APPLICATION FOR FUNDS FROM THE COAL RESEARCH LEVY

(Coal Research Assistance Act 1977)

May 1978

ENERGY CONVERSION GROUP
DEPARTMENT OF ENGINEERING PHYSICS

Research School of Physical Sciences
Institute of Advanced Studies
The Australian National University
Canberra, A.C.T.

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SUBMISSION

Australia faces an increasing shortfall in domestic oil production during the next decade and a consequent increasing dependence on imported oil. The economic impact of this dependence will force moves towards replacement of oil by natural gas and coal, and ultimately by coal alone. These factors coupled with the rapidly growing coal export trade will increase considerably the demand pressure on coal and further, the requirement for rapid growth of the oil replacement industries will create a high demand for investment capital. The transition from our present oil-dominated society to a coal-dominated society is not likely to be without its own set of problems. Already some of these are evident. For example, it will be necessary for strategic reasons that Australia maintains an independent domestic supply of oil for essential services such as air transport and defence requirements. Assuming that insufficient new oil reserves are found, the only alternative source likely to fill these needs in the relatively short term is coal liquefaction. In addition, however, there are several more tenuous problems affecting the longer-term which could ultimately have even more serious consequences. For example, the buildup of carbon dioxide in the atmosphere could present a serious limitation on coal utilization in the future. There are sufficient uncertainties in future energy resource strategies that it would not appear in Australia's best interest that such problems be ignored, even at the present time. Indeed, it may be argued that had research related to Australia's long-term energy strategy been encouraged in the past, then the country would now be both better equipped and better prepared to face the imminent shortfall in oil supplies.

We argue here that it is important for a reasonable fraction of the Coal Research Levy to be allocated to research into forseeable problem areas of future coal utilization and into development of approaches for the optimal use of coal.

The research forming the basis of this submission is related to Australia's coal utilization strategy and, in particular, is directed towards alleviation of demand pressure in two areas: on the one hand, investment capital, and on the other hand, coal, by achieving more optimal utilization. The submission is for a research programme which extends existing work of the Energy Conversion group in the Department of Engineering Physics and which may conveniently be subdivided into three interrelated parts:

a. *Underground storage of substitute natural gas/hydrogen derived from coal.* The research would encompass the physical, chemical and engineering problems specific to underground storage of hydrogen-rich gas mixtures and is justified by the potential capital savings in the areas of production, processing and transportation of substitute natural gas brought about by the smoothing of diurnal and seasonal demand through provision of storage. There are specific problems relating to underground storage of hydrogen which need particular study.

b. *Investigation of methods for producing liquid fuels with optimum coal utilisation by employing coal/solar hybrid systems.* In the particular system under study, a thermochemical energy transfer cycle based on methanol as working fluid and with provision for underground gas storage would be utilized to transport energy from a large scale solar collector array to a central plant. High grade heat regenerated at the central plant would be used to produce sufficient hydrogen through dissociation of water in order to enrich the gas mixture from a coal gasification plant to the level required for methanol synthesis. Output from the plant would be the liquid fuel, methanol. Savings would accrue from the more efficient use of coal since only half the coal is used in the proposed process in comparison with conventional coal/methanol synthesis.

c. *Systems for provision of high grade process heat at industrial locations remote from coal-fired plants, as a means for reducing pollution in populated and industrial areas.* Coal, as the most likely cost effective substitute for oil in providing industrial heat in its many forms, will be used in industrial heat plants in increasing amounts, thereby presenting further environmental problems. Many of these problems can be alleviated through the application of thermochemical energy transfer systems. Heat generated by burning coal would be absorbed by an endothermic chemical reaction at the primary plant. Chemical energy would be transported through pipes at ambient temperature and high grade heat regenerated at a number of secondary industrial locations during the reverse exothermic reaction. Atmospheric pollution therefore would be confined to the primary plant where more effective and more economic control measures could be implemented.

The research programme envisaged for investigating the above proposals would include a general assessment of the problems from the viewpoints of both technical and economic feasibility, leading to the identification of specific problem areas. Each proposal would be assessed during the first year of study and the knowledge gaps and optimum path for research identified in relation to the present activities and expertise of the Energy Conversion Group.

A comprehensive report detailing the significance of the proposals and outlining the options available for further research would be produced in the first year.

There are strong links between the proposed research and our existing research programme, notably in the areas of underground gas storage and thermochemical energy transfer. Work in each of these areas would be expanded on both theoretical and experimental levels. Our work in underground gas storage is related specifically to hydrogen and hydrogen-rich mixtures. Theoretical studies of hydrogen loss mechanisms, well capacity and pumping energy would be extended and complemented by an experimental programme in the areas of hydrogen diffusion and solubility in ground water, and fluid dynamics in porous media. In our second area of existing research into thermochemical energy transfer systems, our present research would be expanded both theoretically and experimentally to cover the specific problems related to the above proposals. In particular, our studies so far have identified the design criteria for optimization of a thermochemical energy transfer system for maximum work production and there is a need to design and construct such a system in order to identify specific engineering problems and assess performance on a pilot plant level.

The Energy Conversion Group at present has 9 members (comprising the project leader, four members with professional qualifications and four with technical qualifications) as well as general workshop personnel. In order to pursue the proposed programme effectively, the Coal Research Levy grant would be used to fund three temporary staff members together with appropriate experimental equipment and use of computing facilities. Fund requirements in the first year are summarised as follows:

1 academic appointment	25,000*
1 professional appointment	25,000*
1 technical appointment	20,000*
Experimental equipment	30,000
TOTAL	$100,000

(* including overheads)

The request of $30,000 for experimental equipment represents only a part of the total expenditure detailed in Section 5, the total representing development of the research programme over a period of several years financed in part from a Coal Research Levy grant and in part from existing and other sources. Requests for continuation of Coal Research Levy support into future years would be based on the detailed assessment of the proposals conducted in the first year and are expected to be of the same order of magnitude as for this submission.

SUPPORTING DETAILS

DEPARTMENT OF ENGINEERING PHYSICS

HEAD: Professor S Kaneff, B E, PhD (Adel)

ENERGY CONVERSION GROUP MEMBERS

PROJECT LEADER: P O Carden, M E (Qld), PhD (ANU)

MEMBERS:
- H P Cantor
- B P Edwards, B Sc(Hons) (ANU)
- K Erick
- R W Parkes
- L Paterson, B Sc(Hons) (Monash)
- K Thomas, Dip Mech Eng (Bendigo), M E (Monash)
- R E Whelan
- O M Williams, M Sc (Otago), DPhil (Oxon)

1. INTRODUCTION

Australia faces an increasing shortfall in domestic oil production during the next decade and a consequent increasing dependence on imported oil. The economic impact of this dependence will force moves towards replacement of the use of oil and petroleum products by domestic coal and natural gas while reserves of the latter remain adequate. Increased overseas demand for Australian export coal and increased local demand for electricity production will add to the pressures as coal becomes our major source of primary energy. The effects of this demand pressure will be twofold: the reduction of the expected lifetime of Australia's coal reserves and, of greater importance in the shorter term, the development of a very large cost infrastructure associated with the opening of new mines, new power stations, increased coal transportation demand, problems of air pollution, and overall development of new technologies based on coal.

The transition from our present oil-dominated society to a coal-dominated society is not likely to be without its own set of problems. Already some of these are evident. For example, by 1990 a shortfall of one million barrels per day of oil equivalent is projected (Glastonbury and Young, 1976). The most likely response will be to import most of the shortfall, paying at least in part for the massive outflow of capital by exporting more coal and thus increasing further the demand pressure on coal. However, even this solution is incomplete since it will be necessary for strategic reasons that Australia maintains an independent domestic supply of oil for essential services such as air transport and defence requirements. Except in the long term, and assuming that insufficient new oil reserves are found, the only alternative source to fill these requirements is coal liquefaction.

The above problem together with other potential problems such as the difficulties of maintaining and policing emission control standards in the advent of a reversion from oil to coal usage by industry, are apparent at the present time. On top of these, however, are several more tenuous problems affecting the longer-term with potentially even more serious consequences and which are already being discussed widely. These relate to the implications of a worldwide reversion from oil to coal as the primary energy source and are being seriously examined as areas for growing concern (see, for example, Sassin and Hafele 1977, Marland and Rotty 1977, and other papers from the Third IIASA Conference on Energy Resources, Moscow, 1977). One area concerns the buildup of carbon dioxide in the atmosphere which could present a serious limitation on coal utilization in the future. While such problems may seem of a long-term nature, there are sufficient uncertainties in future energy resource strategies that it would not be in Australia's best interest that they be ignored, even at the present time. The research proposals outlined in this submission are related to the forseeable problem areas of Australia's coal utilization strategy.

2. OUR PRESENT RESEARCH

The connections between major areas of our present research programme and the extensions proposed are shown in Figure 1. The Energy Conversion Group in the Department of Engineering Physics, ANU, has conducted research over the past five years into problems that have been directed principally at the development of large scale solar energy utilisation. There is a strong link with areas of coal research since a number of features of our present research programme are common to the problems of conventional energy sources in the future. This research is outlined in the following paragraphs in order to set the background for the present research proposal. A list of our publications relevant to the research proposals is attached.

2.1 Thermochemical Energy Transfer

A thermochemical energy transfer system forms one of the basic building blocks of the solar ammonia system, one area of work under intensive study at the present time, and is shown schematically in Figure 2. The attractive feature of a thermochemical energy transfer system is that energy may be transported over considerable distances through pipes at ambient temperature and high grade heat generated where required without the products of combustion or pollutants of any kind being released into the atmosphere at the point of energy utilization. A working fluid such as high pressure ammonia is fed to the energy source and is partially dissociated in a catalytic reactor, the

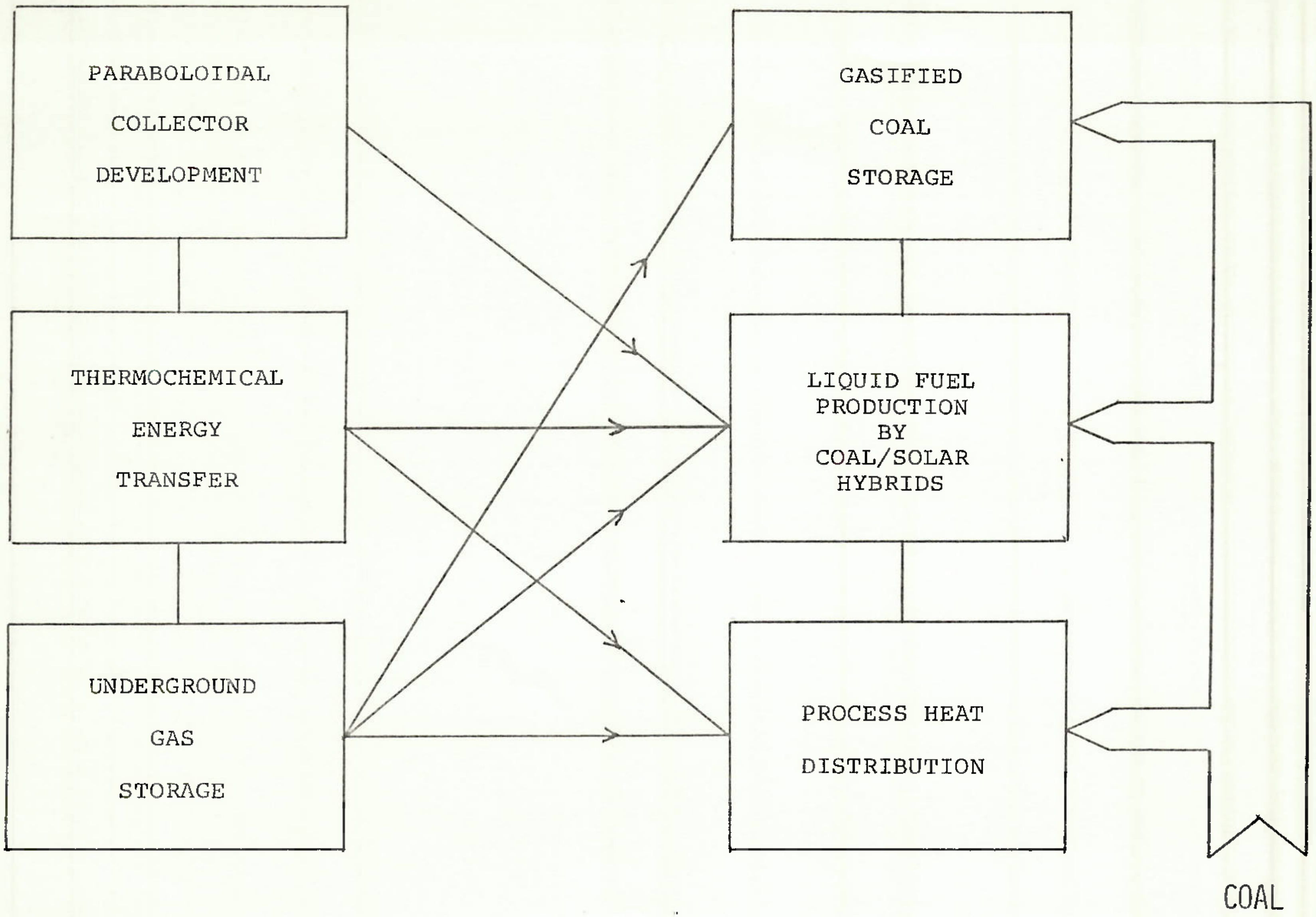

FIGURE 1: Relationships between our present research and proposed coal research

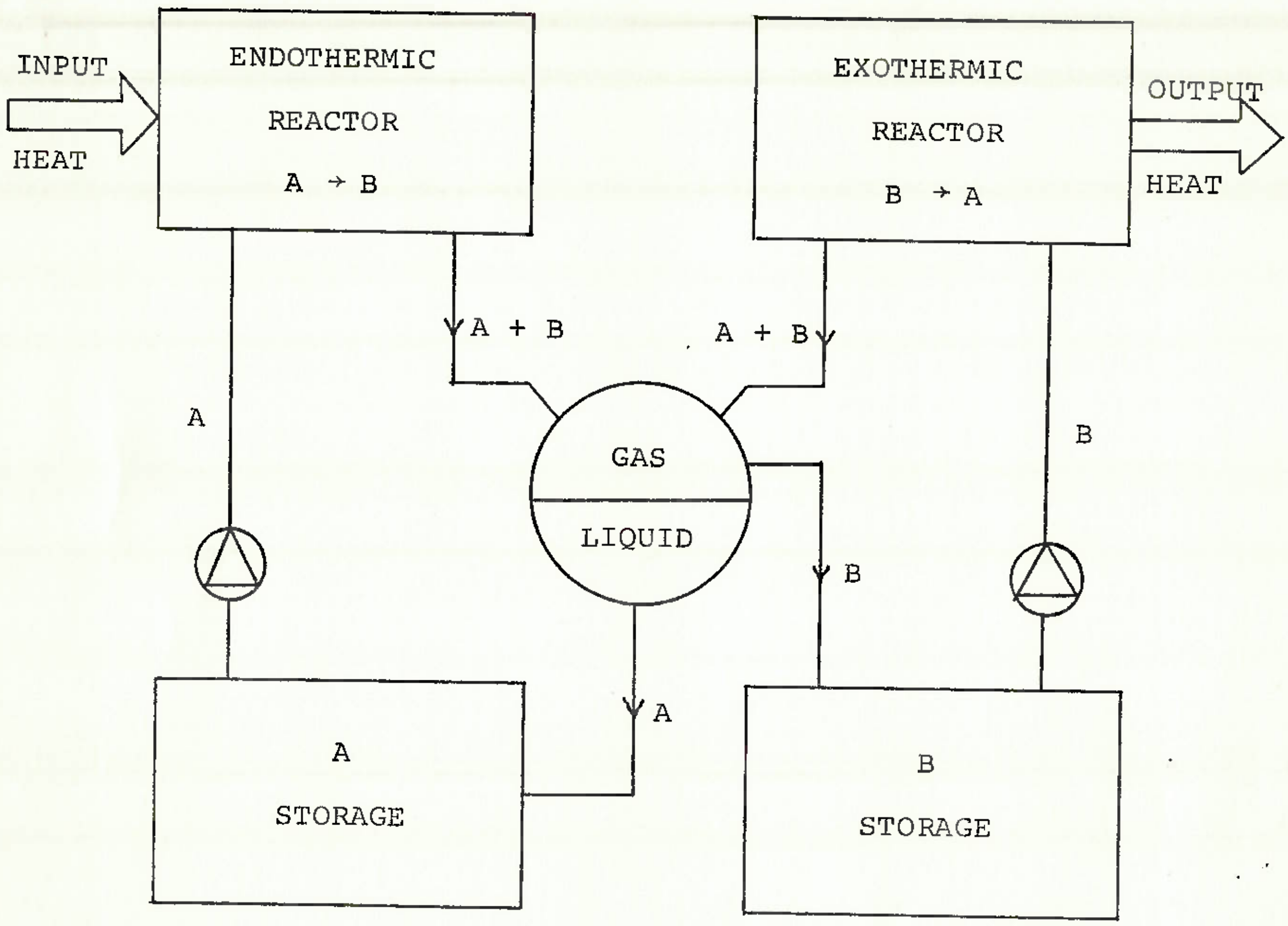

FIGURE 2: Thermochemical energy transfer system with liquid/gas phase separation

endothermic heat of reaction being supplied from the source. The reaction mixture is separated into liquid reactant and gaseous product, the latter being transported through pipes to the region where high grade heat is required. This heat is generated by resynthesis of the original working fluid in an exothermic reactor. Counterflow heat exchangers are employed at both the endothermic and exothermic reactors in order to minimise thermal losses and obviate the need for thermal lagging of connecting pipes.

Current research into thermochemical energy transfer systems is conducted on both experimental and theoretical levels. The work is widely applicable to many areas of energy utilization and is not just confined to solar energy. A prototype ammonia dissociator has been tested thoroughly and the thermodynamics of energy transfer and work production from thermochemical energy transfer systems have been investigated in some detail.

2.2 Underground Gas Storage

The thermochemical energy transfer cycle provides not only a practical method for energy transport but also gives the opportunity for long-term energy storage through storage of the high pressure gas mixture produced during the endothermic reaction. The availability of long term energy storage is a critical feature for a solar power plant designed for base-load heat output or electricity generation since it provides the essential buffer between the variable supply (day and night periods, clouds) and a more steady demand. Provision of energy storage is relevant also to conventional power generation for providing a buffer between the steady supply and fluctuating demand in order to facilitate operation of the heat generation capital plant at full capacity at all times.

While it is uneconomical to store large quantities of high pressure gases in conventional steel vessels, there are strong possibilities that the gas mixture (hydrogen/nitrogen) can be stored successfully underground in aquifers or disused gas and oil wells. Underground storage of natural gas in aquifers has been practised throughout the world for some time, the principal unknowns in the present proposal concerning the behaviour and loss mechanisms of hydrogen stored underground. Preliminary studies on underground storage of hydrogen/nitrogen mixtures were completed two years ago and a full-time research programme has been commenced this year.

2.3 Paraboloidal Collector Development

The third major area of present research involves paraboloidal collector development. Selection of the methods available for collector development is severely limited by the economic constraints that accompany all large scale solar energy development. Research is at present conducted into methods for producing cost-effective paraboloidal shells from sheet metal. The studies are accompanied by research into suitable materials for reflective surfaces and appropriate focal absorber development.

2.4 Fertilizer and Liquid Fuel Production

The research programme of the Energy Conversion Group has to date been aimed principally at the particular problems associated with the production of solar-generated high grade heat and solar electricity generation on a large scale. There are, however, some additional areas to which attention has been directed, each being associated with the particular approach utilising a thermochemical energy transfer system for solar electricity generation. A solar electricity plant incorporating such a system based on ammonia may be expanded to nitrogenous fertilizer production, and if based on methanol and used in conjunction with coal, may be expanded to liquid fuel production. The latter area is one of the proposals of this submission and both areas have been discussed earlier in the Australian Senate submission (Carden and Kaneff 1976) from the Department of Engineering Physics and also by Kaneff (1977).

3. SYSTEM ECONOMICS

New systems for supplying primary energy requirements are not, at this time, likely to be competitive with present energy sources. An economic assessment in present terms is, however, useful for giving a guide to the necessary changes in costs of current energy sources that must occur before the new technology becomes viable. It is useful for guiding those aspects of the research and development of the new system aimed at reducing cost. Although a new technology may appear uneconomic by a large factor at the present time, continued research is likely to lead to cost reductions. At the same time increasing costs of present energy sources are to be expected and in this regard we point to the large changes in conventional energy prices which have already occurred; for example, the price of imported oil has in recent years risen by more than a factor of four and further rises are expected. There seems every reason to expect similar changes in the price of coal in the future as a result of sustained demand pressure.

The economics of the solar ammonia system for electricity generation have been outlined by Carden (1977a). In order to compare the economics of a solar power plant with those of a conventional thermal power plant, the capital cost of collectors, energy transport network and storage system must be offset against the annual cost of fuel for a thermal power plant. Based on comparison with oil at $13 per barrel and export coal at $40 per tonne with an annual 15% rate for costs and charges on capital, it is found that the above components of a solar power plant can be costed at no more than $80 per square metre of collector area when compared to oil, and about $50 per square metre when compared to export coal. These are very severe cost constraints which cannot presently be met. They imply that solar electricity is not cost competitive in our capital cities at the present time. However, our research indicates that electricity could be produced from a solar power plant at a rate of typically 4-5 cents/kWh, or a factor of two to three higher than is current in much of Australia. In view of the arguments of the preceeding paragraph, the potential of solar power plants can be taken seriously, and indeed, research into solar power generation and allied areas should be encouraged, as it is in the Uited States, France, Israel, the European Economic Community and elsewhere.

It seems sound economics to base the above cost comparison on the full opportunity cost of coal (the export price of typically 40 $/tonne) rather than on the present internal price of typically 6-10 $/tonne which represents extraction costs to the electricity generating authorities. The employment of an alternative energy source will save coal which may then be sold at the export price of 40 $/tonne. If the profit so derived is set against the increased cost of energy from the new source, it will be seen that as long as the new energy source is competitive with coal priced at 40 $/tonne, no change will result in the price of energy paid by the consumer. It follows that once a cheaper alternative to export-priced coal is developed, Australians will be denying themselves a reduction in the price of electricity if the alternative is not immediately adopted. A similar argument based on opportunity cost analysis leads to the conclusion that the export price of coal will tend in the future to follow that of oil; that is, the price of coal will increase.

4. COAL RESEARCH PROPOSALS

Our research proposals may conveniently be considered in three interrelated parts.

4.1 Storage of Substitute Natural Gas and Hydrogen

As Australia's supply of natural gas diminishes in future decades, or is reserved for chemical industries based for example on ammonia or methanol production, it will be desirable to supplement and indeed replace its use as a direct fuel by substitute natural gas produced by coal gasification. Since it will be more economical to produce methane/hydrogen mixtures from coal gasification rather than to produce methane alone, it is likely that substitute natural gas will contain a considerable amount of hydrogen. As the production of substitute natural gas becomes more widespread, there will be an increasing requirement for suitable storage areas. The reasons for this are identical to the present reasons for establishing at Gidgealpa (South Australia) an underground store of processed natural gas and currently, as in the past, for establishing similar reservoirs near major demand centres around the world. Since the substitute natural gas will be required to replace in quantity the presently used domestic and industrial oil and eventually to replace natural gas as well, it is unlikely that storage in conventional gasometers will be suitable or of adequate capacity. (For similar reasons, storage existing in pipelines, although significant, would also be inadequate, particularly when lines are comparatively short.)

Underground gas storage generally makes use of closed geological structures in sedimentary strata normally saturated with water. Storage of gas is implemented by drilling into the structure and forcing gas to displace the water. Candidates for reservoirs of this type include disused gas wells, oil wells and most importantly aquifers of the type prevalent in coal bearing districts and in areas adjacent to every highly populated district in Australia.

Underground storage of hydrogen-rich gas mixtures such as substitute natural gas derived from coal, differs from underground storage of natural gas in that hydrogen is known to be more difficult to contain because of its ability to diffuse through a variety of materials and through microscopic fissures. Moreover, several chemical reactions between minerals and the stored gas may be important and need investigation. Storage of hydrogen by displacement of ground water in sedimentary closed structures is argued (Carden 1977b) to be essentially equivalent to storage in a water walled structure. If this argument is proved correct, then the essential loss mechanism will be the diffusion in water of dissolved hydrogen, in which case losses will be small. On the other hand, surface and solid state effects in the mineral particles may play a disproportionately large role in the case of hydrogen when compared to other gases commonly stored underground. The research proposed in this submission is related to the study of these effects and will augment present theoretical studies and experimental work concerned with two phase fluid dynamics in porous media. The proposed research is also related to the complementary mechanisms of impurity pick-up by the hydrogen from ground water. This is clearly relevant to proposals for the underground gasification of coal.

The above proposal for research is relevant to the short-term future since the implementation of widespread coal gasification processing will be rendered more economic by incorporating suitable storage facilities. The availability of gas storage provides the necessary buffer between the production area and a demand sector having seasonal and day-to-day fluctuations. An economic assessment can therefore be made on the basis of comparing the cost of providing a plant sufficiently large to cope with maximum demand, with the combined cost of a smaller gasification plant used steadily at full capacity with underground storage facilities.

4.2 Coal Gasification/Solar Heat Methanol Production

One of the more important demand pressures on Australian coal will be the increasing need for coal liquefaction . The extensive use of coal liquefaction, however, presents some formidable problems. In order to overcome the projected shortfall of one million barrels per day oil-equivalent expected in 1990, an annual consumption of coal for conversion amounting to more than nine times the current total Australian black coal production would be required (Glastonburg and Young 1976). This is clearly not feasible in view of the level of growth expected of the coal industry. Nevertheless, coal liquefaction can provide an important proportion of the oil requirements of the country, the particular level being critically dependent on the efficiency of the coal liquefaction process.

Coal liquefaction processes can be inefficient in two important aspects: a particular process may be thermally inefficient in the sense that the liquid product has much lower heating value than does the coal used to produce the fuel, and secondly, a particular process may use more than the minimum amount of coal in the sense that only a fraction of the carbon in the coal feed appears in the final liquid product. Both of these aspects are related to the use of less coal to produce the same quantity of liquid fuel and thus reduce the demand pressure on coal. Research into areas for increasing the efficiency of coal liquefaction processes should therefore be encouraged.

The present proposal is for research into the second aspect, the optimum use of coal from the point of view of carbon transfer between feed and product. This would involve study and development of a coal gasification/solar hybrid system for producing methanol as a liquid fuel. Methanol has been used successfully in the past as a motor spirit burned either in pure form or when mixed with gasoline. It is also an important basic chemical in its own right, being the basis of a vast chemical industry throughout the world.

In the normal production of methanol from coal, a hydrogen/carbon monoxide mixture suitable for synthesis is produced by one of the modern gasification processes such as the Koppers-Totzek process. Coal is gasified by steam reformation and in this process extra coal (34%) is burned in oxygen as a source of the required endothermic heat of reaction. The resulting gas mixture is deficient in hydrogen which is produced by a water-gas shift reaction with rejection of the carbon dioxide produced. Methanol is synthesised from the appropriately tailored synthesis gas mixture, 2.6 times more carbon than appearing in the methanol product being used in the process.

In the proposed system, the water gas reaction is replaced by water electrolysis using solar derived electricity. This process, which includes a thermochemical energy transfer and storage system based on methanol as well as a large scale solar collector array, is shown in Figure 3. Only 1.3 times the carbon content of the methanol product is used in the process, a saving of half the coal required in the conventional synthesis process.

In order to compare the conventional and proposed systems, the savings accruing from more efficient use of the coal feed must be offset against the increase in capital equipment including collector array, energy transfer and storage system and increased methanol synthesiser capacity. Preliminary calculations based on presently feasible solar technology show that a substantial rise in the price of coal is required before the hybrid system becomes economically competitive. The proposed research has therefore relatively long term significance but in view of the importance of efficient liquid fuel production to Australia and uncertainties in future movements in coal price as demand pressure increases, it is considered relevant and realistic. We recall that international oil prices have increased by more than a factor of four in less than half a decade and further price rises are expected in the future. In parallel with these developments our research has already revealed ways in which solar energy can move towards cost

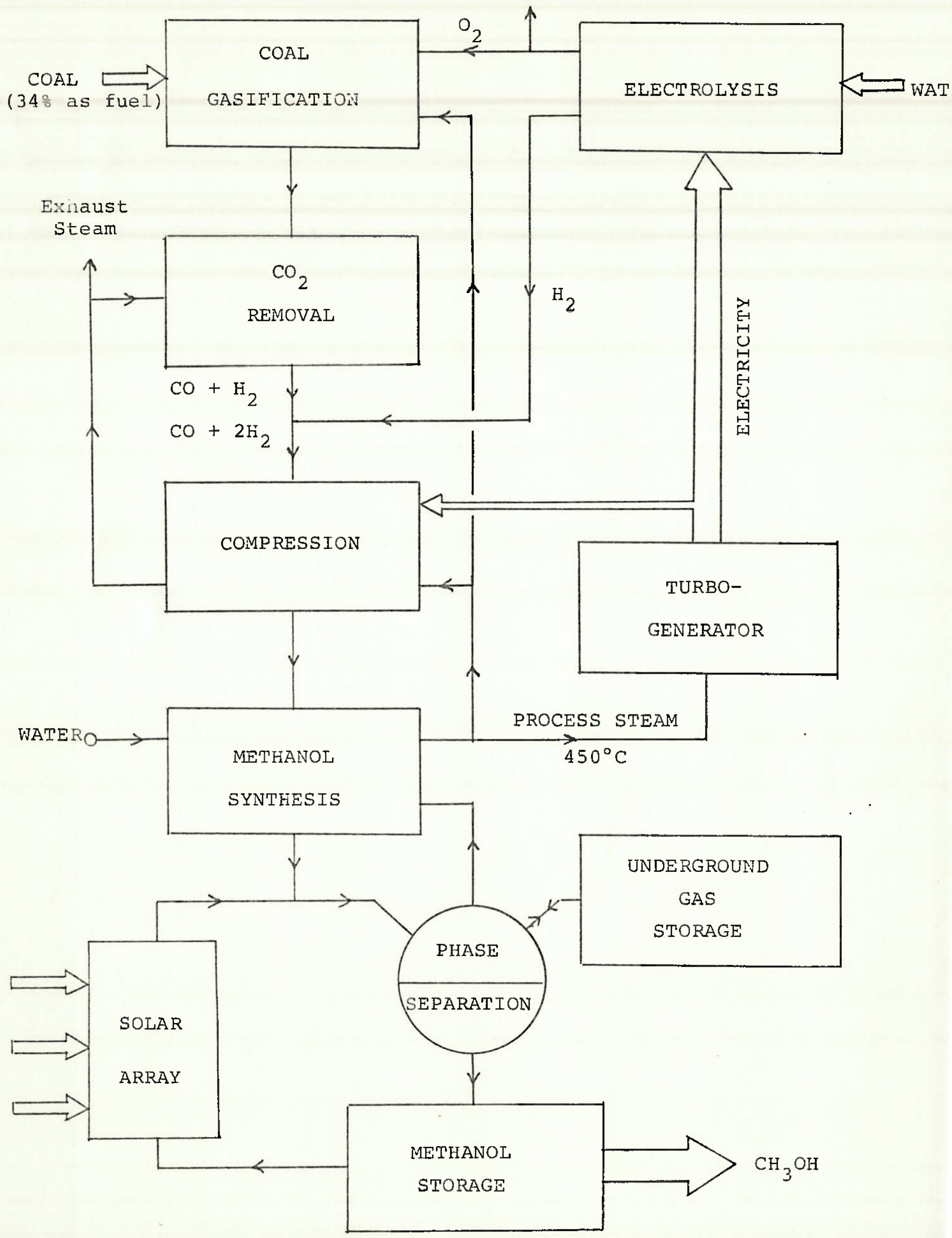

FIGURE 3: Methanol synthesis by a coal/solar hybrid system

effectiveness in comparison with other energy sources and consequently towards significant reduction in the real costs of solar energy utilization are expected as research and development advance. We do not therefore regard it as premature to request support for research in this area, now, particularly when it is linked closely with our current research programmes and with the other aspects presented in this submission.

4.3 Process Heat Generation and Distribution by Thermochemical Energy Transfer

As both oil and natural gas become scarce, there will be an increasing tendency for industry to revert to coal-derived fuels for high grade process heat requirements. It seems unlikely that unprocessed coal will be used in large quantities since it would then be difficult to maintain and indeed improve present industrial atmosphere emission standards. It is more likely, as indicated above in Section 4.1, that industrial requirements will be met largely by gas derived from coal or by refined processed coal (for example, by solvent refined coal).

There is a more radical and potentially more acceptable solution to the problem of supplying industrial process heat requirements, as shown in Figure 4. Heat derived from burning coal at a remote station can be used to provide the endothermic heat of reaction in a thermochemical energy transfer cycle. The gaseous working fluid is then piped to the industrial demand areas where high grade heat is regenerated during the reverse exothermic reaction. The liquid product would then be returned to the remote

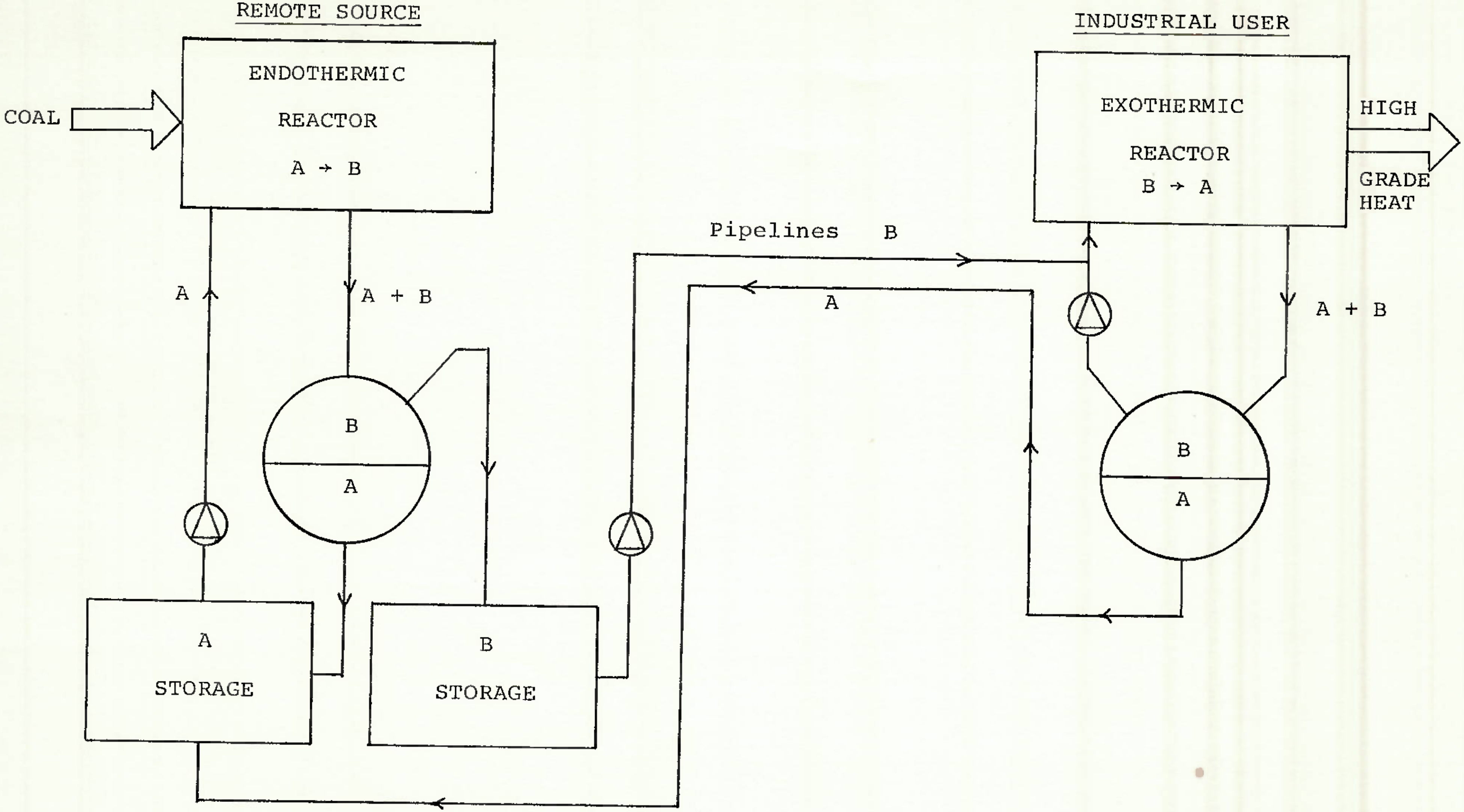

FIGURE 4: Thermochemical energy transfer system for process heat distribution

power plant through pipes which would be considerably smaller than the working fluid feed pipes. Energy storage may be included through underground storage of the gaseous working fluid in the vicinity of the remote station.

The above proposal is not essentially new and indeed has received serious attention in Germany (Hafele 1974) in relation to optimum use of the capital incorporated in nuclear power stations. In this case, a thermochemical energy transfer cycle is employed to transport energy for process heat generation from the power plant in times of low demand for electricity. In this way the power station may be operated close to maximum loading at all times.

In the present context, the proposal relates to the removal of atmospheric pollution from industrial and population areas where only low emission levels can be tolerated, to remote areas where higher levels can be tolerated and further, where more effective and economic emission control measures can be implemented at the flue of the single coal burner. The proposal is complementary to the alternative outlined in Section 4.1 for providing industrial process heat by coal gasification with storage. In the case of thermochemical energy transfer, capital costs include increased coal burning facilities at the power plant, working fluid pipelines to demand areas and individual exothermic reactors at the points of demand. In the case of coal gasification, capital costs include gasification plant, gas pipelines to the demand areas, and costs of individual emission control units. The thermochemical energy transfer proposal represents a departure from more conventional coal usage, but in view of increasing anxiety towards the problem of smog generation and the necessity for implementation of emission control standards in industrial and populated areas, represents a realistic solution of potentially high efficiency and effectiveness. Our research so far into thermochemical energy transfer has revealed high conversion and transport efficiencies using relatively simple technology.

5. RESEARCH PROGRAMME

The research programme envisaged for investigating the above proposals would include a general assessment of the problems from the viewpoints of both technical and economic feasibility, leading to the identification of specific problem areas. Each aspect would be assessed during the first year of study and the optimum path for research identified in relation to the present activities and expertise of the Energy Conversion Group. It is envisaged that a comprehensive report detailing the significance of the proposals and outlining the options available for further research would be produced in the first year.

We have indicated above that there are strong links between the proposed research and certain aspects of our existing research programme. Indeed, the major scientific and technological uncertainties lie within two areas, underground gas storage and thermochemical energy transfer. Work in each of these areas would be expanded with experimental and theoretical programmes initiated to provide solutions to the specific problems related to the above proposals.

5.1 Underground Gas Storage

Our present research in underground gas storage is confined principally to a study of fluid dynamics in porous media in relation to energy dissipation and gas-water interface stability. A second problem area is related to loss mechanisms specific to hydrogen and it is proposed that existing theoretical research in this area be expanded and supported by an experimental programme financed by a Coal Research Levy grant. The programme would be aimed at studying hydrogen diffusion in water-saturated porous media at high pressures. Estimates for experimental equipment requirements are as follows:

1.	Pressure vessel and experimental chamber	5,000
2.	High pressure valves and fittings	5,000
3.	Mass spectrometer	10,000
4.	High vacuum equipment	5,000
5.	Miscellaneous	5,000
	TOTAL	$30,000

5.2 Thermochemical Energy Transfer

Considerable progress has been made to date in our existing programme into our second area of research, thermochemical energy transfer. Experimental studies have been concentrated in the area of solar absorber design and ammonia dissociator operation. Understanding gained from the experiments has led to a detailed theoretical assessment of thermochemical energy transfer systems in general.

We are now in a position to specify the design criteria for a thermochemical transfer system optimised for maximum work production. Further problems exist, however, in the area of thermochemical energy transfer utilisation for high grade heat distribution and further, there is a need for design and construction of a thermochemical energy transfer system in order to identify specific engineering problems and assess performance on a pilot plant level. Work during the first year of a Coal Research Levy grant would therefore be directed towards solution of the remaining theoretical problems, and towards the first stage of development of a thermochemical energy transfer pilot plant. Expenditure is estimated as follows:

6.	Pressure vessels for synthesiser and gas storage	8,000
7.	Synthesiser	4,000
8.	Heat recovery/work production units	5,000
9.	High pressure valves and fittings	5,000
10.	Control electronics	5,000
11.	Data acquisition	10,000
12.	Miscellaneous	4,000
	TOTAL	$41,000

5.3 The First Year

The items 1, 3, 5, 6, 7 and 9 of the above lists for experimental equipment would be required for the first year of development of the specified research programme. These items are estimated to cost a total of $37,000, of which $30,000 is requested in this submission with the remainder financed from other sources. The total expenditure for the experimental research programmes outlined above would be spread over a period of several years. A further sum estimated at $70,000 per year is also requested to cover salaries and overheads for three additional staff required to implement the research programme. The three positions are specified above in Part I.

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