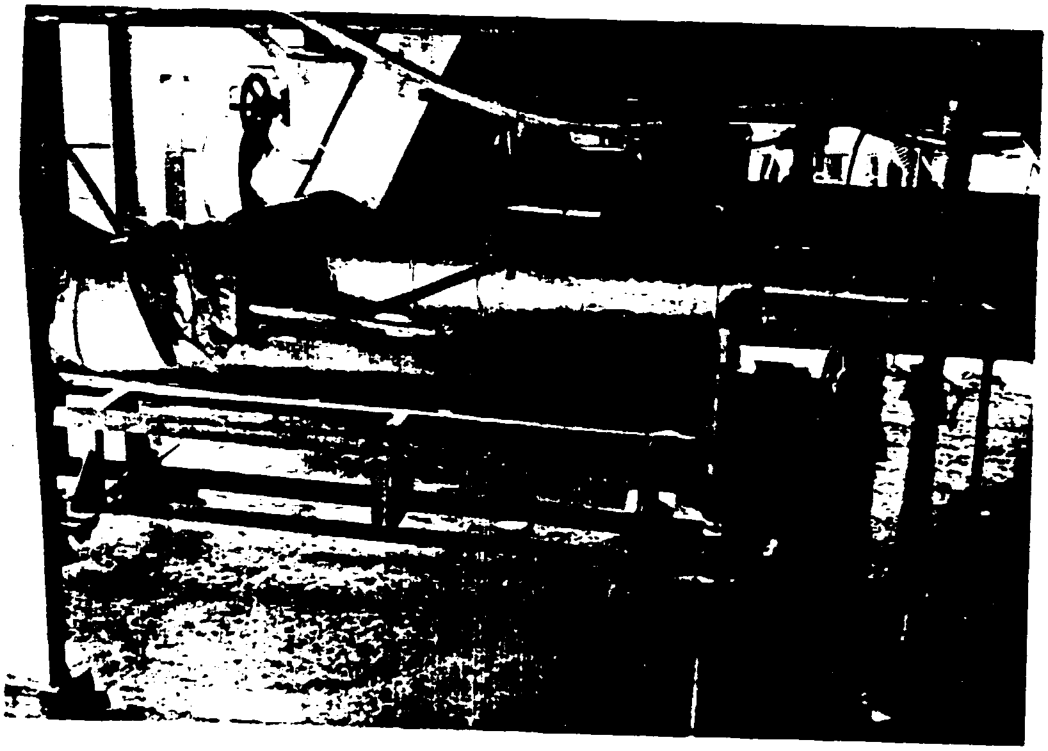


Distributor plate nozzles



Inclined ash conveyor and cart,
1 tph boiler

Discharged ash

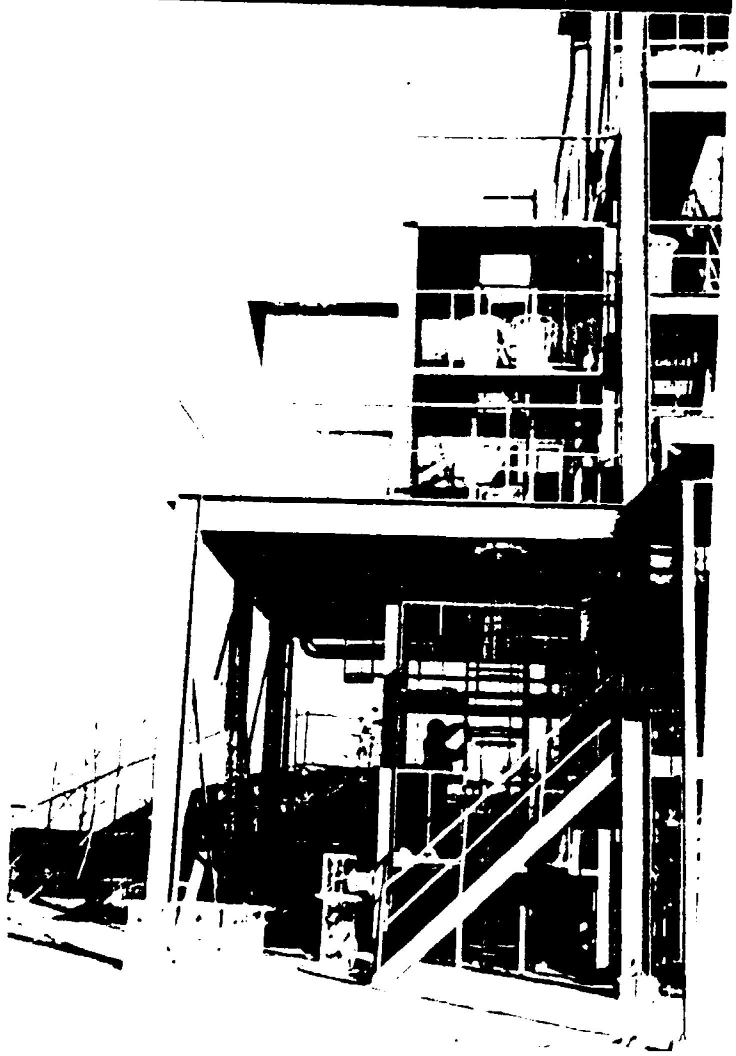


- insulation cladding

Matters for rectification

- pump glands

0. 1 tph boiler
showing
in - bed tube
connections



Perspex
cold model

FBC - SLIDES FOR SEMINAR

1. Principles and onset offluidization - diagrams.
2. Hot fluidized bed inside a glass tube - photograph.
3. The main features of a (British) fbc boiler - different from KIER.
4. One configuration of a vertical fbc boiler - shell type - diagram.
5. Photograph of 1977 version of No.4, installed in a factory - 2.5MW at C.W
6. Double-ended "locomotive"-type boiler - diagram.
7. Photograph of 1978 version of No.6 - installed in a factory - 10MW at Rists - Clonsast.
8. "Compo" boiler diagram - part water-tube, part shell -
9. Photograph of No.8, installed in a factory - 4 MW at Eli Lilly - Babcock & Wilcox.
10. Part section of a small water-tube type boiler - diagram.
11. Photograph of No. 10, installed in a factory - 7.5MW at Woolcombers - Gibson Wells.
12. Part section of a horizontal shell-type boiler - diagram.
13. Photograph of No.12, installed in a factory - 5MW at Dunlop - Wallsend
14. Another configuration of a vertical shell-type boiler - diagram.
15. Photograph of No.14, installed in a factory - 3MW, Tredomen- EMS.

16. Drawing of Johnston single-ended "locomotive"-type boiler - up to c15MW.
17. Water tube boiler drawing.
18. Pressurized fbc boiler drawing - Grimethorp - 20+MW - & cycle.
19. Circulating fbc boiler system.
20. Reduction of sulphur oxides emission - graph.

Dec. 1985

NATIONAL COAL BOARD FILMS (16mm Sound)

1. "Review - Back to coal" - usage development leads to new techniques for handling, distribution, and boilers.

2. "Not just for burning" - new processes for coal.

3. "The shape of fuel to come". General review of coal research at CRE.

4. "Oil from coal" - gasoline produced by solvent extraction, joint work by CRE and BP (British Petroleum Co.Ltd.).

5. "Coal handling by machine" - mainly of historical interest - brought in case there was time.

6. "Two Worlds - changes in the coal industry" - also mainly of historical interest - relating changing attitudes and educational advance - brought in case there was time.

Nos.1 & 2 shown on 17 December at Seminar UK Coal Utilization Developments.

Nos.3 & 4 shown on 18 December at Seminar on Coal Processing after the Seminar on Energy Conservation and Management.

Nos.5 & 6 of mainly historical interest. Could not be shown as there was no time left.

SHEFFIELD UNIVERSITY FBC FILM (VHS Video cassette)

"Fluidised bed combustion"

This film was unable to be shown at the time because apparently the Korean VHS system is incompatible with the European and USA VHS system. (The Korean system seems to use higher tape speeds). It can be made available in future if required.

Dec. 1985

CURRENT PAPERS DESCRIBING THE PRESENT COAL UTILIZATION AND FBC POSITION IN BRITAIN - used in seminars, and left with KIER

A. "Introduction of Petroleum Coke fired fbc boiler on Chuetsu Co. Ltd, Kizu Mill," by Hitachi Zosen Corporation, Osaka, Japan, October 1-4, 1985, at CSL First Licensees' Meeting.

B. "Fluidised Bed Combustion" - CSL - (1985) outlining the organization; and furnaces,and incinerator, calciners, and boilers under its Licences in Britain, USA, Brazil, Korea, Italy, Vietnam, Belgium, Senegal, Madagascar, Japan, Turkey, and Peru.

C. "Oil firing of fbc combustors" - CSL - 1985. Introduction, plant descriptions and two papers.

D. "FBC systems operational or on order and developed with NCB/CRE collaboration or assistance" - NCB - 1985 - a companion list to that in B, but those in Britain only.

E. "FBC boiler installations operating experience" - Virr - 1985. Much data for the Stone Johnston Fluidfire boiler system.

F. "Operating experience with industrial fire tube fbc boilers" - Virr - 1985 - an outline of experience on 25 installations.

G. "Coal for Industry" - NCB - 1985. Outline of NCB activities including coal utilization, and equipment suppliers.

H. NCB-CRE - Annual Report 1984/5 - A complete summary of major research, development and application, on coal, in Britain.

J. "Combustion Systems Ltd" - CSL - 1985 - Brochure.

K. "A summary of bubbling fluidized bed combustion in the UK" - Mills - 1985 - outline of experiences, problems, and designs.

The papers were labelled with the above letters.

Dec. 1985

PAPERS OUTLINING THE BACKGROUND TO FBC AND ITS BASES - - a brief selection - used in seminars and left with KIER

1. "New developments in the energy field" - Brian Locke, 1974 - the world energy scene, possible new sources and developments, issues, considerations and speculations, programmes, and the status of fluidized combustion - National Physical Laboratory, UK.

2. "Fluidized combustion of fossil fuels" - A G Roberts, H R Hoy, H G Lunn, H B Locke, 1975 - outline of opportunities for low grade fossil fuels for heat and power generation cycles usingfluidized combustion, with its advantages of low combustion temperatures and reduction of noxious emissions - "Coal Processing Technology",USA.

3. "Fluidised beds - clean heat and power cycles using fludised combustion" - H B Locke, H G Lunn, 1975 - outline of the process aspects of fluidised combustion, at ambient and elevated pressures, power cycles, and development work - "The Chemical Engineer", UK.

4. "Fluidised combustion in Great Britain - environmentally clean steam and power generation from coal, heavy oil and dirty fuels" - H B Locke, H G Lunn, H R Hoy, A G Roberts, 1975 - across-the-board summary of process issues, ambient and elevated pressure work, load changing,economics,cycles &c - with lists of equipment, fuels used, and results - "Fourth International Conference", Mitre Corporation, USA.

5. "Advances in pollution-free heat and power generation made possible by developments in fluidized combustion technology" - Brian Locke, Howard Lunn, 1976 - status report on the organization, background, process aspects, power cycles and variables, plus the programmes in USA, UK, Germany, Scandinavia, including the shell and water-tube boilers and the pressurized rig, in the UK - "Dechema Monographien", Germany.

6. "Energy flux in chemical engineering design" - Brian Locke, 1982 - includes the interrelationship of fluidized combustion design variables as an example, in the discussion of implications of energy flux Institution of Chemical Engineers, UK.

The papers were labelled with the above numbers.

Dec. 1985

PAPERS BY BRIAN LOCKE ON RECENT ASPECTS OF GASIFICATION - used in seminars and left with KIER

I. "Feedstocks and fuels from coal: the need for process changes" - 1982 - history, processes and status of coal gasification processes, and syntheses for different products, including the needs for large-scale future development - "Energy World" UK.

II. "Small-scale gasification" - 1983 - a survey of the four principal types of small-scale gasifier, especially for direct use of the gas for furnace or dryer use, or for spark ignition or compression ignition engines for power generation - "Energy World" - special supplement on modern gas-making plant and processes - UK.

III "Integrated rural energy centres for agriculture-based economies" - jointly with Air Vice Marshall SNR Choudhury and D C D Lecamwasam - 1985 - outline of agricultural and industrial wastes and their briquetting, gasification and combustion to make saleable briquette fuels and electricity: plus performance figures and costs, and an account of the integrated rural energy centre working in Sri Lanka - Institution of Mechanical Engineers International Conference, UK.

The papers were labelled with the above numbers.

Dec. 1985

ENERGY CONSERVATION AND MANAGEMENT
(notes by Brian Locke)

(i) "Combustion, pollution and conservation" - 1978, IEEE seminar material - several centres in India.

(ii) "Process rearrangement - designing from new" - 1984, Conference "Making Energy Management Pay" - UK.

(iii) "Energy Policy" - components, outline and setting industry targets - 1984 - UK.

- used in seminars and left with KIER

The notes were labelled with the above numbers.

Dec. 1985

OUTLINE OF COAL PELLETING TESTS BY THE NATIONAL COAL BOARD AND THE CALIFORNIA PELLET MILL CO. OF UK - discussed in seminars

The conventional processes for making coal briquettes and other forms of processed solid fuel - including cokes, and the various "desmoked" domestic fuels - are described in the paper "Coal Supplies for Carbonisation Processes" by N.M. Potter and H.B. Locke, in "The Mining Engineer" June 1966. The processes still extant are as described in that paper: some processes have fallen into desuetude. The paper was left with KIER.

Because of the need for cheaper and simpler processes, and especially where the prime requirement is to use fine coals, and those fractions surplus to market needs elsewhere, there has been recent work, not directly concerned with smokelessness. Where the coal is anthracite, or a suitable combination of low-volatile coals, the product can, of course, also be smokeless.

Recent work by the National Coal Board (NCO), and by California Pellet Mill Co. (CPM) is interesting.

CPM have made 10mm dia pellets in UK from coal of 5 mm and less.
The conditions were:
Coal - bituminous - moisture 18%, starch binder 2%
Coal - anthracite - moisture 13%, starch binder 5%
Samples were left with KIER, along with literature about CPM, its pellet mills, and its pellet cooler.

NCB have made 20mm and 25mm pellets in UK from bituminous coal and from anthracite, and sometimes from mixtures. They have pelleted all qualities of coals, and find that bituminous coals are easier to pellet than anthracite, and that a high clay content assists the process. The moisture content has been about 18%, and many different binders have been used, including cement. The pelleting machine used has been a 100 hp CPM pellet mill with producing 4 tons per hour. The product has been at approximately 53°C, so a pellet cooler has also been used. The pellets improve in hardness as they mature.

Samples of these pellets, too, were left with KIER, along with the NCB Patent Application GB 2 122 218 A of 18 June 1982, published 11 January 1984.

Assistance can be provided in taking such matters further.

DUST SEPARATORS FOR FLUE GAS - discussed in seminars

The basic position regarding dust separation was summed up in detail for cyclones in J.Inst.F. Vol XXIX No.1 (Stairmand), and over a range of types of equipment in Ind. Chem. Jan 1955 p.16 (Locke). Since then improvements have been primarily of second order.

Bag filters, hitherto rather confined to chemical industry, and for dryers, became necessary for certain combustion plants with fine flue dust, and where the plant was too small for electrostatic precipitators; and newer materials such as glass fibre, and nomex, have made operation possible outside the conditions where canvas, wool, or nylon could be used as bag material. However, bag filters present problems owing to their liability to become blocked, particularly when flue gas moisture condenses, as may happen at plant start up. They are also expensive in both capital and operating cost.

Batteries of small cyclones are cheaper to buy and to operate than bag filters, but many cannot meet the dust-catching performance required.

A new development, the Paladon multicyclone, has now been under test at several boiler plants for a number of years. Available in 2 inch, 6 inch, and 10 inch size multiples, it seems likely that 6 inch batteries or combined batteries of 6 inch and 2 inch units should handle fluidized bed combustion flue gases to well within legal requirements of environmentally-concerned countries.

A very small (pharmaceutical plant) example was demonstrated at KIER, and a report was left containing details of tests at two separate fluidized bed combustion installations in the UK. A single stage multicyclone of 2 in w.g. pressure drop showed separator efficiencies of over 93% in the three tests. A two stage multicyclone of 3 in w.g. pressure drop showed separate efficiencies of 97.6% and 98.2% in the two tests.

Such cyclones may be of use to KIER in view of their dust problems.

Dec. 1985

PAPERS BY BRIAN LOCKE ON INNOVATION AND PROCESS DEVELOPMENT - a selection

a) "The use of research in industry" - "The Chemical Engineer", UK, 1971

b) "Forecasting, development and innovation in the field of chemicals" - "Industrial Marketing Management", 1972, plus "Developments and outcomes" - b1)

c) "Innovation and design - the formula for progress" - "Design Engineering", 1974

d) "Innovation by design" - "Electronics and power", 1976

e) "Finance, design and innovation" - "Design Interface '76", 1976

f) "Management of new ideas to make sure they go right" - "The Engineer, Industry towards 2002", 1977

g) "Aspects of engineering innovation" - "The Inventor", 1977

h) "The introduction of new technology into systems and plants" "Institution of Chemical Engineers Jubilee Symposium", 1982

j) "Where are science and technology going?" - "Chemistry in Britain", 1985

Left with KIER, illustrating some of the points made in seminars.

The papers were labelled with the above letters.

Dec. 1985

HUYUNDAI HEAVY ENGINEERING CO. LTD.

The visit was arranged by KIER, and took place on 13 and 14 December 1985. Huyundai have a CSL licence for fbc as well as one from Ahlstrom. The people met are listed in Annex 1. Huyundai have 300,000 visitors each year.

Huyundai Heavy Engineering divisions were visited briefly as follows on 13 December:

Industrial Plant - boilers, heat exchangers, pressure vessels
Shipbuilding - ships, dry docks, assembly, completion
Diesel engines - for ships
Offshore engineering

Then, on 14 December:

The Huyundai Motor Car Company - cars plus trucks and coaches.

There were also electric motors, transformers, switchgear, construction, painting, foundry and forge, for which there was no time for visits.

Some time was spent with the boiler personnel concerned with the development of fluidized bed combustion, both under their Ahlstrom licence and under that from CSL. The CSL Design Manual had been transferred to Huyundai covers but did not appear to have been mutilated, except for the apparent removal of title pages and overall contents sections.

The new Manager was Dr Cho Jae Soo. A University of San Diego graduate, returned to Korea after ten years abroad, much of which time post graduate had been spent on ram-jet development with lpg as fuel. He had returned to Korea four months ago to run the Huyundai fbc project, and had spent a week at CRE returning a few days ago. He had twenty staff.

Previously Huyundai had built a 120 tph circulating fbc boiler under Ahlstrom licence, to use imported (bituminous) coal at Inchon. This was the largest Ahlstrom plant in the world, and was apparently working well. They were also erecting a 20 tph boiler using CSL data, and had, a month ago, secured a 10 tph order for a CSL-style boiler - both for imported coal. There was much discussion on design details.

Attempts were made to dispel illusions - and to explain that the CSL Design Manual lists, and digests many research reports - and that it is a set of data and experience from which a licensee can start out and design his own plant to suit the needs of his market. Dr Cho also said that his welcome by CSL in England was greatly appreciated.

It will be useful if Dr Cho, and possibly Mr S K Lee, and some colleagues can visit Britain and be shown the vast range of different types of fbc plant there are, and the different applications of the principles involved.

It will also be useful if the Huyundai and the KIER people can meet and exchange interests and intentions.

. Huyundai should acquire at least two installations

a) an experimental rig and a rudimentary coal laboratory
b) a working development boiler within the Huyundai organisation

They should also ensure that each boiler sold has an operating/maintenance log book available for them as an essential part of of their development literature.

Dec. 1985