Commission
of the European Communities

NEW WAYS TO SAVE ENERGY

THE COMMUNITY'S ENERGY R & D PROGRAMME: ENERGY CONSERVATION

2nd updated edition

Survey of Results
and Compilation of
selected new projects

INDIRECT ACTION

EUR 7389 EN

COMMISSION OF THE EUROPEAN COMMUNITIES

ENERGY R and D PROGRAMME

ENERGY CONSERVATION RESEARCH

SURVEY OF RESULTS (1975-1979) AND COMPILATION OF SELECTED NEW PROJECTS (1979-1983)

2nd updated edition

edited by: P. Zegers

INDIRECT ACTION

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CONTENTS

INTRODUCTION

The aim of this booklet is to provide for dissemination of the results obtained in the Communities' Energy Conservation R and D Programme. An overview of this programme is given by means of a complete list of the projects studied under the Community's first Energy Conservation Programme (1975-1979), a brief description of the work performed and results achieved for each of these projects and a survey of projects selected for the second programme (1979-1983).

On 22 August 1975 the Council of Ministers approved a first four-year Energy R and D programme in which energy conservation R and D formed a part. Energy Conservation R and D was executed in the following sub-sectors:

Improved insulation of buildings	Materials recycling
Use of heat pumps	Production of energy from waste
Urban transport	Industrial processes
Residual heat recovery	Storage of secondary energy

The Commission concluded more than 100 research contracts with organizations or undertakings in the Member States of the European Community. The cost of this R and D programme was around 22 Mio ECU of which half was paid by the Commission. The work performed under most of these contracts is finished now and the results are available in the form of final or summary reports published by the Commission as EUR reports. They can be purchased at the following address:

Office for official publications of the European Communites
P.O. Box 1003
LUXEMBOURG

Both paper copies and microfiche copies are available. The cost amounts to 5 Bfr. per page for paper copies and 90 Bfr. for a microfiche which contains 96 pages. Abstracts are being published in Euro-abstracts. More information on these projects can also be found in the Proceedings of the Conference "New Ways to save Energy" held from 23 to 25 October 1979. These proceedings can be purchased at the following address:

D. Reidel Publishing Company
P.O. Box 17
3300 AA DORDRECHT, NETHERLANDS

Following the first Energy R and D programme (1975-1979) the Council decided on 11.9.79 to adopt a further Energy R and D Programme for a four-year period starting on 1.7.79. A call for tenders was published which resulted in about 600 proposals in the field of energy conservation R and D of which 145 were selected for further contract negociations. A good number of contracts has been concluded. The total cost of the second R and D programme is around 60 Mio ECU of which up to 27 Mio ECU will be paid by the Commission. An overview of the second programme is given in this book.

2nd edition

In the chapter on the first Energy R and D programme (1975-1979), mistakes have been corrected and final report numbers have been added where new final reports became available. In the chapter on the second programme (1979-1983) an overview was added, the list of contracts was updated which now includes the title, contract number, address of the firm and the name of the project leader.

LIST OF PROJECTS (CONTRACTS)

		Final report No*)
1.	**SECTOR A — IMPROVEMENT OF INSULATION IN BUILDINGS**	
	Insulation (windows and walls)	
1.1	Production of infrared reflective layers on glass	EUR 6804 FR EUR 6806 FR
1.2	Infrared reflective coatings on plastic film	EUR 6741 EN
1.3	Heat and sound insulation with coated glass	EUR 6811 D
1.4	Energy savings by infrared reflective finishing	EUR 6323 EN
1.5	Development and optimization of polyurea foam	EUR 6737 EN
1.6	Light concrete panels made from a combination of expanded shales and phenolic resins	
1.7	The detection and classification of heat leaks with help of infrared thermography	
	Optimization studies	
1.8	Energy savings in low cost houses	EUR 7385 EN
1.9	Building characteristics and gratuitious energy	
1.10	Natural ventilation and energy consumption	
1.11	The performance of a heating control system in experimental houses	
1.12	Comparison of the efficiencies of space and water heating appliances	EUR 6851 EN
1.13	Electric hot water heaters	EUR 6598 D
1.14	Heat recovery in buildings	
1.15	Heat recovery in air conditioning systems	EUR 7377 EN
2.	**SECTOR B — HEAT PUMPS**	
	Heat sources	
2.1	Investigation on using the earth as a heat storage medium and as a heat source for heat pumps	EUR 6835 EN EUR 7414 EN
2.2	Analysis of the factors which determine the COP of a heat pump	EUR 7048 EN
2.3	The use of soil with and without artificial heat regeneration as a heat source for heat pumps	EUR 6968 FR
2.4	Recovery of waste heat in sewers by heat pumps	EUR 7061 D

*) The letters at the end of the numbers indicate the language in which the report is written (EN = English, FR = French, D = German).

Conventional heat pumps and components

2.5	Development of domestic heat pumps	EUR 7098 EN
2.6	Air source heat pumps under Northern European climatic conditions	EUR 7388 EN
2.7	Frosting and defrosting behaviour of outdoor coils of air source heat pumps	EUR 7281 EN
2.8	Microprocessor based control system for heat pumps	EUR 7283 EN
2.9	Heat pump models for microprocessor based control systems	EUR 7046 FR
2.10	Analysis of the factors which determine the COP of a heat pump	
2.11	Heat pumps for individual rooms	EUR 7007 EN

Advanced heat pumps

2.12	Development of an absorption heat pump fired by primary energy for domestic heating	EUR 6326 EN
2.13	Design construction and testing of a prototype absorption heat pump fired with primary fuel	EUR 7064 D
2.14	Directly fired heat pump for domestic and light commercial application	EUR 7063 EN
2.15	The design and development of an absorption heat pump for domestic heating	EUR 7129 EN
2.16	Heat pump operating with a fluid mixture	EUR 6848 FR
2.17	Feasibility and design study of a gas engine driven high temperature industrial heat pump	EUR 7657 EN EUR 6262 EN

Heat pump applications

2.18	A gas engine driven heat pump using air as heat source for an apartment building	EUR 7133 EN
2.19	Diesel heat pump for district heating plants and for the heating of large housing blocks	EUR 6740 EN
2.20	Air source electrical heat pumps for 56 apartments	

3. SECTOR C — URBAN TRANSPORT

3.1	Potential for energy conservation by a shift to other types of engines in passenger cars	EUR 7303 EN
3.2	Improved efficiency of a spark-ignition engine in part load operation	EUR 7190 FR
3.3	Reduction of fuel consumption by thermo-dynamical optimization of an Otto-engine	EUR 6711 D
3.4	A feasibility study of a combustion chamber with variable geometry for small high speed diesel engines	EUR 6321 FR
3.5	No coolant ceramic diesel engine	

4. SECTOR D — RECOVERY OF RESIDUAL HEAT

Heat recovery components (heat exchangers and ORC engines)

4.1	Comparative study of a rotating regenerator and a heat pipe heat exchanger	EUR 6792 EN
4.2	Research on heat pipes and thermosyphons for heat exchangers	EUR 7006 D
4.3	Heat pipe heat exchangers for waste heat recovery in the laundry, textile and paper industry	EUR 7127 EN
4.4	Heat recovery at 750°C in the aluminium industry with a "heat wheel"	
4.5	Development of a falling cloud heat exchanger	EUR 7363 EN
4.6	Recovery of heat from exhaust gases at 250°C from a ceramic tunnel oven with an organic Rankine cycle engine	EUR 7642 EN
4.7	Recovery of heat from exhaust gases at 300-350°C with an organic Rankine cycle engine	EUR 6916 EN EUR 7159 EN

Heat recovery in specific industrial processes

4.8	Heat recovery in the iron melting industry	EUR 6604 EN
4.9	Recovery of heat from flue gases for preheating glass granulates	EUR 6324 FR
4.10	Possibilities for heat recovery in the coke industry	EUR 7161 FR
4.11	Heat recovery by dry cooling of hot coke	
4.12	Heat recovery in the aluminium industry	EUR 7387 D
4.13	Heat recovery from exhaust gases and hydrogenation of edible oils and fats	EUR 6837 EN
4.14	Heat recovery from milk with a heat exchanger or a heat pump for hot water production on farms	EUR 6915 EN
4.15	Heat recovery from exhaust air of spray dryers in the dairy industry	EUR 7576 EN

5. SECTOR E — RECYCLING OF MATERIALS

5.1	Recyling of thermoset resins reinforced by glass fibres	EUR 6833 FR
5.2	Saving of energy and raw materials by recycling plastic waste extracted from urban garbage	EUR 6917 FR

6. SECTOR F — PRODUCTION OF ENERGY FROM WASTE

6.1	Energy from waste and use of the remaining slag for building material	EUR 7621 D
6.2	Optimization of conditions for suspension firing of refuse derived fuel (R.D.F.)	EUR 6985 EN
6.3	Fluidized bed combustion of low grade coal	EUR 6823 EN

6.4 Fluid bed gazification of low grade coal and waste

6.5 Experimental study of the combustion of low calorific fuels

7. SECTOR G — INDUSTRIAL PROCESSES

General energy analysis

7.1	Optimized plant design to ensure energy conservation	EUR 6322 FR
7.2	A computer model for the evaluation of the electric energy consumption in mechanical plants	EUR 7189 EN
7.3	Application of the second law of thermodynamics to basic industrial processes	EUR 6752 EN
7.4	Development of an economic method for industrial energy saving projects taking into account non economical effects (pollution, safety)	EUR 6834 FR

Paper industry

7.5	Energy analysis of the paper industry	EUR 7192 EN
7.6	Reduction of power consumption in refining paper stock	EUR 7128 EN
7.7	Energy saving in paper drying	EUR 7152 FR
7.8	Energy saving in paper making by increased water removal by pressing	EUR 6679 EN

Textile industry

7.9	Dying wet fabric without intermediate drying after bleaching	EUR 6889 EN
7.10	Energy saving in heat setting and dye fixation of plastic fibres	EUR 7362 EN
7.11	Economy and energy saving in the textile industry	EUR 7302 FR

Food industry

7.12	Energy saving opportunities in the UK food industry	EUR 7073 EN
7.13	Combined heat power production in a milk powder factory	EUR 7134 EN
7.14	Research on energy saving in a brewery	

Combustion control of industrial boilers

7.15	Comparison of four combustion control systems for industrial boilers	EUR 7279 EN
7.16	Combustion control system for industrial package boilers using the flame radiation peak seeking technique	EUR 7191 EN
7.17	Methods of measuring the overall efficiencies of industrial boilers	

Power production

7.18	Recovery of energy from LNG vaporization	
7.19	Steam extraction from turbines for heating purposes	EUR 6325 FR
7.20	Energy saving in wet and dry cooling tower systems for large power plants	
7.21	Study of lean gas internal combustion engines	

Miscellaneous

7.22	Energy saving in waste water treatment plants	EUR 6680 EN
7.23	Polarization pyrometry	EUR 7045 EN
7.24	Energy saving in a blast furnace	

8. SECTOR H — ENERGY STORAGE

Heat and flywheel storage

8.1	Systems for chemical and latent heat storage in a temperature range from − 25°C to + 150°C	EUR 6936 EN
8.2	Study of organic materials for latent heat storage	
8.3	Storage of heat at 40-70° in salt solutions	EUR 7266 EN
8.4	Physical and chemical properties of latent heat storage materials in the temperature ranges 200-450°C and 700-900°C	EUR 7065 D
8.5	A feasibility study of heat storage in shallow aquifers	
8.6	Stationnary flywheel storage	EUR 7088 D

Electricity storage

8.7	Development and industrial production of beta-alumina electrolyte tubes by electrophoresis for a Na/S battery	EUR 6345 FR EUR 6719 FR
8.8	Development of high energy density Li/S cells with fused salts as electrolyte	EUR 7072 D
8.9	Materials R and D on new electrodes and electrolytes for advanced batteries (Anglo-Danish battery project)	EUR 7595 EN EUR 6372 EN
8.10	Synthesis and characterization of new intercalated lithium cathodes	EUR 7069 FR
8.11	Synthesis and characterization of new glassy lithium electrolytes	EUR 7070 FR
8.12	Contribution to the study of a fluorine-metal battery	EUR 7071 FR

SUMMARY OF THE R AND D RESULTS OF THE FIRST ENERGY CONSERVATION R AND D PROGRAMME

INTRODUCTION

The results of the first R and D programme, the consequences for future R and D in the European Community and their impact on energy savings will now be summarized.

The sectors A and B deal mainly with domestic energy consumption. About 40% of the final energy in the Community and 40% of the oil is used in the domestic sector and energy savings will therefore have a big impact.

The work performed in the sectors D, E, F and G was mainly of an industrial nature. The industrial sector consumes 40% of the final energy of which more than 2/3 is required for process heat. About 24% of the imported oil is consumed in this sector. Industry is a very heterogenous area with a large variety of industrial processes. The possibilities for reduction of costs by mass production for most energy saving technologies is therefore limited. This and the fact that the required pay back times are mostly very short (2-3 years) hamper the possibilities for energy saving in industry. On the other hand in seven years, energy costs increased from 2% to 10-12% of the GNP in the European Community. This increase is bound to have a strong impact on the profitability of the energy intensive industries. In this time where profits are marginal in many manufacturing branches, energy saving is becoming more and more important for the survival of an increasing number of industries. Further fuel price increases will strenghten this trend. The potential for energy savings in industry is difficult to estimate but may lie around 15% for the next 5-10 years. In the long term savings up to 30% are believed to be possible.

Sector A — Insulation of houses

— *Wall roof and window insulation* could bring energy savings of 20-30%. Insulation of walls and roofs is already in the manufacturing stage. Window insulation still needs more R and D. Infrared reflective coating has the promise of considerable energy saving. Heat losses through windows can be reduced with help of layers, transparent for light, which reflect the infrared heat radiation and keep the heat in the house. Generally a single pane glass coated with a reflective layer has approximately the same heat insulation as a double window. With tin and indium oxide layers the transparency is 80% and the cost 10-30 ECU/m^2. Gold and silver layers reduce the visibility to 60%; moreover silver corrodes very quickly. As coating can only take place in the factory, windows in existing houses cannot be treated and complete panes must be replaced. This problem may be avoided by coated plastic sheets, which can be fixed easily on windows. R and D demonstrated the feasibility of coating plastic (transparency 60%, cost 1,5 ECU/m^2).

— In the area of wall insulation a light self extinguishing insulation material (cost 40 ECU/m^3), and light concrete with good insulating properties have been developed. A catalogue with reference thermograms of typical insulation defects in buildings has been made.

— *Optimization studies:* a coordinated research programme for low cost houses has been carried out by four laboratories with the aim to minimize energy consumption. Passive solar energy, air infiltration and heating systems are problems which have been studied in this programme. In another study the potential for economically attractive energy saving by recovery of heat from waste water, exhaust air and flue gases was found to be very small (2% and 4% of the energy consumption in buildings for existing and new buldings respectively).

Sector B — Heat pumps

The large scale introduction of heat pumps could bring 30-50% energy savings, but this introduction can only be expected in the long term. The heat pumps presently available (mainly electrically driven compressor heat pumps with air as heat source) are still too expensive and their energy conversion efficiency from primary fuels (90%) is comparable to good classical heating systems. R and D to decrease the cost and increase the efficiency was therefore done. More advanced heat pumps with higher efficiencies (120-150%) have also been investigated. Combustion engine driven heat pumps which have high efficiencies due to heat recovery from the combustion engine, are not likely to be suitable for single houses as they are rather complicated and require careful maintenance. Absorption heat pumps have the promise of being cheap, very efficient and reliable. From results of the first programme it was shown that future R and D efforts should be focussed on absorption heat pumps and in particular on the development of a cheap and reliable fluid circulation pump and new working fluids. Also heat sources should be studied.

Sector C — Urban transport

The transport sector consumes about 20% of the total primary energy in the Community and accounts for 36% of the oil consumption. The fuels used in this sector are virtually all petroleum based. The energy conversion efficiency of internal combustion engines in road vehicles from fuel to mechanical energy is very low (15-20%) and the potential for energy saving therefore is very large.

Work in the first programme showed that with improvements of existing engines, 10-20% can be saved. With more advanced engines, medium term options (e.g. stratified charge engines, lean burning engine), offer savings of another 20%. Long term options (e.g. ceramic engines) may save even more. Energy saving with electrical vehicles is limited if one takes into account the efficiency of power plants and battery storage. They do contribute to a reduction in oil consumption and allow for load-levelling and pollution abatement.

Internal combustion engines still have a long time to go, be it with normal petrol or with synthetic fuels. In view of the large energy saving potential and the relatively large part of oil consumed, energy conservation R and D on internal combustion engines is very important.

Sector D — Heat recovery

Research projects in this sector have been divided in two categories:

- heat recovery in specific industrial processes
- heat recovery components.

Research carried out in the part of the programme on *recovery in industrial processes* shows that significant energy savings can be achieved by recovery and re-use of heat. The most interesting and significant results are given below:

- In a scrap-iron melting plant a new design in the heat recovery section permits a 60% recovery of waste heat (flue gases) which gives an estimated pay back time of about one year.
- An energy saving of about 25% in the glass industry (furnaces) was obtained by recovering heat from flue gases in order to preheat the powder charge. This gives a 40% productivity increase and a pay back period of less than 3 years.
- Dry cooling of coke could lead to considerable energy savings. If all the coke produced in Western Germany should be dry cooled and users could be found for the resulting steam production, some 10^6 TOE could be saved per year.
- The biggest potential for energy savings in the primary aluminium industry lies in waste heat recovery,but economic feasibility was difficult to achieve in the project investigated.
- Significant savings can be achieved in the food industry (edible oil production, milk cooling on farms etc...).

The part on *heat recovery components* focussed on heat exchangers and organic Rankine cycle engines. Economic and technical feasibility of heat pipe heat exchangers has been demonstrated in the paper, laundry- and textile industry. Waste heat from ceramic tunnel kilns has been succesfully converted into electricity with an ORC engine. E.C. work on industrial heat pumps was very limited in the first programme and should be considerably expanded.

Sector E — Recycling of materials

In this programme work was executed on the recycling of plastic waste. The yearly production of urban and industrial plastic waste in the community is about $3{,}5.10^6$ tonne/year and $4{,}5.10^5$ tonne/year respectively. Recycling of this waste material is of interest both from energetic and environmental point of view. Projects on recycling of urban and industrial plastic waste gave good technical results. The economic feasibility should now be tested in demonstration plants.

Sector F — Production of energy from waste

The production of energy from urban, industrial, or coal waste is attractive as it not only produces energy from low value material but also contributes to pollution abatement. Fluid bed combustion/gasification has some important advantages over normal combustion: low combustion temperatures (800 to 950°C), increased heat conversion efficiency, possibility of reducing SO_2 levels with limestone, reduced volume. Combustion of waste material was investigated both with normal and fluid bed combustion. These experiments gave good technical results, but economic feasibility is still a problem.

SECTOR G — Assessment of specific energy of industrial processses

Whereas in sector D the possibilities for energy saving by heat recovery in industry have been investigated, sector G focussed on other improvements of industrial processes leading to energy savings.

Amonst the general studies for improved energy savings a computer programme was developed to select components and to determine their optimum arrangement for energy saving in an industrial process. This programm has been applied to a chemical refining plant. A survey in the mechanical industry gave some more insight in the optimum arrangement of electrical machine tools. Finally an attempt was made to take into account non-economical effects such as pollution abatement and safety, in the economical evaluation of energy saving projects.

Different aspects of energy saving in the paper industry have been studied by four laboratories from France, Netherlands, and the UK. In the drying sector and the pulp refining processes practical proposals emerged for energy savings.

In the field of textile manufacturing, energy savings in the dying process have been explored. In total, energy savings of 30-40% are believed to be possible. One of the energy saving options is direct dying of wet tissues, thus avoiding energy expensive intermediate drying. In the heat treatment of fabrics from thermoplastic fibres (e.g. nylon) for greater stability or dying, energy savings in the EC of 18.000 TOE/year are feasible.

A good overview of energy use in the food industry was obtained from a survey of the UK food industry. More detailed studies of breweries and on heat power coupling in the milk industry explored energy saving possibilities.

Three contracts were concerned with the optimization of boiler operation and their control. An automatic control system which keeps the boiler at its optimum point, in particular also for part load operation, requires very good combustion conditions for a start. These are often not fulfilled.

A combination of power production with closed gasturbines and LNG evaporation could bring about a higher gasturbine efficiency. The potential primary energy savings in Europe are believed to be about 200.000 TOE/year. Economic feasibility will depend very much on the price which will be paid for the power produced. A study on the possibilities to use low calorie syngas (H_2 and CO) in combustion engines unveiled that much more R and D will be required to come to useful results.

Aerators of water purification plants have large possibilities for energy saving (pay back times of 4 months).

Sector H — Energy Storage

Research in the field of energy storage has been divided in three groups: heat storage, flywheels and storage of electricity.

The heat storage programme was of an exploratory type where a large number of compounds was tested on their suitability to serve as a heat storage material (latent —, sensible —, and chemical heat storage) in different temperature ranges (− 50°C + 450°C and 700-900°C). In this programme the technical feasibility of latent heat and salt solution heat storage systems at 50-100°C has been demonstrated. However the energy density of these systems is on the average only a factor two higher than simple and much cheaper hot water storage in insulated tanks. Also the cost of latent heat storage is high (400 ECU for a heat storage capacity equivalent to one liter oil). Economic feasibility however has not yet been achieved. The feasibility study on shallow aquifer heat storage which aimed at long term (possibly seasonal) heat storage, gave rather disappointing results. A discussion of experiments in the framework of the IEA implementing agreement, where this project was the EC contribution, showed that shallow aquifers are less suitable for long term heat storage. Deeper aquifers (30-500 m) confined above and below by clay layers are believed to be much better candidates for this purpose.

Flywheel applications have been explored. The final conclusion was that economical feasibility can only be achieved for high charging and discharging frequencies.

In the third group on electricity storage, work was executed on advanced batteries (Na/S, Li/S) and material research for advanced batteries by twelve laboratories from France, Germany, Denmark and UK. Seven laboratories from the UK and Danemark worked together in the "Anglo-Danish" project on material R and D for "all solid" advanced batteries. The collaboration between the twelve laboratories was very close and consisted of an exchange of data, of materials to be measured and different coordination meetings. This collaboration should be continued. Apart from a continuation of work on Na/S and Li/S batteries, future work should be focussed on a new "all solid" battery with LiAl and TiS_2 electrodes and $LiAl_2O_3$ or polymers as electrolytes. Also work on fuel cells for car traction should be included in order to keep this option open. In a seminar of battery contractors and potential users of advanced batteries (power utilities, car manufacturers) it was agreed that car traction is likely to be the most important application for high energy density batteries, with power utilities as second best.

ABSTRACTS OF FINAL REPORTS

The abstracts have been written completely or in part by the editor. On top off each abstract the names have been given of persons responsible for and/or involved in the project, together with the name and address of the firm. Also the contract number and the final report number are indicated.

SECTOR A

Improvement of insulation in buildings

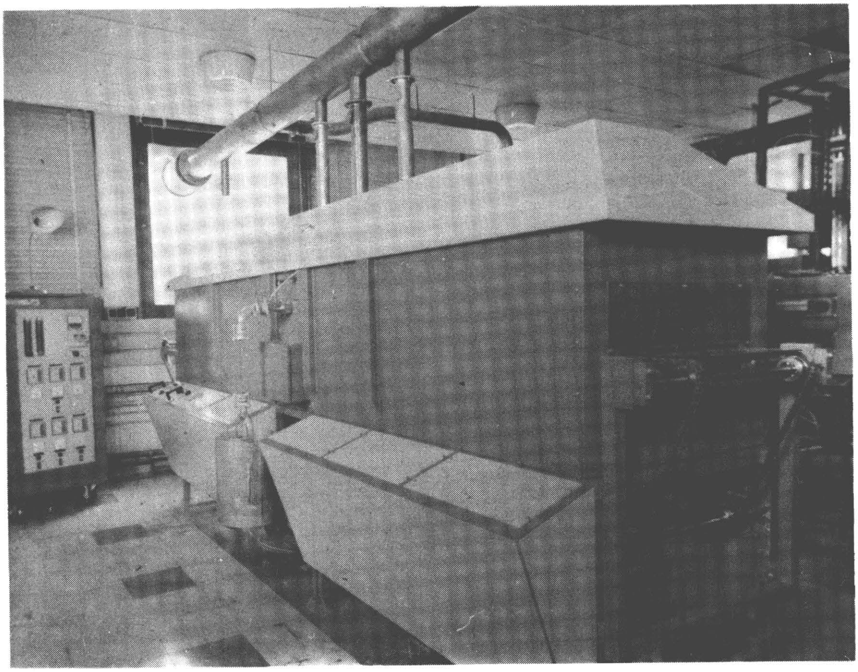


Figure 1.1.1. Machine for coating glass with an infra-red reflective layer.

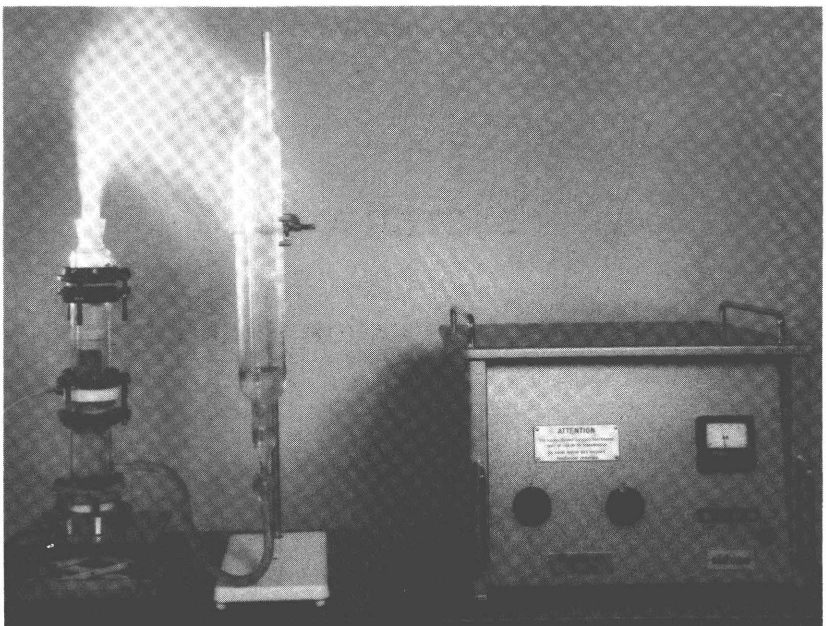


Figure 1.1.2. Production of aerosols for coating.

INSULATION (WINDOWS, WALLS)

Production of glass with infrared reflective coating 1.1.

G. BLANDENET

Y. LARGARDE

Commissariat à l'Energie Atomique — Centre d'Etudes Nucléaires de Grenoble — Département de Métallurgie

85 X 38041 Grenoble Cedex France

Final report number: EUR 6804 FR (1979)
EUR 6806 FR available in French

Contract number: 201-77 EEF and 334-78 EEF

The production of glass with infrared reflective layers has been studied by CEN-Grenoble. An industrial pilot plant has been developed which produces layers on single window panes with an emissivity of 0,15 by applying tin doped indiumoxyde coating on glass. Their insulating properties approach those of double windows (3,2 W/m2°K) and the light transparency is 80% of normal glass. Up to now only small panes (30 × 30 cm) have been produced, but it is expected that the size can be easily increased. With the present pilot installation the cost of depositing an infra-red reflective layer on glass is around 30 ECU/m^2. With the above-mentioned method, windows in existing houses cannot be treated and replacing of windows is likely to be too costly.

Infrared reflective coatings on plastic film 1.2.

R.P. HOWSON

Loughborough University of Technology
Department of Physics
Loughborough, Leicestershire LE11 3TU

Final report number: EUR 6741 available in English

Contract number: 212-77 EEUK

To solve the problem of retrofitting, Loughborough University developed a production technique which enables Cd_2SnO_4, TiO_2-Ag-Tio_2 or Si-Ag-Si systems to be deposited on a thin plastic film. These films can then easily be fixed on windows of existing houses. Normal coating techniques are not suitable for this purpose as the required temperatures are too high and would melt the plastic substrate. The developed process called reactive evaporation and sputtering ion bombardment, operates at room temperatures and does not have the above-mentioned inconvenience. A single window pane with a coated plastic film has about the same heat insulation as a double window (3 W/m2°K). The light transparency is 60%. Manufacturing costs of the film are 1,5 ECU/m2.

Heat and sound insulation with coated glass 1.3.

P. DERNER
R. GROTH
D. MERTIN
W. ZERNIAL

Flachglas AG
Auf der Reihe 2
D — 4650 GELSENKIRCHEN

Final report number: EUR 6811 available in German

Contract number: 254-77 EED

Double purpose windows providing both improved heat and acoustic insulation have been studied by Flachglass AG. Single and double glazed panes coated with gold or silver have been investigated. Gold coated double windows reached heat insulation values of 1,6 $W/m^2 {}^\circ K$. The transmission of visible light was 60% of normal windows. An additional advantage was an improved acoustic insulation of 10db. An attempt to replace expensive gold by cheaper silver failed due to the corrosion of the silver coatings. Manufacturing costs have not be given.

REMARKS		Energy conservation in %		
		Radiator heating ($\varepsilon = 0.9$)	Floor heating ($\varepsilon = 0.9$)	Air heating
None; $\varepsilon = 0.9$		0	0	0
Glass area treated	$\varepsilon = 0.3$	15	17	14
	$\varepsilon = 0.2$	18	19	17
	$\varepsilon = 0.1$	23	21	19
Insulating glass		21	21	21
Glass area treated	$\varepsilon = 0.2$			
other inner surfaces	$\varepsilon = 0.3$	23	26	14
	$\varepsilon = 0.2$	28	29	13
	$\varepsilon = 0.1$	34	32	9

Figure 1.4.1. Energy conservation achieved by use of infra red reflective paints and coating (window area 13.6 m^2, outside temperature ± 5°C)

Product	Application	Expected duration of life	Price per m^2 treated surface	Energy conservation per year per m^2	
				MJ	Currency
Tindioxide $\varepsilon = 0.2$	Plate or sheet glass in windows	50 years	f 25,00	600	f 6.00
Tindioxide on enamelled steel plate $\varepsilon = 0.15$	Wall finish	50 years	f 10.00	60	f 0.60
Heat reflective paint $\varepsilon = 0.25$	Wall finish	5 years	f 1.00	40	f 0.40
Aluminium foil decorated by chemical or electronical treatment $\varepsilon = 0.15$	Wall finish	10 years	f 15.00	60	f 0.60

1 f (dutch gulden) = 0.356 ECU

Figure 1.4.2. Cost — benefit analyses for different heat reflective coatings, applied in a radiator heated room. Assumed price of 1 MJ is 0.01 Dutch Guilder

Energy savings by infrared reflective finishing 1.4.

IR.J. DE JONG

Technisch Physische Dienst TNO-TH
Schoemakerstraat 97
Delft

Final report number: EUR 6323 available in English

Contract number: 144-76 EEN

The concept of infrared reflective layers on windows has been extended to walls, ceilings etc. by developing infrared reflective paints. TNO calculated that an overall application of infrared reflective materials can lead to energy savings of 28%. The largest part of this energy saving is brought about by tin oxyde based coatings on single windows which can lead to 15% energy savings. The remaining energy savings are mainly brought about by infrared reflective paint on walls and ceilings. The K value for infrared reflective single windows is 3,5 W/m^2 °K (5.8 W/m^2 °K for normal single windows). Transparency is 80%. The cost of the coated glass is 10 ECU/m2. Payback times of the extra investment for window coating and infrared reflective wall painting are 3 and 2 years respectively.

Development and optimization of polyurea foam 1.5.

H.S. CREYF

PRB — Recticel R&D Center
Damstraat 2
B — 9200 Wetteren

Final report number: EUR 6737 available in English

Contract number: 364-78-EEB

A low density (7 kg/m^3) and self extinguishing insulation material has been developed by PRB. R and D was carried out on laboratory, semi-industrial and industrial scale. The selling price is 1 700 BF/m3 and the payback times of wall and ceiling insulation with this material are 2 and 1 year respectively. This material can be used for new constructions only; retrofitting in cavity walls is not possible as the insulating material is delivered in panels.

Light concrete panels made from a combination of expanded shales and phenolic resins 1.6.

R. LÖDEL

Centre d'Etudes et Recherches des Charbonnages de France (CERCHAR)
B.P. 2
F — 60550 VERNEUIL-EN-HALATTE

Final report number:

Contract number: 343-78 EEF

Light concrete insulating panels made from a combination of expanded shales and phenolic resins have been developed by Cerchar. This light concrete has a high insulation value (K = 0,83 Kcal/hm 2°C) and very good fire resistance. It is believed that production of this material is economically feasible but no data have been given.

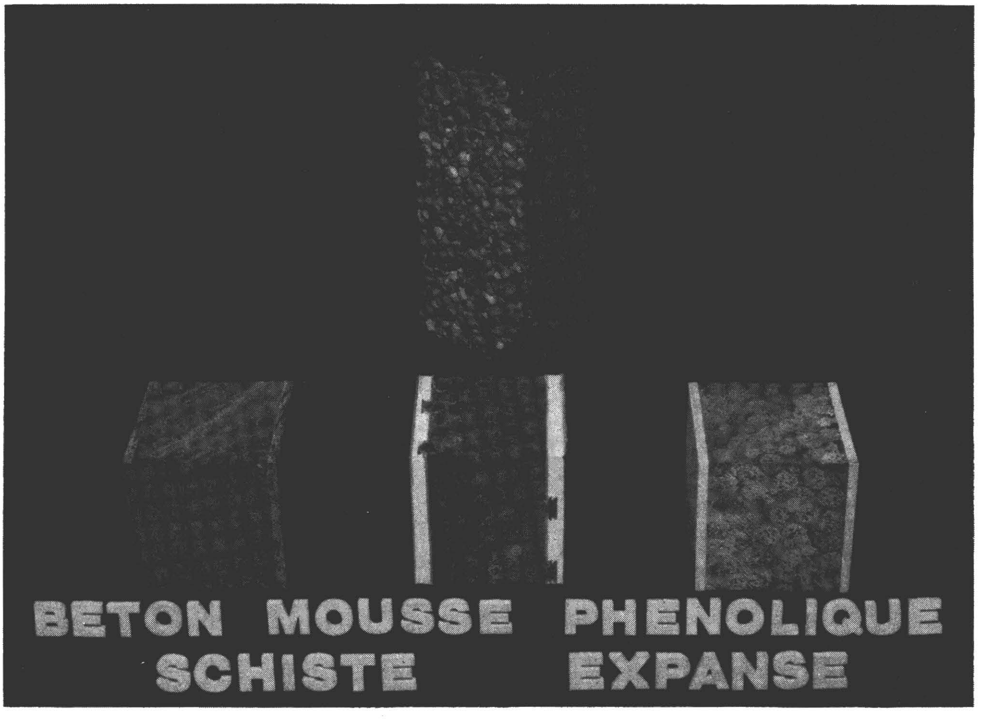


Figure 1.6. Different types of sandwich panels consisting of a combination of expanded shales and phenolic resins.

The detection and classification of heat leaks with help of infrared thermography 1.7.

G. VENUTI

Laboratoire National d'Essais
1 rue Gaston Boissier
F — 75015 PARIS

Final report number:

Contract number: 247-77 EEF

A preliminary classification of heat leaks in buildings has been prepared with the help of infrared thermography by Laboratoire National d'Essais. Detection of thermal insulation defects on building envelopes by means of infrared thermography requires correct interpretation of the thermographs taken in the field. On-site thermographic surveys and laboratory investigations were combined to establish a catalogue of typical reference thermogramps; analysis of 80-on site surveys on buildings on various kinds provided a list of 25 typical defects. They were then reproduced on six full-scale built-up sections placed in a dual climatic chamber to collect the reference infrared thermograms. They will be included in the catalogue for a set of typical climatic conditions.

OPTIMIZATION STUDIES

Energy savings in low cost houses 1.8.

A. DUPAGNE

J. LEBRUN

Laboratoire de Physique du Bâtiment
Université de Liège
Avenue des Tilleuls 15
4000 LIEGE

Final report number: EUR 7385 EN

Contract number: 615-78-1 EEB

A study of the basic characteristics of low-cost housing with a view to reducing energy consumption has been conducted by the University of Liège. This technical program was supplemented by three subprogrammes carried out by the CSTC (Centre Scientifique et Technique de la Construction — Science and Technology Center for the Building Industry) by the TNO and the BRE (British Research Establishment). Liège University is coordinating the subprograms and analysing the results of this work which is nearly finished. *Work of the above mentioned laboratories will be brought together to produce a design guide enabling the architects to introduce energy consciousness within the actual design practice.* This guide will permit architects to estimate the consequences for the consumption of energy of certain design decisions. Summaries of the subprogrammes are given below.

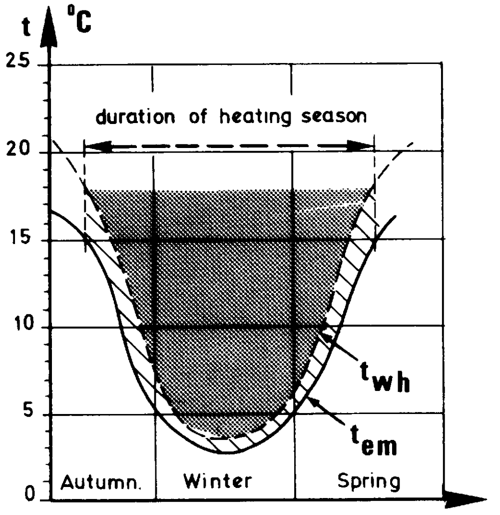


Figure 1.9.1. Air temperature and temperature without heating and degree-days during a normal heating season

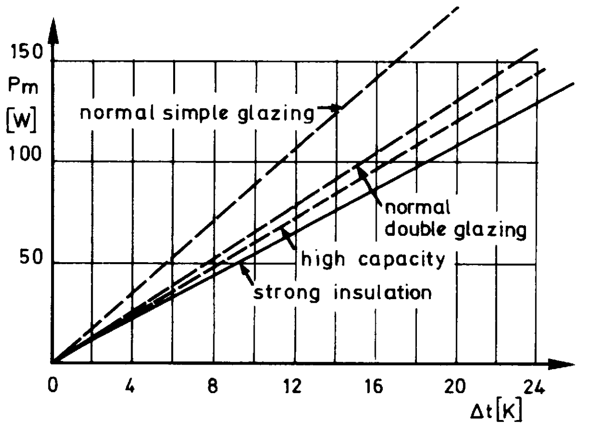


Figure 1.9.2. Mean power vs, temperature difference t_i-t_{wh} (preliminary tests)

Building characteristics and gratuitious energy 1.9.

H. HEIKHAUS

Centre Scientifique et Technique de la Construction CSTC
41 rue du Lombard
Bruxelles

Final report number:

Contract number: 361-78-1 EEB

The temperature in houses without heating is a very important characteristic of a building and can be used to calculate the energy consumption required, to heat the same building in order to obtain the desired comfort temperature. In this project CSTC developed two mathematical models: one for the calculation of the temperature without heating, from the thermal characteristics of the building and weather data, the second model for the calculation of the dynamic behaviour of the building under the influence of variable outdoor climate and changing internal heat loads. The two models were tested with the data from a measuring campaign on site on twelve reduced-scale models of houses and on one real house and from laboratory tests on the reduced-scale model. The results are very satisfactory, though the formules may be improved by further research. The architect can use these formulas when making a choice between different designs for a given project to select the most efficient design from the point of view of energy consumption.

Natural ventilation and energy consumption 1.10.

W.F. DE GIDS
Instituut voor Milieuhygiëne en Gezondheidstechniek TNO
Postbus 214
NL — 2600 AE DELFT

Final report number:
Contract number: 362-78-1 EEN

Energy losses due to ventilation and air infiltration was studied by TNO. Measurements of pressure differences across walls and ventilation shafts, indoor and outdoor temperatures, air tightness have been made. Air infiltration was determined with tracer gas. Two types of low cost houses have been studied: an apartment house and a row house. The air infiltration (m3/s) in a row house is 6 times higher than in an apartment house. In a single house (wind 6m/sec and an inside-outside temperature difference of 15°C) 25% of the consumed energy is lost by air infiltration. By reducing the air change rate from the measured value of 1 h^{-1} to 0,5 h^{-1} which is the dutch standard air change rate, considerable energy could be saved in row houses.

The performance of heating control systems in experimental houses 1.11.

R. RAYMENT
K. MORGAN
Building Research Establishment
Garston, Watford Herts

Final report number:
Contract number: 363-78-EEUK

The heating systems in the collaborative programme were studied by BRE. In the work carried out so far, detailed experiments on a comparison of room thermostats and thermostatic radiator valves controlling a heating system have been executed. A very good prediction calibration between the test houses enables some statistically significant results to be shown. Firstly, the thermostatic radiator valves do not save energy and secondly do not achieve more comfortable conditions compared with room-thermostat control of these test houses. Generalisation on these results requires a number of qualifications and these are stated. Computer models of heating systems and their control have been made and losses in flue gases have been measured.

Comparison of the efficiencies of space and water heating appliances 1.12.

G. HAMILTON
Building Services Research and Information Association
Old Bracknell Lane
Bracknell, Berkshire, U.K.

Final report number: EUR 6851 available in English
Contract number: 187-77 EEUK

Possibilities for energy saving in space and domestic hot water heating were explored by BSRIA. Three types of boilers providing both space and domestic hot waterheating were tested for different occupancy profiles: an oil and a gas fired high thermal capacity (HTC) boiler (± 14 KW) and a gas fired low thermal capacity (LTC) boiler (8 KW) all connected with radiators and a domestic hot water storage tank (140 liter). The results of the study show that:

— the part load efficiency of the appliances at a given load factor is generally insensitive to the occupancy profile
— the use of an electric immersion heater to provide domestic hot water in summer is not advantageous in terms of primary energy consumption as compared to the use of a central heating system
— for HTC boilers the overall efficiency is the same for thermostatic radiative valve control and for central room thermostat control. For LTC boilers, thermostative radiators valve control gave a poorer efficiency.

Electric hot water heaters 1.13.

K.F. EBERSBACH
Forschungsstelle für Energiewirtschaft
Am Blütenanger 71
D — 8000 MUNCHEN 50

Final report number: EUR 6598 available in German
Contract number: 190-77-EED

Electric hot water heaters were studied by the Forschungsstelle für Energiewirtschaft. The study shows that the maximum efficiency is obtained with instantaneous water-heaters of the water-flow controlled type when regulated for maximum water throughput. Various types of mixing valves for showers and baths have also been studied; the thermal valve is the most economical from the energy point of view, although, its price is generally six times higher than the twin-valve mixer unit.

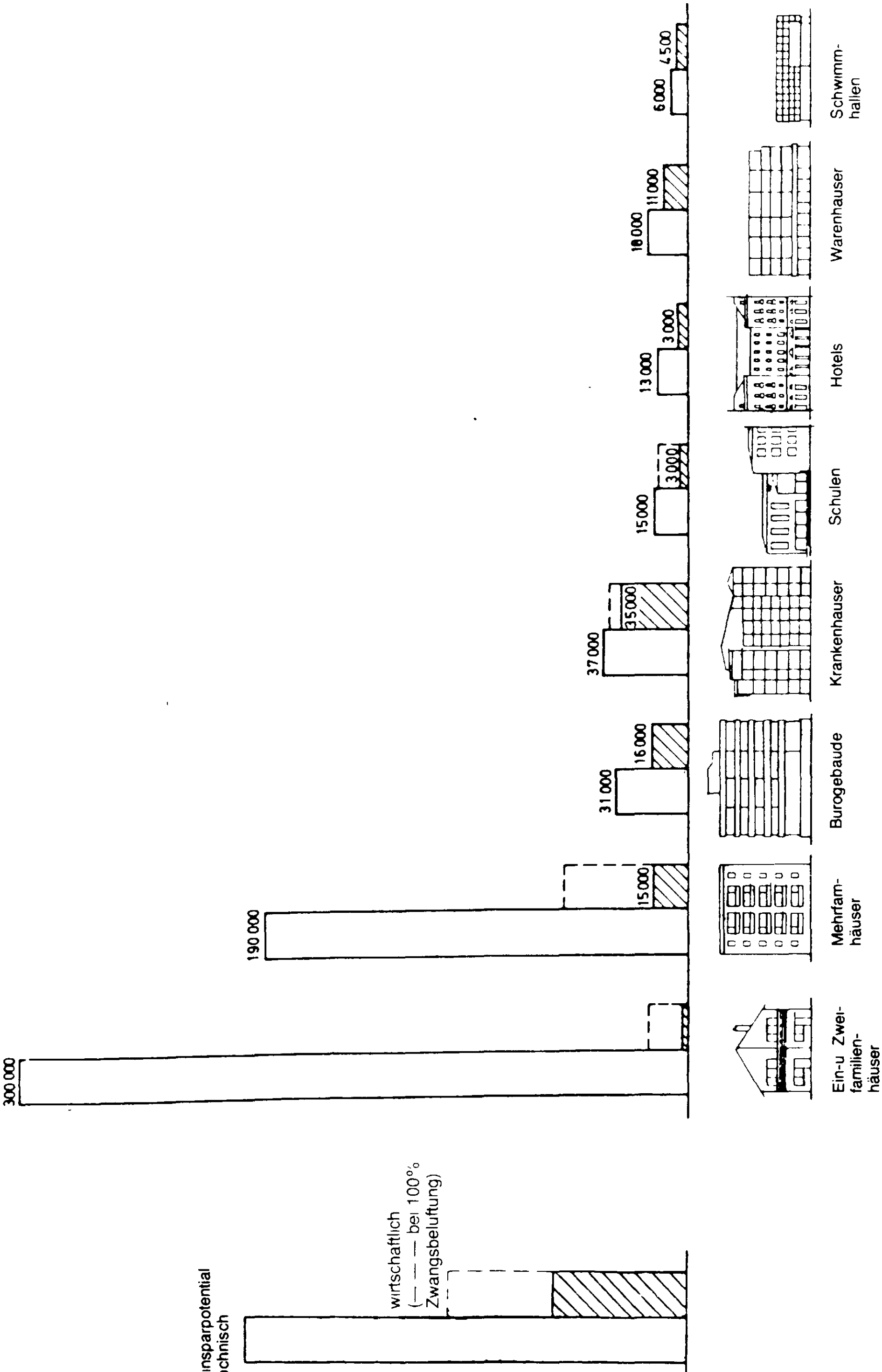


Figure 1.14. Energy saving by heat recovery in the European Community in different types of buildings (Gwh/a)

Heat recovery in buildings 1.14.

Dr A. GAHRMANN

Dipl.-Ing. B. WEIDLICH

Battelle-Institut e.V.
Am Römerhof 35
D — 6000 FRANKFURT 90

Final report number:

Contract number: 279-77-9 EED

The potential in the European Community for energy savings by heat recovery in buildings was evaluated by Battelle. Different types of buildings have been taken into account and about 90% of the total buildingstock has been included in this study. Heat recovery from waste water, exhaust air and flue gases from heating systems has been studied. It was shown that it is technically feasible to save 15% of the energy consumed for heating in buildings. In existing houses only 1/6 of these savings are also economically feasible. For new buildings this fraction is 1/3.

Study of energy savings by heat recuperation in air conditioning systems

1.15.

R.D. CROMMELIN, L.L.M. van SCHINDEL

J.W.J. HEEREN, J. de BOER, W.F. SULILATU

Final report number: EUR 7377 available in English

Contract number: 624-12 EENL

Measurements have been made at two different types of heat recovery systems in the air conditioning system. One system has a rotary type heat exchanger, the other system has two liquid-coupled heat exchangers (closed type). The measurements were made in different periods of the heating season. From the results of the measurements, heat transfer rates and thermal efficiencies have been calculated.

Besides the measurements a literature study of existing types of heat recovery systems in buildings has been made. From the data obtained by the measurements a cost-benefit analysis of both heat recovery systems has been made. Both systems appear to be equally attractive from the economical point of view if they are evaluated for a whole heating season. Pay-out times are between 5.5 and 6.5 years. The great possibilities of the regenerator with respect to heat recovery cannot be utilized to the full, yielding an average efficiency far below its maximum efficiency.

SECTOR B

HEAT PUMPS

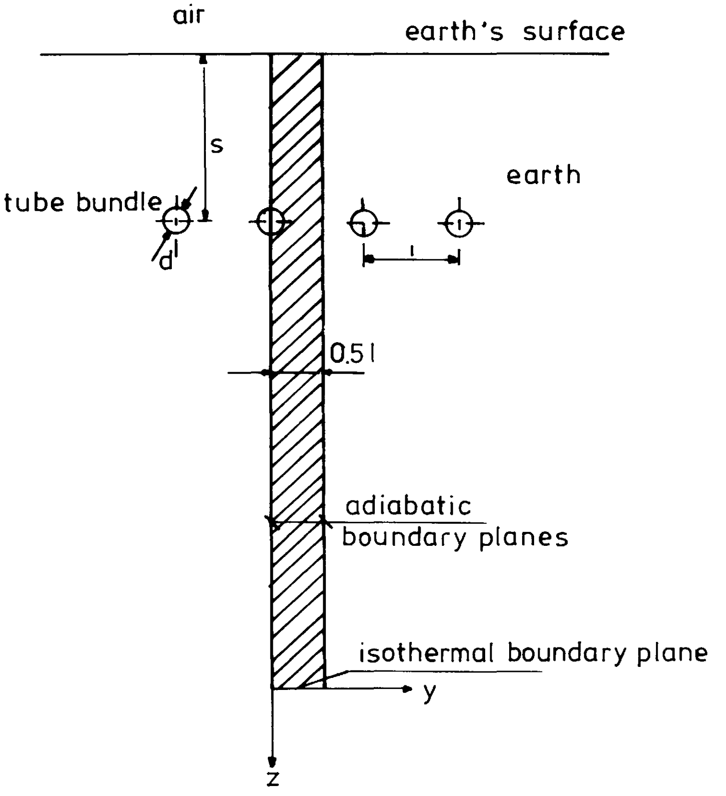


Figure 2.1.1 Model representation of earth heat exchanger consisting of buried horizontal tubes

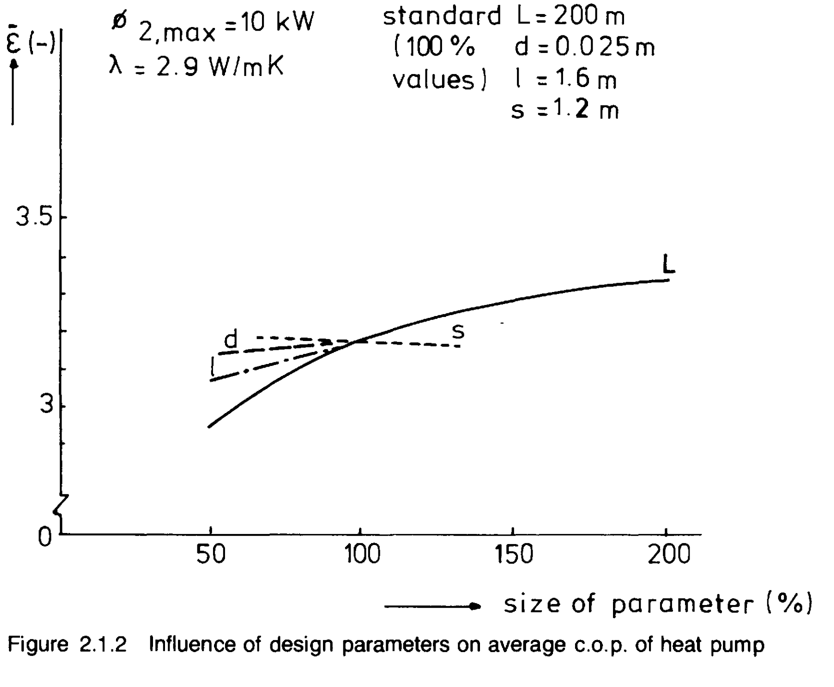


Figure 2.1.2 Influence of design parameters on average c.o.p. of heat pump

HEAT SOURCES

Investigations on using the earth as a heat storage medium and as a heat source for heat pumps — 2.1.

P.G.M. NIEVERGELD

AD. KOPPENOL

Organization for Industrial Research TNO
P.O. Box 342
Apeldoorn

Final report number: EUR 6835 and EUR 7414 available in English

Contract numbers: 231-77-EEN and 367-78-EEN

Heat extraction from and heat storage in the earth have been calculated for conditions as prevail in the Netherlands. Computer models based on a finite element method have been drawn up, with which the thermal performance of horizontal and vertical earth heat exchangers can be calculated. Calculation results show that the influence of the variation in thermal proporties of Dutch soil, including the effect of soil-freezing on the c.o.p. of an electrically driven earth/water heat pump for space heating is small. The influence of several design parameters of the earth heat exchanger on the performance of the heat pump is also moderate. Typical c.o.p.'s vary from 3 to 3.5. From calculations for a vertical type of exchanger it appears that, for the same thermal performance as that of a horizontal earth heat exchanger, the required earth surface area and tube length are considerably smaller. From a technical and economical evaluation it is evident that electrically driven earth/water heat pumps for residential heating contribute to a saving in fossil fuel. However, pay pack times are still too long.

Analysis of the factors which determine the cop of a heat pump

2.2.

M. FORDSMAND

A. EGGERS-LURA

European Heatpump Consultors Ltd
38 Skovshovedvej
DK - 2920 CHARLOTTENLUND

Final report number: EUR 7048 available in English

Contract number: 370-78-EEDK

The various heat sources and delivery installations have been discussed. Measurements on horizontal and vertical soil heat exchangers have been done and different combinations of heat pumps, solar collectors and heat extraction from soil have been studied. The most economical solution appeared to be a heat pump system with the soil as heat source and with floor heating. A total COP of four was expected to be feasible.

The use of soil with and without artificial heat regeneration as a heat source for the heat pumps 2.3.

B. GEERAERT

J.C. STEFFENS

Laborelec (Section 8 + S.M.)
P.O. Box 11
1640 RHODE SAINT GENESE

Final report number: EUR 6968 available in French

Contract number: 374-78-EEB

This report is an experimentally verified study of the conception of a horizontal soil heat exchanger and its potential coupling with solar collectors as a heat source for heat pump room heating.

The main conclusions are:

— the accuracy of computation methods for the performance of the soil heat exchanger is of the order of 20-25%.

— the optimal depth of the pipes is as near to be soil surface as can be allowed for safety reasons.

— the horizontal distance between the pipes must be between once and twice their depth.

— a double layer heat exchanger (with pipes burried at two different depths) is a good solution in order to reduce the required soil surface.

— careful attention shall be devoted to insure a sufficient flow rate at the lowest working temperature of the glycol-water mixture.

— coupling of the ground heat source with solar collectors is only interesting and economically feasible with very cheap collectors (e.g. energy roof).

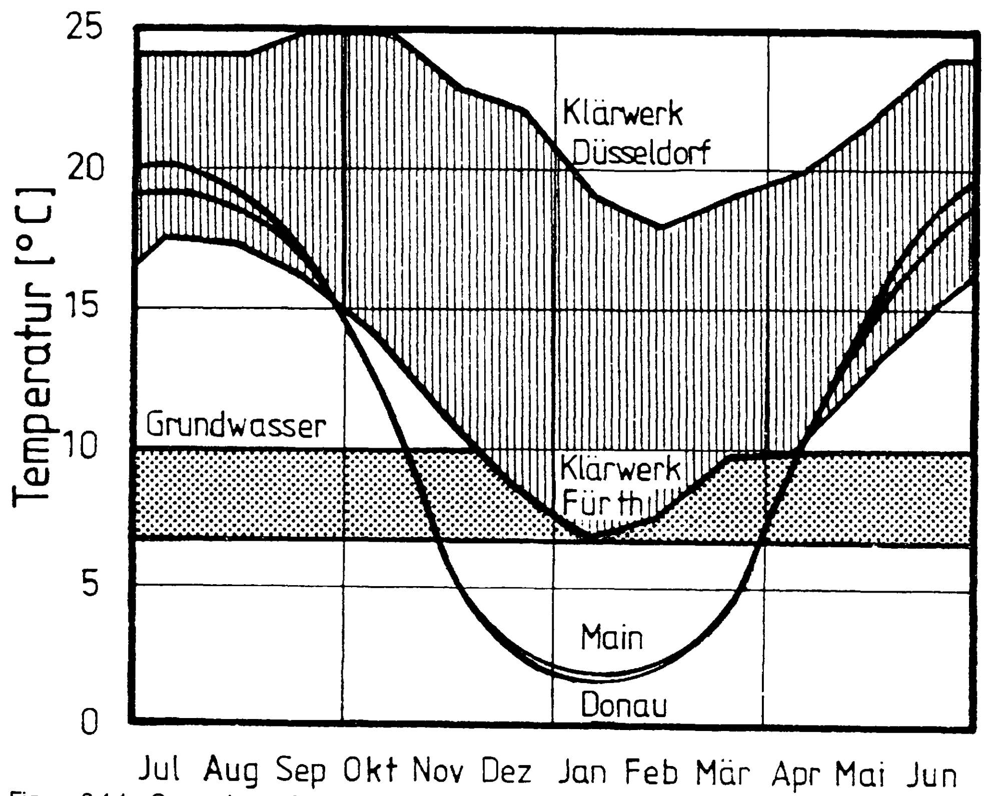
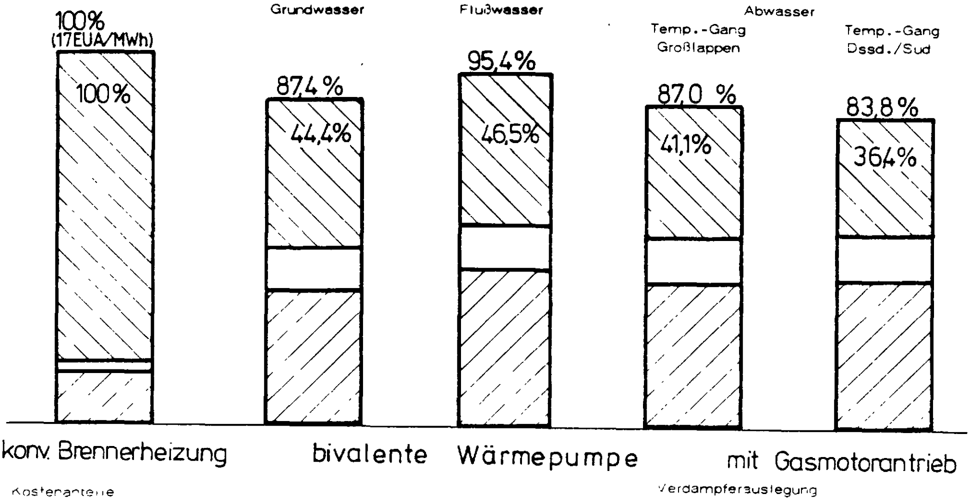


Figure 2.4.1 Comparison of water temperatures of different waste water treatment plants and natural water



Kostenanteile

Verdampferauslegung

Brennstoff (12 EUA/MWh) Primarenergiebedarf

Instandhaltung und Wartung

Kapitaldienst 10.3 p.a.

	Flußwasser	Grundwasser	Abwasser
Auskuhlspanne der Warmequelle	0,5	5,3	2,5
Gradigkeit des Warmetauschers / K	3,5	2,0	2,5

Figure 2.4.2 Specific heating costs of a diesel driven heat pump with different heat sources and a conventional heating system

Recovery of waste heat in sewers by heat pumps 2.4.

Dr. U. WIEDMANN

R. FLOHRSCHÜTZ

Maschinenfabrik Augsburg-Nürnberg
Aktiengesellschaft
Neue Technologie
Ludwigsfelderstrasse 238
8000 München 50

Final report number: EUR 7061 available in German

Contract number: 211-77 EED

The possibility of recovering waste heat from waste water has been studied by MAN. The local waste water is attractive as a heat source for heat pumps due to the high temperature levels and the availability in the immediate vicinity of the consumer.

There are two possibilities as far as the place of heat withdrawal is concerned: the decentralized heat withdrawal from the non-purified waste water in the network of sewers or the centralized heat withdrawal from the purified waste water behind the water treatment plant.

In both cases basically heat exchange systems (exchanger and cleaning system) with conventional components can be used. The design and operation of the overall system in the waste water should be tested in a pilot plant.

With respect to the economics a comparison of costs for a 2.4 MW conventional boiler heating and combustion-driven heat pump with different heat sources (underground water, river water, waste water) showed advantages of the heat pump system. The lowest costs were those for the utilization of waste water as heat source.

Additional expenses for heat transport are economically feasible up to about 4 ECU/MWh. A long-distance connection between consumers is, however, advisable only if large heat pump systems are used.

Cost of Heat Pump	£1200
Cost of equivalent parts of oil system	£650
	£550

Oil boiler efficiency assumed at 70% so effective heat value of oil is 32.4 kWh/gall

Oil cost is £0.61 per gall (Sept. 1st 1979) i.e. effective cost £0.0188/kWh

Heat demand	28,800 kWh	
Cost of supplying by oil		£542
Energy consumption	9,750 kWh	
Cost of electricity supply		£321
Energy saving Seasonal COP 2.95*	19,050 kWh	
Financial saving		£230
PAYBACK PERIOD		2.39 yrs

Rate of Return on Capital

Rate of Return

Life time (yrs) \ Inflation Rate (%)	0	5	10	15
9	39.8	44.4	49.1	53.8
12	41.1	46.0	50.9	55.7
15	41.6	46.5	51.5	56.4

* The direct heating component was 1310 kWh and if this is allowed for, the seasonal COP of the heat pump alone becomes 3.26

Fig. 2.5 Comparison of Heat Pump with Oil Fired Heating System

Development of domestic heat pumps 2.5.

J.T. McMULLAN

R. MORGAN

New University of Ulster
Coleraine
Northern Ireland BT52 1 SA

Final report number: EUR 7098 available in English

Contract number: 269-77-1 EEUK

This R&D project had the following objectives:

- to optimize operation of a domestic heat pump system for partial and full-load operation
- to investigate the dynamic response of the heat pump under changing environmental conditions
- to examine the influence of refrigerant turbulation on evaporator performance
- to examine the effect of air-borne moisture on evaporator behaviour (sub contract from University College Galway).
- to conduct field trials of domestic heating units.

The programme therefore involved both experimental developments in the laboratory and field testing of pre-production prototypes, together with extensive computer analysis of the experimental data and computer modelling of the behaviour of system components.

The experimental measurements were conducted in a highly flexible controlled environment laboratory which allows extensive variation of both temperature and humidity to match outdoor conditions.

Experimental and theoretical modelling showed that the probable contribution of the latent heat of air-borne water to the evaporator heat pick-up, lies between 10 and 13%.

When investigating the effects of refrigerant turbulation, it quickly became apparent that the degree of turbulation was already high, but that at no point in the evaporator did tubewall dry-out occur. When this factor was coupled with the observation that saturation pressure and temperature did not correspond to the published refrigerant data, it was realised that the lubricant was playing an important role. This was investigated and a number of conclusions were drawn.

The economic analysis of the field tests showed that under the conditions pertaining, the heat pump shows a likely payback period of 2,5 years against a new oil-fired system.

Air source heat pumps under northern European climatic conditions 2.6

T.C. O'CONNOR

J.A. McGOVERN

Department of Physics
University College
Galway, Ireland

Final report number: EUR 7388 EN

Contract number: 271-77 EEEIR

The maritime climate of the islands and western coast of continental Europe is suitable for the use of air source heat pumps, working in the heating mode only, for domestic space heating. Field trials of several types of air to air and air to water heat pump systems in homes in Ireland are described. Laboratory investigations were also made into component performance and design modifications to produce a system with optimum performance for this purpose.

With a variable climate the calculation of seasonal coefficients of performance requires a study of the thermal response of the buildings as well as the characteristics of the heat pump system. A computer programme to study this has been developed.

Frosting and defrosting behaviour of outdoor coils of air-source heat pumps

2.7

J.W.J. BOUMA

Organisation for Industrial Research TNO
P.O. Box 342
Apeldoorn

Final report number: EUR 7281 EN

Contract number: 366-78-EEN

A literature investigation shows that in spite of the fact that defrosting of outdoor coils of air-source heat pumps does not yield many problems, a lot of units however are capable of improvement. Many Western European countries have mild winters. Temperatures between − 7°C and + 2°C and high humidities where are quite normal. These are conditions where severe frosting occurs. An air source heat pump has been tested in a test facility with a controlled environment (temperature, humidity).

- From the first test runs it appears that no real defrost problems occur with these heat pump coils, while defrost times are rather short (3 to 6 min.)
- The model of Lotz enabled the calculation of the simultaneous heat and mass transfer processes in air coolers with frost formation and was of great use for the design of improved coils
- In order to improve the COP, the fan and fan motor should be designed for minimum power consumption and not for maximum air flow.

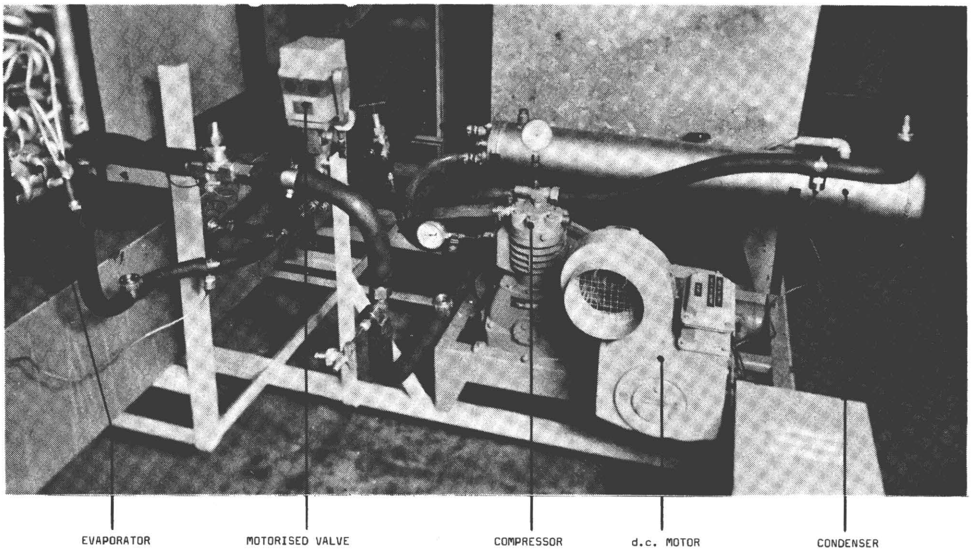


Figure 2.8.1 Microprocessor controlled heat pump

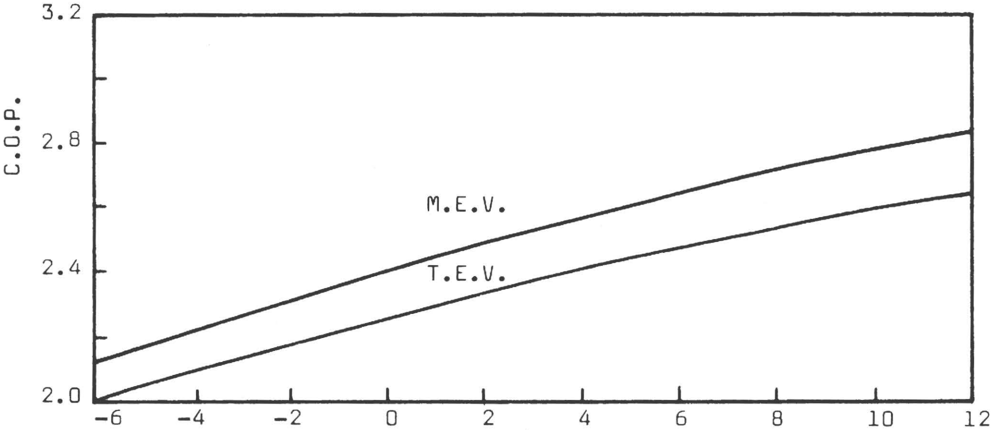


Figure 2.8.2 Variation of the COP with air temperature for a motorized (MEV) and thermostatic TEV expansion valve

Microprocessor based control system for heat pumps 2.8

R.K. GREEN

D.F. NEALE

M. SEARLE

D.R. WILSON

Division of Engineering
Polytechnic of Central London
New Canvendish street
London W1M 8 JS

Final report number: EUR 7283 EN

Contract number: 306-77 EEUK

The work described is a part of a research project performed jointly by the Ecole Supérieure d'Ingénieurs en Electrotechniques et Electronique (ESIEE) and the Polytechnic of Central London.

An electrically driven air to water heat pump offering compressor speed control, motorised expansion valve and a variable speed air flow fan has been designed and tested.

The heat pump system has been fully instrumented and connected, for control and data logging purposes, to a microprocessor based control unit.

By means of suitable control algorithms it has been possible to accurately control the heat pump to optimum design conditions throughout a range of ambient and load energy levels.

Results show that such a control system can result in improved C.O.P.'s when compared to conventional heat pump systems.

Heat pump models for microprocessor based control systems

2.9

P. BILDSTEIN

Y. HAMAM

J. EHRHART

Ecole Supérieure d'Ingénieurs en Electrotechnique
et Electronique
81 Rue Falguière
F - 75015 PARIS

Final report number: EUR 7046 available in French

Contract number: 305-77-EEF

The work described in this report is a part of a research project performed jointly by the Polytechnic of Central London (PCL) and the Ecole Supérieure d'Ingénieurs en Electrotechnique et Electronique (ESIEE).

The object of the research is to develop the control strategy and the microprocessor system software, necessary for the operation of a heat pump with minimum energy consumption. The system software developed will be applied to the experimental air/water heat pump which was built and instrumented at the PCL.

The elaboration of models for representing the heat pump have been studied. Two such models have been developed. The first is related to the operation of the pump under steady state conditions. The second describes the transient behaviour of the heat pump in as far as the thermal energy storage within the heat exchangers is concerned.

Computer programs have been written to test the models and a comparison is made between the calculated behaviour and the data measured on the experimental pump built by the Polytechnic of Central London.

Finally the applicability of models to microprocessor based heat pump control systems are discussed and a proposal is made.

Analysis of the factors which determine the cop of a heat pump

M. FORDSMAND

A. EGGERS-LURA

European Heatpump Consultors Ltd
38 Skovshovedvej
DK - 2920 CHARLOTTENLUND

Final report number:

Contract number: 142-76

The present project is an analysis of the factors which determine the COP of a heat pump, and a feasibility study on ways and means of increasing its performance.

The report has been devided as follows:

Firstly it presents a survey of ground heat pump installations established in Denmark between 1956 and 1972. The installations and the experimental and measuring work which has been undertaken is described, and the experiences that have been gained are presented.

In particular the fact that a vertical soil heat exchanger (20 m deep) extracted very little energy after 3 or 4 years demonstrated the necessity of heat storage in the summer for vertical heat exchangers.

Thereafter the development of the "first generation" Fordsmand soil (water/water) heat pump, the first heat pump that was industrially produced in series in Europe, is described.

Finally, a description is given of the development and testing of the "second generation" Fordsmand soil heat pump. The test results show that improvements in the evaporator resulted in a 21% increased heat output. The introduction of asub cooler with which the refrigerant after heat delivery is further cooled down to around 0-5°C with incoming air, increased the heat output with another 30%.

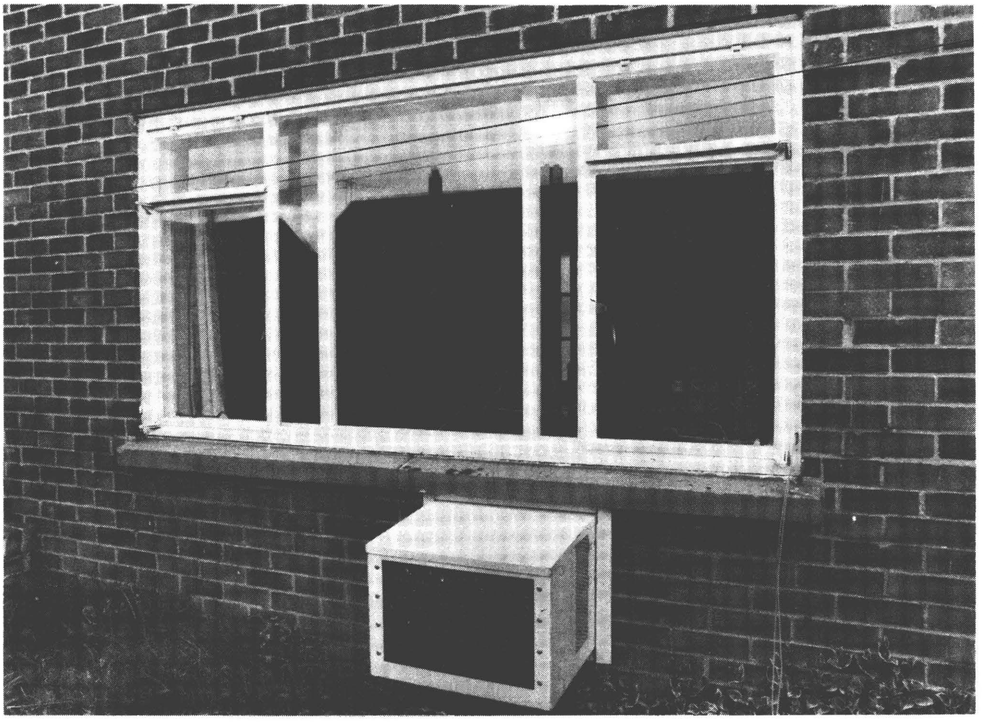


Figure 2.11.1 Outdoor view of a heat pump for a single room

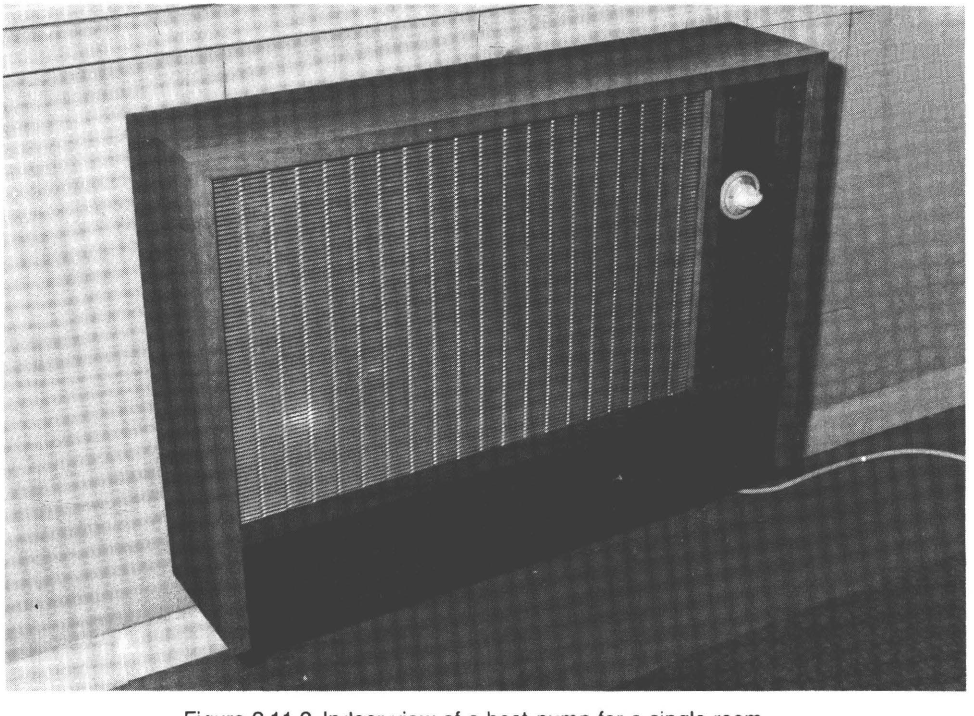


Figure 2.11.2 Indoor view of a heat pump for a single room

Heat pumps for individual rooms 2.11

K.J. SEYMOUR-WALKER

Building Research Establishment
Building Research Station
Bucknalls Lane
Garston
Watford, Herts. UK

Final report number: EUR 7007 available in English

Contract number: 372-78-1 EEUK

A provisional specification for an air-to-air heat pump suitable for heating a single room (output 2.25 KW) was produced, and a machine built to this specification was tested in a controlled environment facility. As a result of the tests, various modifications were made to the machine, resulting in a version which produced a steady state Coefficient of Performance of 2.15 at a simulated mean wintertime outdoor temperature for Southern England. Three machines of a version with further slight improvements were then used to heat a typical small British family house; although a full heating season's results were not obtained, it appears that the corrected seasonal Coefficient of Performance in this case would be aout 2.13.

The reliability of these individually-built machines was not very good, but even if the resulting high maintenance cost is included in the calculations, such heat pumps show a high value of internal rate of return (ROR) as replacements for direct electrical-resistance heating, though not for gas. These findings are considered to warrant further work on such single-room sized heat pumps.

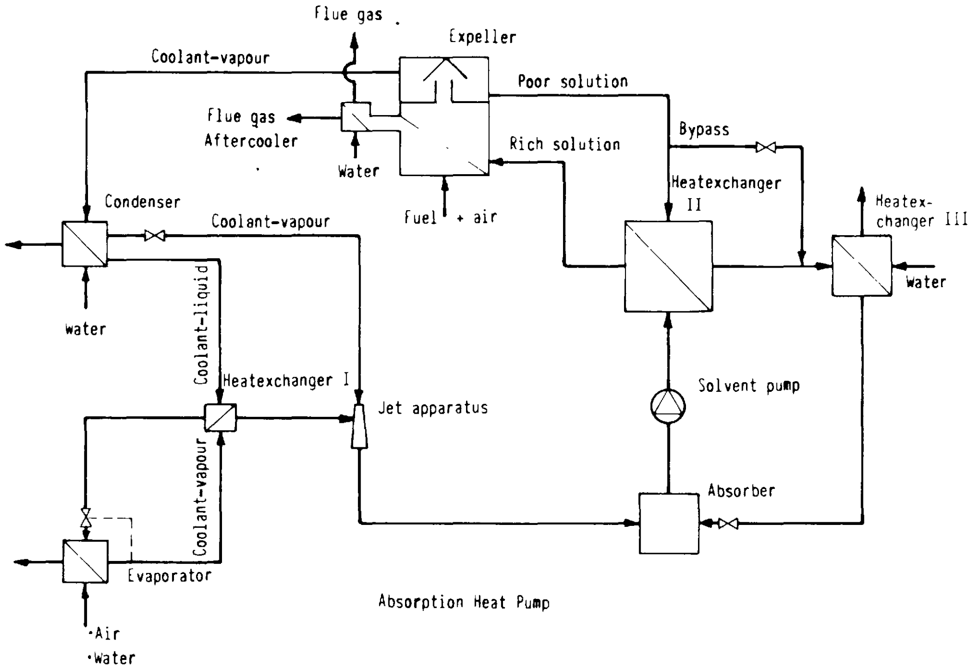


Figure 2.12 Process Flow of the absorption heat pump

ADVANCED HEAT PUMPS

Development of an absorption heat pump fired by primary energy for domestic heating 2.12

G. OELERT

H.A. JANSSEN

Battelle Institut e.V.
Am Römerhof 35
D-6000 Frankfurt 90

Final report number: EUR 6326 available in English

Contract number: 214-77 EED

A feasibility study was made of a 12 KW monovalent absorption heat pump delivering heat at 55°C in the heat pump mode and which at low outside temperatures functions in a "normal heating" mode with the fuel fired expeller operating as a "boiler" delivering 20 KW at 80°C.

The absorption cycle developed is characterized by:

— R22 and E181 as working pair
— an adiabatic absorber

In brief, the working programme comprised:

— the development of the advanced absorption cycle
— the selection of a suitable organic working pair
— the search for commercially available hardware components for prototype units and the component rating
— an assessment of operating and total cost compared with conventional warm water central heating.

The seasonal coefficient of performance of the system developed was calculated to be 1.26, based on the ambient air temperature characteristics of an average heating period in the area of Hamburg.

Design construction and testing of a prototype absorption heat pump fired with primary fuel

2.13

Dipl.-Ing. Hans-Jürgen KOHNKE

Stiebel Eltron
Dr. Stiebelstrasse
D - 3450 HOLZMINDEN

Final report number: EUR 7064 available in German

Contract number: 368-77 EED

A prototype of an absorption heat pump fired with primary fuel, which has been theoretically studied by Battelle (contract n° 214-77-EED) in the previous project, has been constructed and tested. The membrane of the fluid pump turned out to be the main problem. Cheap pumps with the right properties are not available on the market. The experience with the jet pump was negative; the high pressure drop decreased the efficiency. Both the designed condensor and the expeller turned out to be too small.

With the prototype a COP of 1,2 was obtained with a heat delivery temperature of 45°C and evaporation temperature of 0°C.

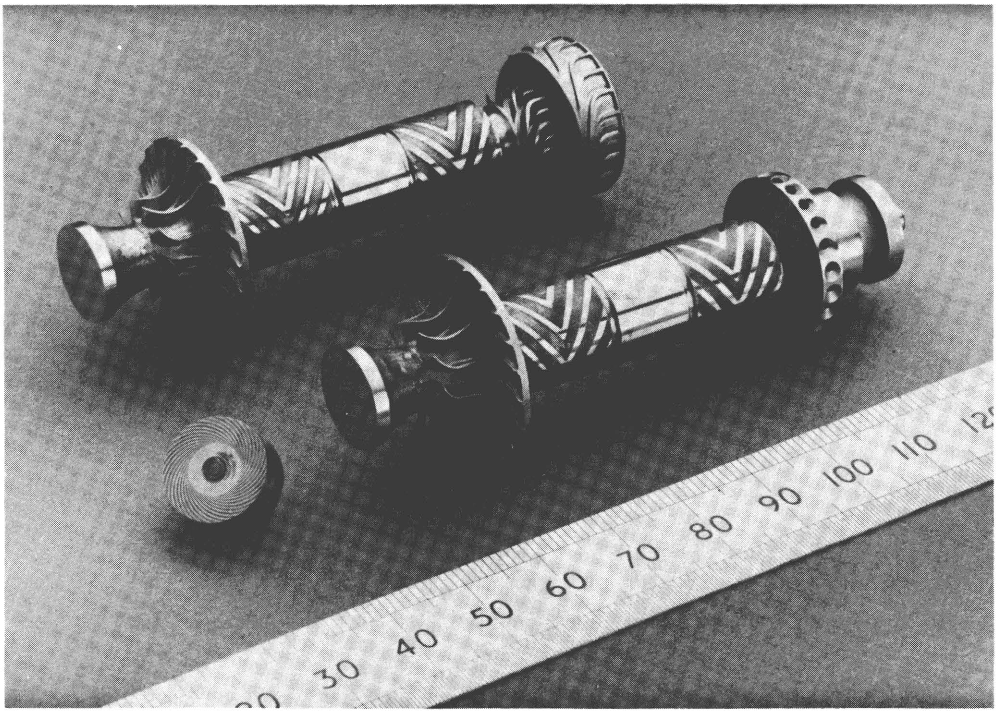


Figure 2.14.1 Turbomachine rotors of an O.R.C. engine driven heat pump

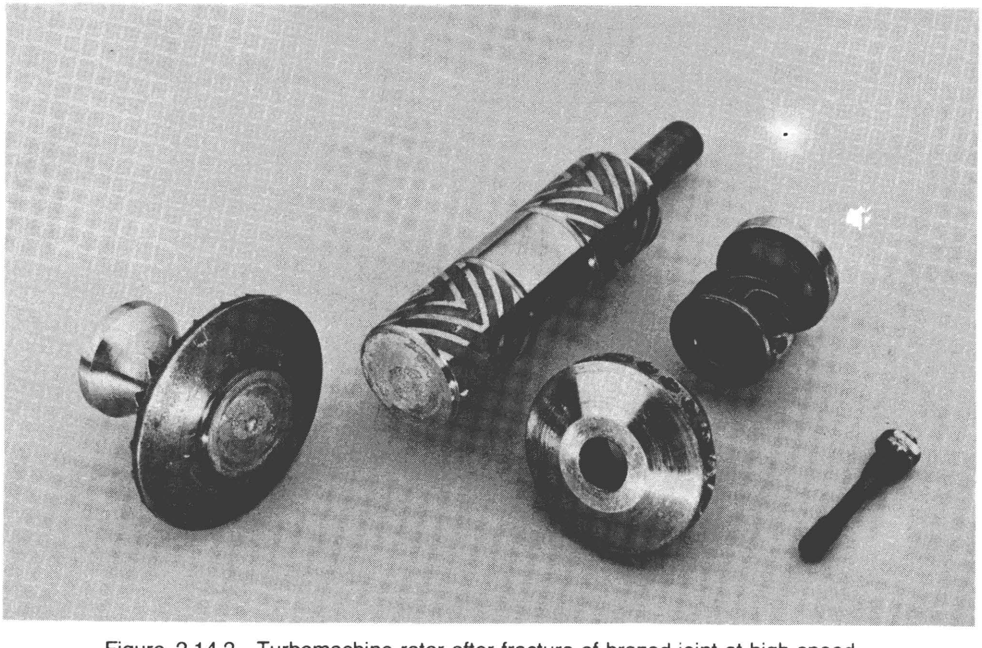


Figure 2.14.2 Turbomachine rotor after fracture of brazed joint at high speed

Directly fired heat pump for domestic and light commercial application

2.14

David T.G. STRONG

GLYNWED CENTRAL RESOURCES UNIT
Cranmore Drive
GB - Shirley, Solihull
West Midlands B 90 4 PG

Final report number: EUR 7063 available in English

Contract number: 375-78 EEUK

The object of the research exercise was to demonstrate a working prototype gas fired heat pump based upon the use of miniature turbomachinery.

A Rankine vapour power unit is coupled directly to a vapour compression heat pump cycle—with the advantage of only having one major moving component, oil free lubrication and gas bearings giving long life with minimal metallic wear. Other advantages of the proposal include, silent and pollution free operation, total versatility in choice of fuel, and small physical size.

This directly fired heat pump offers a potential fuel utilization coefficient of about 1.45 (more than twice the efficiency of a gas fired boiler, having an efficiency of 70%) and a short pay back time.

A laboratory prototype system has been constructed, and performance measurements have been made over a wide range of operating conditions. The following conclusions have been established as a consequence of the work carried out:

- A traditional organic working fluid has been shown to have satisfactory thermal stability characteristics at elevated temperatures
- A gas fired fluid heater has been designed and tested and shown to have adequate performance
- Unsatisfactory bearing operation at elevated temperatures, as a result of inappropriate material selection caused a number of high speed rotor seizures. The turbine has shown satisfactory performance, with the compressor requiring further modification before specified design performance can be achieved
- Based upon measured performance of the turbine, compressor and fluid heater the estimated overall coefficient of energy utilization is 1.17
- A considerable development effort is required before a marketable product could be specified. In particular a microprocessor based control system must be developed to provide full control and monitoring of the unit at all times. Also required is the development of a satisfactory bearing system, together with a detailed production engineering exercise.

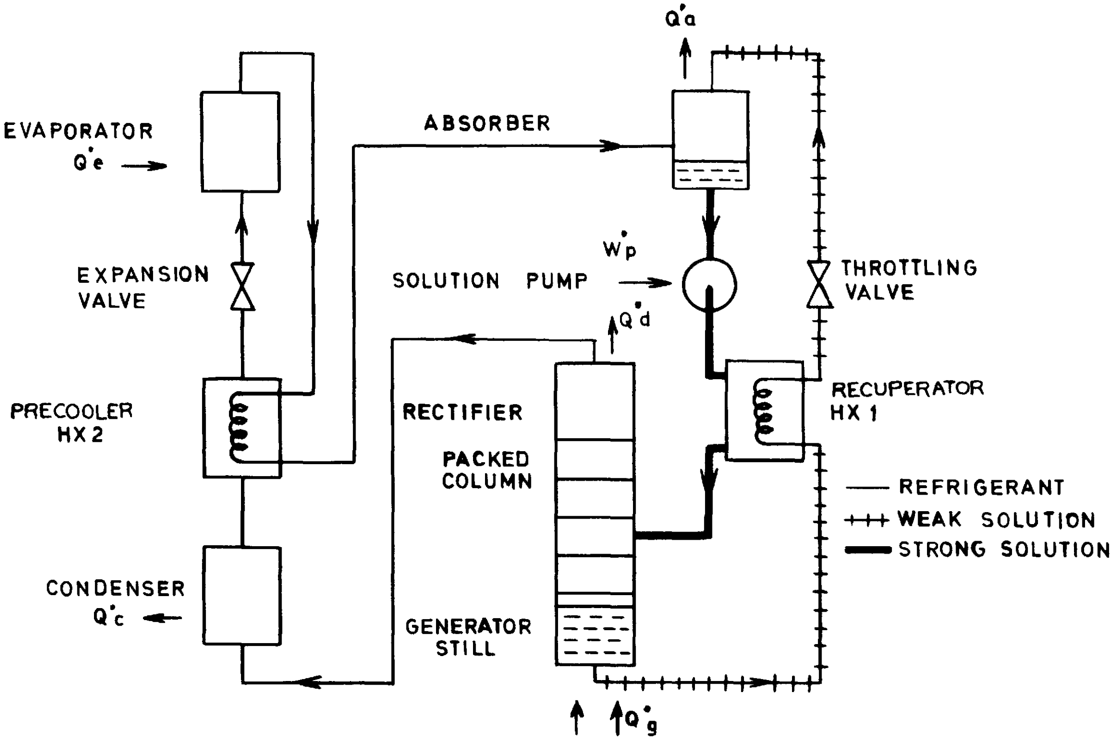


Figure 2.15.1 Schematic diagram of absorption heat pump cycle

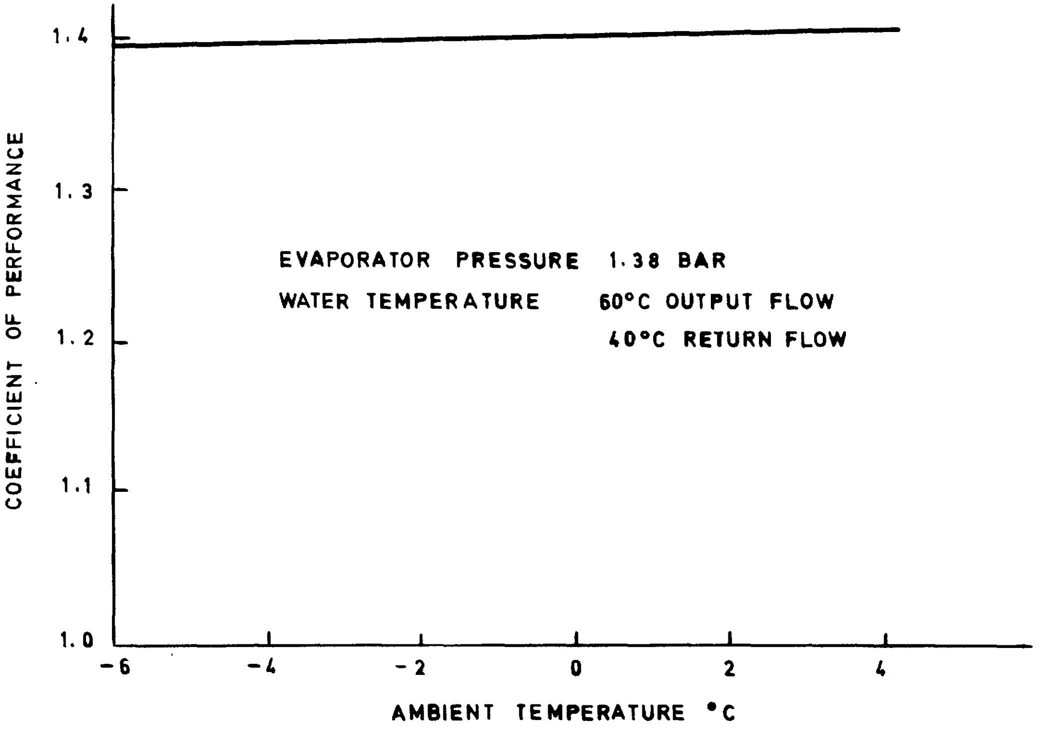


Figure 2.15.2 C.O.P. against ambient temperature

The design and development of an absorption heat pump for domestic heating

2.15

A.M.S. QASRAWI

R.E. BLAKELEY

R.J. TREECE

Lucas Group Services Ltd
Lucas Research Centre
Shirley
Solihull
West Midlands

Final report number: EUR 7129 available in English

Contract number: 376-78-EEUK

This report describes the results of a research programme, concerned with the design of a directly fired absorption cycle domestic heat pump optimised for the achievement of maximum coefficient of performance. The main aspects of the programme included a feasibility study, the development of a mathematical model to facilitate computer simulation and the provision of a test rig together with some component design studies.

The feasibility study which included an assessment of candidate working fluid pairs and cycle designs, indicated that an ammonia/water mixture would be most propitious for an immediate term investigation. The mathematical modelling led to the development of a computer programme capable of predicting the steady state behaviour of a specified cycle for selected boundary conditions, together with procedures for optimising the evaporator and refrigerant precooler operating variables.

A comprehensively instrumented test rig, capable of operating over a wide range of stimulated source and sink temperatures, has been built and used in conjunction with the computer programme to evaluate the influence of changes in cycle parameters on steady state behaviour and performance.

Initial experimental work has confirmed the efficiency of the generator and absorber designs adopted in the rig and indicated that Primary Energy Ratio (PER) can remain substantially constant over a specified range of evaporator heat source temperatures.

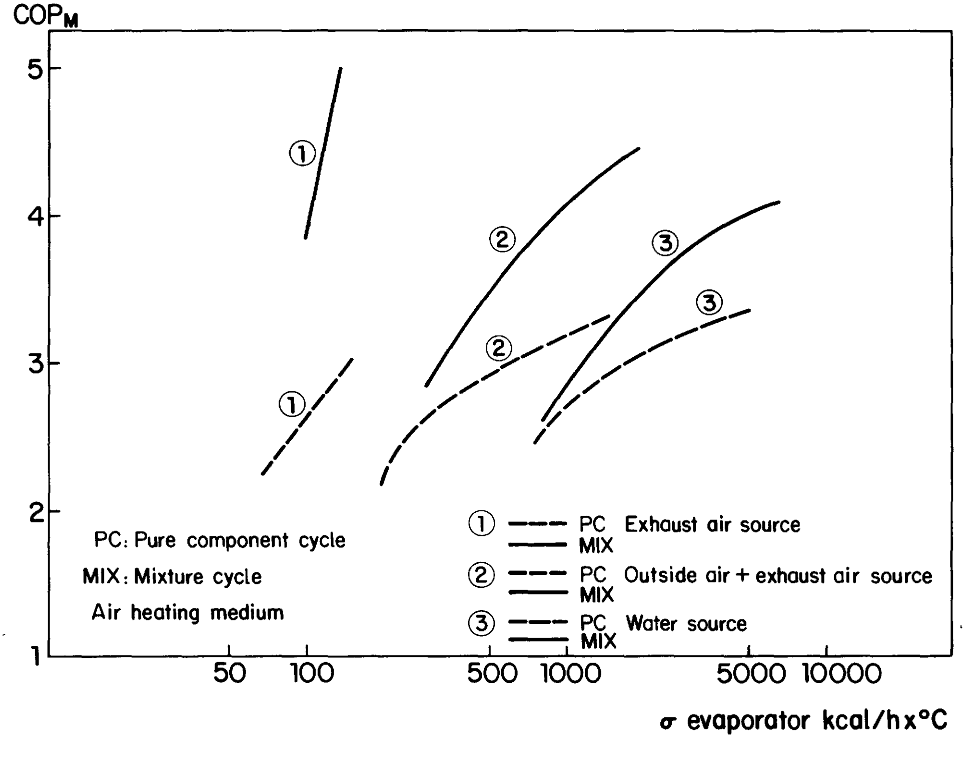


Figure 2.16 Comparison of the heat pump COP for a pure fluid and a fluid mixture (R22: 30%, R11: 70% molar)

A heat pump operating with a fluid mixture 2.16

A. ROJEY

C. MEYER

B. CHOFFE

J. JACQ

L. ASSELINEAU

J. VIDAL

Institut Français du Pétrole
1-4 avenue du Bois Préau
92502 RUEIL-MALMAISON

Final report number; EUR 6848 available in French

Contract number: 365-78-EEF

Whenever heat is recovered and delivered the coefficient of performance of a heat pump can be increased by using a fluid mixture selected to have a temperature variation, during the vaporization and condensation stages, parallel to that of the outside fluid with which the heat exchange takes place. Such a solution was investigated both theoretically and experimentally.

It has been shown that significant savings can be expected ranging up to 50% of the energy consumption of conventional heat pumps in some cases.

Various applications for home and industrial heating have been examined, and the economic prospects have been found to be satisfactory. Further work is needed to develop such heat pumps on a commercial basis.

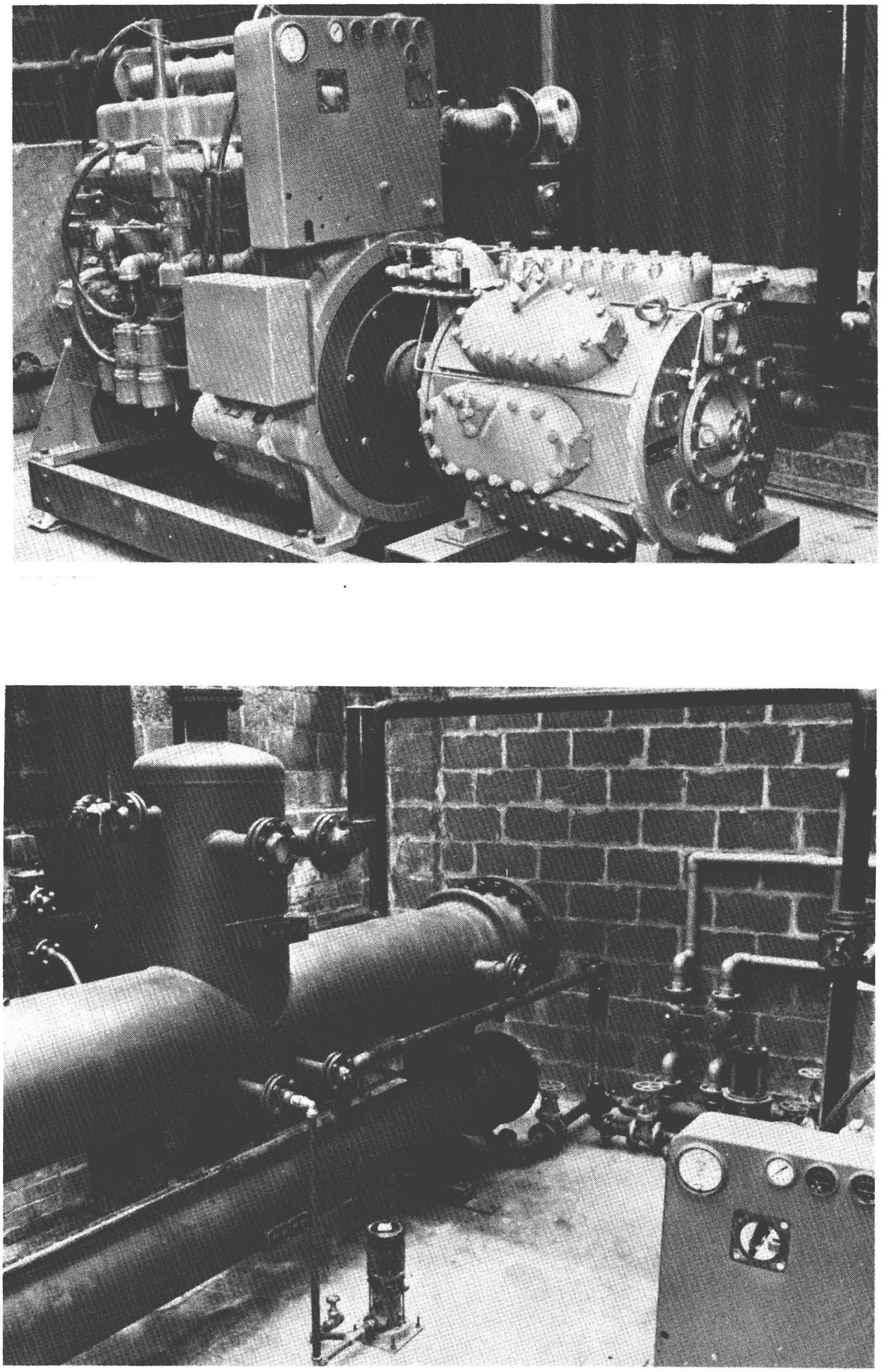


Figure 2.17 Test rig for heat pump at IRD

Feasibility and design study of a gas engine driven high temperature industrial heat pump

D.B.A. MACMICHAEL

D.A. REAY

International Research and Development C° Ltd
Fossway
Newcastle upon Tyne
NE 6 2YD
UK

Final report number: EUR 6262 and EUR 7657 available in English

Contract number: 175-77-EEUK and 369-78-EEUK

This is the final report of the work done on a high temperature industrial heat pump project combining the feasibility and design study, the construction and testing of a 75 kW drive prototype.

The design study has produced an outline design of the prototype consisting of a reciprocating gas engine driving a reciprocating compressor. The working fluid will be refrigerant 114 with a condensing temperature of 120°C and an evaporating temperature of 60°C. The condenser and the gas engine waste heat recovery units will act as boilers, producing steam at about 110°C. The coefficient of performance (COP) of the heat pump cycle will be 3.19.

Refrigerant selection has been a key item in the study, with the final adoption of R-114 being based on its suitability to reciprocating compressors, and because it is the most stable of the possible conventional refrigerants.

The compressor selected is of the wet-piston reciprocating type, with modified seals and bearings for the high lubricating oil temperature. This is required to prevent refrigerant condensation in the sump, causing oil dilution. The oil will be a high viscosity grade and oils tested under the design conditions are available from more than one supplier.

The heat exchangers principally the condenser and evaporator, have had to be specially designed to allow the use of R114 since its heat transfer characteristics are quite different from R12, R22 or ammonia. The condenser has been designed to produce low pressure steam, as opposed to high pressure hot water. All the possible users contacted expressed a preference for steam.

The primary energy ratio (PER) for the unit is estimated to be 1.47 with ebullient cooling. When taken together with estimated capital costs, this gives a payback period (for 8000 hours p.a.) of 2.3 years and a 40% rate of return on investment. These figures will be attractive to the industrial user.

The heat pump has been tested with a hot source of 80°C. It produced saturated steam of 110°C at the condenser and delivered 333 KW heat while consuming 221 KW of gas.

Figure 2.18.2 Apartment building heated with gas engine driven heat pump (with heat pump and heat exchangers on the roof)

Energy conservation by use of a gas engine driven heat pump for an apartment building using outside air as heat source

2.18

O. HEIBURG

W. LOHSTRÄTER

Dortmunder Stadtwerke Ag
Degginstrasse 40
D - 4600 DORTMUND 1

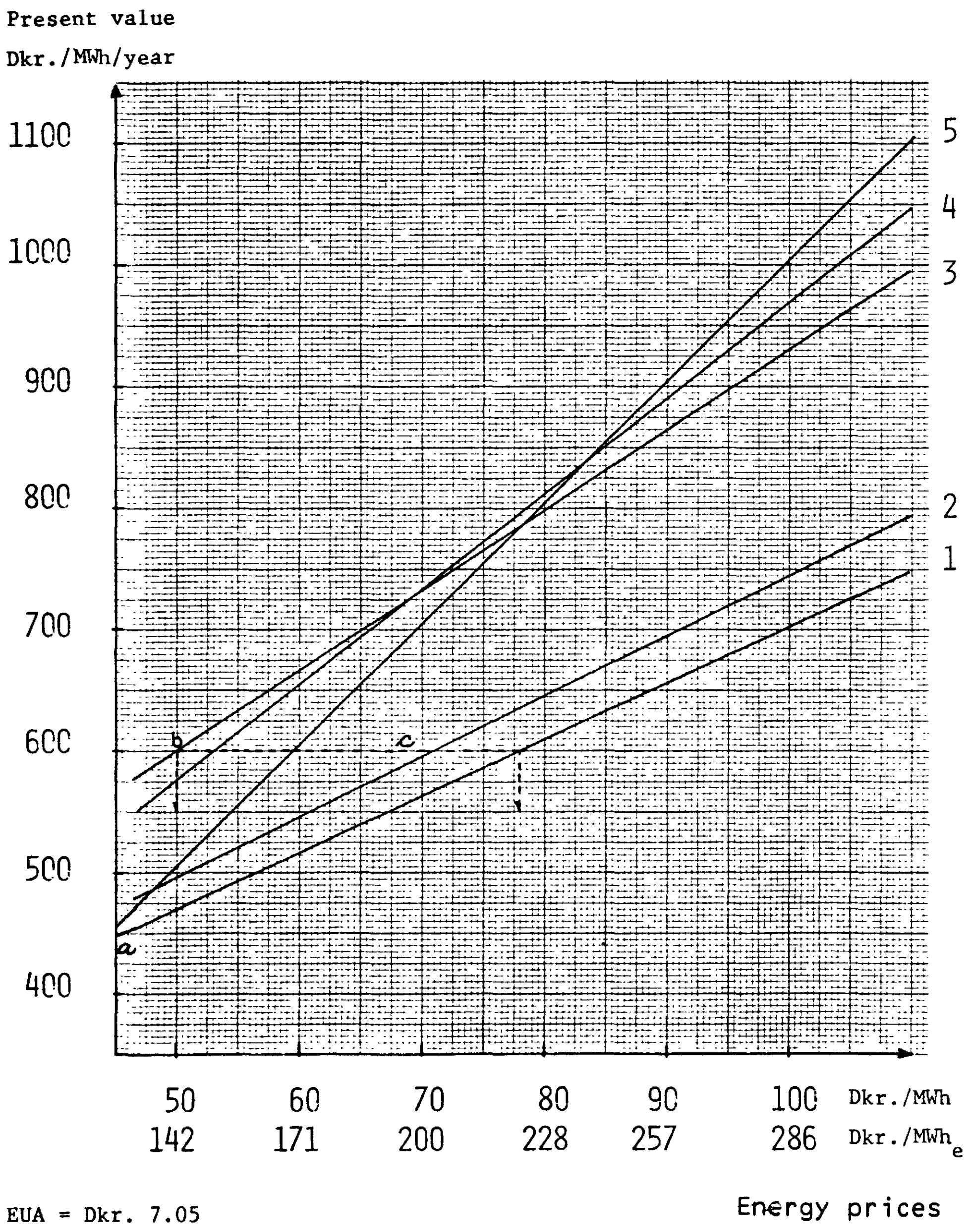
Final report number: EUR 7133 available in German

Contract number: 309-77-EED

A monovalent air/water heat pump consisting of a reciprocating gas engine driving a reciprocating compressor supplies an apartment building of 64 apartments with heat and hot water.

Heat capacity is 465 kW at a temperature of −12°C. The gas engine is fuelled with coke-oven gas containing 57,4% hydrogen. The heat pump system uses R 22 as refrigerant. The energy conservation is up to 50% compared with conventional heating systems.

The report discusses the heat pump equipment, the technical data and the experience during the period october 1978 - 31 march 1980 when the heat pump ran 1 500 hours. Problems with the evaporator and compressor are described and much attention has been paid to the limitation of the noise level. The pay back time was estimated to be 8 years.



1 EUA = Dkr. 7.05

Rate of interest 10%

Life time 20 years

1. Diesel engine
2. Dual fuel engine
3. Steam turbine (coal)
4. Electric motor
5. Boiler fuel at 85% efficiency

Figure 2.19 Present value of heat production cost in 20 years for large heat pump plants with different prime movers.

Diesel driven heat pump for district heating and for the heating of large housing blocks

2.19

Benny PETERSEN

Burmeister & Wain
Torvegade 2
1449 COPENHAGEN K

Final report number: EUR 6740 available in English

Contract number: 373-78 EEDK

The aim of this project is to investigate technical, economic, and environmental aspects of large diesel driven heat pump plants for district heating and for central heating of large buildings.

A study has been made of the possible heat sources for large heat pumps, and information on the operation of existing district heating centrals has been analysed. A computer model of the heat pump system has been made to study the influence of these parameters and to make design calculations of large heat pumps.

A turnkey diesel heat pump with a heating effect of 10 MW has been designed, and the investment has been calculated to be 30 ECU per MWh of yearly heat supply or related to fuel saving, the investment will be 540 ECU per tonne of oil saved per year.

The possibility of using other prime movers like gas turbines, coal fired steam turbines and electric motors has been analysed with regard to the economy and the energy savings. Electrically driven heat pumps are the best solution for villages up to 2000 inhabitants. Diesel driven heat pumps are most suitable for towns with 2 000 to 20 000 inhabitants, where energy savings of 50% are possible.

Outside the scope of the study, it has been decided to build a prototype plant.

Experience with monovalent electrical heatpumps with air as heat source for 56 apartments 2.20

Dipl.-Ing. PETER MÜLLER
Ing. (grad) HEINZ KLAUS

V.E.W. A.G. Dortmund

Final report number:

Contract number: 310-77-9 EED

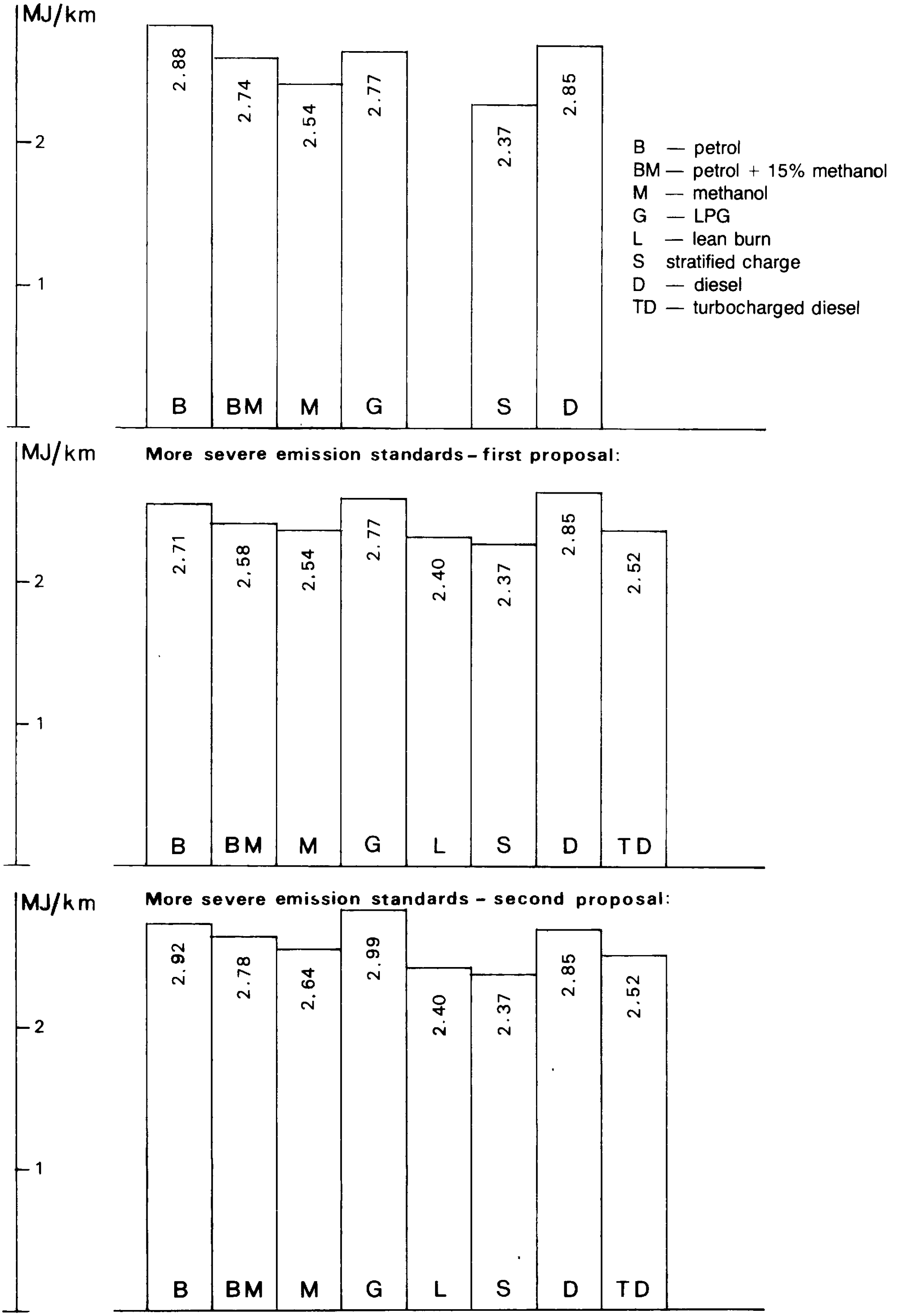
The operation of four 50 KW_{th} and thirteen 15 KW_{th} monovalent electrical heat pumps for floor heating with air as heat source have been tested in 56 apartments. The measurements have been taken over a period from July 1979 to December 1980.

As compared to conventional oil heating the overall heating costs per year for heat pump heating were 10 DM per heated m2 higher. The energy saving was 30%. A large part of the higher cost was due to the high investment cost for floor heating.

SECTOR C

Urban transport

Figure 3.1 Computed overall fuel consumption for present engine options at equal performance levels



Potential for energy conservation by a shift to other types of engines in passenger cars 3.1

Drs. W. SMIT

Centre for Energy Studies TNO
P.O. Box 342
7300 AH APELDOORN

Final report number: EUR 7303 EN

Contract number: 246-77 EEN

TNO investigated whether energy savings can be obtained when car traction switches from petrol and diesel engines to other types (e.g. methanol, lean burning engine).

In the medium term, oil fuels will become scarcer in the transport sector as well as in other sectors and substitute fuels such as methanol and alcohol will have to be introduced gradually. Therefore, a large-scale switch from petrol and Diesel engines to lean burn, stratified charge and turbo-charged engines and use of methanol and synthetic petrol has been studied in a number of scenarious, taking also into account environmental constraints. From the computed results it can be concluded that fuel savings of nearly 20% may be achieved by switching from petrol and Diesel engines to lean burn and stratified charge engines. In the medium term the possible substitutes for gasoline such as methanol and synthetic petrol may also be used in these improved engines.

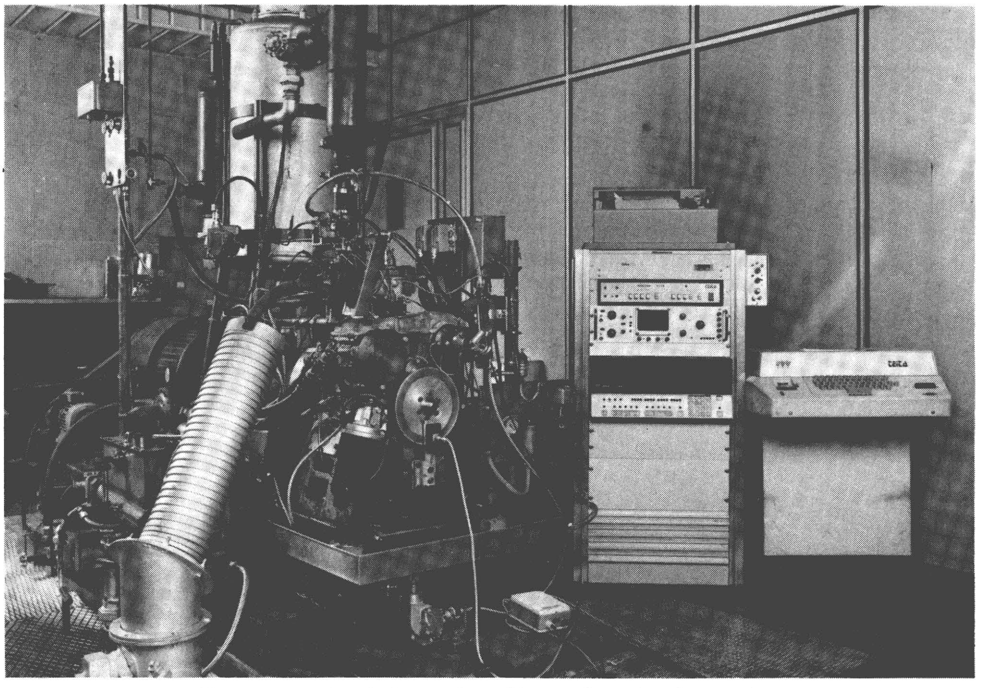


Figure 3.2 Testrig for testing of internal combustion engines

Improved efficiency of a spark-ignition engine in part load operation 3.2

A. DOUAUD

P. EYZAT

Institut Français du Pétrole
1-4 avenue de Bois Préau
F - 92506 Rueil-Malmaison

Final report number: EUR 7190 available in French

Contract number: 122-76-EEF

Ways to improve the efficiency of a spark-ignition engine in part-load operations have been investigated by IFP France. The influence of both tuning and design parameters have been investigated successively on an experimental single-cylinder engine and on a regularly produced multicylinder engine. The test-bench results were interpreted and reaffirmed by means of mathematical models describing the phenomena occuring inside the cylinder i.e. combustion, heat exchange, and mass transfers. Three ways have been selected and investigated to obtain improvements in consumption with a vehicle using standardized driving cycles (ECE15, CVS, etc.). A reduction below the stoechiometric level of the main fuel/air ratio provides a saving of 10%. Increasing the compression ratio decreases consumption by 3,5% per ratio point. A 25% decrease in friction between parts by using improved lubricants brings about a saving of about 8%. The compatibility of the solutions gives rise to the hope that an improvement of more than 20% can be obtained in urban traffic by combining them. The practical implementation of these solutions has been considered, and some of them are already being applied.

Reduction of fuel consumption by thermo-dynamical optimization of an Otto-engine

Dr. D.O. GRUDEN
R. HAHN
H. LÖRCHER

PORSCHE AG
Entwicklungszentrum
7251 Weissach

Final report number: EUR 6711 available in German

Contract number: 377-78-EED

Optimization of a petrol engine has also been investigated by Porsche. Also here ways to improve the efficiency of the part load operation were: increase of compression ratio (CR = 13) and use of leaner fuel-air mixtures (λ = 1,2). In addition ignition timing and the combustion chamber shape were found important. Energy savings of 5-30% as compared to the conventional engine are possible. An improved Otto engine and a diesel engine with the same displacement have been tested in the same car. The diesel engine consumed 8% less fuel in city driving. At high speed the Otto engine had a 2-8% better fuel economy. On the average the fuel consumption of both engines was identical. Due to the higher power of the Otto engine (97 KW) as compared to the diesel engine (39KW), the performance of the Otto engine driven car was much better.

Vehicle	924-TOP-CEC	924-Diesel
Max. speed km/h	206,5	147,2
Acceleration time sec		
0- 100 km/h	9,7	24,2
0- 500 m	17,4	24,9
0-1000 m	29,9	42,5
40- 100 km/h	18,4	32,6
Fuel consumption 1/100 km		
B_{ECE}	10,5	9,6
B_{90}	6,1	6,2
B_{120}	7,6	8,2
B_{City} (US)	9,2	9,2
$B_{highway}$	6,1	5,8
Consumption during Normal road driving	6,5-9,0	7,0-9,6
Idle consumption l/h	0,8	0,6

Figure 3.3 The driving performance and fuel economy values of the Otto engine and the Diesel engine

A feasibility study of a combustion chamber with variable geometry for small high speed diesel engines 3.4

A. ECOMARD

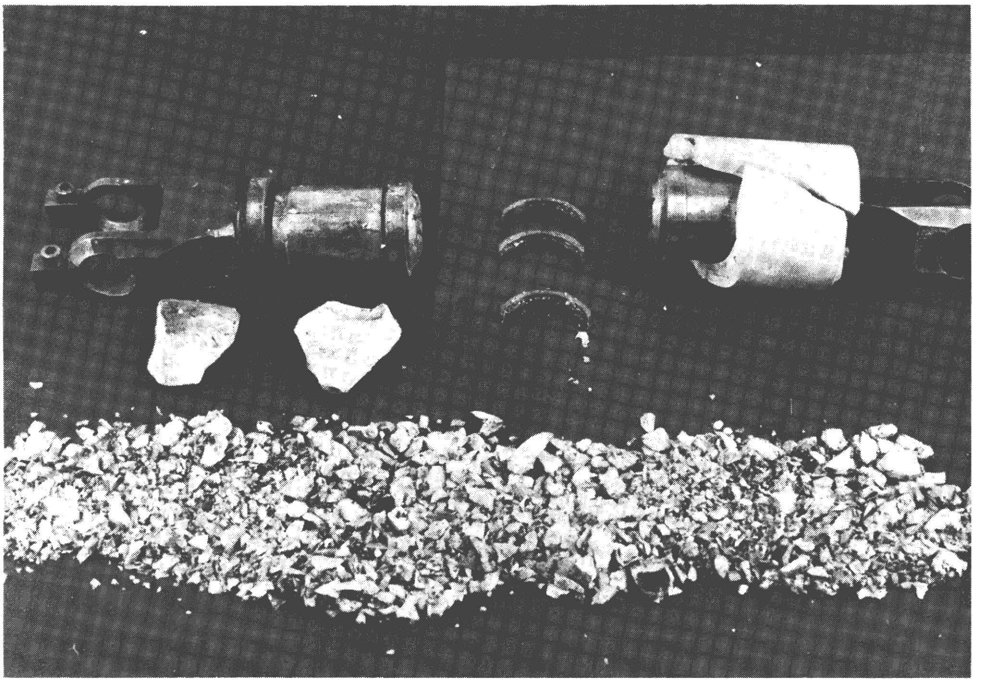
P. EYZAT

Institut Français du Pétrole
1-4 avenue de Bois Préau
29506 Rueil Malmaison

Final report number: EUR 6321 available in French

Contract number: 123-76-EEF

For large diesel engines (e.g. for train traction) energy savings of 5-10% have been obtained with help of a prechamber for combustion which brings about a good mixing of fuel and air. The aim of this study was to investigate whether such a modification could obtain the same results for smaller and high speed diesel engines. After tests with many different types of prechambers it was clear that a scaled down prechamber for smaller diesel engines did not bring about energy savings. Good mixing was not possible due to the small size of the prechamber as compared to the fuel injector and the pressure. The fuel jet also deformed the shape of the prechamber.



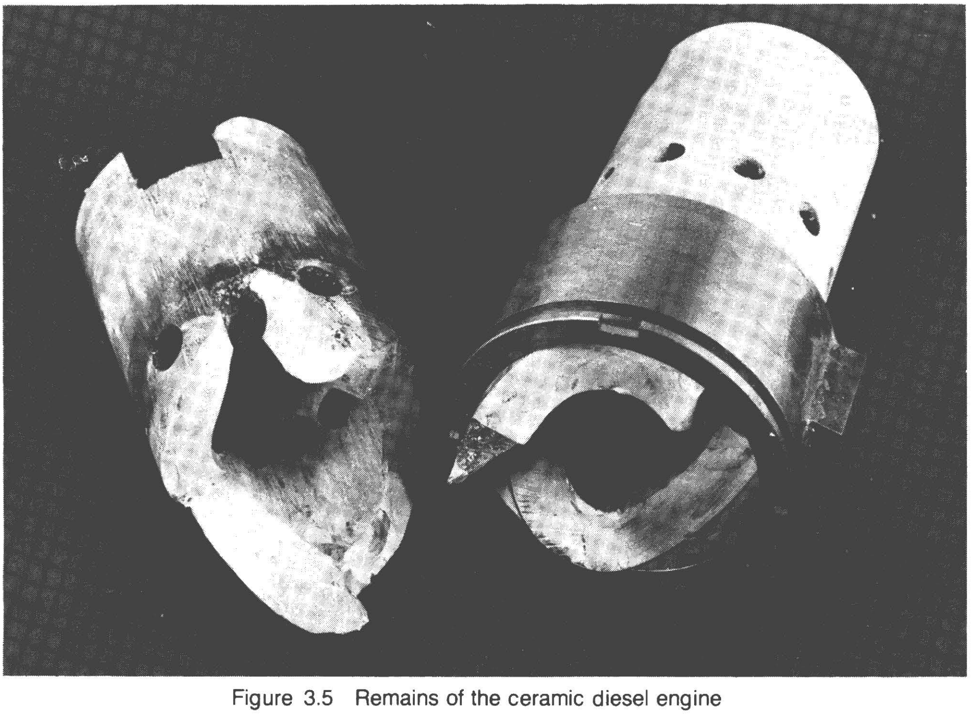


Figure 3.5 Remains of the ceramic diesel engine

No coolant ceramic diesel engine 3.5

S.G. TIMONEY

Engineering School
University College Dublin
Merrion Street
Dublin 2

Final report number:

Contract number: 143-76-EEEIR

Diesel engines with ceramic pistons and cylinder liners are expected to achieve higher energy conversion efficiencies (45-50%) than normal diesel engines (35%) due to the higher temperatures possible. A drawback of ceramic material is their brittleness. At the University College of Dublin such an engine was built and tested. The engine is characterized by a variable compression ratio, opposed piston, compression ignition, two stroke operation. The engine had no cooling system or piston rings. The compression pressure with a compression ratio of 20 to 1 was 4,5 MPa.

When fuel was injected the engine ran smoothly for three minutes and then broke down due to the fact that the piston had broken and the liner was cracked. The cause of failure is not yet known.

SECTOR D

RECOVERY OF RESIDUAL HEAT

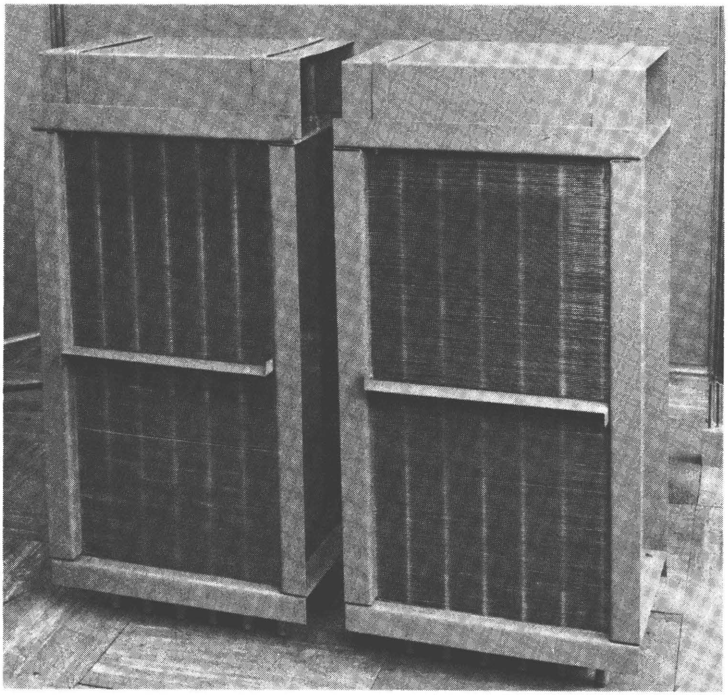


Figure 4.1.1 Heat pipe heat exchangers

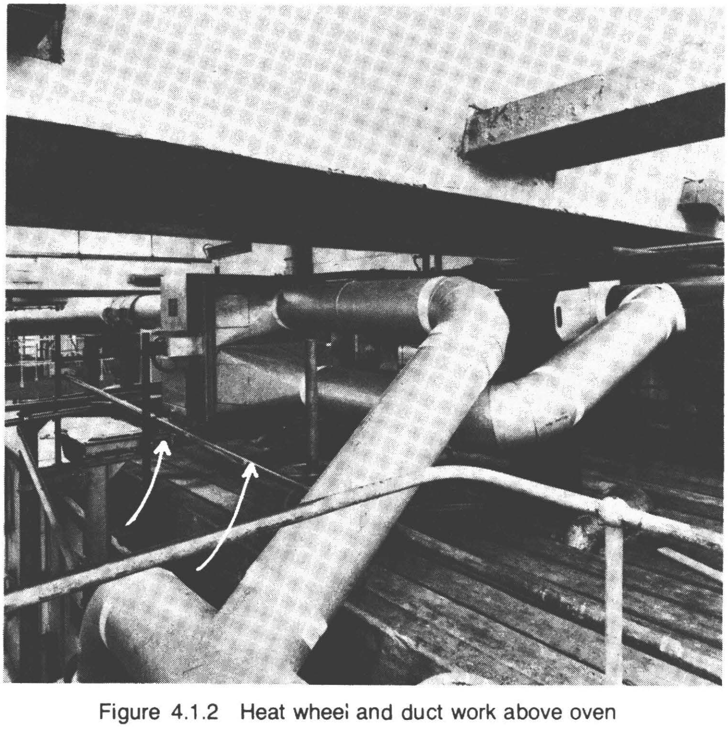


Figure 4.1.2 Heat wheel and duct work above oven

HEAT RECOVERY COMPONENTS

(HEAT EXCHANGERS AND ORC ENGINES)

Comparative study of a rotating regenerator and a heat pipe heat exchanger 4.1

D.A. REAY

DR. E.L. FOSTER

International Research and Development C° Ltd
Fossway
Newcastle upon Tyne
NE 6 2YD

Final report number: EUR 6792 available in English

Contract number: 184-77 EEUK

An attempt was made to compare the performance (fouling, efficiency, convenience) of a heat pipe heat exchanger of IRD manufacture and a commercially available rotating regenerator (heat wheel), when recovering heat from the exhaust of a synthetic fibre drying/setting oven and transferring it to the inlet air. Neither of the devices achieved its design rating when transferring between 23 and 31 kW. Although it was concluded that the method of heat recovery is technically feasible, it is economically unattractive in this case because of oven design. The open ended form of the oven means that additional internal dampers and controls are required to prevent excessive stray leakage and to direct the hot exhaust to the heat recovery devices with greater efficiency. Retrofitting a heat exchanger is too expensive due to expensive ductwork. On the question of comparative performance of the two heat exchangers it is not possible to propose that one type is preferable to the other: the heat wheel created more problems in respect of maintaining airflow but it had a higher temperature efficiency. For neither of the exchangers fouling will be a problem.

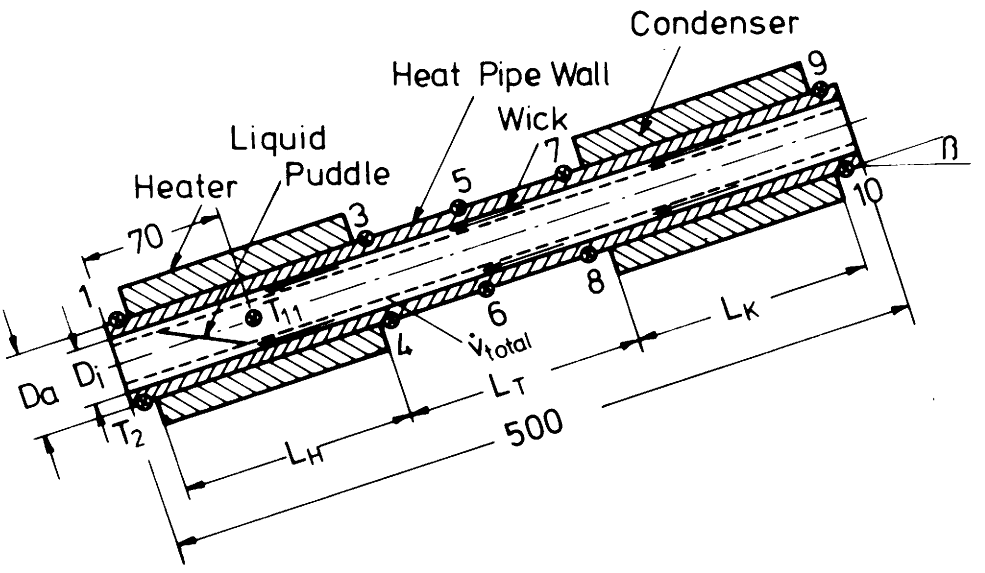


Figure 4.2.1 Heat Pipe-Thermosyphon Instrumentation

Structural Material \ Working Fluid	Freon 21	Acetone	Methanol	Water	Octane	Diphyl[1]	Diphyl-o[2]	Silicone-Oil
AlMn	80°C +	80°C +						
AlMgSi0.5	80°C ⊕	80°C -						
SF-Cu		80°C ⊕	80°C +	150°C +				
CuNi 30Fe	80°C +			150°C +				
CuZn28Sn	90°C +			150°C ⊖				
CuZn36	80°C ⊕	80°C ⊕	80°C -	150°C -				
CuZn20Al	80°C +			150°C ⊕				
mild steel	80°C +				200°C ⊕	270°C ⊕	210°C ⊕	300°C -
stainless steel					210°C ⊕	320°C ⊖	230°C -	300°C -

[1] Diphyl corresponds to Dowtherm A or Thermex, respectively. [2] Diphyl-o corresponds to Dowtherm E.

The upper values in the boxes represent the mean operating temperature and the lower symbols indicate the long-time behaviour according to the following categories:

- \+ compatible
- ⊕ fairly compatible
- ⊖ not particularly compatible
- \- not recommended

Figure 4.2.2 Materials combinations for compatibility tests

Research on heat pipes and thermosyphons for heat exchangers 4.2

M. GROLL

H. NGUYEN-CHI

H. KRÄHLING

Institut für Kerntechnik und Energiewandlung e.V.
Holderbuschweg 52
7000 Stuttgart 80

Final report number: EUR 7006 available in German

Contract number: 379-77-10 EED

Gravity assisted heat pipes and two phase thermosyphons have excellent heat transport properties. Typically 400 W can be transferred through a tube with a diameter of 10 mm. Heat introduced at the hote side of the tube is vaporating a liquid and the vapor transports the heat to the cold end of the tube where it condenses and releases the heat; the condensliquid returns to the bath. In a heat pipe the return of the condensliquid is brought about by capillary forces of a wire gauze in the inside wall of the tube. In a thermosyphon the liquid returns by gravity. IKE studied the heat transfer of heat pipes and thermosyphons as a function of the amount of liquid in the tube, length of the hot and cold zone, etc. For heat pipes the influence of the number of grids and the mesh size and for the thermosyphon the roughness of the inner surface was studied.

Generally, thermosyphons performed better than heat pipes. It was also shown that thermosyphons with a rough inner surface performed better than thermosyphons with a smooth surface. Theoretical calculations of the maximum heat transfer based on the dry-out limit (when part of the inside wall is not wetted) and burnout (when between the liquid and the wall of the tube a vapor film hampers heat transfer between wall and bath) are not in agreement with the experimental results.

The long term compatibility of structural materials (ALMn, AlMgSi 0,5, SF-Cu, CuNi30Fe, CuZn 28Sn, CuZn36, CuZn20 Al, Baustahl, Edelstahl) and working fluids (Freon 21, Aceton, Methanol, water, octane, diphyl, diphyl 0 and siliconoil) were tested. The major part of the 30 combinations tested performed well.

Finally a literature review is given of heat pipe and thermosyphan applications. Payback times are estimated to lie between 1,5 and 4 years.

Heat pipe heat exchangers for waste heat recovery in the laundry, textile and paper industry

4.3

M. J. DAVIES

G.H. CHAFFEY

United Kingdom Atomic Energy Authority
Harwell Laboratory
Building 424 AERE Harwell
GB - Oxfordshire OX11 ORA

Final report number: EUR 7127 available in English

Contract number: 385-77-EEUK

A heat pipe (thermosyphon) heat exchanger of significantly improved performance has been developed by UKAEA Harwell. The basis of an efficient thermosyphon is one where the internal wall of the tubes with grooved surfaces running longitudinally along its length had a much better performance than smooth tubes (9 W/°C.cm^2 and 2 W/°C.cm^2 respectively). This is in agreement with the results of the previous study. Heat exchangers made with improved thermosyphons, have been built and installed in four industries (Laundry batch drying, laundry continuous drying, wool drying, and paper making). The payback periods based on 1978 hardware costs are 3.6, 3, 2.3 and 1.7 years respectively.

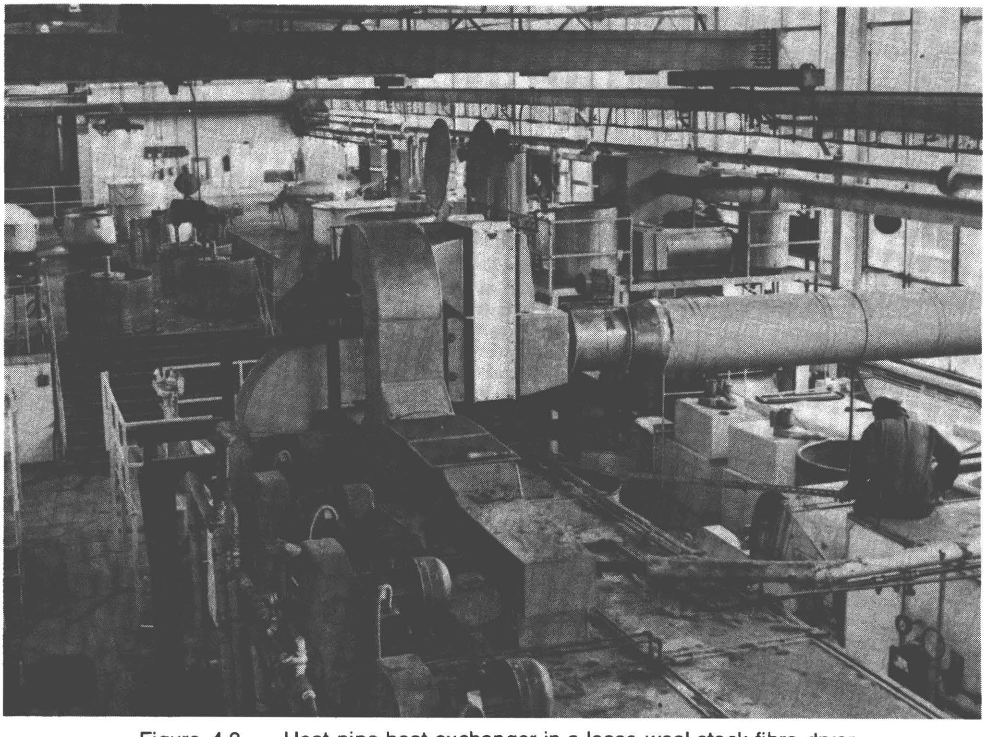


Figure 4.3 Heat pipe heat exchanger in a loose wool stock fibre dryer

Heat recovery at 750°C in the aluminium industry with a "heat wheel" 4.4

M.M. GORDON

James Howden & Company Ltd
Glasgow G5
Scotland

Final report number:

Contract number: 386-78-1 EEUK

A modified version of a Ljungstrom "heat wheel" has been conceived by James Howden & Company to preheat combustion air with exhaust gases from an aluminium melting furnace. These flue gases are kept at 750°C. Energy savings of 30% are believed to be possible. Both the design and construction of a pilot plant were foreseen. The design phase has now been completed and work is in progress to install such a heat exchanger in an aluminium plant.

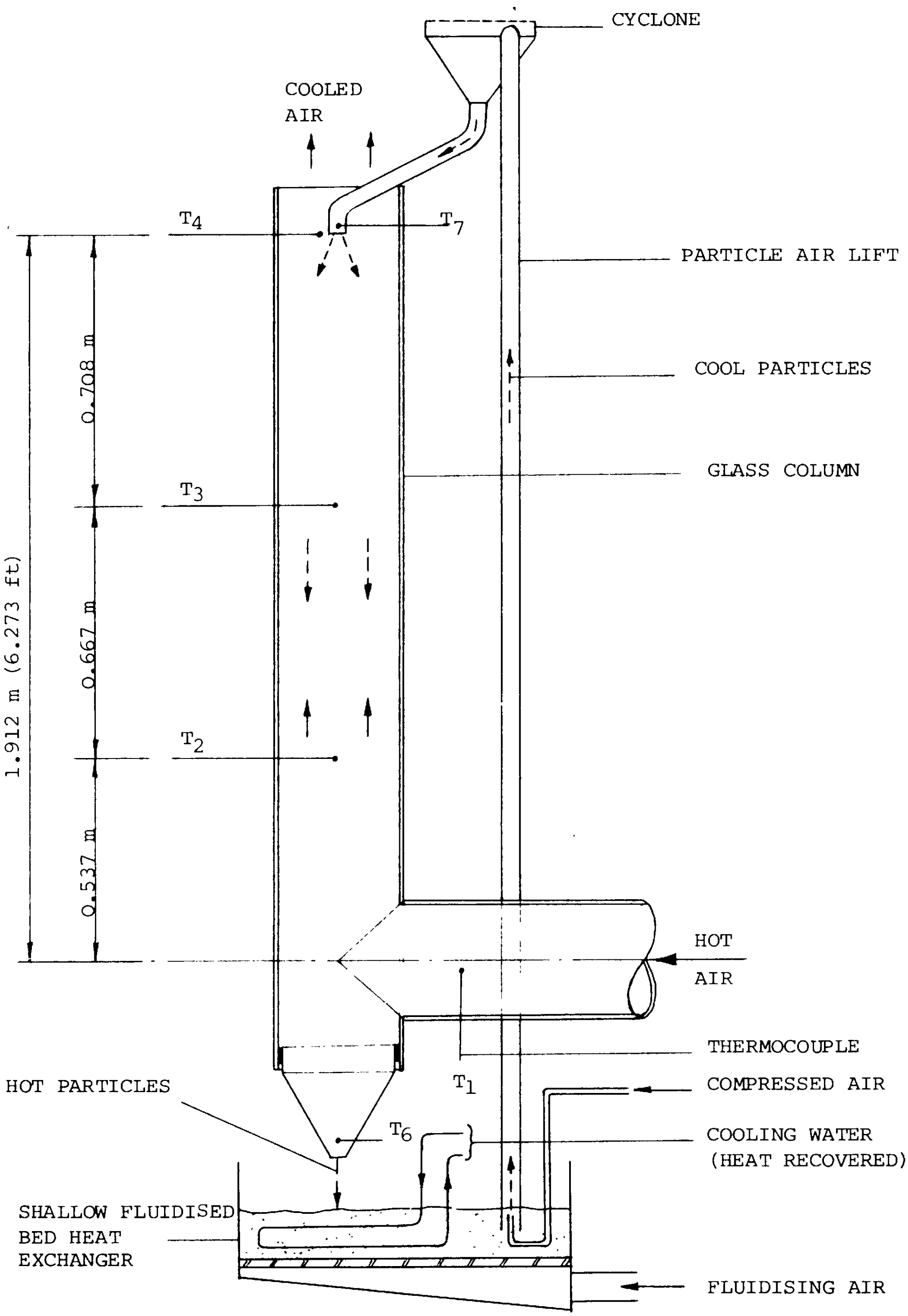


Figure 4.5.1 The falling cloud heat exchanger experimental rig

Development of a falling cloud heat exchanger

M. S. SAGOO

Stone Platt Fluidfire Limited
Washington street
Netherton, Dudley
West Midlands DY2 9RE
England

Final report number: EUR 7363 EN

Contract number: 382-78-EEUK

A falling cloud heat exchanger extracting heat from hot (up to 1000°C), corrosive and contamined gases is being developed by Stone Platt Fluidfire. This is realized in a two-step process. In the first step heat is transferred to small inert particles in a kind of fluid bed. In the second step heat is extracted from these particles by another fluid. An experimental rig has been constructed to test this concept. This installation was designed for temperatures up to 300°C with a maximum gasflow through the fluid bed of 0,01 m^3/s. Initial tests revealed that the formation of eddy currents in the vicinity of the air entry section, reduced the effective heating length and the thermal ratings of the rig. Further tests were, therefore, conducted under constant air flow conditions. The heat transfer coefficient for steel particles was found to be greater than that for alumina. But the higher specific heat and specific surface area resulted in alumina recovering more heat per unit mass of the particles. There was some evidence of the heat transfer coefficient increasing directly with particle concentration in the heating column. This was pronounced for alumina. This effect needs further investigation. The effects of particle material and particularly the particle change due to contamined hot gases are discussed.

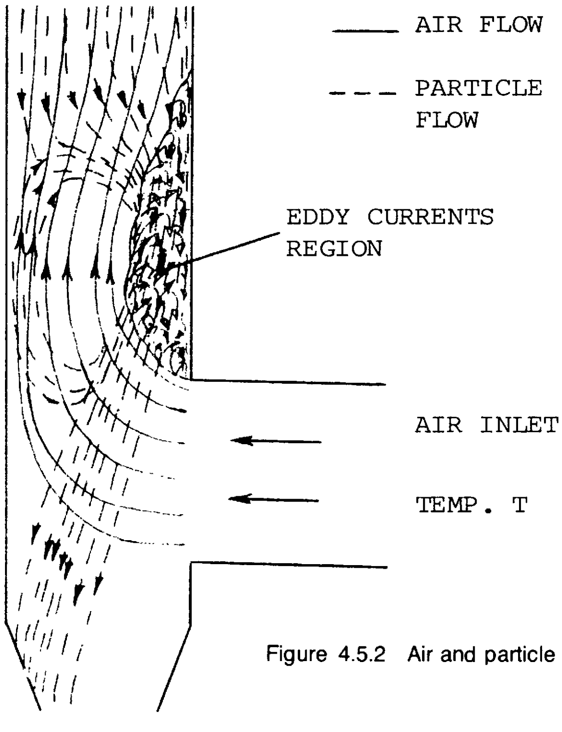


Figure 4.5.2 Air and particle flow at tee section

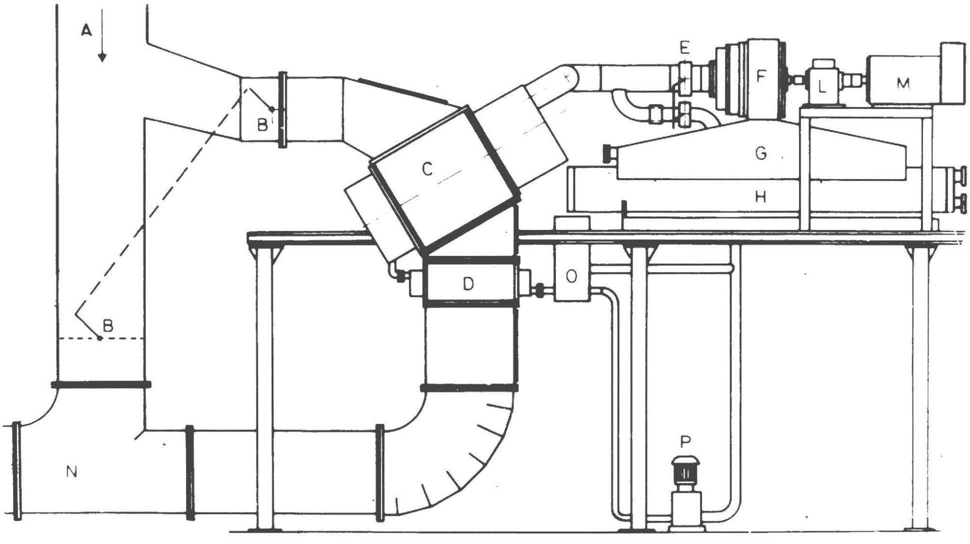


Figure 4.6.1 Layout of the heat recovery with a ORC engine. A = Hot gases from the oven, B = Gas flow regulation valves, C = Tetrachloroethylene evaporator, D = Liquid tetrachloroethylene preheater, E = Turbine control valve, F = Turbine casing, G = De-superhetaer casing, H = Condenser casing, L = Speed reducer, M = Alternator, N = Exhaust duct, O = Constant level hot well, P = Feed pump

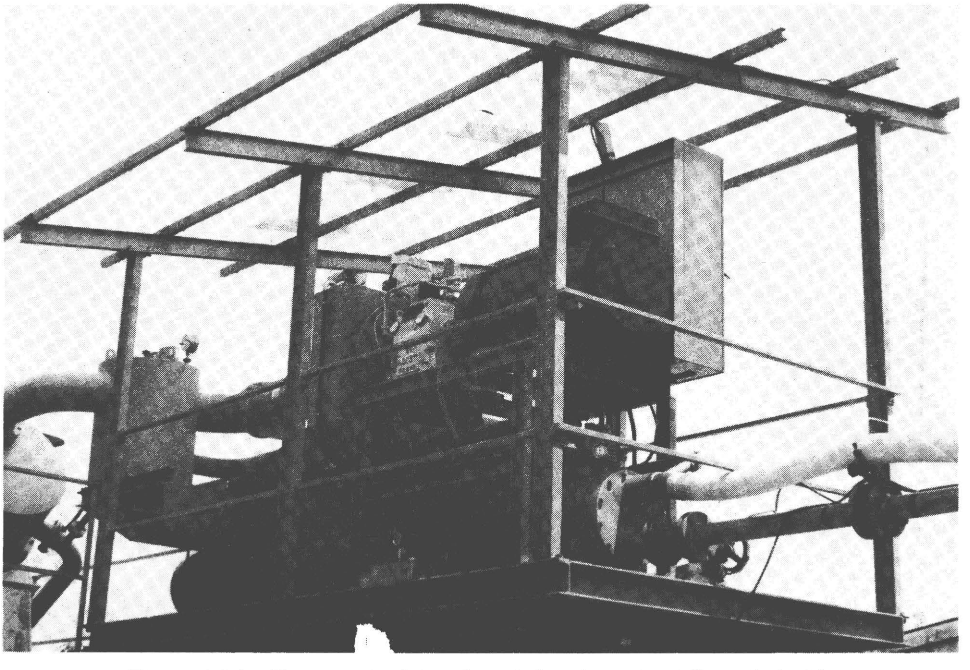


Figure 4.6.2 Photograph of the plant during the tests at Gemmindustria

Recovery of heat from exhaust gases at 250°C from a ceramic tunnel oven with an organic Rankine cycle engine 4.6

M. GAIA

E. MACCHI

Gemmindustria
Via Falcone 7
20123 Milano
Italy

Final report number: EUR 7642 available in English

Contract number: 198-77 EEI

Exhaust gases of ceramic tunnel ovens leave at temperatures of 250°C and large quantities of heat can be recovered if users could be found. As this is often not the case it was intended to transform the heat into electricity with an Organic Rankine Cycle engine and to use the electricity for the power requirements of the furnace. An ORC engine was designed by Gemmindustria with tetrachlorethylene as working fluid. The calculated maximum power output is 40 KW (efficiency 11%) at an evaporation temperature of the working fluid of 110°C (exhaust gas inlet temperature of 220°C). The engine performed well but the calculated maximum power has not yet been achieved due to the fact that the exhaust gases cooled down in the duct from 250°C to 175^{C} before they reached the ORC engine. The maximum power obtained was 22 KWel. The duct will now be insulated in order to reach the maximum power. No check on corrosion of the components has been made. The cost of the ORC engine is estimated to be around 500 ECU/KWel and the pay back time 3 years. A large interest has been shown by ceramic manufacturers.

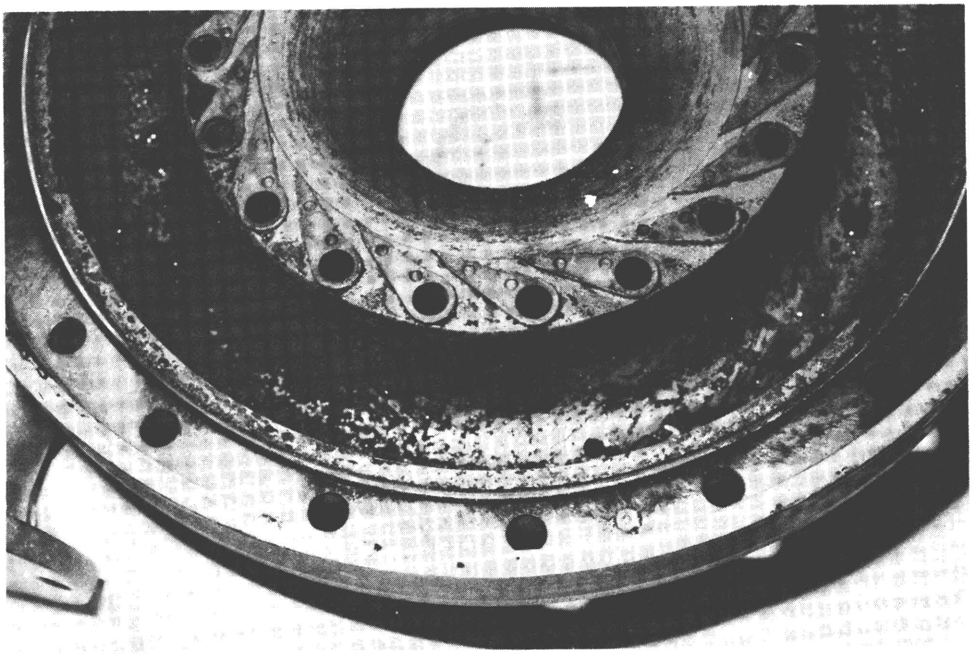


Figure 4.7.1 Turbine housing: freon leakages due to non uniform contact of the metallic O-Ring.

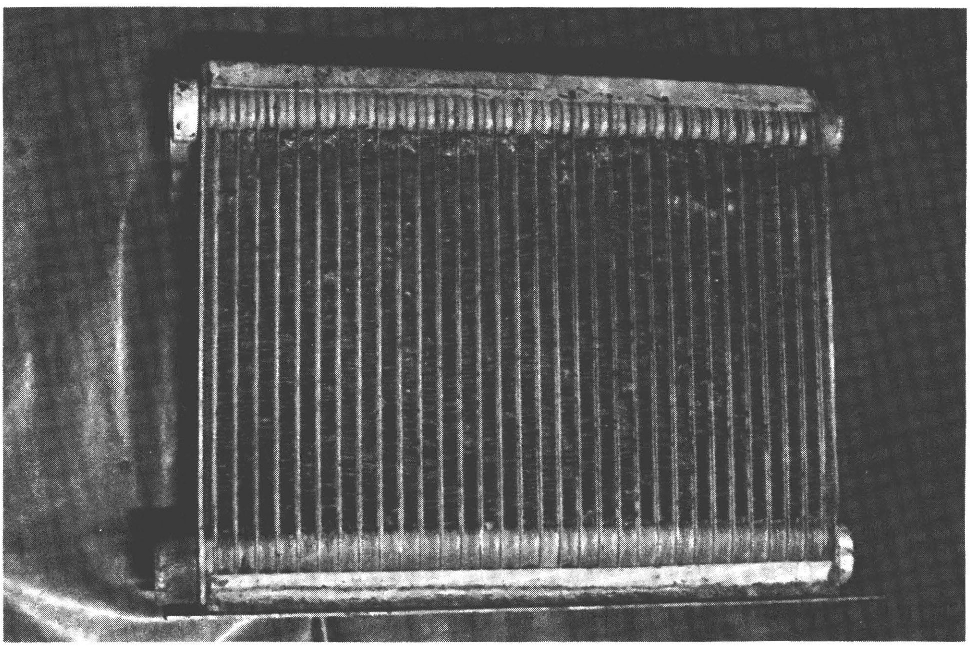


Figure 4.7.2 Condenser: corrosion of aluminum radiators due to hydrochloric attack.

Recovery of heat from exhaust gases at 300-350°C with an organic Rankine cycle engine 4.7

G. CIPOLLA

Centro Ricerche Fiat
St. Torino 50
10043 Orbassano (Torino)
Italy

Final report number: EUR 6916 and 7159 available in English

Contract number: 196-76-7 EEI and 383-78-EEI

When waste heat of 300-350°C has no application for heating purposes it may still be usefully transformed into electricity. For small quantities of heat up to about 2000 Kcal this transformation may be done efficiently with an Organic Rankine Cycle turbine. Fiat developed such an engine with a maximum power of 95 KW at expander inlet temperatures of 250°C. The machine was designed to reach energy conversion efficiencies of 15% at 250°C with freon 11 as a working fluid.

However, due to serious corrosion problems the maximum power was never reached. Above 150°C freon 11 was not chemically stable and caused creation of HCL and subsequent corrosion of different engine components.

Using another more stable working fluid (perfluorohexane) the engine performed well up to 250°C (30 bar). However, due to the fact that the engine was not designed for this working fluid a maximum power of only 37 KW and an efficiency of 7% was obtained. Perfluorohexane is not suitable for the simple non-regenerative cycle engine which was designed for freon 11 and would require a much more expensive machine in order to obtain efficiencies of 15%. Moreover, perfluorohexane is very expensive and it is unlikely that its price will decrease, when it is mass produced.

HEAT RECOVERY IN SPECIFIC INDUSTRIAL PROCESSES

Heat recovery in the iron melting industry 4.8

M. DEL BORGHI

M. FOPPIANO

D. DE FAVERI

G. FERRAIOLO

Chemical Engineering Department
University of Genoa Italy
Via Opera Pia 11
16145 GENOVA

Final report number: EUR 6604 available in English

Contract number: 252-77 EEI

The problem of heat recovery in electrical steel scrap melting furnaces was studied by the University of Genova. Fifty steel making plants throughout Northern Italy were contacted in order to establish the type of furnace which should be studied. A steel plant with a daily production of 210 tonnes with a mean installed power of 9500 K.V.A. was selected. For this plant the possibility of preheating scrap with flue gas has been studied. This flue gas leaves the furnace at 800°C and has to be cooled down to 120°C in order to pass the purification installation. It was found that 60% of the flue gas heat could be recovered. The pay back time of the extra investment is about half a year. In a meeting with the contacted firms it was suggested that in view of the promising results a pilot plant should be constructed as soon as possible.

Recovery of heat from flue gases for preheating glass granulates 4.9

BOBLETER

BERTIN & CIE
Boîte Postale n° 3
78370 PLAISIR

Final report number: EUR 6324 available in French

Contract number: 169-76-EEF

Recovery of heat from flue gases of glass furnaces for the preheating of glass granulates was studied by Bertin & Cie. The aim of the research was to make the use of organic binding materials in the confection of the granulates superfluous and to avoid the premature destruction of the granulates during preheating phase. For the manufacturing of both glass and expanded glass, this type of heat recovery was studied. Energy savings of 20-25% and payback times of 3 years are believed to be possible. It is now planned to construct a glass manufacturing plant with heat recovery on an industrial scale.

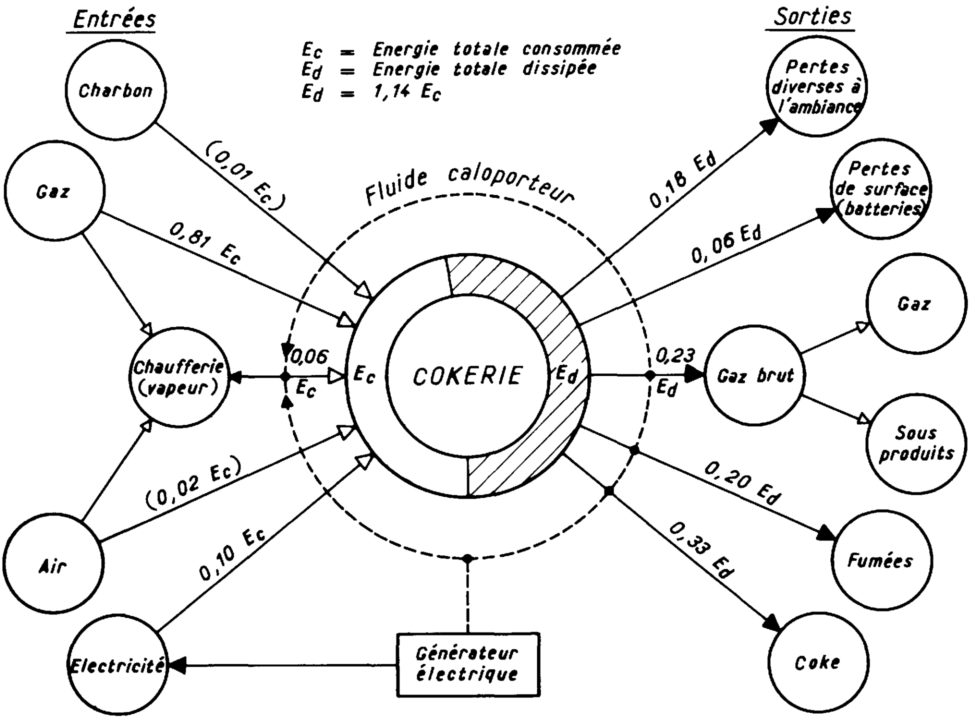


Figure 4.10.1 Energy use in a classical coke industry.

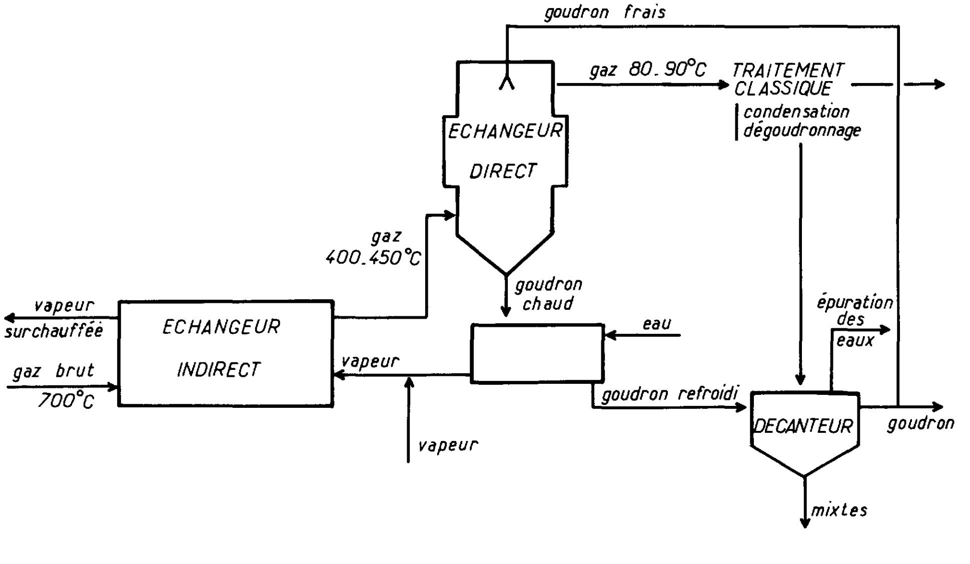


Figure 4.10.2 Principle of heat recovery in the coke industry.

Possibilities for heat recovery in the coke industry **4.10**

R. H. BUSSO

P. TRIBODET

Centre d'Etudes et Recherches des Charbonnages de France
B.P. n° 2
60550 VERNEUIL-EN-HALATTE

Final report number: EUR 7161 available in French

Contract number: 173-76 EEF

The possibilities for heat recovery in the coke industry were studied by Cerchar. Coke production is a large energy consumer: for the production of a tonne siderurgical coke on the average 1100 KWh is consumed. A large part of this heat is wasted at present and may be recovered:

— 410 KWh/tonne coke (33%) is lost during the cooling of coke after leaving the furnace at 1000°C

— 290 KWh/tonne coke (23%) is lost in distillation gases which leave the furnace at 700°C

— 250 KWh/tonne of coke (20%) in exhaust gases of the combustion process.

In this contract possibilities to recover heat from distillation gases have been further developed. The aim was to recover 10%, equaling 140 KWh per tonne of coke. Tests in the laboratory and in the coke factory enabled the design of a recovery system consisting of two heat exchangers in series which are to produce superheated steam. Designs were made for a pilot facility for one coke furnace and an industrial installation working with about 30 furnaces. The pilot facility is meant to test the technical feasibility for the recovery of heat from distillation gases and will cost about 200.000 EUA. The industrial recovery system is expected to have a pay-back time of 5 years.

Heat recovery by dry cooling of hot coke 4.11

G. VOLLRATH

K.H. FLASCHE

J. LANG

Stahlwerke Röchling-Burbach GmbH
Postfach 101980
D-6620 Völklingen

Final report number:

Contract number: 359-78-EED

Recovery of heat from the cooling of hot coke is the subject of a feasibility study executed by Röchling-Burbach. In Western Europe cooling of coke is mostly done with water and the heat is not recovered. In USSR and Japan "dry coke quenching" with recovery of heat is applied using N_2, which heats up water to produce vapor of 13 bar and 330°C. In view of a possible introduction of this technique in Western Europe, a feasibility study for a small and a large "dry coke cooling" installation was made.

For a new battery of 40 coke furnaces producing 0,33 Mio ton coke/year a dry coke cooling installation would cost between 19 and 22 Mio DM and produce 120.000 to 160.000 tonnes steam per year at 330°C and 13 bar. A large variety of pay back times can be calculated depending on the investment cost, steam production, availability or not of nitrogen (10 Nm^3 per ton coke), increase of energy cost per year (3,6, 9,12%) and the cost of steam (15-30 DM/ton). Generally it may be concluded that for this size (0,3 Mio ton coke/year) the construction of a dry coke installation is economically not attractive.

However, a dry coke cooling installation for a new cokery of 2.2 Mio ton coke/y with a steam production of 1.1 Mio t/a is expected to be economically feasibility. The total cost will be around 60 Mio DM. It is crucial however to find users for the produced steam and this is not always easy. In Germany the saving potential with a coke production of 28.10^6 ton/year is 10^6 TOE.

Heat recovery in the primary aluminium industry 4.12

Vereinigte Aluminium-Werke
Aktiengesellschaft
Lippewerk
Postfach 2110
D-4670 Lünen

Final report number: EUR 7387 D

Contract number: 253-77-EED

Aluminium production is one of the most energy intensive industrial branches. In Western Europe about 2 Mio tonnes of aluminium are produced per year and the energy requirements per tonne aluminium are 15.000 KWh electricity and 16.000 KWh heat which amounts to a total primary energy requirement of 6 TOE/tonne Al. (Recycling of aluminium costs only ± 5% of this energy). The possibilities for energy saving in the primary aluminium industry were investigated by VAW.

From energy measurements the quantities of waste heat at different temperature levels were established. The total amount of waste heat in the plant was 237 GJ/h (1 liter petrol = 40 MJ) of which 42,7 GJ/h was technically recoverable. A network into which all recoverable waste heat could be fed, to produce hot water at 140°C, was found to be economically not feasible (minimum pay back time 6 years). The main sources of waste heat are exhaust gases in Al_2O_3 production (43 GJ/h at 130-300°C), evaporation of caustic soda (90 GJ/h at 65°C), exhaust gases from the foundry (9 GJ/h at 500-700°C) and exhaust gases of the power plant 58 GJ/h at 200°C.

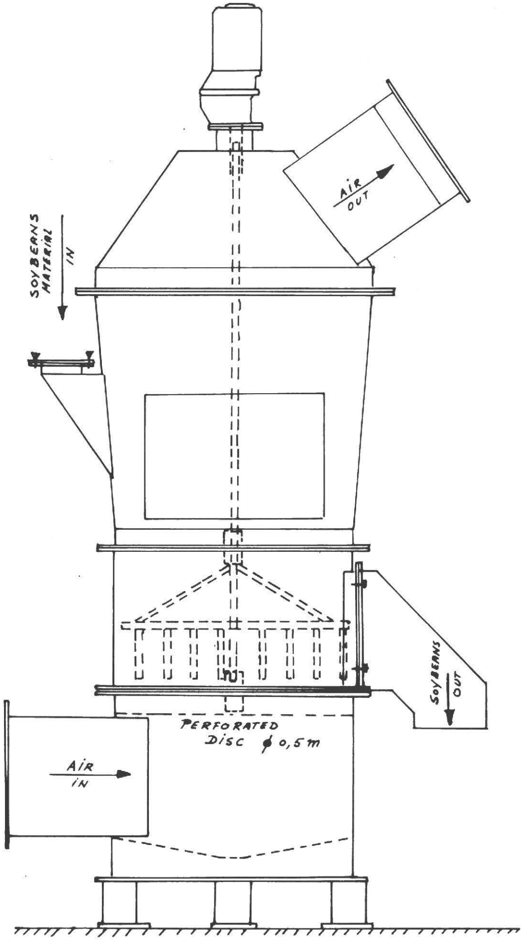


Figure 4.13.1 Details of batch heater for soy beans.

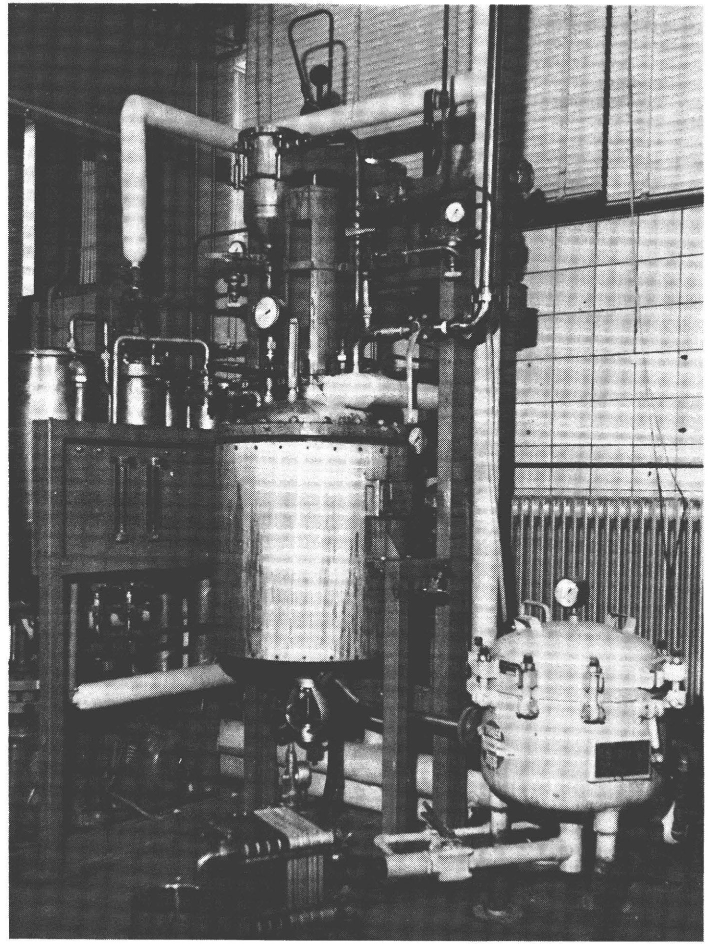


Figure 4.13.2 Hydrogenation autoclave CAP, 50 kg.

Heat recovery from exhaust gases and hydrogenation of edible oils and fats 4.13

T.L. ONG

Organisatie voor Toegepaste Natuurwetenschappelijk Onderzoek TNO
Centraal Instituut voor Voedingsonderzoek
P.O. Box 297
Den Haag

Final report number: EUR 6837 available in English

Contract number: 381-78 EENL

In the food industry two possibilities for heat recovery in soybean drying were studied by TNO:

The use of exhaust gases from gas fired steam boilers for drying soymeal was found not to be possible due to the high nitrogen oxide contents of the gases and the long distance between the gasboiler and the soymeal dryler. The use of exhaust gases however is believed to be possible for the heating and conditioning of soybeans. For a capacity of 1000 tonnes of beans per day an extra investment of about 250.000 ECU, will be required. The payback time is 3,5 years and the rate of return 20%. Oil fired boilers have stack gases with a different composition, for which bean heating and conditioning may not be possible.

From the results of the experiments on the recovery of reaction heat in the hydrogenation of edible oils and fats, it can be concluded that it is quite feasible to utilize this heat for preparing low pressure steam of about 140°C or hot water of about 75°C. For a hardening plant with a capacity of 60 tons of oil per day, the necessary investments are estimated at 36.000 ECU. The pay back period and rate of return will be 3 years and 20% respectively. The construction of a demonstration plant is needed to demonstrate the feasibility.

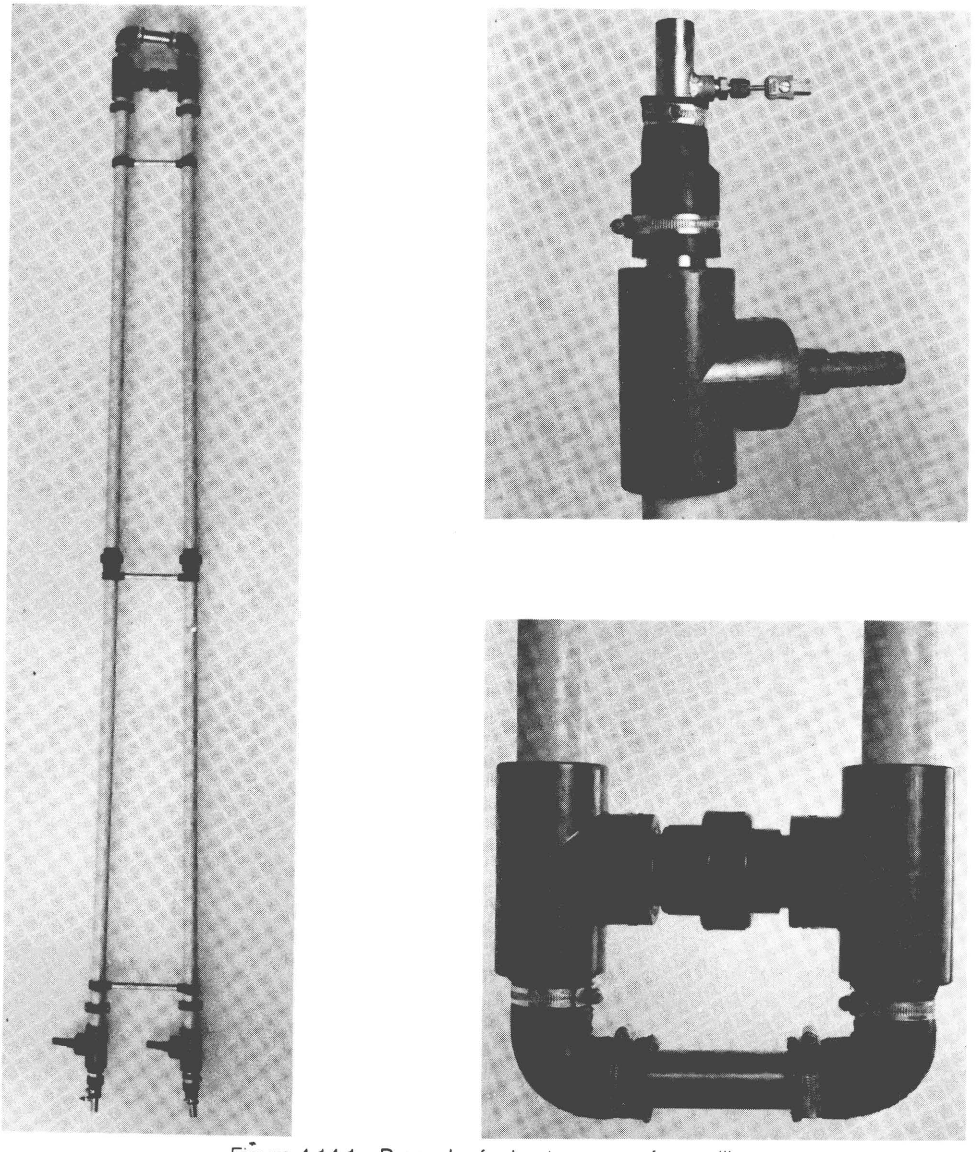


Figure 4.14.1 Precooler for heat recovery from milk.

Heat recovery from milk with a heat exchanger or a heat pump for energy saving in hot water production on farms

J. UBBELS

A.P. MEULMAN

C.P. VERHEIJ

Nederlands Instituut voor Zuivelonderzoek
Kernhemseweg 2
Ede

Final report number: EUR 6915 available in English

Contract number: 215-76 EEN

The heat recovered from cooling milk (35°C → 4°C) can be used for heating water required at the farm. A study, evaluating two possibilities for energy saving, was executed by NIZO. The results are as follows:

— Precooling of milk, using a heat exchanger, from 35°C tot 20°C, with water which is warmed up from 10°C tot 18°C and which subsequently is heated to 80°C with a normal electrical boiler. The payback time for a precooling installation for a farm of 50 cows is 6,5 years. (50% of the milk production in the Netherlands is produced by farms with 50 or more cows).

— Use of a heat pump which extracts heat from the milk refrigerating tank, thus cooling the milk to 4°C. and heating up water from 11°C to ± 60°C. For a farm with 22 cows, where the ratio of hot water required and the milk produced is about 0,3 the payback time of such a heat pump installation is 5 years. The primary energy saving potential in the Netherlands will be 40.000 TOE per year if this technique is generally introduced.

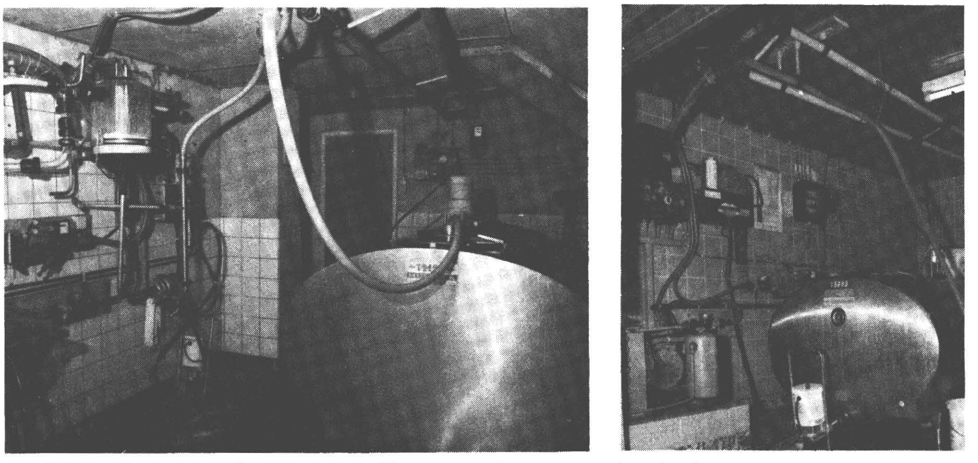


Figure 4.14.2 Two precoolers mounted at the farm.

Heat recovery from exhaust air of spray dryers in the dairy industry

4.15

L.A. JANSSEN

A.E. STEENBERGEN

Nederlands Instituut voor Zuivelonderzoek
2 Kernhemseweg
P.O. Box 20
NL-6710 BA Ede

Final report number: EUR 7576 available in English

Contract number: 591-78 EEN

The possibilities for recovery of heat from exhaust gases (up to 98°C) from a spray drying process used for the manufacture of milk powder were explored by NIZO. The presence of skin milk powder with a powder content up to 400 mgr/m^3 was found to be a less important cause of fouling of the heat exchanger than the moisture content. For a 50 mg/m^3 moisture content, condensation occurred in the heat exchanger which lead to rapid fouling. It is possible to recover a part of the heat from exhaust air for skin milk production when heat exchangers are cleaned daily. To ensure thorough cleaning, the construction of the heat exchangers had to be adapted leading to a lower efficiency (e.g. larger fin distance). By filtering the exhaust air, the cleaning could be reduced to once every two weeks, thus reducing the cleaning cost and allowing for heat exchangers with a higher efficiency. Pay back periods of the heat recovery installation with and without filtering are 4,6 and 2,4 years respectively.

SECTOR E

Recycling of materials

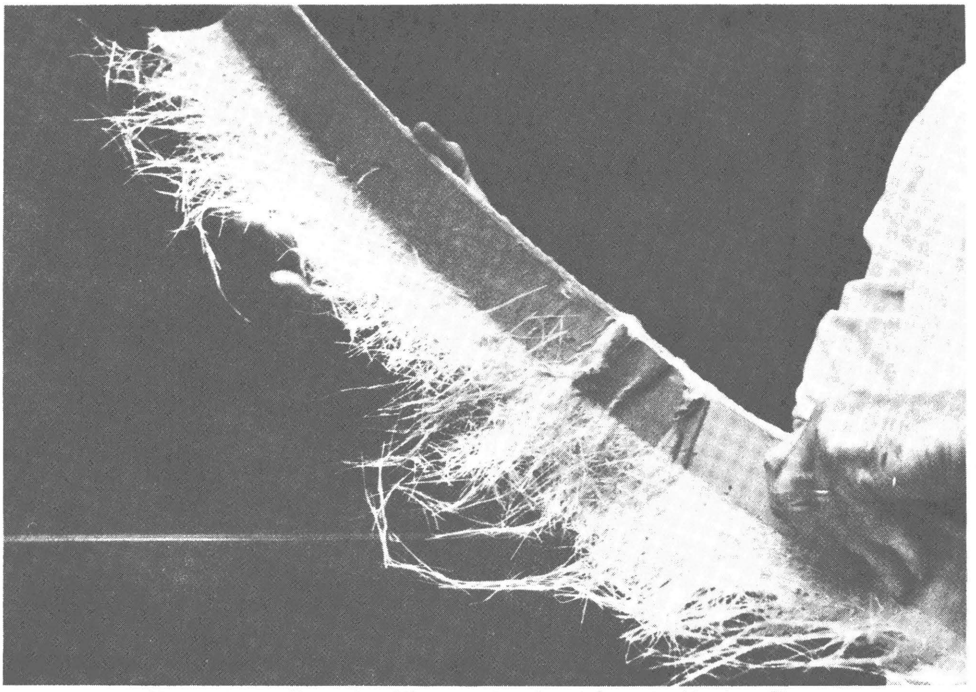


Figure 5.1.1 Example of thermoset resin reinforced with glass fibres

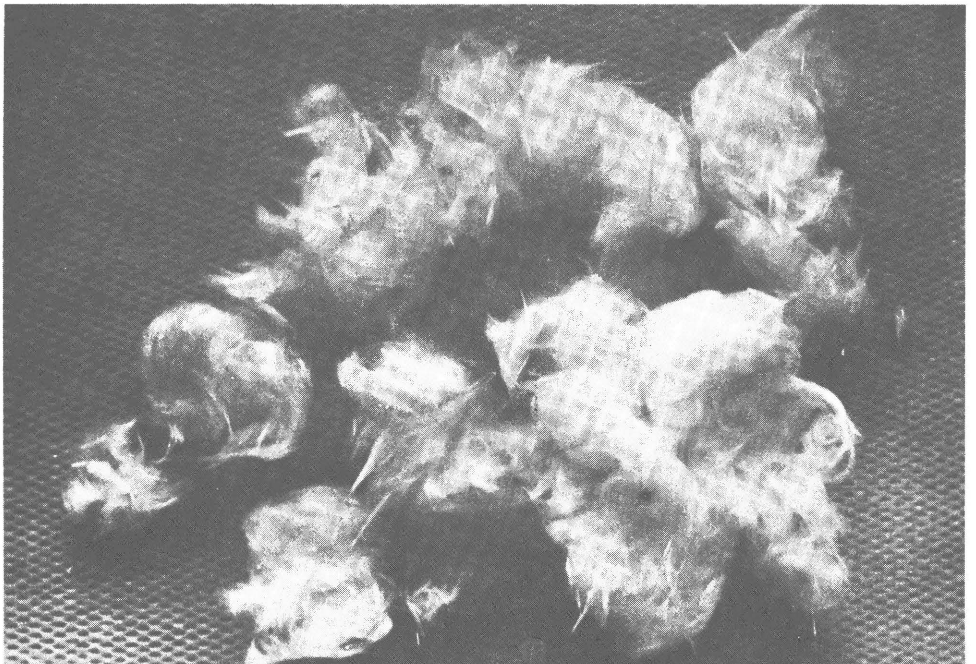


Figure 5.1.2 Recycled glass fibres from thermoset resins

Recycling of thermoset resins reinforced by glass fibres 5.1

E. MOREL

G. RICHERT

CH. MARTIN

IRCHA
Institut National de Recherche
Chimique Appliquée
rue Jules César 16 F
75012 PARIS

Final report number: EUR 6833 available in French

Contract number: 222-77 EEF

Recycling of thermoset resins reinforced by glass fibres is a difficult problem. About 4% of the production quantity are scrap or rejects. The main part consists of a polyester matrix with a mean glass content of 40% under the form of woven fabrics, mat or rovings. This type of waste is very difficult to eliminate and it seems interesting to reuse the glass fibers, the production of which needs large amounts of energy. In a first step the waste is ground to allow separation of fibers from matrix. Several processes have been studied to separate the fibers. The most interesting one seems to be a process which destroys the polymer by heat. A pyrolysis technique with direct utilization of products for combustion would permit to recover the total amount of fibers from the wastes. These fibers can be used to reinforce thermoplastics wastes to improve their mechanical properties. From laboratory tests it is difficult to estimate the cost of a plant for the recycling of glass fiber. However, taking into account the cost of energy it appears that for a fuel cost price of 0,011 ECU/KWh (values begin 1980) the pay back period is about 3 years for a plant of 250 T/Year capacity producing 100 T of fiber glass and assuming a possible selling price of 0,175 ECU/kg.

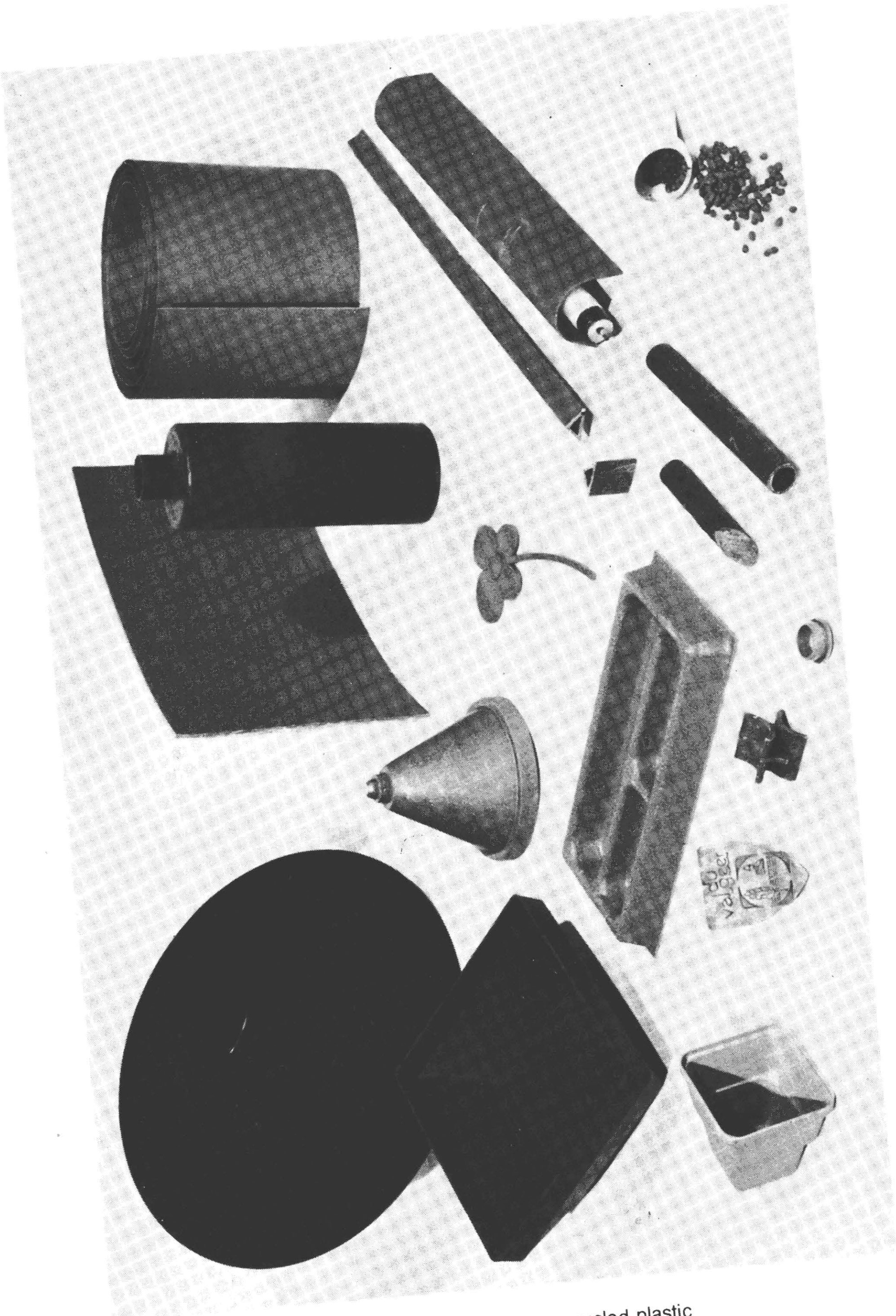


Figure 5.2 Products from recycled plastic

Saving of energy and raw materials by recycling plastic waste extracted from urban garbage 5.2

J. MICHAUX

CRIF
Rue de Chera 200
4000 Liege

Final report number: EUR 6917 available in French

Contract number: 202-76 EEB

Considering the favorable conclusions of a market assessment, CRIF developed a new technique to recycle plastic waste in form of granules by means of industrial machines and devices. The granules are manufactured of mixed plastic waste without preliminary sorting.

After grinding, washing and drying, the mixed plastic material is transformed by the CRIF plastification devices into a homogenous product which is crushed in form of granules. These granules are used as feeding material for injection moulding, extrusion and blow moulding extrusion of plastic products.

An industrial plant was designed for the reprocessing of 2400 T/year plastic wastes coming from an automatic sorting plant or obtained by a mixed selective collection of dirty glasses and plastics. The construction of this plant will be sponsored by EEC (Demonstration project) and INTRABEL (Association of Cities of Liège Area). The plant will be operational in 1981.

SECTOR F

Production of energy from waste

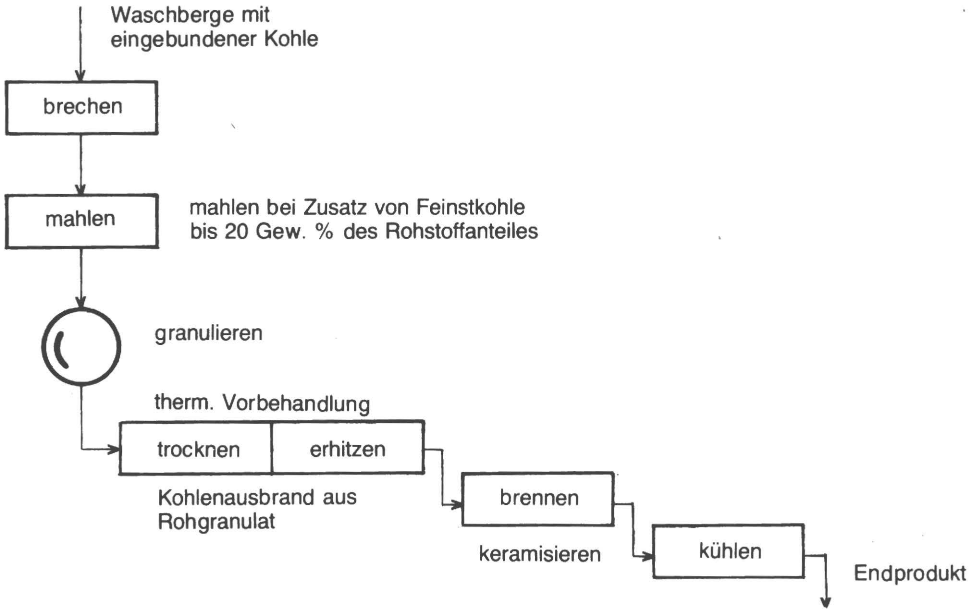


Figure 6.1.1 Production process of granules from slag

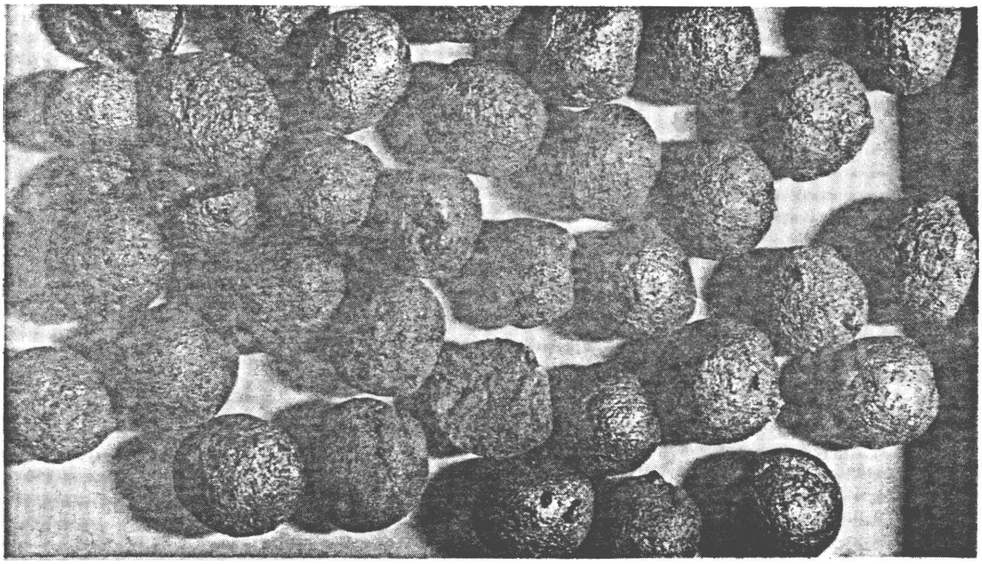


Figure 6.1.2 Granules produced in a furnace at 1100°C

Energy from waste and use of the remaining slag for building material 6.1

Prof. Dr. Ing. P. NEUMANN-VENEVERE

W.I.P.
Wirtschaft und Infrastruktur Planungs KG
Sylvensteinstrasse 2
D - 8000 MÜNCHEN 70

Final report number: EUR 7621 available in German

Contract numner: 259-77 EED

The following objective was pursued by WIP: energy recovery from refuse under special observation of the possibilities to produce high quality granulate for building material using this energy. The refuse or better the residual materials which have been analyzed, are garbage, sewage-sludge, low grade coal and furnaces ashes. The innovation of the programme exists in the fact that the basic-substance used is undesired residual material which so far has to be disposed off with enormous costs. The energy in this waste material is now used to transform the remaining slag into high quality granulate for building material.

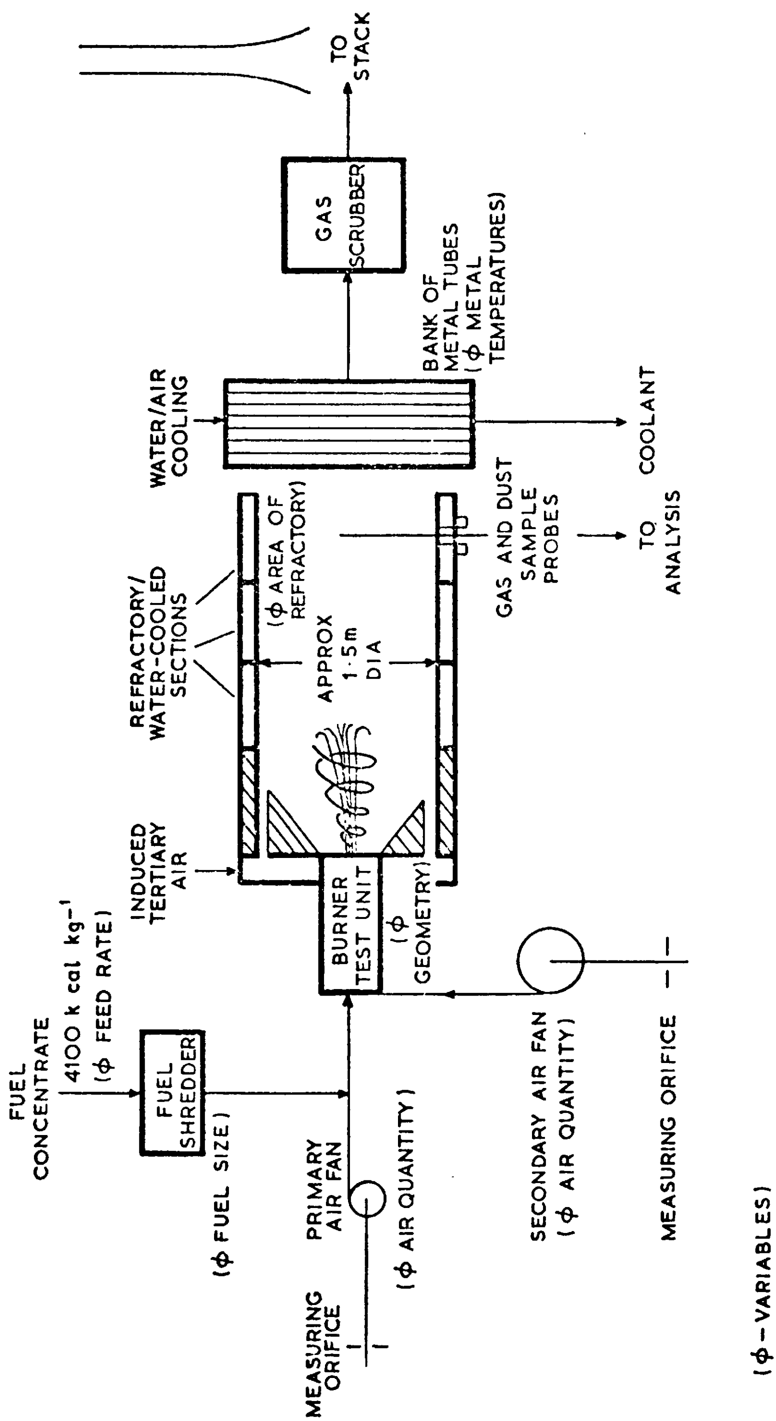


Figure 6.2 Burner and combustion test unit

Optimization of conditions for suspension firing of refuse derived fuel (R.D.F.) 6.2

E. DOUGLAS

J. POLL

Warren Spring Laboratory
Gunnels Wood Road
Stevenage Herb. U.K.

Final report number: EUR 6985 available in English

Contract number: 260-77-EEUK

Fuel concentrates extracted from domestic refuse (Refuse Derived Fuel — RDF) are now in commercial production and the investigation of their combustion characteristics when burned in suspension is the subject of this report. Practical problems in storage and feeding and their solutions are described together with details of the design of a test facility on which more than fifty firing trials have been completed. Problems with establishing stable self supporting ignition are described, the application of theoretical concepts to these problems is discussed. Areas requiring further investigation to establish the conditions which must be fulfilled to establish stable self-supporting combustion are indicated.

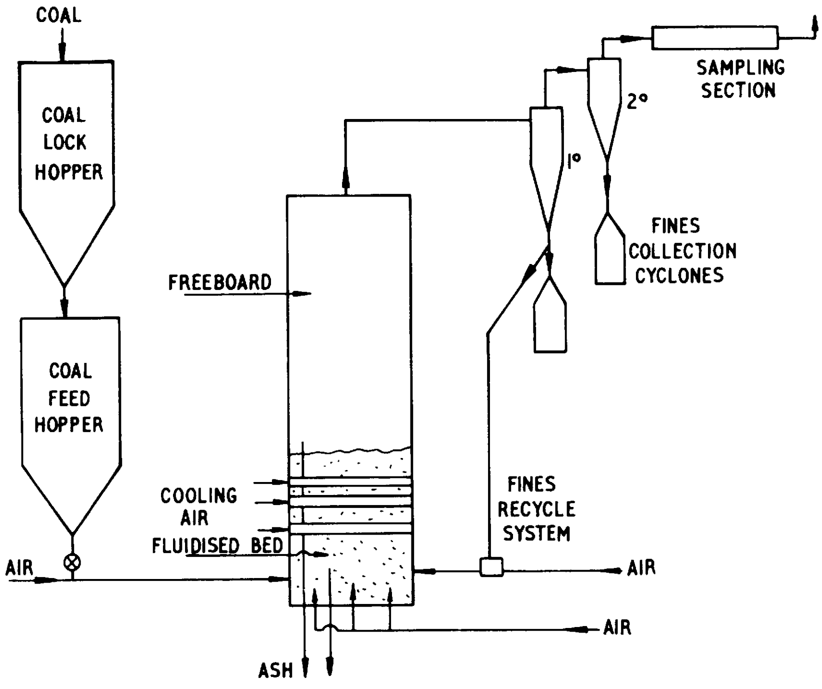


Figure 6.3.1 The 0.3 m square fluidised bed combustor

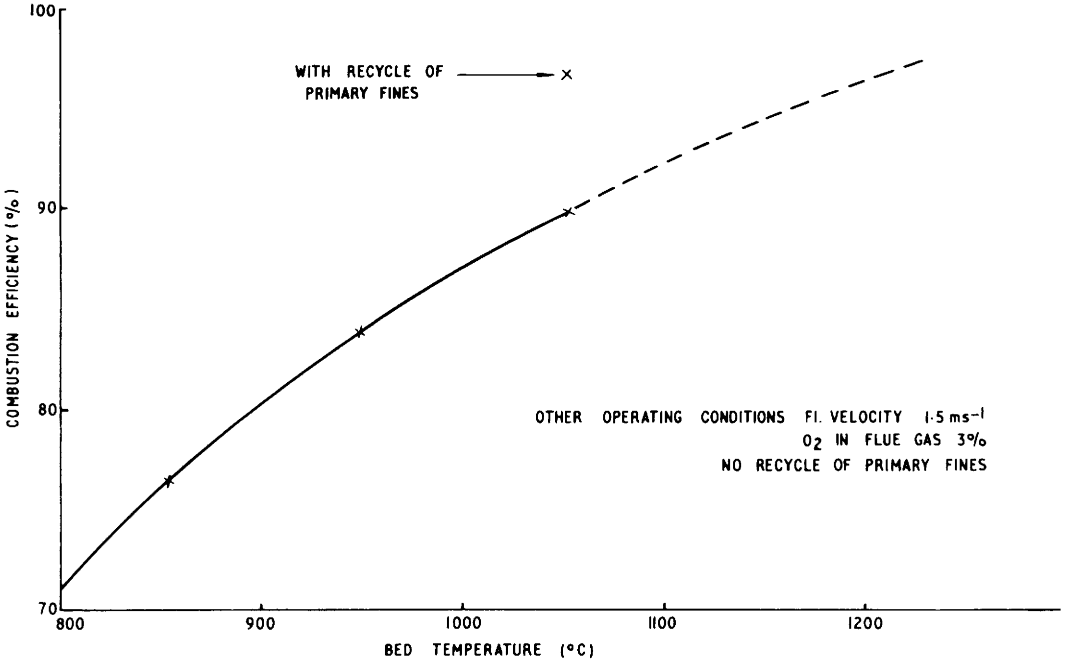


Figure 6.3.2 Effect of bed temperature on the combustion efficiency of high ash coal

Fluidized bed combustion of low grade coal 6.3

E.A. ROGERS

A.J. MINCHENER

National Coal Board
Coal Research Establishment
Cheltenham
England

Final report number: EUR 6823 available in English

Contract number: 188-77 EEUK

The feasibility of recovering useful heat from waste materials by combustion in a fluidized bed has been studied by the National Coal Board. An appraisal of the fluidized bed combustion process indicated that the technique was capable of accepting fuels of lower calorific value than conventional combustion processes, fuels of variable quality and fuels with high sulphur contents. A survey of available and suitable waste materials in the UK has been undertaken which identifies and quantifies possible feedstocks.

When burning low grade fuels, high combustion efficiencies are often difficult to achieve and a review of factors influencing combustion efficiency in a fluidized bed was undertaken. This review highlighed the possibility of operating the system at temperatures higher than those normally accepted for the fluidized bed combustion process to improve carbon utilization.

A coal with an ash content of 55% was selected for an experimental programme on a 0.3 m square fluidized bed combustor. In these tests a combustion efficiency of 97% was achieved when operating at 1.5 ms^{-1} and 1050°C with recycle of the primary cyclone fines. The data collected have been used for a process outline design of a 10 MW (thermal) fluidized bed boiler to burn this fuel.

Further experimental studies would be required before a fully optimized design of a 10 MW boiler to burn high ash coal could be attempted. These could need to be undertaken on a larger scale pilot plant rather than on the small test plant which was used in this experimental programme.

The potential economic benefits of the numerous systems for producing refuse derived fuels should be examined. If these processes are considered economically viable, a programme should then be implemented to assess the suitability of the materials for co-firing with coal in a fluidized bed combustion system.

Fluid bed gazification of low grade coal and waste 6.4

G. CHRYSOSTOME

S.A. HEURTEY
32 rue Guersant
F - 75017 PARIS

Final report number:

Contract number: 200-77 EEF

The aim of the research carried out by HEURTEY was to develop a process and equipment in order to valorize low grade material by means of combustion in two stages:

— Gasification by partial combustion in a fluidized bed at low temperatures

— Post combustion in a boiler or in a furnace.

1. The research carried out should be seen as a first exploratory phase of the development of a combustion process for coal shales which is to take place in two stages. Testruns were made with coal shales from North and South of France. Testruns on shales from South confirmed that no decarbonisation of ashes occured at temperatures lower than 800°C.

2. In the course of this exploratory phase difficulties have been met which were inherent in the nature of the waste utilized. Complete gasification of organic matter was difficult to achieve and tests suggested that it was necessary to keep an oxygen level of 5% in the fluíd bed.

3. It seems that oxydation of shales is regulated by the diffusion of different gases in the particles. Contrary to what was expected, shale particles are particularly resistant to erosion. In order to improve oxydation in a fluidized bed, shales would have to be pulverized. Experimentation also suggests that fine crushing—i.e. less than 1 mm of coals shales is needed in order to perform complete gasification.

4. The gas produced has a low calorific value and had to be mixed for normal combustion with natural gas. With advanced combustion techniques these admixtures are superfluous. Due to the fact that ashes have a high content of shales at high temperatures the thermal losses are considerable. Taking into account the cost of pulverizations, which implies combustion in a reducing environment, the energy concersion efficiency should be improved by an advantageous feature of this process: absence of decarbonisation.

Experimental study of the combustion of low calorific fuels 6.5

R.H. BUSSO

J. CH. DUBART

Centre d'Etudes et Recherches des Charbonnages de France
B.P. n° 2
60550 VERNEUIL-EN-HALATTE

Final report number:

Contract number: 199-77 EEF

An experimental study on the combustion of low-calorific-fuels with the aim of exploiting their energy content has been carried out by Cerchar. The ultimate aim of this study is to recover the energy contained in low-grade fuels by pushing back the present techno-economic limits (ash content 15-20%).

The study showed that combustion of bituminous shales from Toarcien layers is not possible in industrial installations without adding normal fuel such as coal or natural gas. Even in the case of indirect combustion (e.g. pyrolysis) the economic prospects are not very good. Bituminous shales with a higher calorific content however may approach economic feasibility.

For coal shales the combustion in pulverized form is perfectly feasible. In an economic evaluation for industrial installations one has to take into account additional costs derived from fuel preparation and environmental abatement. The use of coalshales in mixtures with normal coal is believed to be economically feasible.

The use of low calorific fuels such as bituminous and coal shales is strongly hampered by the fact that they require large industrial installations. These are very costly and the risks involved are difficult to evaluate and worsened by maintenance problems.

SECTOR G

Industrial processes

GENERAL ENERGY ANALYSES

Optimized plant design to ensure energy conservation 7.1

C. RAIMBAULT

A. ROJEY

J. SALVAT

Institut Français du Pétrole
1-4 avenue Bois Préau
F-92506 RUEIL MALMAISON

Final report number: EUR 6322 available in French

Contract number: 124-76-EEF

In order to determine the **possibilities for energy conservation in a variety of industrial plants** a study was made of the different technologies leading to energy savings. A method was developed to select the devices and determine their optimum arrangement. This optimization method is based on linear programming and can be applied to most production systems. It was used for a refinery and predicted a potential for energy savings of 9%.

A computer model for the evaluation of the electric energy consumption in mechanical plants 7.2

G.F. MICHELETTI

Prof. A. DE FILIPPI

Prof. R. IPPOLITO

Istituto di Tecnologia Meccanica, Politecnico di Torino
Corso Duca degli Abruzzi 24
10129 TORINO
Italy

Final report number: EUR 7189 available in English

Contract number: 395-78 EEI

Another computer model was made for the optimization of energy consumption in small to medium mechanical factories using machine tools. With the data obtained from an inquiry amongst 600 factories (90 replies) a stochastic model was made, with which energy consumption and peak power can be predicted with help of a limited number of data. As compared to experimental data the accuracy of the model was 10-15%.

Application of the second law of thermodynamics to basic industrial processes 7.3

J.J. DEROUETTE

Battelle
Centre de recherche de Genève
7 route de Drize
1227 CAROUGE-GENEVE

Final report number: EUR 6752 available in English

Contract number: 261-77 EED

Batelle investigated the specific energy consumption of several selected groups of processes with respect to the fundamental laws of thermodynamics and particularly the second law. The second law allows the identification of process irreversibilities in the various sections of a given process. Therefore, the main incentive for performing this thermodynamic analysis is to define possible process improvements from energy saving points of view. Six important branches of industry have been studied: steel, organic chemistry, chloralkali, paper drying, steam power plants, cement. The recommendations emerging from this study, however, do not add much new information to what already is known.

Development of an economic evaluation method for industrial energy saving projects taking into account non economical effects such as pollution and safety. 7.4

M. CASTAGNE

J. CHEF

J.J. PICARD

Département de Gestion Industrielle de l'Institut National
Polytechnique de Lorraine
1, rue Grandville
F-54042 NANCY

Final report number: EUR 6834 available in French

Contract number: 224-77 EEF

Introduction of energy saving technologies is often only judged in purely financial terms such as payback times. Other factors however do play a very important role (e.g. pollution abatement, safety). The Institut National Polytechnique de Lorraine developed a method where in the Discounted Cash Flow calculation parameters are introduced which take into account these non economical effects. The method has been applied to three practical cases: two refineries and one chemical plant. External factors which have been taken into account in these examples are: pollution abatement, improved working conditions, safety value of sub-products, technical improvement. In these examples pollution abatement was mentioned most often. The weighting of these external factors determines very much the outcome of the economical assessment.

PAPER INDUSTRY

Energy analysis of the paper industry 7.5

N. LADOMATOS

N.J.D. LUCAS

W. MURGATROYD

A. SAVIOLAKIS

Energy Policy Unit
Imperial College
London SW7

Final report number: EUR 7192 available in English

Contract number: 596-78 EEUK

An attempt to make an energy analysis for the paper industry was made by Imperial College. Regression models were developed which gave the dependence of the power and fuel use as a function of the pulp production. The specific analysis of paper factories was hampered by the fact that a survey amongst manufacturers gave very little results. A detailed analysis has been made of five machines. These data however were not sufficient to obtain a good overview of the energy saving potential in the paper industry.

Reduction of power consumption in refining paper stock 7.6

P.G. BURKITT

E.R. GATES

M.W. MOORE

PIRA
Randalls Road
Leatherhead, Surrey KT22 7RU

Final report number: EUR 7128 available in English

Contract number: 263-77 EEUK

In most paper and board factories, refining paper stock is the biggest user of electrical energy. In this process fibres are chopped until they have the required properties. PIRA executed experiments on bleached soft wood and bleached hard wood sulphate pulps and showed that particular paper qualities can be obtained by different combinations of applied power on the refiner and mass flow rate of the pulp. The total specific refining energy used, however, is very dependent on the combination and can differ by more than 30%. In practice, the power and mass flow rate also have to satisfy other requirements, such as the ability of the pulp to receive the power and the time available to process a tonne of pulp. With proper control, refining energy could be saved in many mills and a target of 10% seems to be realistic. The overall saving in the UK paper and board making industry could equal 24 kTOE, financially worth £ 2.4 10^6 (4 Mio ECU per annum) In a fine paper mill making 10,000 tonnes per year, the payback time on the necessary control equipment could be 2-4 lyears. The viability of the investment however would vary from mill-to-mill. It is proposed that the technical and economic assessments should be applied to a wider range of pulps and checked by mill trials.

Energy saving in paper drying 7.7

A. RAMAZ

J.L. VIDEAU

Centre Technique de l'Industrie des Papiers, Cartons et Celluloses
B.P. 7110
38020 Grenoble Cedex

Final report number: EUR 7152 available in French

Contract numbesr: 266-77-7 EEF

Possibilities to save energy in the drying sector of the paper industry have been investigated by CTP. For a multicylinder drying section heated with steam (by far the most often used technology) a computer simulation model has been developed. The static model was applied to industrial installations and the results were compared with experimental data, which demonstrated the possibilities and limits of the model. The model showed that the usual diameter of 1.5 m is not optimal for minimum energy consumption. It did not explain the large influence of the temperature of the web on the heat transfer at the beginning of the drying part. Also dynamic behaviour of the drying process has been simulated. No estimates of possible energy savings have been made.

Energy saving in paper making by increased water remoal by pressing

7.8

H.A. WESTRA

Fibre Research Institute TNO
Schoemakerstraat 97
2628 VK Delft

Final report number: EUR 6679 available in English

Contract number: 262-77 EENL

Means were investigated for the improvement of the pressing process in order to decrease the amount of water that has to be removed by means of evaporation, which requires more energy consuming process. The first phase of the research project describes a theoretical analysis of the processes taking place in a press nip and the development of an experimental technique for the determination of the material properties which exert an influence upon these processes. An experimental technique has been developed which permits a reliable determination of the relationship between the flow resistance, the compressibility and the stresses in fibrous webs. These relationships can be represented by simple mathematical formulae. Introduction of these formulae into the differential equation shows that in general this equation is non linear and has to be solved by numerical methods. No estimates of the energy saving potential have been made in this study, which was of a very fundamental nature.

TEXTILE INDUSTRY

Dying wet fabric without intermediate drying after bleaching 7.9

Ir. R.B.M. HOLWEG

Fibre Research Institute TNO
97 Schoemakerstraat
2628 VK Delft

Final report number: EUR 6889 available in English

Contract number: 392-78 EENL

The possibility for dying wet tissues directly, thus avoiding the energy expensive intermediate drying process normally required after bleaching, was investigated by TNO. Of the different methods, a system where paint was brought on the wet tissue with an engraved roller which in its turn is wetted by a rubber roller which passes through the trough with dye, was found to be satisfactory. From the strongly varying investment and energy savings data, one may deduce a payback time somewhere between 3 and 10 years.

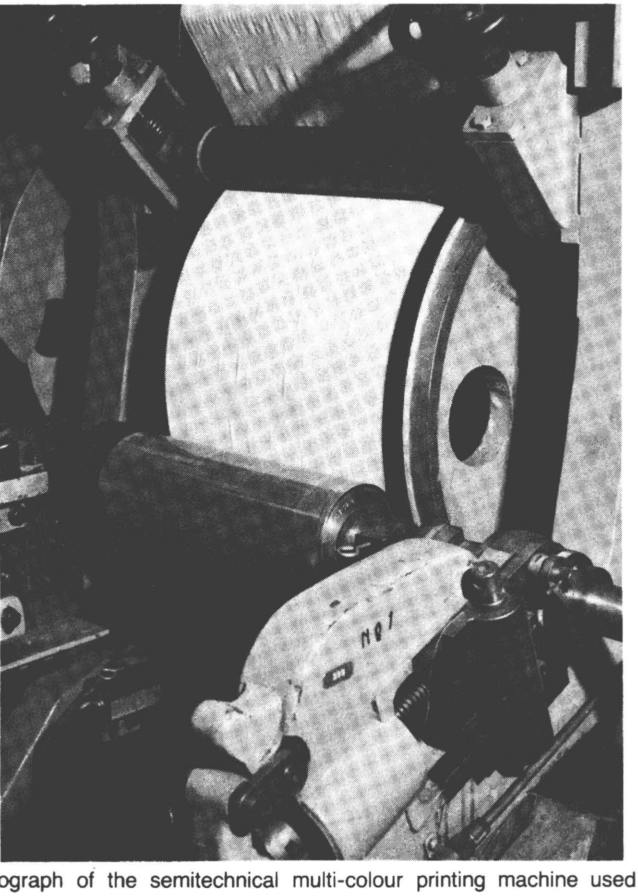


Figure 7.9. Photograph of the semitechnical multi-colour printing machine used in the experiments.

Energy saving in heat setting and dye fixation of plastic fibres

G.J. PARISH

C.M. REED

Shirley Institute
Didsbury, Manchester M20 8RX
U.K.

Final report number: EUR 7362 EN

Contract number: 225-77 EEUK

The heat-setting process is employed to give dimensional stability to fabrics containing thermoplastic fibres (for example, polyester and nylon alone or in blends with other fibres) by taking advantage of the effect of heat on the properties of these fibres. The fixation of dyestuffs on these fibres may also be achieved by theat treatment as it causes the molecules of suitable dyestuffs to diffuse into the fibre. Continuous flow-ovens (stenters) are used for this process, which require temperatures around 200°C. About 80% of the energy is discharged as hot air. This exhaust is required to remove volatile impurities such as spinning oil, dyestuffs from the fabric.

Energy saving can be achieved by reducing the exhaust air flow rate at the expense of a higher concentration of volatile matter. It was found that concentrations up to 1200-1600 mg/m^3 at 200°C did not contaminate the fabric and concentrations up to 1000 mg/m^3 are believed to be completely safe. This will allow the air flows and the energy consumption to be reduced by 30-50% as compared to the normally allowed air flows and volatile matter concentration levels (500-700 mg/m^3). Additional energy savings may be obtained by routing the exhaust air to the burner where the volatile matter may be burned. A total reduction of the energy use from 4 MJ per kg of fabric to 2 MJ is feasible.

The total potential for energy savings in the EC is about 18.000 TOE/per year.

Economy and energy saving in the textile industry

J. LANERES

J. PERRIN

Institut Textile de France-Nord
35 rue des Abondances
F-92100 Boulogne-sur-Seine

Final report number: EUR 7302 FR

Contract number: 248-77 EEF

A survey on the possibilities for energy savings in dying fibres and tissues was made by Institut Textile de France in additon to a systematic search for energy saving opportunities. The survey amongst 159 manufacturers (70% of the French production) gave an averaged heat and electricity use for dying of 14.800 Kcal/kg and 1,09 Kwh/kg respectively. It was also clear from the survey that heating of the building formed a relatively large part (14%) of the total energy consumption. Opportunities for energy saving can be realized in the following ways:

— the recovery of a part of the heat discharged in waste water (27% of the total energy imput). Pay back times of 12 to 35 months are possible. The use of a heat pump, however, would have a pay back time of 48 months

— As compared to classical methods for mechanical water removal from fibre or tissue, more advanced methods remove 30 to 50% more water

— A comparison of different industrial dryers lead to the conclusion that their energy efficiency varies as much as 35%

— Recovery of heat from air released from the dryers has a payback time of three years

— Recovery of heat from exhaust gases.

In total energy savings of 30% to 38% are believed to be possible.

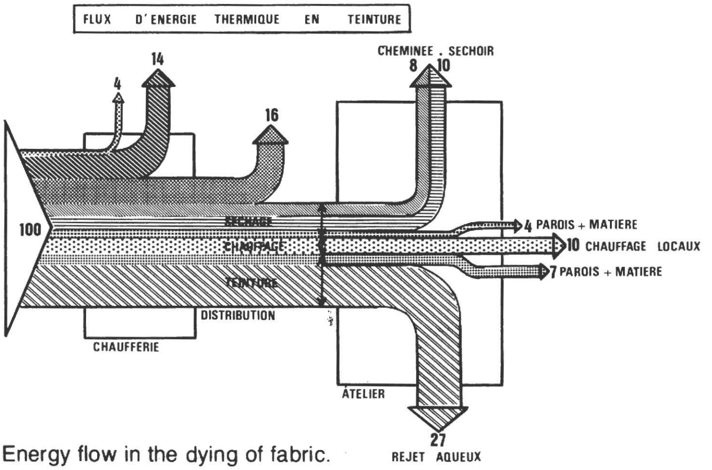


Figure 7.11 Energy flow in the dying of fabric.

FOOD INDUSTRY

Energy saving opportunities in the U.K. food industry

7.12

W.E. WHITMAN

C.R. ELSON

A.G. CRAWFORD

Leatherhead Food Research Association
Randalls Road
Leatherhead
Surrey U.K. KT 22 7RY

Final report number: EUR 7073 available in English

Contract number: 245-77 EEUK

A survey in the UK food industry was made to detect possibilities of energy savings in this manufacturing branch. Of the 400 factories 74 replied. The total energy consumption in this sector in the UK was $1.6.10^6$ TOE of which 32% was spent in milling other than wheat, meat and fish processing, sugar confectionary. A major recommendation resulting from this survey is, that more effort should be devoted to demonstrating to the food industry, the value of carrying out energy audits to identify areas of wasted energy. More demostration projects also need to be set up to prove the economic feasibility of many of the available systems for heat recovery. There is a need to develop a heat pump to use low grade heat to produce hot water at 100°C or low pressure steam. Forms of motive power, other than electrical, should be more seriously considered especially in the case of energy intensive process machinery (e.g. diesel). Separate detailed studies are required of both the energy used to provide refrigeration and the energy used by transport to distribute raw materials and finished goods.

Combined heat power production in a milk powder factory

7.13

L.A. JANSEN

H. PIES

Netherlands Institute for Dairy Research
Ede

Final report number: EUR 7134 available in English

Contract number: 590-78-EEN

The possibilities for combined heat power poduction in the milk powder industry in the Netherlands has been investigated by NIZO. In the dairy industry the heat demand/power demand ratio ranges from 9 to 26, the milk powder industry being in the higher ranks with a value of 22. The temperatures required are of the order of 200°C (when modern evaporators are used). In the study the different available heat power systems were considered (back pressure steam turbine, gas turbine, diesel or gas engine). The diesel or gas engine was found to be most promising for this purpose. However, the heat/power ratio is very small and ranges from 1,3 and 1,8 for a diesel or gas engine respectively, the total energy conversion efficiencies being 82% and 87%. The waste heat from a diesel engine (cooling water 34%, exhaust 17%, oil 4,3%) is used for preheating drying air. Of the two engines, the gas engine is most attractive as the price of gas is 30% lower than the price of diesel oil, also the energy conversion efficiency is somewhat higher. The investment costs are lower for a diesel engine. A gas engine using the power utilities as a back up system, costs less than a second engine as stand by. For the milk powder production including the milk handling (pumping, refrigerating) a 720 KWel gas engine would be required for the Coberco plant in Ede. The payback time of this engine varies between 4-6 years. The total energy saving potential for heat power coupling in the milk powder industry in the Netherlands is 10.000 TOE per year.

Research on energy saving in a brewery 7.14

T.S. KAMPFFMEYER

Forschungsstelle für Energiewirtschaft
Am Blütenanger 71
D-8000 München 50

Final report number:

Contract number: 388-78-7 EED

The energy consumption and possibilities for energy saving in breweries have been investigated by the Forschungsstelle für Energiewirtschaft. A literature study and a detailed investigation of three breweries was carried out. It was found that the energy consumption ranges from 200 to 440 MJ (one liter of petrol is equivalent to 40 MJ) per hl of beer produced. For one of the investigated breweries the energy consumption was 295 MJ heat and 14,5 KWh electricity per hl beer produced. Main energy consumers were malt production (does not always form part of a brewery) 75 MJ/hl and 2,9 KWh/hl, wort production 58 MJ/hl and 0,3 KWh/hl, filling and cleaning of bottles 45 MJ/hl and 1,9 KWh/hl. Most of the heat is required at temperatures below 150°C. Possibilities for energy recovery in the malt and wort production have been identified. It was also suggested to use a high pressure cooking technique for wort production; this would reduce heat cost in this part of the brewery by 25%. An economic evaluation of the energy saving methods was not presented.

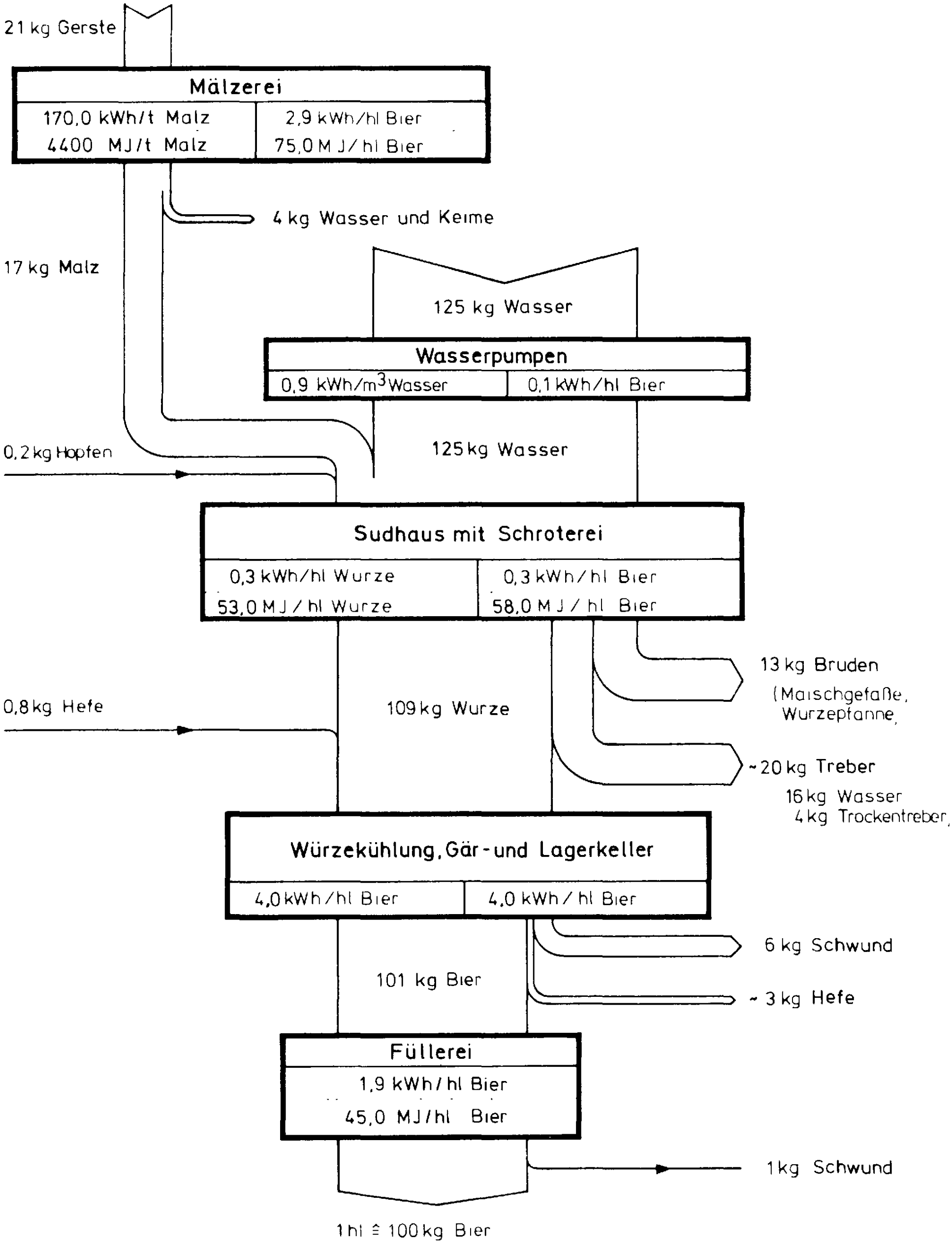


Figure 7.14 Energy use in a brewery.

COMBUSTION CONTROL OF INDUSTRIAL BOILERS

Comparison of four combustion control systems for industrial boilers

7.15

B. FOLEY

IIRS
Institute for Industrial Research and Standards
Ballymum Road
DUBLIN 9
Ireland

Final report number: EUR 7279 EN

Contract number: 588-78-EEEIR

Boilers of 1/2 MW to 10 MW often have a lower efficiency in part load operation. By modifying the conditions e.g. fuel/air ratio, the efficiency may be improved considerably (± 8%). For this purpose a fast and accurate method of measuring the thermal efficiency of a boiler is required. Four measuring techniques have been tested: on direct method (measuring energy input and useful heat output) and three indirect methods deducing the efficiency from the CO_2 content and the temperature in flue gases. It was found that the Fyrite and Dwyver test equipments (both indirect) fulfilled the requirements best.

Combustion control system for industrial package boilers using the flame radiation peak seeking technique 7.16

J.M. HARFOOT

LAND PYROMETERS LTD
Wreakes Lane
Dronfield
Sheffield
England

Final report number: EUR 7191 available in English

Contract number: 654-78-10 EEUK

A method has been developed with which the efficiency of boilers between 1/2 MW and 10 MW in particular in part load operation can be kept at an optimum value. The technique is based on the fact that maximum efficiency is achieved for the air/fuel ratio where the flame gives a maximum radiation emission. The apparatus was designed to keep the flame at this maximum radiation point. In practice the flame peak seeking technique did not work out, due to bad combustion conditions of the boilers used. It is believed that the technique should work under good combustion conditions. No cost estimate has been given for the control system.

Methods of measuring the overall efficiencies of industrial boilers

7.17

PER EENHOLT

Dansk Kedelforening
Gladsaxe Møllevej 15
2860 SØBORG

Final report number:

Contract number: 589-78 EEDK

Optimization of the boiler operation has also been investigated by Dansk Kedelforening. As part of this project, a data collecting system has been developed scanning every two minutes all operation parameters (such as the temperature of flue gas and feed water, sootnumber, steam pressure, etc.). The average boiler efficiency was calculated at intervals of half an hour. The O_2-content in the flue gas is measured by a zirconiumoxide cell with a response time of 3 milliseconds. At the same time the oil burner is adjusted to optimal combustion performance through a newly developed combustion control system, adjusting continuously the combustion to a specific soot number. Another combustion control system has also been tried out. The results obtained from the project observations so far, indicate that use of such combustion control systems is not always recommendable. E.g. when the modulation frequency of a plant is very high, or when the combustion is abnormally poor. The results obtained indicate clearly that a fuel saving in the order of 1% is attainable, even using an oil burner showing a good combustion performance, provided that the adjustment of the combustion control system is based on a thorough determination of carbon concentrations in the flue gas.

POWER PRODUCTION

Recovery of energy from LNG vaporization 7.18

D. WEBER

Gutehoffnungshütte Sterkrade AG
Bahnhofstrasse 66
D - 4200 Oberhausen 11

Final report number:

Contract number: 308-77-EED

The liquifaction of natural gas to LNG at −160°C for transport on boats requires a lot of energy which partly could be recovered when LNG is evaporated again at the terminal. At present not only this energy is not recovered, but additional heat is required for evaporation.

Gutehoffnungshütte Sterkrade proposed to use the waste heat of a closed gasturbine to evaporate LNG and use LNG to lower the low temperature point of a gasturbine cycle from 5°C to −125°C, thus increasing the energy conversion efficiency of the gasturbine from 37% to 52-55%. Their study showed that this concept was technically and economically the most interesting solution. Other possibilities which have been investigated were: direct use of the cold without power production (e.g. use in refrigeration, "coldplex" ethylen and ammonia production) and three other concepts with power production (diesel engine with a closed gasturbine, open gasturbine together with a closed gasturbine, diesel engine with a hydrocarbon turbine). A market study showed that the potential in the world for power production by gasturbines in combination with LNG evaporation amounts to 6000 MWel. About 3000 MWel could be realized by 1990 of which 800 MWel may be located in the European Community. For the EC this would be a yearly energy saving of around 200 000 TOE. The economic feasibility of this project depends very much on the price which the power utilities are prepared to pay for the electricity. In a meeting held in 1979 it was decided to evaluate two other concepts: cold gas turbine (−160°C to + 25°C) and the cold gasturbine in combination with a steam turbine. It was also agreed to make the technical feasibility study for a 100 MW closed gas turbine installation instead of 17 MW, this on request of a potential user.

Steam extraction from turbines for heating purposes 7.19

J.M. SNOECK

P.J. WAUTERS

Catholic University of Louvain
Thermodynamics and Turbomachinery Department
Place du Levant 2
B - 1348 LOUVAIN-LA-NEUVE

Final report number: EUR 6325 available in French

Contract number: 174-76 EEB

The possibility to restart old and adapt running power plants for heat power production was investigated by the Université Catholique de Louvain. In particular the limitations imposed by the turbine have been studied. A high extracted flow may cause critical conditions in the throat of the rotor blading which may result in choking and a limitation of the mass flow. The big enthalphy drop over the last stages prior to the point of heat extraction may cause excessive stresses on the rotor blades. This can be avoided by symmetrical bleedings. It is advised to execute turbine adaptation studies in close collaboration with the manufacturer.

Energy saving in wet and dry cooling tower systems for large power plants 7.20

F.R. GIELEN

CH. HIRSCH

Vrije Universiteit Brussel
Dienst Stromingsmechanica
Pleinlaan 2
1050 Brussel

Final report number:

Contract number: 380-78 EEB

The optimization of cooling towers (wet, dry, hybrid) in relation to energy saving has been studied with help of a computer model by the Vrije Universiteit, Brussels. After a brief introduction the important parameters are described: the cost of non-delivered power and the payback time of investments aiming at energy savings. A computer code has been developed, containing an enlargeable number of subprogrammes for different types of cooling towers, which optimizes the cooling system. At the present time, seven families of cooling systems have been computed. Wet cooling towers were found to have a higher energy saving potential than hybrid towers. A users guide with a description of the computer programmes has been made available.

Study of a lean gas internal combustion engine 7.21

X. LYS

Institut Français du Pétrole
1-4 avenue de Bois Préau
F - 92506 RUEIL MALMAISON

Final report number:

Contract number: 394-78 EEF

For many coal liquifaction and gasification processes, synthetic gas containing H^2 and CO in different percentages, forms an intermediate step. IFP investigated whether this low calorie gas could be used directly in internal combustion engines. This contract covered in particular a study on the self ignition point of lean gases, which depends on the gascomposition, pressure and temperature.

The experimental work was done with a standardized research CRF engine, under the assumption that the Arrhenius model which applies for air/petrol mixtures is also valid for syngas mixtures (H_2, CO_2, N_2).

This assumption was shown not to be valid. During combustion with syngas a slow oxydation took place which does not occur in air/petrol mixtures. The Arrhenius model should be modified for this phenomenon when one wants to use this model for lean gas combustion engines.

Energy saving in waste water treatment plants 7.22

J.G. ANDERSSON

Vandvalitetsinstituttet ATV
11 Agern Allé
DK - 2970 Hørsholm

Final report number: EUR 6680 available in English

Contract number: 314-77 EEDK

In order to estimate the energy consumption of biological waste water treatments plants (activated sludge) and evaluate some possibilities for energy savings, a study has been carried out at eight plants in Denmark, by the Water Quality Institute. At each plant the energy consumption of all major units was measured. The study showed that the aeration was the major energy consuming operation in all plants, using up to 90% of the total energy. It was found that in several plants the energy consumption was higher than it had to be, either because of aerators with a low efficiency or because of too high sludge concentrations in the aeration tanks. Installation of aerators regulated by oxygen control at seven of the eight plants meant savings in the total energy consumption between 2,5% and 60%.

It was possible to obtain aerator efficiencies of 0,5 KWh/kg B0D5 — removed (BOD — Biological Oxyg-Demand). A cost benefit analysis showed that the payback time averaged for the seven plants with oxygen control, was 0,37 years, and the rate of return was 273% year.

PLANTS	ΔI investment EUA	Energy ΔE kwh/year	savings $\Delta E \cdot P_E$ EUA/year	PBP years	ROR %/year
Aså	3546	126000	12500	0.28	350
Bramdrupdam	3546	4380	430	8.2	~ 4
Fakse	3546	340000	34000	0.10	960
Jyllinge	3546	200000	20000	0.18	560
Slagelse	3546	290000	29000	0.12	820
Tårnby	3546	180000	18000	0.20	510
Viborg	3546	450000	45000	0.08	1270
All seven plants	24823	1590000	159000	0.16	640

Figure 7.22 Cost benefit analysis for energy saving investments in water treatment plants

Polarization pyrometry 7.23

K.H. BERRY

National Physical Laboratory
Teddington
Middlesex
UK

Final report number: EUR 7045 available in English

Contract number: 397-78 EEUK

In certain areas of industry satisfactory techniques for measuring or controlling temperatures do not exist. This results in inefficient use of energy. Methods where the temperature of a surface is determined by its radiation may constitute a solution. A draw back of this method however is the fact that the emissivity of the surface has to be known. National Physical Laboratory developed a polarization pyrometer which measures the temperature of the surface by radiation without requiring the knowledge of the emissivity. The temperatures measured with the polarization pyrometer have been compared with values for the temperature obtained with thermocouples. Agreement was good for stainless steel and aluminium. The agreement for copper was less good. The temperature range was 200-500°C. The technique has not yet been completely developed during this contract period and more research is required.

Energy saving in a blast furnace 7.24

R. CAPELANI

IRSID
Station d'Essais
Rue du Président Roosevelt 185
F - Saint-Germain-en Laye 78104

Final report number:

Contract number: 391-78 EEF

The energy consumption in a blast furnace, the thermal losses and the productivity are strongly influenced by the gas and material distribution (e.g. whether and where it is inhomogeneous) and by the shape of the fusion area. In this project a sonde has been developed which can take gas samples, from inside the furnace continuously.

Both the degree of gas oxydation and the speed and temperature of the gas could be measured. The shape of the melting zone has been established by bringing in the furnace capsules containing radioactive gas which melt at the temperature of the melting zone. Their melting is detected when radioactive gas is present in the exhaust gases. It is believed that a better knowledge of the gas distribution in the blast furnace will allow a better regulation of the process. Energy savings are expected of the order of 10-20 kg coke per tonne of melted iron which requires in total 600 kg of coke.

SECTOR H

Energy storage

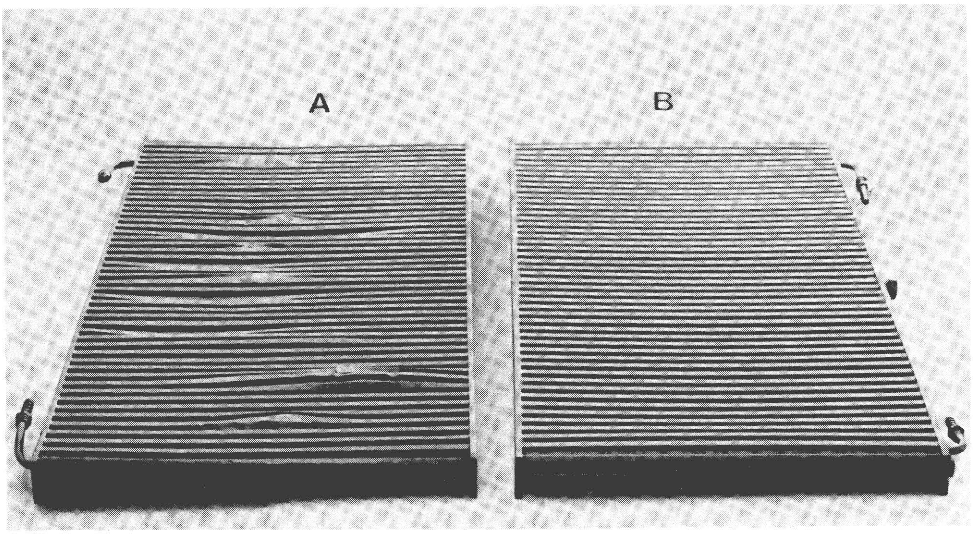


Figure 8.1.1 Flat plate storage vessels with flexible walls of 0.1 mm steel foil; A filled with pure water, showing strong bulging of the walls after only one storage cycle; B filled with water and an addition of 3 Vol% of (H_2O + 19.5 weight% NH_4CL), showing no defects after many hundred storage cycles.

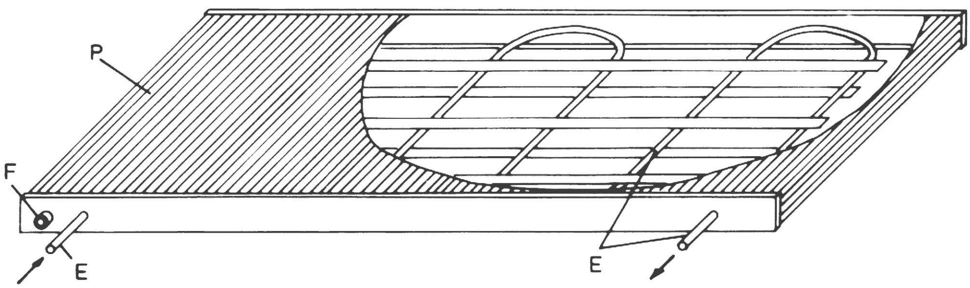


Figure 8.1.2 Flat plate storage vessel; P = profiled, flexible wall, e.g. of 0.1 mm mild steel; E = internal heat exchanger; F = filling tap.

HEAT AND FLYWHEEL STORAGE

Systems for chemical and latent heat storage in a temperature range from − 25°C to + 150°C 8.1

J. SCHRÖDER

Philips GmbH
Forschungslaboratorium
Weisshausstrasse
5100 Aachen

Final report: EUR 6936 available in English

Contract number: 213-77 EED

An exploratory study of the possibilities of storing low grade heat by means of latent heat and reversible chemical reactions has been carried out by Philips-Aachen. On the basis of thermodynamical considerations, criteria are discussed for the selection of suitable reactions. The investigations for latent heat storage have indicated that water, some salt hydrates and eutectic mixtures of water and salt hydrates possess high heats of fusion. Their melting points ranging from about − 50°C to + 130°C fit well for storing low grade heat in residential energy systems. Detailed experimental investigations on a large number of these media show that about 30 of them satisfy the quality requirements for the practical application in storage units. Flexible flat-plate storage containers especially developed for these selected storage media, showed unobjectionable performance over long periods of operation in laboratory storage units. In the field of chemical heat storage more than 30 systems have been investigated. All but one (vic. H_2O liquid/Na_2S) were based on gas/solid and gas/liquid interactions. In addition, chemical heat pump systems, using heat from environmental air or soil, have been included in this study. The highest energy density of a storage unit can be obtained with systems working as chemical heat pump, taking heat from soil. For the storage of 1 MWh energy a volume of 2 m^3 is required for the gas/solid system H_2O/Na_2 S and about 4.5 m^3 for the gas/liquid reaction H_2O/H_2SO_4 aq. Small scale seasonal soil storage was shown to be economically not attractive.

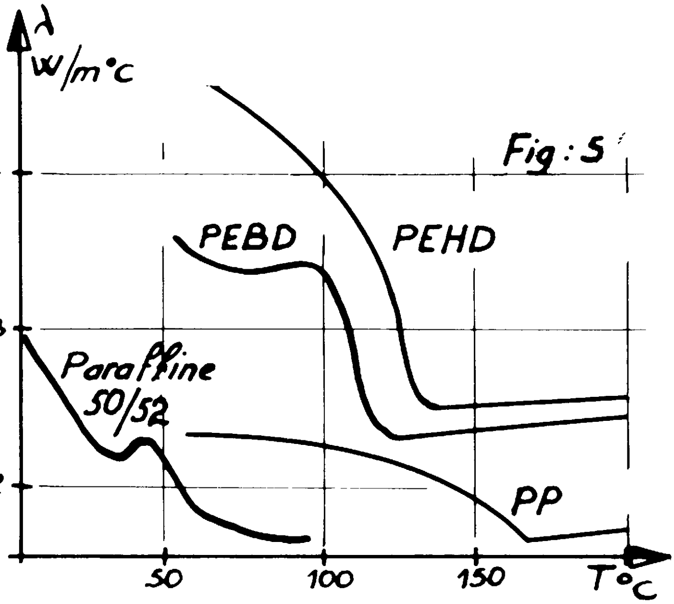


Figure 8.2.1 Thermal conductivity as a function of temperature

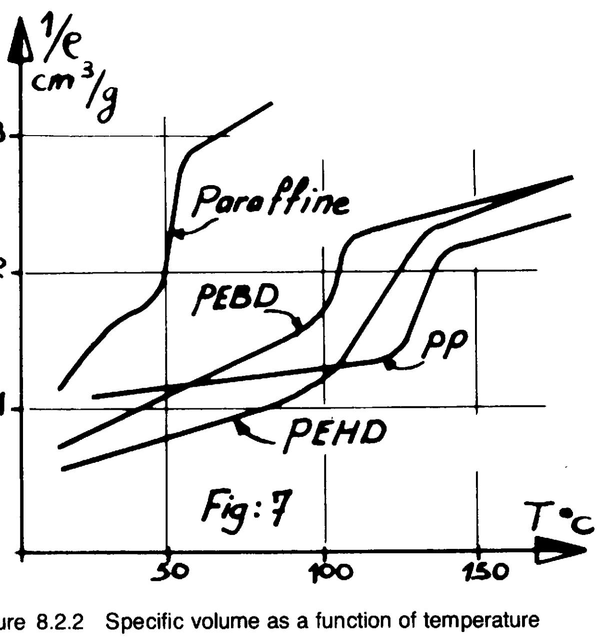


Figure 8.2.2 Specific volume as a function of temperature

Study of organic materials for latent heat storage 8.2

DUBOIS P.

HOCHON B.

Laboratoire de Marcoussis
Centre de Recherches de la Compagnie Générale d'Electricité
Route de Nozay
91460 Marcoussis

Final report number:

Contract number: 399-78-1 EEF

The storage of thermal energy using melting heat of organic materials has been studied by Marcoussis, France. Paraffins for 50-70°C and polyethylenes and polypropylenes for 110-170°C have been investigated on thermal stability, aging properties, crystallization behaviour and thermal conductivity. It was found that the latent heat of polyethylenes and polypropylenes is not very high; this makes them less suitable as storage medium. Latent heat of paraffins was found to be 50 cal/gram. The chemical stability was very good; after 1 400 cycles between the molten and solid phase, paraffin properties had not changed. The thermal conductivity of paraffins was very low (5.10^{-4} cal/s cm°C) but could be strongly improved (a factor three) by adding 30% carbon. (This resulted in a decrease by 20% of the latent heat per unit volume.) For paraffins, two arrangements for heat storage have been studied: one using air and another using water as heat transport medium. Different configurations have been considered such as paraffin filled pipes, deformable paraffin blocks etc. Aluminium and polypropylène turned bout to be good encapsulation materials. A paraffin heat storage system with water as heat transport medium will be constructed.

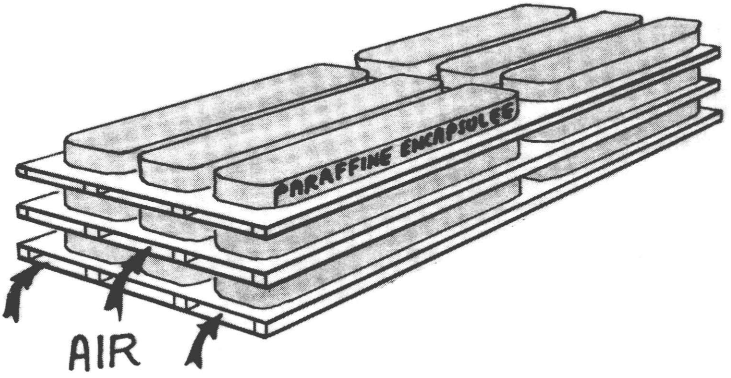


Figure 8.2.3 Storage of paraffine

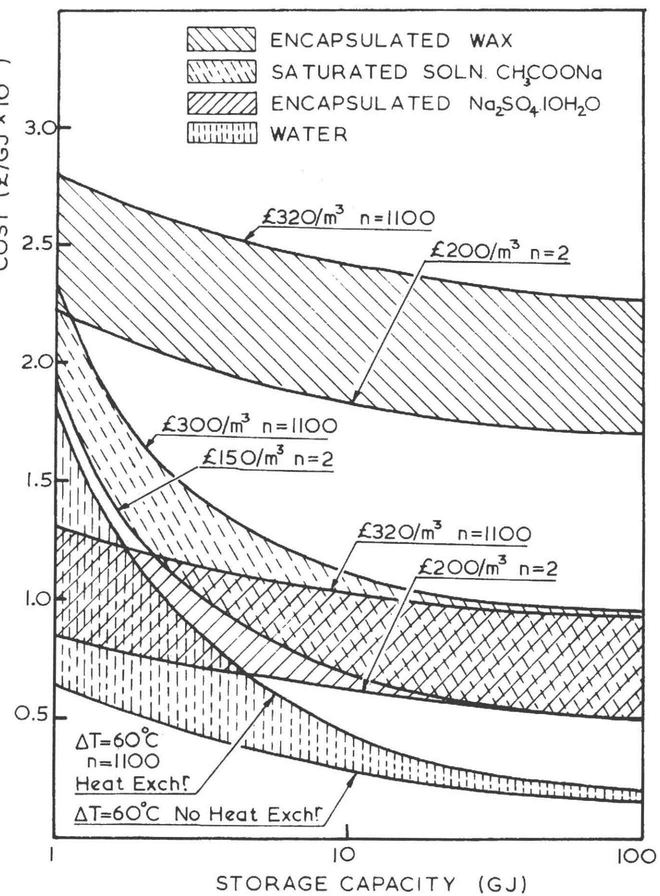


Figure 8.3.2 Comparative capital costs of various storage systems

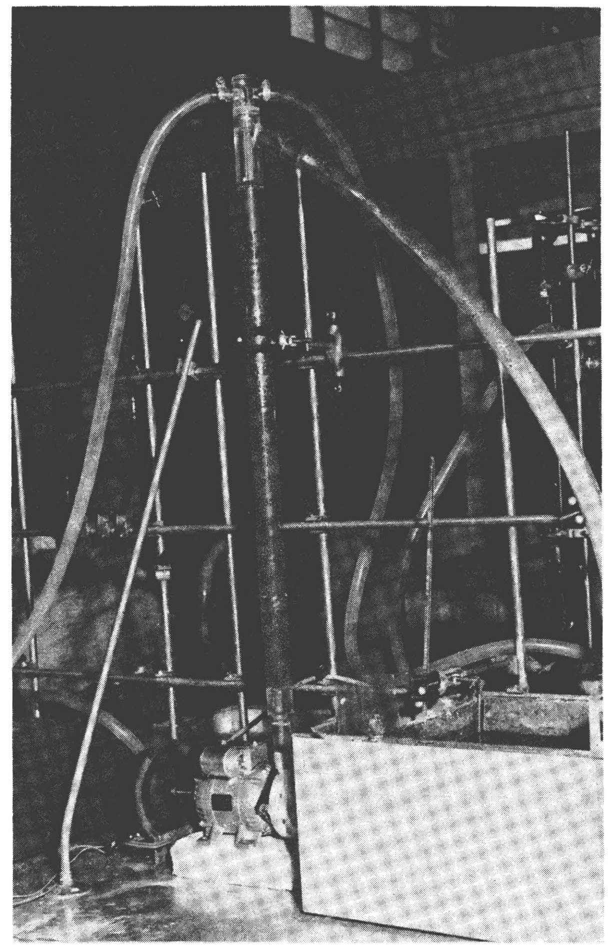


Figure 8.3.1 Heat exchanger with small spheres to avoid crystal deposition

Storage of heat at 40-70° in salt solutions 8.3

M.A. BELL

P.W. O'CALLAGHAN

I.E. SMITH

S.D. PROBERT

Cranfield Institute of Technology
Cranfield, Bedfordshire,
England

Final report number: EUR 7266 EN

Contract number: 398-78-EEUK

Storage of heat at 40-70°C in salt solutions has been studied by Cranfield. The advantages are a higher energy density (up to a factor four higher than water) and an enhanced stratification due to a much stronger density variation of the solution. As at high temperatures more salt is dissolved the layers with the highest density and temperatures will be at the bottom and the cold and less dense layers at the top of the container. Different salts have been investigated on their usefulness for this type of storage and the best candidates were: KNO_3, NH_4NO_3, $Na_3PO_4.12H_2O$, $Na_2S.9H_2O$, $Ca(NO_3)_2.4H_2O$, $CH_3COONa.3H_2O$. The problem of crystal deposition on the heat exchanger surfaces has been overcome in two ways: With a heat exchanger containing small spheres in the salt solution part, which were very effective in cleaning the heat exchanger surfaces. The second sollution was to mechanically remove the crystals with a scraper. The first type needed close control of the solution flow rate and did not operate effectively for a high crystal/solution ratio. For these reasons the mechanically cleaned heat exchanger was preferred. A 46 liter thermal store was constructed and tested. It showed a high degree of stratification.

	$KCl - ZnCl_2$		$NaNO_3$		$MgCl_2 - NaCl$	
	w $mm\ a^{-1}$	corrosion type	w $mm\ a^{-1}$	corrosion type	w $mm\ a^{-1}$	corrosion type
St 37	0.08	intergranular corrosion	0.009	uniform corrosion	-	-
13 Cr Mo 44	0.15	uniform corrosion	0.005	uniform corrosion	0.01	uniform corrosion
Cu Ni 10 Fe	-	-	0.009	intergranular corrosion	-	transgranular corrosion
Ni Cu 30 Fe	0.05	uniform corrosion	-	-		diffusion

Figure 8.4.1 Corrosion behavior; temperature range 200-450°C
w = corrosion rate

	$MgCl_2$		$NaCl$		KF	
	w $mm\ a^{-1}$	corrosion type	w $mm\ a^{-1}$	corrosion type	w $mm\ a^{-1}$	corrosion type
X 10 Cr Ni Al Ti 3220	0.03	diffusion	-	diffusion through the wall	-	diffusion through the welding zone
NiCr 20 Ti	0.04	diffusion	-	diffusion through the wall	0.03	diffusion
NiCr 15 Fe	0.06	diffusion	0.01	diffusion	0.01	diffusion

Figure 8.4.2 Corrosion behavior; temperature range 700-900°C
w = corrosion rate

Physical and chemical properties of latent heat storage materials in the temperature ranges 200-450 °C and 700-900 °C

8.4

D. HELNE

F. HEESS

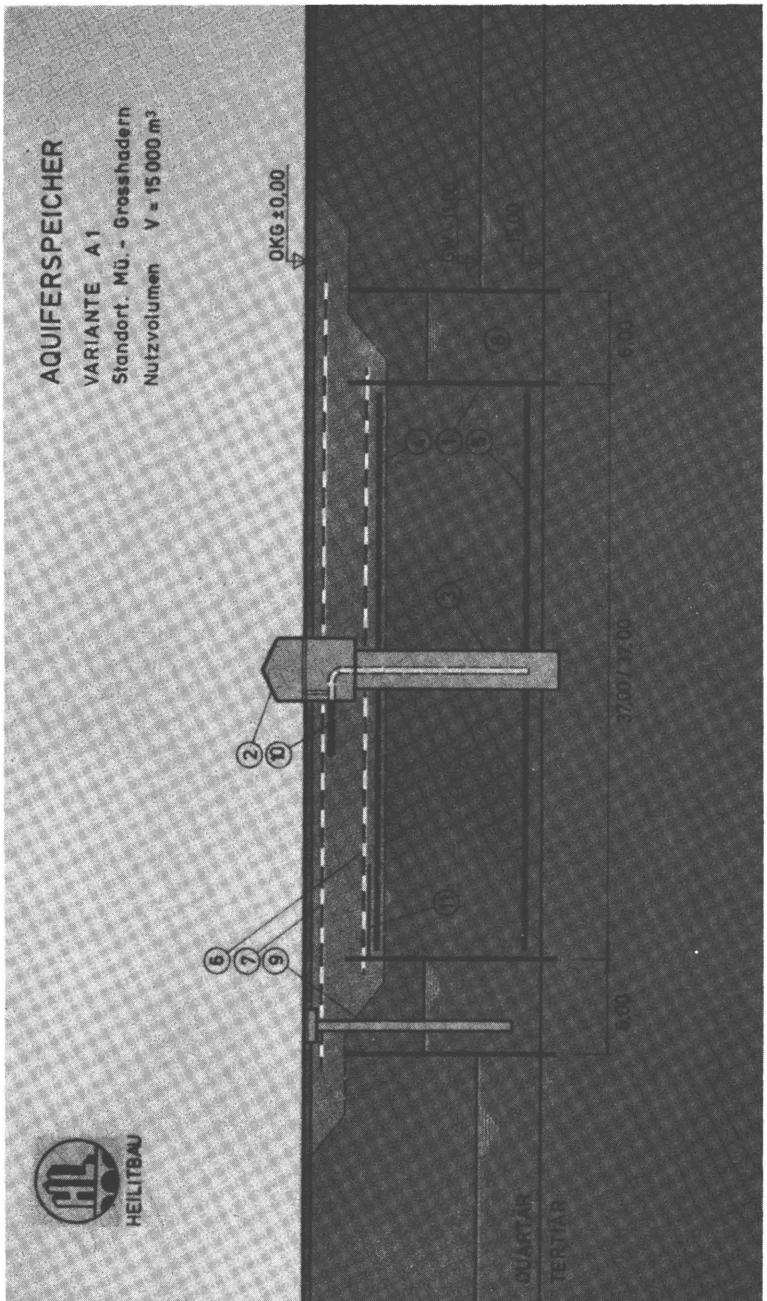
M. GROLL

Institut für Kerntechnik und Energiewandlung e.V. IKE
Holderbuschweg 52
7000 STUTTGART

Final report number: EUR 7065 available in German

Contract number: 401-78-EED

The long term behaviour of salts to be used as latent heat storage material in the temperature ranges 200-450°C and 700-900°C has been investigated by IKE. Thermal stability, aging, and melting/freezing behaviour of the salts and their compatibility with several container materials has been studied. From corrosion tests, the mass losses of sheet metal samples have been measured and the corrosion rate calculated. Furthermore, the type of corrosion was determined with an electro-microscope. During cyclic tests the melting and freezing curves have been measured. The combinations mild steel with $NaNO_3$, boiler steel with KCl-$ZnCl_2$; $NaNo_3$ and $MgCl_2$-NaCl and NiCu30Fe with KCl-$ZnCl_2$ are compatible (temperature range 200 to 450°C). Within the temperature range 700 to 900°C the structure materials were all badly corroded.



(1) Schmalwand d 10 cm
(2) Meß- u. Regelhaus
(3) Vertikalschacht ∅ 250 cm
(4) oberes Entnahmesystem
(5) unteres Entnahmesystem
(6) Dampfsperre
(7) Oberflächenwassersperre
(8) Sicherheitsraum
(9) Sicherheitsbrunnen
(10) Fernleitungsanschluß
(11) max. Speicherfüllstand

Figure 8.5 Natural shallow aquifer

A feasibility study of heat storage in shallow aquifers

8.5

Dr. B. WEISSENBACH

Messerschmitt-Bölkow-Blohm GmbH
Postfach 80/1169
8000 München 80

Final report number:

Contract number: 587-78-EED

The availability of cheap, long term (possibly seasonal) heat storage could bring about large energy savings (e.g. storage of waste heat from industry and power plants for use in the winter). MBB investigated technical and economical feasibility of a large variety of shallow aquifers with the following characteristics: shallow aquifer confined at the bottom by a clay layer at a depth of about 15 m, artificial thermal insulation at the top, sideways confined by a double wall of betonite by which the system is hydraulically insulated from water currents in the aquifer. Different types of storage aquifer systems have been investigated, varying the following parameters: size ranging from 5 000 m^3 to 175.000 m^3), soil preparation (natural aquifer, removal of soil and replacement by material with the right properties e.g. permeability); different types of walls. The price estimate for the aquifers varied between 30 and 160 ECU/m^3 water equivalent. (Water storage by heat insulated steel containers, costs 60 ECU/m^3 water equivalent.) None of these systems therefore achieved the economic feasibility of seasonal heat storage, which is around 14-20 EUA/m^3 water equivalent. MBB proposed to build a 15.000 m^3 artificial heat storage aquifer for a hospital. By storing heat produced with electrical heat pumps during the night and using it during the day when electricity is more expensive, considerable financial savings can be achieved. The economical feasibility however depends completely on a price reglementation which might change. The cost of the proposed aquifer is 150 ECU/m^3 water equivalent.

Stationnary flywheel storage

A. GILHAUS

E. HAU

Maschinenfabrik Augsburg-Nürnberg
Ludwigsfelder Strasse 238
8000 München 50

Final report number: EUR 7088 available in German

Contract number: 318-78-EED

Applications for stationnary fly wheel storage in industrial processes have been explored by MAN. The study showed that the possibilities for flywheel storage are very limited. The use of flywheels for electricity load levelling and the recovery of waste energy such as brake energy from trams and trains is economically not feasible. More advanced flywheels which operate in vacuum may find applications in stand by for power supplies. Wind energy has been identified as one of the few promising areas.

ELECTRICITY STORAGE

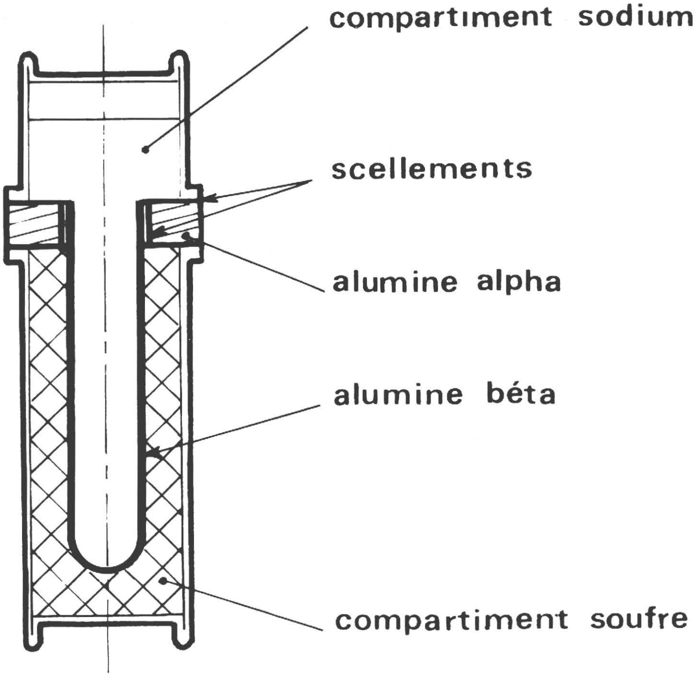


Figure 8.7.1 Na/S cell

Figure 8.7.2 Alumina electrolyte tubes

Development and industrial production of beta-alumina electrolyte tubes by electrophoresis for a NA/S battery

8.7

G. DESPLANCHES

A. WICKER

J.P. DUMAS

Laboratoires de Marcoussis
Centre de Recherches de la Compagnie Générale d'Electricité
Route de Nozay
F - 91460 MARCOUSSIS

Final report number: EUR 6345 and EUR 6719 both available in French

Contract number: 179-77 EEF and 322-78 EEF

The aim of the project carried out by Marcoussis was to study and to solve the technical and economical problems in the development and industrial production of beta-alumina electrolyte tubes for a Na/S battery of 242 Ah.

A technico-economical evaluation of the production and a simulation programme of the functioning lead to the choice of a tubular form with a length of 435 mm, a diameter of 29 mm and a wall thickness of 1.5 mm.

The electrolyte should be impermeable and the tube should have a uniform texture, a density over 95% of the theoretical figure and a very uniform thickness over the aera to prevent non-uniform current distribution leading to hot spots and subsequent cracking. A large number of methods was investigated to find the most satisfactory starting material. A mixture of beta-alumina obtained by fusion and by solid state reaction was found to be best. The green tube electrophoretic deposition of the powder was adopted, as it was found to lead to a very uniform tube.

The next stage after drying is the isostatic compression of the green tube followed by sintering at 1650°C in a special gas-fired furnace with a lining of beta-alumina. Research was centered around the last two process steps to find the optimal conditions which lead to straight, uniform, closely circular tubes of good mechanical and electrical resistance. The many problems encountered have been satisfactorally solved and patents have been obtained. A good number of tubes have been produced, meeting narrow specifications. Performance tests of the tubes in sodium-sulfur cells gave very satisfactory results: a constant capacity of 80% of theoretical capacity after up to 660 charge-discharge cycles at current densities of 72 mA/cm^2 and a low failure rate. Much higher rates of charge up to 182 mA/cm^2 (charge times from 8h50 to 3h20) were possible with only a very small loss of capacity. The electric cycling is coupled every 3-4 cycles with a thermal cycle down to ambient temperature and up again to the operating temperatures of 330-340°C.

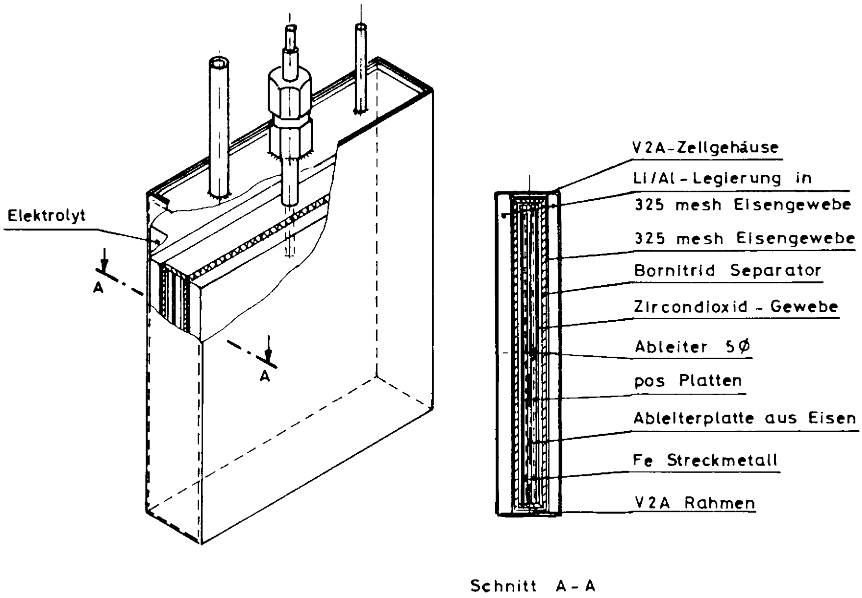


Figure 8.8.1 Lay-out of a 100 Ah LiAl/FeS-cell with fused LiCl.KCl salts as electrolyte

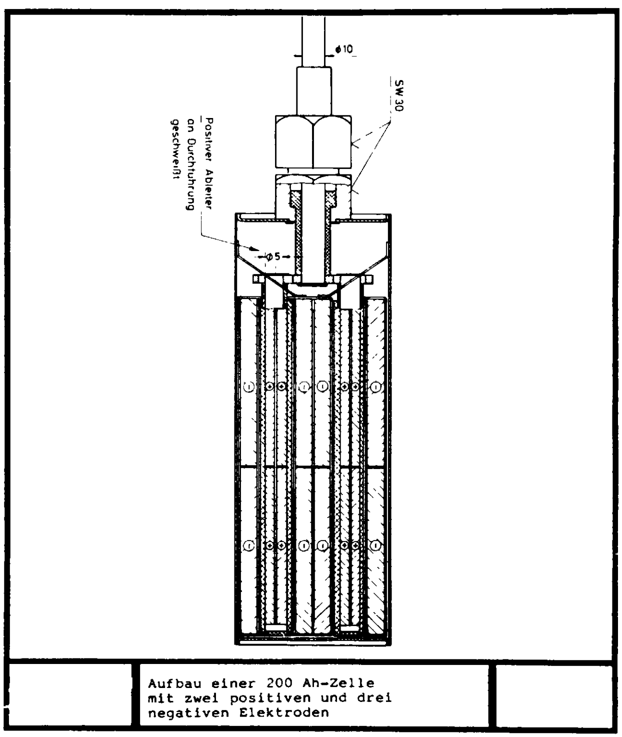


Figure 8.8.2 Lay-out of a 200 Ah -cell with two positive and three negative electrodes

Development of high energy density Li/S cells with fused salts as electrolyte

8.8

W. BORGER

D. KUNZE

H.S. PANESAR

VARTA Batterie AG
Gundelhardstrasse 72
6233 Kelkheim/Taunus

Final report number: EUR 7072 available in German

Contract number: 244-77 EED

The development of high energy density Li/S cells with fused salts as electrolytes by Varta encompassed three sub-projects:

— System analysis and choice of a promising cell system. Extensive calculations were made on 28 combinations from 143 possible combinations of electrode materials. A careful evaluation based on 12 criteria resulted in the choice with highest marks of the combination of LiAl alloy as negative electrode with FeS, as positive electrode and molten LiCl.KCl eutectic as electrolyte.

— Production of 10 prototype cells for 100 Ah and to find and apply suitable production methods

— Extensive testing of the cells under variable conditions in order to evaluate the cells for application in traction and for load leveling.

In the course of time, production methods were developed for the positive (FeS) electrode material and for the handling of the hygroscopic lithium containing components of cells. Assembling was done in dry-boxes. Corrosion problems of electrode leads were overcome. For these purposes small 10 Ah cells were built. A first series of 100 Ah cells was then built and tested and a second series of 150 Ah cells were fabricated and tested. The capacity was found to be 80% of the theoretical figure at 10 A charge and discharge current. The energy density reached was 70 Wh/kg and a cycle life was found to be exceeding 400 cycles. By decreasing the weight of inactive cell components, e.g. the amount of electrolyte, the energy density could be increased to 80 Wh/kg on a 5h discharge.

Also cells were built with two negative and one positive and with three and two electrodes respectively with a capacity of 200 Ah (20 A discharge) and with an energy density of up to 108 Wh/kg.

It was also found that the costly boron nitride fabric used as separator around the positive electrode could well be substituted by very much cheaper aluminium nitride powder. Higher operation temperatures of 470°C instead of 450°C resulted in an appreciable increase of energy and power densities with current densities of 100-200 mA/cm^2.

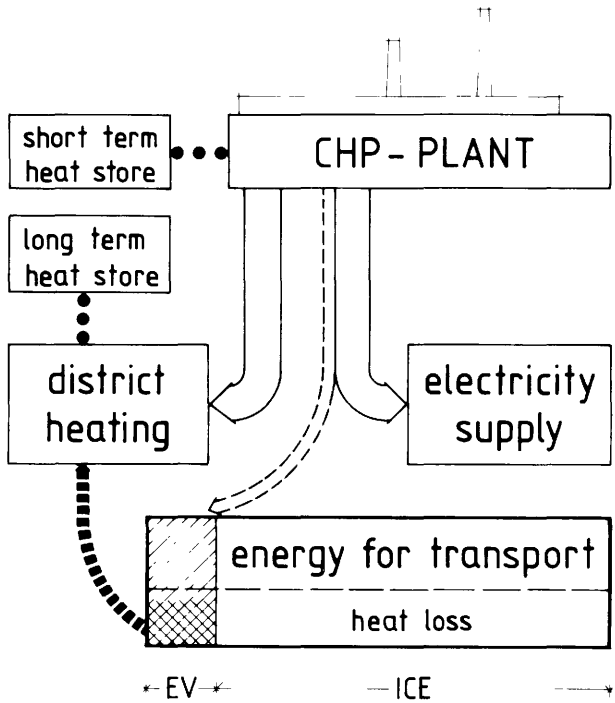


Figure 8.10.1 Electrical vehicles as part of the total transport sector. Electricity supplied from a CHP plant

Efficiency	Petrol	Diesel	Battery x)	Fuel Cell	B+Fc
η_{tot} % based on oil	10 - 15	20 -25	10 -15	20 -25	>25
$\eta_{tot.}$ % based on coal	5 - 10	5-10	10-15	20 -25	>25

Figure 8.10.2 Comparison of total efficiencies for Internal, Combustion Engines and electrical vehicles with energy supply based on crude oil and coal respectively
x): without braking energy recuperation

Materials R and D on new electrodes and electrolytes for advanced batteries (Anglo Danish battery project)

Project Leader: Dr. R.M. DELL

Harwell Laboratory Materials Development Division AERE, Harwell, Oxfordshire	Dr. B.C. TOFIELD
Inorganic Chemistry Laboratory University of Oxford	Prof. J.B. GOODENOUGH
Department of Ceramics University of Leeds	Prof. R.J. BROOK
Department of Metallurgy and Materials Science, Imperial College London	Dr. B.C.M. STEELE
Department of Chemistry Odense University	Dr. Johs JENSEN
Department of Metallurgy Risø National Laboratory	Dr. SÖRENSEN
Fysics Laboratory III Danish Technical University	Dr. NIELSEN

Final report number: EUR 6372 on subproject 4 and EUR 7595 both available in English

Contract number: 315-78 EEDK and 316-78 EEUK

Materials research and development on new electrodes and electrolytes for advanced batteries has been carried out in the framework of the Anglo-Danish project which involved a succesful multinational, interdisciplinary and multi-laboratory collaboration of four British and three Danish laboratories. The aim of this research was a systematic search for new electrodes and electrolytes which might enable the development of a high energy density battery operating at lower, possibly room temperatures. The project was divided into four subprojects.

Subproject 1

Fabrication and properties of solid electrolytes:

The aim was to develop procedures for the selection and fabrication of solid electrolytes for advanced batteries. Investigated were composite electrolytes such as the best known lithium conductor mixtures of lithium iodide, etc. with aluminium oxide. Though high values of the conductivity reported in the litterature could be reproduced, it was conclusively shown that the cause of the high conductivity at room temperature is high conductivity of the interface, which in turn contains some water, present either as a liquid salt solution phase or as a solid hydrate $LiI.H_2O$, even without deliberate addition of water. Thus the high conductivity is difficult to reproduce and it is not stable in time. High temperature oxygen conductors of the type CeO_2 doped with R.E. oxides and R.E. aluminates doped with CaO were developed to obtain more insight in the conduction mechanism and on the influence of ion size on conductivity.

Subproject 2

New fast ion conductors:

Work was concentrated on three different aspects of materials design:

— Preparation and characterization of some known materials in order to investigate the feasibility of an all solid battery. The solid electrolyte lithium nitride (Li_3N) was explored, mainly as single crystal. At ambient temperatures a very high conductivity of 3×10^{-3} $Ohm^{-1}cm^{-1}$ was observed perpendicular to the c-axis. Doping, with Mg^{2+}, Cu^{2+} and Al^{3+} did not improve the conductivity but contamination with 1-2% hydrogen (H^+) lead to a significant improvement up to double the value. All solid cells consisting of LiN_3 between metallic Li and TiS_2 as electrodes showed open circuit voltages of 2.3 V. However, poor diffusion of lithium into the latter electrode limited the current density to 1 mA/cm^2.

— Both static and dynamic computer simulation techniques were applied to the conduction mechanism of Li_3N after being tested on beta alumina. A satisfactory description was obtained for the pathways of conduction in stoechiometric Li_3N.

— The work on new materials demonstrated for the first time that ion exchange provides an unexplored preparative route to compositions which cannot be prepared directly. In a study of the mixed $LiMO_2$ (M = V, Cr, Mn, Fe, Co, Ni) very interesting results were obtained for $LiNiO_2$ obtained by ion exchange from the layer like structure of $NaCrO_2$ and for the analogous $LiCrO_2$. Through room temperature electrochemical extraction lithium deficiency and thus enhanced valency of the Ni and Co ions can be induced. With these compounds as intercalation electrodes high open circuit voltages against lithium were observed but slow lithium diffusion restricted the current densities obtainable.

Subproject 3

Characterization and performance of solid-solution electrodes:

The aim was to investigate insertion (intercalation or solid-solution) electrodes with material parameters necessary for incorporation into high energy secundary batteries. This includes the study of homogeneity ranges, thermodynamic properties, electron and mass transport as a function of composition. Also the interfacial electrolyte/electrode kinetics under cycling are to be considered.

In these investigations a good lithium solid conductor would have to be used. Lisicon, $Li^{14}ZnGe0_{16}$ was found to have a too low conductivity, contrary to the initial data reported in the literature. Solid solutions of Li_3PO_4 and Li_4SiO_4 were prepared by vacuum pressing to nearby theoretical density, with good conductivities.

Lithium trifluoromethane sulfonate complexes with polyethylene and polypropylene polymers gave acceptable conductances, when used in the form of thin casted films (10-50 m). These thin films follow the irregularities of solid electrodes assuring very good contacts: a unique asset.

As a lithium insertion electrode to be investigated, $Li_xMo_6S_{8-y}$ was prepared from non-stoechiometric Mo_6S_8, but the lithium conductivity of 3.4×10^{-3} Ohm at 415°C proved to be low compared to that of the already known Cu^+ analogue. Thus there remained the use of the well tried Li_xTiS_2 material.

In the temperature range 60-110°C very reproductible EMF-values were obtained for Li_xTiS_2 (x = 0.3 - 0.6) in combination with the organic polymer electrolyte. These values remained constant for a period of 6-8 weeks.

Other candidate electrode materials e.g. Li_xFe_5O VSe_2, FeOCL, $NiPS_3$ have been prepared and characterized, but these materials offered no advantages over TiS_2, especially not with respect to the volume changes on the incorporation of lithium. A three dimensional framework insertion electrode eg. V_6O_{13} was prepared and investigated.

Attention was also given to the negative electrode. At high temperatures alloys such as LiAl have been used, but the solid solution range is rather small at lower temperatures. Though $FeSi_2$ was the best material tested with a D (Li) value around 10^{-11} cm^2 sec^{-1}, plating out of lithium or other surface phases could not be circumvented at lower temperatures.

A theoretical analysis of the dynamical aspects of insertion electrodes for electrochemical power sources was made, resulting in concentration profiles for electrolyte and electrode, leading to the formulation of limiting factors for the performance of such batteries.

Subproject 4

Battery application and assessment studies:

A thorough study was made to gauge the extent of battery use for electricity storage in the areas: electric traction, utility distribution networks, renewable energy sources. It was concluded that electric vehicles provide the largest potential new market for storage batteries during this century and that advanced secondary batteries will have a significant role to play in Europe in the 21st century.

Vehicle specifications, battery performances of conventional and advanced batteries have been extensively listed. Lead-acid and nickel-cadmium batteries are the only present options, with the nickel-zinc battery as a medium term possibility. It was concluded that a high energy density, all-solid-state, maintenance free, low-cost battery is needed. Comparison of the energy efficiency for internal combustion and electrical vehicles lead to equal values of 10-15% for both types based on oil as primary energy. However, based on coal these values are 5-10% for ICE (on synthetic liquid fuels) and the same 10-15% for EV vehicles. This would lead to a very considerable conservation of energy, especially if electricity is produced from combined heat and power stations.

In conclusion this extensive materials research and development has lead to a very significant increase in our knowledge and insight. Many new materials have been prepared and investigated. Several had to be rejected but this happened also to some known materials on which too optimistic reports had been published earlier. Based on the results of this project, research in a follow-up programme is now focussing on cells with LiAl and TiS_2 electrodes and $LiAl_2O_3$ or polymers as electrolytes, which are expected to operate at temperatures considerably lower than those of the Li/S or Na/S cells. The projects' interdisciplinary and multilaboratory approach was very successful and will be continued in the R & D to be carried out.

Synthesis and characterization of new intercalated lithium cathodes

8.10

J. ROUXEL

R. BREC

Laboratoire de chimie minérale A
UER de Chimie
Université de Nantes
2 rue de la Houssinière
44072 NANTES CEDEX

Final report number: EUR 7069 available in French

Contract number: 622-78-EEF

Intercalated lithium electrodes which could provide important component materials for advanced batteries have been investigated by the University of Nantes.

A large number of compounds with the formula MSP_3 with M = Mn, Fe, Ni, Zn or Cd have been synthesized and extensively studied with regard to crystal and magnetic structure and especially with respect to electronic conductivity and intercalation capacity. $NiPS_3$ and to a lesser degree $FePS_3$, are promising materials for intercalation of lithium. Li_xPS_3 shows three regions with $x = 0\text{-}0.5$, $0.5 - 1.5$ and $1.5 - 3.0$ respectively, with high reversible electric potentials (against lithiummetal) or about 2.2 V.A., high (theoretical) energy density of 288 Wh/kg decreasing to 115 Wh/kg after 100 cycles. However, both the electronic conductivity and the diffusion rate of lithium are probably still too low to expect useful current densities in cells with these electrode materials.

Synthesis and characterization of new glassy lithium electrolytes

8.11

P. HAGENMULLER

A. LEVASSEUR

J.C. BRETHOUS

J.M. REAU

Laboratoire de Chimie du Solide du C.N.R.S.
351 cours de la Libération
F - 33405 TALENCE CEDEX

Final report number: EUR 7070 available in French

Contract number: 621-78-7 EEF

Further materials R and D has been done on new glassy lithium electrolytes in the system B_2O_3 - Li_2O - $Li_x(MO_4)$ (M = S, Mo, W, P, Si).

They could be expected to provide suitable electrolytes for batteries if a sufficiently high ionic lithium conduction would be found. Glassy electrolytes can be formed into very thin films, adhering well to solid electrodes, contrary to cristalline valid electrolytes.

A very large number of different compositions was prepared and investigated. Good conductors were found e.g. B_20_3 - 0.7 Li_20-1.1 $LiSO_4$ also with 0.7 LiCl instead of the sulphate, showing conductivities of 2×10^{-3} Ohm^{-1} at 300°C. These new materials are among the very best solid lithium electrolytes known.

Contribution to the study of a fluorine-metal battery

8.12

J. LUCAS

University of Rennes
Campus de Beaulieu
Laboratoire de Chimie Minérale D
Avenue du Général Leclerc
F - 35042 RENNES

Final report number: EUR 7071 available in French

Contract number: 623-78 EEF

The possibility of solid batteries with fluorine ions has been investigated by the University of Rennes. The aim was the discovery of new solid and glassy electrolytes with a high fluorine-electric mobility which might be used in high energy density all-solid-batteries.

A large quantity of high quality research has lead to materials such as PbF_2 + SnF_{2-1} solid solutions which have indeed high conductivities of 10^{-2} Ohm^{-1} cm^{-1} at 150°C. However, these materials are of little practical value in batteries as the range of electrochemical stability is small. Non-stoechiometric fluorides MF_{3+x} with e.g. M = Yb and Zr have been shown to have too low conductivities to be useful as electrolytes. This is also the case for a large range of glassy fluorides composed of ZrF_4 and ThF_4 with BaF_2 and LaF_3 and also with alkali fluorides as components.

SECOND ENERGY CONSERVATION R & D SUBPROGRAMME

1979-1983

CONTENTS

OVERVIEW OF WORK IN PROGRESS IN THE SECOND ENERGY CONSERVATION R AND D PROGRAMME

INTRODUCTION

The second programme is subdivided in the following sectors:

A. Domestic Sector
B. Transport
C. Industry
D. Energy transport and transformation
E. Storage of secondary energy

The major part of the 145 contracts selected for further negociations have now been signed. Contractors working in the same field have been brought together in contractor groups. These groups correspond approximately to the subtitles of the list of contracts given below. About 28 contractor groups have been formed. The aim of these groups is to exchange information, discuss ongoing work, establish future lines of R and D etc.

An overview is given of the work carried out in the second Energy Conservation R and D programme, followed by a complete list of contracts with the title, contract number, address of the contractor and the name of the projectleader.

Sector A — Domestic sector

In the domestic sector, the ongoing work on energy saving techniques such as window coating, heating systems, insulation and heat pumps is being continued. However, in the first R & D Programme several important subjects were not covered or only superficially dealt with. (e.g. shutters, air infiltration, conventional heating systems). These activities have been considerably expanded in the Second Programme.

Work in infrared reflective coating on glass and plastic sheets is being continued. Research is now focussed on the improvement of visible transmittance from 60% to 80% and on durability tests for coated plastic sheets and on a reduction of the cost for coated glass. In order to complete the range of window insulation techniques, work has been initiated on the mobile window insulation such as blinds, shutters and curtains. New insulation materials for walls and roofs are being developed both for new houses and retrofitting.

Conventional heating and ventilation systems and their control, which were hardly studied in the first programme, are now extensively covered. Topics are the performance of several heating systems, air distribution, development of a low temperature radiator, heat meter automation. Also several studies on computer control of heating systems are carried out.

When energy consumption in houses is reduced by better insulation and more efficient heating systems, the heat losses by natural ventilation are becoming relatively more important. In order to cope with this type of losses, natural ventilation is studied for different types of buildings.

Extensive R and D is carried out on new heating concepts and in particular on heat pumps. A major part of the work is focussed on absorbtion heatpumps as they have the promise of being cheap very efficient and reliable. Research is done on the development of a cheap and reliable solution pump and new working fluids. Work to improve the efficiency of compressor heat pumps is basically a continuation of the first programme with research on variable speed compressors, micro-processor regulated expansion valves, fluid mixtures and soil as a heat source for heat pumps. The study of the effect of compressor oil dissolved in refrigerants on the heat pump performance, has been added.

Internal combustion engine driven heat pumps have not yet achieved the maturity to be applied in single houses as they are complicated, have a limited lifetime and require careful maintenance. Further research is being carried out at present in order to improve this situation.

Sector B — Industry

In the industrial sector more than two thirds of the energy used is required in the form of process heat and large quantities of waste heat are dissipated. The development of heat recovery techniques is therefore very important. This is reflected in the extensive R and D work which is being executed on heat exchangers, heat pumps and ORC engines.

The development of heat exchangers is strongly emphasized. The amount of waste heat discharge in industry as a function of temperature has two peaks: one between 100 and 400°C and another around 1 000-1 200°C. For the low temperature range, heat pipe heat exchangers are being developed. This work includes studies on working fluids for use in such heat exchangers operating up to 600°C. Heat exchangers operating at high temperatures (above 800°C) hardly exist due to material problems. To fill this gap, work is carried out on the development of a ceramic heat exchanger for use at 1 200°C and of fluid bed heat exchangers operating between 700 and 1 000°C. Further on work on compact and plastic heat exchangers is going on. Closely linked with work on heat exchangers are several heat recovery projects in the coal, steel and aluminium industry.

In the low temperature range of 50-400°C, heat recovery with heat pumps is an interesting option. At present only the lower end of this range is covered with work on large internal combustion engine driven heat pumps which reach 110°C, using 70°C waste heat as a heat source. A more advanced Brayton cycle heat pump is expected to reach 165°C with waste heat of 90°C. Also the application in industry of absorption heat pumps and heat transformers is being investigated and research on the identification of working fluid pairs which operate up to 400°C is in progress.

If recovered waste heat can not be used in the factory it may be transformed into electricity. In the temperature range of 100°C-400°C this is most efficiently done with Organic Rankine Cycle engines. For this purpose extensive investigations are being carried out. Thermal stability and physico-chemical characteristics of working fluids and structural material are being studied in order to develop technical and economical feasible solutions for ORC engines of 100Kw working in the temperature range up to 300-400°C.

The control of combustion is another way of reducing energy use. In the aluminium industry a better control of melting and holding furnaces led to average savings of 30%. Further on a system with microprocessor control is being developed for the adaption of steam supply to steam demand in view of a lower energy use.

The possibilities for energy saving in heating or drying with microwave radiation are now investigated for cement, wood, PVC and paper manufacturing.

In three important sectors of the food industry the energy flow of the whole manufacturing process is analysed with a view of recommanding more efficient energy utilization (baking, soyabean extraction and edible oil processing).

In the textile industry an overall study is executed by several laboratories on low energy processes such as: use of catalysts to accelerate bleaching reactions, presteaming to improve wettability and dying of wet fabric without intermediate drying.

In the cement industry research is concentrated on feed regulation of cement kilns and the improvement of the cyclone heat exchanger. Under certain conditions also steelmaking slag may be used in the cement industry.

R and D in the metallurgy sector is mainly concerned with finished or semi-finished products. Improved stripped casting processes are being developed in order to avoid reheating of castings. Also the application of new alloys is being studied in order to reduce the number of annealing processes.

Finally research for energy saving in chemical industry is carried out on energy saving in a cracking furnace, H_2S removal from a gas mix and biological removal of sulphur in coal.

Sector C — Transport

The improvement of internal combustion engines is a continuation of work carried out in the first programme. Research on different new fuels such as alcohol, water-gasoline mixtures, and lean gases was added in this programme. Also recovery of waste heat and its use (e.g. bottoming cycle) are now being studied. Of the new concepts; the rectilinear engine and the Stirling engine with electro-magnetic coupling are studied. Finally an international cooperation was set up in the field of composite/metal jointing for vehicle weight reduction. Sixteen laboratories in six countries, mainly from the car and chemical industry, are participating in this project. Electric vehicle traction systems are being developed in order in the long term to increase the flexibility and diversification of fuel use and to reduce the environmental problems in urban transport. The lack of economically viable advanced batteries is the bottleneck for large scale commercialization of electrical vehicles. Research is therefore done to develop advanced batteries with a high power (150 W/kg) and energy density (150 Wh/kg). This work will be described in the secyor E on Energy Storage. In addition a control system is developed which incorporates a high frequency power supply for battery charing and motor field control for electrical vehicles.

Sector D — Energy transformation and energy transport

In view of the fact that the world coal resources are an order of magnitude larger than oil and gas resources, technologies promoting the use of coal and low grade fuel are being developed. Fluidized bed combustors (FBC) offer a number of advantages as compared to classical boilers in particular: high heat transfer, low SO_2 levels in fumes when limestone is added, reduced fouling and less corrosion of heat exchangers. Although FBC is not expected to decrease the overall energy consumption, it provides for a better diversification of fuels and it contributes to comply with environmental constraints.

In a number of well coordinated contracts different parameters of circulation fluidized bed combustors are studied such as: the combustion behaviour of different types of coal (composition and grain size of the fuel, SO_2, ash content, calorific value etc.), optimal operation condition, heat exchange, erosion, operation temperature, ratio of fly ash recycling, additives etc...)

In industry great quantities of lean gases are wasted. Their utilization or disposal by means of a specific recuperative burner are studied.

The overall efficiency of electric power plants may be increased by means of a topping cycle, which is situated above a water Rankine cycle. If sulphur is used as working fluid (750°C), efficiencies around 60%, involving fuel savings of 30%, are expected. However, a number of problems still have to be examined, the thermodynamic characteristics of sulphur and its molecular species, the corrosion behaviour of structure materials and the operation behaviour of sulphur in a loop experiment.

Sector E — Energy storage

Of the three areas covered in this sector heat storage has been considerably reduced as compared to the first programme. Latent heat storage was found to be very expensive (400 ECU for a storage capacity equivalent to one liter oil LOE) and the energy density was only a factor two higher than for hot water storage which costs only 20 ECU per liter oil equivalent. Considerable higher energy densities may be obtained with chemical heat storage and work in this field is therefore pursued. Also storage of heat in water conducting layers in the subsoil (aquifers) is studied. These systems are expected to be very cheap and may become economically viable for seasonal heat storage.

In the field of advanced battery storage a close collaboration was established between 12 laboratories. This collaboration will be continued. The aim of this R and D is to develop batteries with a high power (150 W/Kg) and energy density (150 Wh/kg). Focal points are:

— Development of β''-alumina electrolytes for Na/S batteries and an increase of energy and power density
— Development of molten salt Li/S batteries, in particular increase of energy and power density and reduction of cost
— Development of an "all solid battery" with LiAl and TiS_2 electrodes and $LiIAl_2O_3$ or polymers as electrolytes.
— Development of a battery with glass electrodes and electrolytes.

Work on fuel cells started during the second programme. They will be designed for car traction. One study is concerned with a hydrogen/air fuel cell where released hydrogen is stored in a rare earth electrode. In another project methods are being developed to immobilize the liquid alkaline electrolyte.

Applications for flywheel storage in trains and cranes are being studied.

List of Projects

DOMESTIC SECTOR

Heating systems

• Development of a system which controls the efficiency and energy consumption heating systems with fluids using a newly developed heat meter (EEA1-11-D)	Batelle Institute e.v., Mr. E. Brockmann Am Römerhof 35 D-6000 FRANKFURT-AM-MAIN
• Heat meter with a microprocessor (EEA1-12-I)	Ottica Meccanica Italiana Spa, Mr. R. Leopardo Via della Vasca Navale 81 I-00146 ROMA
• Development of a computer model for the selection of boiler plants with the aim to achieve 1% energy conservation (EEA1-1-N)	TNO, Heat & Refrigeration Mr. M. Kiel — Postbus 342 NL — APELDOORN
• The effect of upgraded insulation on heating systems and control (EEA1-2-UK)	BRE, Mr. S.J. Leach GB — Garston, Watford Herts. WD2 7JR
• Air distribution methods for low temperature domestic air heating systems (EEA1-10-GB)	BSRIA, Mr. Jackman Old Bracknell Lane GB — Bracknell, Berkshire RG12 4AH
• Plastic water/air radiator for domestic heating operation at 50°C (EEA1-3-F)	Laboratoire de Marcoussis, Mr. P. Dubois Route de Nozay F-91460 MARCOUSSIS

Control of heating systems

• Transmission of signals for heating control using existing electrical wiring (EEA1-4-D)	Periphere Computer Systems, Mr. H. Radde Pfälzer-Waldstrasse 36 D-8000 MÜNCHEN 90
• Electronic control of combustion and of the total heating system (EEA1-5-I)	Adriatica Componenti Elettronici Spa, Mr. Fonzi Viale della Repubblica I-67039 SULMONA
• The application of micro-processors in climatic and lighting control in office buildings (EEA1-6-N)	Technisch Physische Dienst TNO-TH, Mr. Euser P.O. Box 155 NL-2600 AD DELFT

• An investigation of the performance of various heating systems in a matched pair of house (EEA1-7-IR)	National Institute for Physical and Construction Research LTD, Mr. P.T. Pigott IR-764211 DUBLIN
• Distribution control network for thermal energy saving in residential and social buildings by means of a precise flexible control of consumption and an optimized control of the centralized thermal resources (EEA1-9-I)	CSEA, Mr. G. Papa Via Ventimiglia 201 I-10127 TORINO

Wall insulation

• The use of bituminous materials to make insulating materials in granules and fibres waterproof (EEA2-17-I)	Industria Italiana Petroli Spa, Mr. L. Boechi Piazza della Vittoria 1 I-16121 GENOVA
• Insulation materials meeting the fire safety requirements for buildings using a phenolic resin of the type NOVOLAQUE in the form of reinforced foam (EEA2-13-F)	Laboratoire de Marcoussis, Mr. J.S. Bobo Route de Nozay F-91460 MARCOUSSIS
• Testing and in particular life time testing of low cost multi layer walls with a high thermal insulation (EEA2-14-I)	Istituto Sperimentale per l'Edilizia Istedil Spa, Mr. Paribeni P.O. Box 7237 I — ROMA NOMENTANO
• Research on buildings' general quality of insulation, especially with respect to developing and improving methods of post-insulation (EEA2-23-DK) (*)	Technological Institute, Mr. P.F. Collet Gregesensvej DK-2630 TAASTRUP
• Improvement of the functional thermal resistance of rigid polyurethane foams (PUR) (EEA2-15-F)	CSTB, Mr. G. Roux Rue Joseph Fournier 24 F-38400 ST-MARTIN-D'HERES
• Study of bricks which act as a heat accumulator (EEA2-16-I)	Impresa Luigi Rossi Srl, Dr. A.M.Tonelli Viale Romana 14 I-20133 MILANO

Shutters

• Mobile insulation of windows (EEA2-18-DK)	Technical University of Denmark, Mr. Korsgaart Building 118 DK-2800 LYNGBY
• Energy saving by using rolling shutters in houses (EEA2-19-N)	TNO, Mr. M. Dubbeld P.O. Box 214 NL-2600 AE DELFT

(*) Contract which is still being negociated.

- Fabrication, laboratory testing and field-evaluation of thermally insulating blinds, for both retrofit and newly built houses (EEA2-10-GB)(*) — Polytechnic of Central London, Dr. G.F. Littler, 35 Marylebone Road, GB — London NW1 5LS

Window coating

- Deposition of infrared reflective films by the pyrosol process. Technical and economic development (EEA2-22-F) — CEA/CENG, 85X, Mr. Blandenet, F-38041 GRENOBLE CEDEX
- The production of selective optical coatings on plastic sheets (EEA2-21-GB) — Loughborough University of Technology, Mr. R.P. Howson, Ashby Road, GB — LEICESTERSHIRE LE11 3TU

Air infiltration

- Natural ventilation in buildings (EEA5-50-GB)(*) — BRE, Mr. R. Rayment, UK — GARSTON WATFORD HERTS WD2 7JR
- The measurement of air infiltration rates in large enclosures and buildings (EEA5-51-GB) — BSRIA, Mr. Bakes, Old Bracknell Lane, GB — BRACKNELL, BERKSHIRE RG12 4AH
- Fresh air change rate and ventilation; optimization of mechanical and/or natural ventilation (EEA5-52-DK) — Technological Institute, Mr. J. Nørgard, Gregersensvej, DK-2630 TARSTRUP
- Analysis of the factors influencing pressure differences on houses in relation to natural ventilation and energy consumption in low cost houses (EEA5-63-N) — TNO, Mr. W.F. de Gids, P.O. Box 214, NL-2600 AE DELFT
- Ventilation control of buildings based on CO_2 content in extracted air (EEA5-53-F) — Société Bertin & Cie, Div. Energétique, Mr. F. Thellier, B.P. 3, F-78370 PLAISIR

Management of buildings

- Planning, design, experimental realization and environmental control of a residiential prototype unit (sample of a multistored building especially planned with energy saving criteria) (EEA5-58-I) — INSO Spa, Mr. P. Cannavo, Via F. Matteucci 2, I-50127 FIRENZE

(*) Contract which is still being negociated.

Energy saving design

• Energy saving on exposed domestic sites (EEA5-54-IR) (*)	An Foras Taluntais, Mr. F.O'Farell DUBLIN, IRELAND
• Integration of different energy saving measures in houses (EEA5-56-B)	CSTC, Mr. J. Uyttenbroeck Avenue Pierre Holoffe B-1342 LIMELETTE
• Energy saving in low cost houses making optimum use of gratuitious energy (EEA5-57-B)	CSTC, Mr. J. Uyttenbroeck Avenue Pierre Holoffe B-1342 LIMELETTE
• Building characteristics of low cost houses in view of energy saving for heating (EEA5-60-B)	Université de Liège Lab. de Physique du Bâtiment Mr. A. Dupagne Av. des Tilleuls 15 — Bât. D1 B-4000 LIEGE
• Extension of the ESP energy simulation model for buildings (EEA5-59-GB)	University Strathclyde BACUS Dept. of Architecture Dr. J.A. Clarke 131 Rottenrow UK — GLASGOW G4 ONG

Appliances

• Low temperature washing machines equipped with means for electrolyses of the washing fluid by which oxygen is formed (EEA3-24-I)	Riber Spa, Mr. Morello Via Manzoni I — BEINASCO
• Development of energy efficient electrical household appliances (EEA3-25-DK)	Technical University of Denmark Mr. D.J. Nørgard Phys. Lab. Building 309 DK — 2800 LYNGBY
• Energy saving in the commercial catering market (EEA3-26-GB)	British Gas Corporation R & D Division, Mr. N.E. Ross Watson House Petersborough Road GB — LONDON SW6 3AN

(*) Contract which is still being negociated.

HEAT PUMPS FOR DOMESTIC AND INDUSTRIAL APPLICATIONS

Absorption and other advanced heat pumps for buildings and industry

• Development and construction of a cheap and efficiently adjustable solvent pump for absorption heat pumps (EEA4-30-D)	Stiebel Eltron GmbH & C° Abt. TG, Mr. H.J. KOHNKE D-3450 HOLZMINDEN
• Development of single and multiple-stage absorption heat pumps operating with new working fluids (EEA4-31-D)	Universität Essen, Prof. Steimle Institut für Klimatechnik Universitätsstrasse 15 D-4300 ESSEN
• An absorption-resorption heat pump for space heating. Investigation of solute-pairs (EEA4-42-F)	Institut Français du Pétrole Mr. Cohen 14 avenue de Bois-Préau B.P. 131 F-92506 MALMAISON CEDEX
• Design and development of absorption heat pumps capable of producing hot water compatible with current wet heating systems and collecting heat from air (EEA4-39-GB)	Cranfield Institute of Technology Mr. Smith GB — BEDFORDSHIRE MK43 OAL
• Periodically operating absorbtion heat pump (EEA4-645-F)	RWTH, Prof. Knoche Schinkelstraße 8 D-5100 AACHEN
• A theoretical and experimental investigation into the performance of absorption cycle heat pumps applied to industrial processes (EEB1-146-GB)	IRD, Mr. V.A. Eustace Fossway GB — NEWCASTLE UPON TYNE NE6 2YD
• Development and construction of a counterflow absorption system capable of raising industrial waste heat to a desired temperature level (EEB1-134-D)	MAN Advanced Technology, Mr. K. Mötz Dachauerstrasse 667 D-8 MÜNCHEN 50
• Development of an absorption heat pump for industrial applications (EEB1-136-B)	KUL — Dep. Werktuigbouwkunde Prof. J. Berghmans Celestynenlaan 300A B-3030 HEVERLEE
• 10 KW fossil-fuel fired ORC engine driven heat pump for use in a domestic environment (EEA4-43-GB)	Glynwed Group Services Ltd Central Resources Unit Mr. D.J. Strong 15 a Cranmore drive, Shirley GB-Solihull West Midlands B90 4PG

• Study and realization of an industrial Brayton cycle heat pump for high temperatures (150-300°C) (EEB1-119-F)	CEM CERCEM, Mr. Magdalenat 49 rue commandant Rolland F-93350 LE BOURGET
• Development of heat pumps operating with fluid mixtures for space heating (EEA4-45-F)	IFP, Mr. Durandet 1-4 av. de Bois Préau B.P. 311 F-92506 RUEIL MAL-MAISON
• Thermo electric heat pump for heat transfer from waste to water for domestic heating (EEA4-44-F)	Laboratoires de Marcoussis Mr. P. Dubois Division Energie Route de Nozay F-91460 MARCOUSSIS

Other Industrial Applications

• The application of an internal combustion engine driven heat pump for grain drying combined with refrigerated storage (EEB1-125-IR)	An Foras Taluntais, Mr. M.B. Cunney Oak Park Research Centre IRL — CARLOW
• Industrial application of high temperature gas engine driven heat pumps (EEB1-147-GB)	IRD Dept. of Mechanical Engineering, Mr. V. A. Eustace Fossway GB — NEWCASTLE UPON TYNE NE6 2YD

Heat sources

• Experimental investigations on the possibilities to use the earth as a heat source for heat pumps and as a storage medium (EEA4-32-DK)	EHC, Mr. M. Fordsmand Skovshovedvej 38 DK-2929 CHARLOTTEN-LUND
• Use of the soil as a heat source and heat storage medium for heat pumps: experimental investigation of a complete heat pump system in a one family dwelling (EEA4-33-N)	TNO Afd. WKT, Mr. P.A. Oostendorp Postbus 342 NL-7300 AH APELDOORN
• Room heating with a combined soil and energy roof heat pump (EEA4-37-B)	Laborelec, Mr. B. Geeraert B.P. 11 B-1640 RHODE SAINT GENESE

Components of compressor heat pumps and their control

• Optimal operation of a frosting evaporator of a monovalent heat pump by fluctuating the airflow and using an expansion valve regulated by a micro-processor (EEA4-49-D)	Institut für Umweltschutz Un. Fortmund, Mr. R. PLeininger Postfach 500500 D-4600 DORTMUND 50

- Optimization of engine driven heat pumps (gas/oil) for power ranges up to 20 kW for domestic heating with different environmental heat sources (EEA4-38-D) — Fichtel & Sachs AG, Hauptabt. Entwicklung und Energietechnik, Mr. K. Hierl, D-8720 SCHWEINFURT 2
- Installation and operation of heat pumps in an existing apartment building where the existing radiators will have to be used (EEA4-46-D) — VEW, Mr. P. Müller, Postfach 941, Rheinland Damm 24, D-4600 DORTMUND
- Study of a single screw, high performance 30 kW heat pump with a single screw compressor (EEA4-29-F) — Omphale, Mr. E. Kallmann, 33 rue Godefroy, F-92800 PUTEAUX
- Testing of a variable speed heat pump for application to space heating, after designing and optimizing its components (EEA4-48-F) — Société Bertin & Cie, Div. Energy, Mr. Patureau, Dép. Transferts de chaleur, B.P. 3, F-78370 PLAISIR
- Study of capacity control and the influence of lubricating oil on system and evaporator design, in heat pumps with rotary sliding vane compressors (EEA4-28-GB) — The New University of Ulster, Energy Studygroup Coleraine, Mr. MacMullan, Northern Ireland, GB — BT52 1SA
- Overall control system for heat pumps driven by internal combustion engines (EEA4-62-F) — Renault Techniques Nouvelles, Mr. Legre, 67 rue des Bons Raisins, F-92508 RUEIL MALMAISON

INDUSTRIAL PROCESSES

Energy Management

- Economic study of the energy exchange between factories in an industrial site (EEB3-171-B) — SCK, Mr. G. Spaepen, Toegepaste wiskunde, Boeretang 200, 2400 MOL
- Energy savings in an electromechanical industry (EEB3-170-B) — ACEC — PLG, B.P. 4, B-6000 CHARLEROI

Food industry

- Energy saving in edible oil processing (EED1-303-N) — TNO — CIVO, Mr. Ong, Utrechtseweg 48, P.O. Box 360, NL-3700 AJ ZEIST

• Energy saving in the soybean extraction industry by reducing the steam consumption for desolventizing toasting and drying extracted beans (EEB1-138-N)	TNO CIVO Technology, Mr. Ong Utrechtseweg 48 P.O. Box 360 NL-3700 AJ ZEIST
• Energy saving in the bakery by improvement of energy efficiency and recovery of waste heat (EEB1-148-N)	TNO Instituut voor Graan, Meel en Brood, Mr. L.W.B.M. de VRIES Postbus 15 NL-6700 AA WAGENINGEN

Metallurgy

• Saving of energy by immediate use of the stripped casting, thus avoiding reheating of castings from room temperature to 1 000°C (EEB1-120-F)	Centre de Recherche de Pont-à-Mousson Mr. R. Bellocci P.B. 28 F-54700 PONT-A-MOUSSON
• Finding energy savings in making forged parts (EEB1-115-F)	Régie Nationale des Usines Renault Dir. Lab. Automobiles, Mr. El Haik Avenue Emile Zola 8 F-92109 BOULOGNE BILLANCOURT
• Lubrification of the continuous casting of steels (EEB1-117-F)	Armines, Mr. E. Felder 60 Boulevard St-Michel F-75272 PARIS
• Development of bainitic nodular iron for the construction of gears for the car industry (EEB1-149-I)	Fiat Auto Spa Direzione Ingegneria di Prodotto Mr. I. Montanaro Corso G. Agnelli 200 I — TORINO
• Reduction of the energy requirement in converting liquid aluminium to semi-fabricated rolled products (EEB1-102-GB)	The British Aluminium Cy Ltd Mr. T.J. Dennis Chalfont Park — Gerrards Cross GB — BUCKINGHAMSHIRE SL90QB

Textile

• Continuous wet-on-wet treatment of fabric webs: impregnation of fully wet fabrics directed towards practical applications (EEB1-139-N)	TNO Vezelinstituut, Ing. R.M. Holweg Postbus 110 NL-2600 AC DELFT

- Low energy processes in the wet processing of textiles (EEB1-140-GB) — Shirley Institute, Mr. J.G. Roberts, Didsbury, GB — MANCHESTER M20 8RX

Cement industry

- Use of tracers to investigate the transfer parameters in the system regulating the chemical composition of the feed of cement kilns in order to optimize their output (EEB1-141-F) — CEA CENG, Lab. des Traceurs 85 X, Mr. Guizerix, F-38041 GRENOBLE CEDEX
- Ceramic materials from molten blast-furnace slags by directly controlled cooling (EEB4-184-GB) — Imperial College, Royal School of Mines, Mr. V.A. Eustace, Department of Metallurgy, Prince Consort Road, GB — LONDON SW7 2BP
- Cyclone heat exchanger for the cement industry (EEB1-106-F) — Lafarge, Mr. Ch. Douvre, B.P. 8, F-07220 VIVIERS-SUR-RHONE
- Study of the treatment of oxygen steelmaking slag for utilization in cement industry (EEB4-183-F) — IRSID — Station d'Essais, Mr. R. Pazdej, F-57210 MAIZIERES-LES-METZ

Chemical

- Modification of cracking furnaces at existing plants to increase yields of valuable products and to reduce fuel consumption (EEB1-109-I) — MONTEDISON Spa, Div. Basic Petrochemicals R and D, Ing. V. Zaccone, Large Donegani 1/2, I-20121 MILANO
- Selective removal of H_2S from gaseous mixtures containing CO_2 (EEB1-130-I) — SNAM Progetti Spa, Servizio PRC/GAS, Dr. L. Gazzi, Assoreni — Via Fabiana 1, S. DONATO MILANESE, I-310246 MILANO
- Energy conservation in the chlor-alkali industry (EEB1-111-GB) — The City University, Dept. of chemistry, Dr. Tseung, Northampton square, GB — LONDON EC1 OHB
- Critical evaluation of anaerobic fermentation of waste products (EEB4-180-GB) — IRD, Biotechnology Dept., Mr. D. Gibbs, GB — NEWCASTLE UPON TYNE NE6 2YD

- Desulphurization of sub-bituminous coal by means of biological leaching (EED2-324-I)

  SAMIN Spa, Prof. F. Rinaldi
  Via Po 19
  I-00198 ROMA

- Recovery treatment and utilization of solids bearing effluents produced at coke ovens (EEB4-181-GB)

  British Carbonization Res. Ass
  Mr. V.J. Pater
  Wingerworth Chesterfield
  GB — DERBYSHIRE S42 6JS

- Scrap tyres processing (EEB4-182-F)

  IFP, Mr. Audibert
  B.P. 3
  F-69390 Vernaison

- Composite metal jointing for vehicles (internationally coordinated project with 16 participating laboratories mainly from the car and chemical industry) (EEC4-261-GB)

  AERE Harwell,
  Mr. D.H. Bowen
  Building 47
  GB — DIDCOT, OXON OX11 ORA

Microwave heating

- Building of prototype oven using a combination of hot air and microwaves for the thermal continuous treatment of plastics, especially plasticized PVC (EEB1-112-L)

  EUROFLOOR S.A.
  Labo R & D, Mr. Roussel
  1 rue Neuve B.P. 10
  L — WILTZ

- Application of microwave heating in the production of building materials (EEB1-135-B)

  Rijksuniversiteit Gent
  Lab. voor Electromagnetisme,
  Prof. J. van BLADEL
  St. Pietersnieuwstraat
  B-9000 GENT

- Development of microwave applicators to dry thin structures (EEB1-137-B)

  KUL, Prof. LUYPAERT
  Dep. Elektrotechniek MIL
  Kardinaal Mercierlaan 94
  B-3030 HEVERLEE

Heat exchangers

- Heat recovery units employing reflux heat pipes as components (EEB1-133-D)

  IKE, Mr. Spendel
  Abt. Energiewandlung
  Holderbuschweg 52
  D-7000 STUTTGART 80

- The development of a high temperature heat pipe heat exchanger for the recovery of residual heat (EEB1-104-GB)

  UKAEA — Harwell
  AERE — Engineering Sciences Division
  Mr. Ralph
  GB — OXFORDSHIRE OX11 ORA

- Improved heat exchanger (fins) in a circulating fluid heat exchanger (EEB1-113-F) and
- Self maintained circulation in view to improve heat transfer between fluid bed and tubes (EEB1-114-F)

  CREUSOT-LOIRE
  Dept. Produits Nouveaux,
  Mr. Chrysostome
  Div. Energie B.P. 31
  F-71208 LE CREUSOT

- Development of a high temperature gas/air circulating fluidized bed heat exchanger (EEB1-142-GB) — Stone Platt Fluidfire Ltd, Mr. Virr, 56 Second Avenue, Brierley Hill, GB — WEST MIDLANDS DY6 7PP

- Fluidized bed heat exchanger/filter for recovery of waste heat from dirty and corrosive exhaust gases (EEB1-110-I) — Centro Ricerche Fiat, Unita di Ricerca Sistemi Meccanici, Mr. D. Petrucioli, Strada Torino, I — ORBASSANO

- Design and construction of a prototype gas to gas ceramic heat exchanger for high temperature energy recovery (1 200°C) in industrial furnaces (EEB1-107-F) — Société BERTIN & Cie, Div. Energie Dep. Transferts de chaleur, Mr. Galant, B.P. 3, F-78370 PLAISIR

- Development of a new type of compact gas-gas heat exchanger. Survey of equipment available and market study (EEB1-116-F) — IFP, Dir. Physico Chemie Appliquée, Mr. Rojey, 1-4 Avenue du Bois Préau, F-92506 RUEIL-MALMAISON

- Evaporation of viscose process liquors using vapour recompression in conjunction with a plastic heat exchanger (EEB1-101-GB) — Courtaulds Ltd, Mr. R. Thorston, Dep. Chem. Engineering, P.O. Box 16, 345 Foleshill Road, GB — COVENTRY CV6 5AE

Heat recovery

- Energy recovery from exhaust gases of cast iron melting furnaces for the production of electricity (EEB2-162-I) — TEKSID Spa, Direzione Tecnica, Ing. C. Chiabotti, Corso Mortara 7, I-10149 TORINO

- Feasibility study of an indirect heat exchanger in a coking plant for recovering a part of the heat contained in the distillation gases discharged from a coke-oven (EEB2-161-F) — Cerchar, Groupe thermique, Mr. Gaget, B.P. 2, F-60550 VERNEUIL-EN-HALATTE

- The design of waste heat boilers for the recovery of energy from the waste gases of electric arc furnaces (EEB2-160-GB) — British Steel Corporation, Fuel and Furnaces Department, Mr. J. DIXON, Swinden House, GB — MOORGATE, ROTHERHAM, S. Yorkshire S60 3AR

- Heat regeneration in Al-furnaces (EEB1-151-GB) — James Howden & C° Ltd, Mr. Donald Mc Callum, 195 Scotland street, GB — GLASGOW

Combustion

- Improved boiler control in food factories (EEB1-124-GB) — British Food and Manufacturing Industries, Mr. Whitman, Randalls Road, GB — LEATHERHEAD, SURREY KT22 7RY
- Efficiency of reverberatory furnaces (EEB3-103-GB) — The British Aluminium CY ltd, Mr. Subramian, Chalfont Park — Gerrards Cross, GB — BUCKINGHAMSHIRE SL90GB
- Energetic optimization of the furnaces and the coupled heat exchangers (EEB1-150-F) — IRSID, Station d'Essais, Mr. Roth, F-57210 MAIZIERES-LES-METZ

Organic Rankine Cycle engine

- Design, building and testing of a hermetically sealed 100 kW Organic Rankine Cycle engine for medium temperature (200-400°C) heat recovery (EEB1-131-I) — TURBODEN, Mr. F. Gaia, Via Circo 1, I-20123 MILANO
- Industrial waste heat recovery using Organic Rankine Cycle (ORC) engines (EEB1-108-D) — MBB, Energy Systems, Mr. H. Hopmann, P.O.B. 801169, D-8000 MÜNCHEN 80
- Optimization of a multivane expander in an Organic Rankine Cycle engine (EEB1-121-GB) — Cranfield Institute of Technology, Mr. P.W. O'CALLAGHAN, GB — CRANFIELD BEDFORDSHIRE MK43 OAL

Energy cascading

- Energy cascading and industrial heat storage (EEB1-145-GB) — Cranfield Institute of Technology, Mr. R.J. WOOD, Cranfield, GB — BEDFORDSHIRE MK43 OAL
- Sulphur topping cycle (EED3-341-F) — CEA — DEMT BP 2, Mr. Caizergues, F — GIF-SUR-YVETTE 91190

TRANSPORT

Internal combustion engine improvement

- Design and realization of a system capable of converting the energy delivered by a rectilinear engine into mechanical energy to be supplied in the form of a circular movement of variable speed (EEC1-202-F) — Mothelec, Mr. G. Faul, 18 rue Chauveau-Lagarde, F-75008 PARIS

• Decrease of the energy consumption and the improvement of the thermodynamic properties of an Otto engine (comparison of an Otto and a Diesel engine) (EEC1-203-D)	Porsche AG Mr. D. Gruden Abt. Forschung Postfach 400640 D — STUTTGART ZUFFENHAUSEN
• Design and testing of a thermodynamic process operating with engine waste heat (bottoming cycle) allowing a reduction in fuel consumption of Diesel engines (EEC1-204-D)	MAN Neue Technologie Abt. ENP, Mr. K. Mötz Dachauerstrasse 667 D-8000 MÜNCHEN 50
• Research and development programme for semi-high RPM Diesel engines burning alcohol as a main fuel and operating according to a cycle close to the Diesel gas cycle (dual fuel) (EEC1-205-F)(*)	Renault Techniques Nouvelles (and Duvant) Dép. Energie, Mr. Leorat 147 Avenue Paul Daumer F-92500 RUEIL-MALMAISON
• Study of water fuel mixtures for Diesel engines (EEC1-201-I)	AGIP — SOLAR 77 Mr. A. Cantoni Via del Commercio 1/A I-0046 ROMA
• Study of a two stroke engine (EEC1-207-D)	Ficht GmbH Mr. L. Hamann Spannleiterberg 1 D-8011 KIRCHSEEON
• Utilization of waste heat from vehicle engines (EEC4-265-D)	Daimler Benz AG Mr. H.D. Gwinner Mercedesstrasse 136 Postfach 202 D-7000 STUTTGART 60
• New type of internal combustion engine of a rotary type (EEC1-208-GR)	General Supply (Constructions) Co. Ltd, Mr. E. Pelekis 25 Stournaristreet GR — ATHENS
• Matching internal combustion engines to the gas produced (EED2-323-B)	UCL, Dept. Thermodynamique, Prof. J. Martin Place du Levant 2 B-1348 LOUVAIN-LA-NEUVE
• Development of a Stirling engine of 10-100 kWe with a monocylinder, a free piston, a linear alternator or electromagnetic coupling in helium (EED1-301-F)	Société Bertin & Cie Div. Energétique, Mr. Boy-Marcotte B.P. 3 Allée Gabriel Voisin F-78370 PLAISIR

Miscellaneous

• Design of sailing bulkcarrier of ABT 30000 TDW (EEC4-263-B)	Cockerill Yards NV Design Office, Mr. I. Fehervari L. Bosschartlaan 1 B-2710 HOBOKEN

(*) Contract which is still being negociated.

ENERGY CONVERSION

Fluid bed combustion and lean gases

• Experimental development of circulation fluid bed combustion for steam production, firing waste coal and other inferior fuels (EED3-342-D)	L & C Steinmüller GmbH Abt. Forschung und Entwicklung, Mr. H. Dürrfeld Postfach 1949/1960 D-5270 GUMMERSBACH 1
• The burning of refuse derived fuel and industrial boiler wastes in a fluidized bed (EED3-343-GB)	Stone Platt Fluidfire Ltd Mr. R. Burrows 56 Second Avenue Pensnett Trading Estate Brierley Hill GB — WEST MIDLANDS DY6 7PP
• The design and development of a small scale fluidized bed boiler with a micro-processor based automatic control system (EED1-302-IR)	National Institute for Higher Education, Dr. J.E. Bannard IRL — LIMERICK
• Hot drying gas produced by fluid bed combustion (EED2-322-GB)	National Coal Board Mr. R.C. Payne Stoke Orchard GB — GLOS GL52 4RZ CHELTENHAM
• Construction, operation and optimization of a furnace for the economic burning of low calorific gases (EED2-325-GB)	University College Cardiff Dept. of Mechanical Engineering, Mr. R. Syred P.O. Box 78 GB — CARDIFF CF1 1XL

Use of catalysts

• Valorization of asphaltic material by hydrogenation under very severe conditions on entrained catalyst (EEB1-122-F)	Cerchar, Groupe Thermique Mr. Chiche B.P. 2 F-60550 VERNEUIL-EN-HALATTE
• Development of production methods for liquid fuels from water and coal, which will replace petrol (EED2-326-B)	Université de Liège Institut de Chimie Prof. Ph. Teyssie B-4000 LIEGE
• Catalytic synthesis of liquid fuels and chemical feedstocks from coal after gasification (EED2-327-B)	Katholieke Universiteit Leuven Centrum voor Oppervlakte Scheikunde Prof. J.B. Uytterhoeven De Croylaan 42 B-3030 LEUVEN

ENERGY STORAGE

Heat storage

- Chemical heat storage with salts in a temperature range from 300 to 650°K (EEE1-401-D)

MBB GmbH Abt. RT 32
Hauptabteilung Energietechnik, Mr. H. Hopmann
D — MÜNCHEN 6000-1

- Heat storage based on the melting of paraffine and coupled with a heat pump for domestic heating (EEE1-402-F)

Laboratoires de Marcoussis
(and Université de Nantes)
Division Energie,
Mr. P. Dubois
Route de Nozay
F-91460 MARCOUSSIS

- Prediction and measurement of the behaviour of a captive aquifer used as an induced geothermal reservoir at temperatures above 100°C (EEE1-403-F)

CEA, Mr. Rastoin
Département des Etudes Mécaniques et Thermiques
B.P. 2
F-91190 GIF-SUR-YVETTE

- Investigation of the potential for energy cascading combined with thermal energy storage in industry (EEB1-145-GB)

Cranfield Inst. of Technology
Mr. Mc O'Callaghan
GB — BEDFORDSHIRE
MK 43 OAL

Electricity storage

- Galvanic high energy cells (LiAl-FeS) with a molten salt electrolyte (EEE2-427-D)

Varta Batterie AG,
Mr. W. Borger
Postfach 1620
D-6233 KELKHEIM

- Investigation of new solid electrolytes and their associated cathodes. Study and realization of new batteries (EEE2-425-F)

Université de Bordeaux I
Laboratoire de Chimie du solide du CNRS,
Mr. A. Levasseur
F-33405 TALENCE CEDEX

- Advanced battery development (EEE2-421-GB)

UK Atomic Energy Authority
Applied Electrochemistry
Building 220, Dr. R.M. Dell
AERE Harwell
GB — DIDCOT, OXON
OX11 ORA

and

- (EEE2-429-DK)

Odense University
Mr. Johs Jensen
Campusvej 55
DK-5230 ODENSE

• Development of a total vehicle control system incorporating a high frequency power supply for both battery charging and motor field control for electric road vehicles (EEE2-221-GB)	Chloride Legg Ltd Mr. A.R. Edwards Fordhouse Road GB — WOLVERHAMPTON WV10-9EB
• Development of a modular electrochemical energy storage system for road electric vehicles (EEE2-423-I)	Centro Ricerche Fiat Unita di Ricerca Sistemi Meccanici Mr. P. Montalenti Strada Torino 50 I-10043 ORBASSANO
and	
• (EEE2-426-DK)	Elektronikcentralen Mr. Axel Laursen Venlighedsvej 4 DK-2970 HØRSHOLM
• Development and testing of a β″-alumina electrolyte to be used in NaS batteries (EEE2-422-F)	Laboratoires de Marcoussis Mr. R. Vic Route de Nozay F-91460 MARCOUSSIS
• Study and realization of hydrogen-air-fuel cells with hydrogen storing electrodes (EEE2-424-I)	Centro Ricerche Fiat Spa Unita di Ricerca Technologie Mr. C.V. Folonari Strada di Torino 50 I-10043 ORBASSANO
• Hydrogen fuel cell with a non flowing alkaline electrolyte (EEE2-428-F)	SORAPEC Mr. Doniat 192 rue Carnot F-94120 FONTENAY-SOUS-BOIS

Flywheels

• Design study for the retrofitting of flywheel units under the car body of existing commuter trainsets (EEE3-441-N)	N.V. Nederlandse Spoorwegen Storg St. & O Ir. F. Oudendael Moreelsepark 1 NL — UTRECHT
• Development of a flywheel energy storage system for crane driving gear (EEE3-442-D)	Fried. Krupp GmbH Mr. E. Hejj Dept. Driving Technology Münchenerstrasse 100 Postfach 102252 D-4300 ESSEN 1

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