Commission of the European Communities

energy

The second energy R&D programme Energy conservation (1979-83)

Survey of results

Report
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Directorate-General
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PREFACE

Research and Development has an important role to play in achieving the objectives of a complex industrial society such as the European Community. One of the most pressing problems currently facing all industrial nations is the provision and maintenance of secure energy supplies, and the importance of this topic in an European context is clearly seen by the large fraction of the total R & D budget which is devoted to energy matters. Indeed, energy topics, including fossil fuels, nuclear power, alternative energy supplies and energy conservation, account for well over one half of the total R & D expenditure of the Commission of the European Communities.

Energy R & D is carried out within the European Community's Framework Programme for Scientific and Technical Activities, under a number of R & D programmes which are executed by the Commission of the European Communities either directly in its Joint Research Centre or by concluding contracts with research institutions in the EC Member Countries. Energy conservation work is carried out within two particular four year programmes, "The First Energy R & D Programme" approved by the Council of Ministers of the European Communities in 1975, and "The Second Energy R & D Programme" approved in 1979. These made available a total of 164 Mio ECU (corresponding to about 200 Mio US $) for supporting contract research on a cost-sharing basis. These programmes included the five subprogrammes "Solar Energy", "Geothermal Energy", "Hydrogen as Energy Vector", "Energy Modelling" and last, but not least "Energy Conservation". (Nuclear Energy and Fossil Fuels were not involved as these are funded in separate R & D programmes).

In the field of Energy Conservation R & D the Commission concluded between 1979 and 1983 more than 150 research contracts with organizations or undertakings in the Member States of the European Community. The total cost of this research is around 50 Mio ECU of which 25 Mio ECU is paid by the Commission. Research is carried out in the domestic, industrial and transport sector and first results are now becoming available.

This booklet is a follow up of the survey of the first Energy Conservation R & D Programme (EUR 7389) and gives one page descriptions of the projects in the second programme. It is meant to give the widest possible dissemination of the results. I sincerely hope that it will succeed in achieving this aim.

A. STRUB
Director

Head of the Energy R & D Programme
of the Commission of the European Communities

NAMES RELEVANT TO ENERGY CONSERVATION R, D AND D IN THE EUROPEAN COMMUNITY

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OVERVIEW OF THE R & D RESULTS OF THE SECOND ENERGY CONSERVATION R & D PROGRAMME (1979-1983)

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COMMISSION OF THE EUROPEAN COMMUNITIES

Introduction

The overall gross primary energy consumption in the Member States of the European Community was in 1982, 872 million TOE (970 million TOE in 1979). The energy consumption in the different demand sectors was approximately distributed as shown in Table 1.

Domestic heating	Electricity use in the domestic sector	Electricity use in industry	Non energetic use of oil and gas in industry	Process heat	Transport
26%	15%	13%	7%	21%	18%
Domestic and commercial 41%		Industry 41%			Transport 18%

Table 1: Consumption of primary energy in the demand sectors

In ten years the energy cost increased from 2% of the GNP in the European Community to around 10%. Although recently energy prices decreased some what due to the economic stagnation, in the long term one may expect prices to increase again in particular for oil and gas. Therefore energy conservation and replacement of oil and gas by other energy sources such as nuclear energy, coal and renewable energies should also in the future have a high priority.

The potential for energy savings is still considerable. In the long term we may expect that for domestic heating the fuel requirements can be reduced by 50% with better insulation, lower air infiltration and introduction of advanced heating concepts (e.g. heat pumps, district heating). Industrial process heat requirements may be reduced by 30% using heat recovery, more efficient combustion and improved manufacturing processes. In the transport sector the long term energy saving potential is 20-40%. The fuel requirements for power production may be reduced by 20-30% by a more efficient power production and electric equipment in domestic appliances and industrial installations.

A second objective is the substitution of premium fuels such as oil and gas by coal or nuclear energy. This is pursued in research on coal or solid waste fired fluid bed combustors which may replace oil or gas fired boilers and the development of batteries and fuel cells for electrical vehicles, where electricity from coal or nuclear energy is replacing oil and gives cleaner air as an additional advantage.

To achieve these objectives a coherent policy is needed to develop technical solutions and to stimulate their introduction on a larger scale by information, education, financial incentives, removing legal and other barriers and demonstration projects. The role of the Community's Energy Conservation R & D Programme is to develop technologies which may lead to energy savings and replacement of premium fuels. Below a summary is given of this work carried out in 160 projects between 1979 and 1983.

Domestic and commercial sector

About 26% of the primary energy is required for the heating of buildings. A reduction of at least 50% of these energy requirements may be achieved in roughly three ways:

— Energy savings of 20-30% by reduction of transmission losses through walls, roofs and windows. Wall and roof insulation materials are already commercially available but problems still exist due to aging, condensation and inflammability. A considerable part of the heat losses in buildings (up to 30-40%) are caused by windows. Window insulation is therefore very important. Infrared reflective window coating, transparent for visible light, reflects heat radiation and doubles the heat insulation. This technique is being developed for new houses and for retrofitting in existing houses.

- Energy savings of 10-12% by reduction of ventilation losses. With increased insulation, the fraction of heat losses by ventilation (typically one volume exchange per hour), which already now can be as high as 30-40%, will become still higher. Different possibilities are being explored to reduce these heat losses. The basic idea in all approaches is the construction of very tight houses with heat exchange between outgoing and incoming air or with ventilation which is controlled by CO_2 or H_2O vapour level detection. A problem is that human behaviour, by opening doors and windows, frequently interferes with this heat saving measure. Even so it was demonstrated that with tight houses and controlled ventilation considerable energy savings can be obtained. Different projects deal with the development of tracer techniques for measuring the heat exchange rate; in particular in large buildings.

— Energy savings of 20-50% by more efficient heat production. In this programme work is focussed on heat pumps and improvement of conventional heating systems. Better control of heating systems for apartment buildings, office buildings and schools may lead to energy savings up to 20%. A cheap and reliable heat meter is indispensable for bringing about energy savings and in two projects such heat meters are being developed. Work is also carried out on cheap low temperature plastic radiators. Heat pumps may in the long term reduce the primary energy need for domestic heating by 30-50%; they will be discussed in the next chapter.

Cogeneration in combination with district heating is already used extensively (e.g. Scandinavian countries) and passed the R & D phase. No R & D work in this field is therefore carried out in this programme.

The work described above deals with the development of specific energy saving techniques. A second step towards the introduction of these techniques on a large scale is the development of an energy saving design of buildings which incorporates these techniques and minimizes the energy use in buildings. In such a design, computer simulation models, which simulate the thermal behaviour of buildings and their components, play an increasingly important role to such an extend, that these models are used by architects even although they are far from reliable and often give big discrepancies. The study of computer models and their experimental validation was therefore an important subject in this programme. Several simulation models were further developed, compared and experimentally verified. Still much research work has to be done to reach the objective of reliable and cheap simulation models for energy saving design which can be used on simple and cheap computers.

The electricity consumption in the domestic sector uses as much as 37% of the primary energy for this sector. It is therefore essential to look into the energy saving possibilities for both electricity production and electricity use. In this programme new refrigerators, washing machines and cooking equipment have been developed in collaboration with industry which consume considerably less energy than the appliances which are presently used.

Heat pumps

Domestic applications

More efficient production of heat with heat pumps may reduce fuel requirements for domestic heating in the long term by 30-50%. Presently in the European Community 100 000 to 150 000 heat pumps have been installed. The type which is most frequently used is an electrically driven compressor heat pump with air as heat source. Such a heat pump of 10 kW costs around 3 500 ECU(*) and the installation cost is about 2 000 ECU(*). The seasonally averaged energy conversion efficiency lies between 80% and 100% but an overall improvement of 15 to 20% is still possible. To this end experiments were carried out to study the use of working fluid mixtures, the influence on the performance of lubrification oil which dissolves in the working fluid and the overall optimization of the heat pump. Work was also executed to bring about an efficient control which avoids oscillation of temperatures in the heat pump. A considerable cost reduction (± 10%) could be achieved by using working fluid mixtures. Heat pumps with these mixtures are now close to commercialization. The use of air as a heat source for heat pumps has the disadvantage that on cold days the heat pump efficiency is very low and that back up oil or gas heating is needed. It is therefore being investigated whether low grade heat for heat pumps could be extracted from the soil, by a system of vertical or horizontal tubes with a circulating fluid (e.g. water/glycol). Due to the constant soil temperatures (below a certain depth) the heat pump efficiency will be high throughout the year.

(*) 1 ECU = 1 $. (1983.)

Another way to improve the energy conversion efficiency is to drive a compressor heat pump with a petrol or diesel engine and recover the waste heat of the engine. In this way efficiencies of 140% to 180% can be achieved. A drawback is the higher cost and maintenance. This concept is particularly suitable for large units of over 150 kW, but was also succesfully developed for a heat pump with a 20 kW heat output.

A still different route to a higher heat pump efficiency is the absorption heat pump which may achieve efficiencies of 120-140%. During the second programme extensive R & D was done on working fluids and on a cheap and reliable circulation pump. Several promising working fluid pairs have been identified and also the work on the circulation pump gave good results.

Applications in Industry

Unlike domestic heat pumps where heat has to be extracted from air or soil, the heat source for industrial heat pumps is generally waste heat. With the present state of the art heat pumps can produce heat up to 120°C. The national energy saving potential for industrial heat pumps is modest (1-2% of the total national primary energy consumption) but can be trebled if heat pumps can be developed which produce heat up to 300-400°C. The only project which has the promise of producing heat at these temperatures is the Brayton cycle heat pump which is designed to produce heat at 165°C from waste heat at 90°C with an energy (power-heat) conversion coefficient (COP) of 3.18. This heat pump concept with a turbo-compressor may be also used at higher temperatures. Furtheron work is being carried out on high temperature (over 120°C) working fluid pairs for industrial absorption heat pumps and transformers.

Industrial combustion and waste heat recovery

In the industrial sector about 21%, 13% and 7% of the total primary energy consumption are used for process heat, electricity and non energetical use (e.g. chemical industry) respectively.

Energy use for process heat may be reduced by more efficient combustion and recovery of industrial waste heat.

More efficient *combustion* techniques have been developed for the steel, aluminium and food industry and energy savings amount to 5-10%. In addition work in four projects is focussed on fluid bed combustors. Here the objective is to replace premium fuels by coal and waste material. Moreover the low combustion temperatures (700-900°C) result in low NO_x levels and also the sulphur content in exhaust gases can be kept very low at a low cost, by adding limestone.

The energy saving potential for *recovery* of waste heat in industry is very large. The amount of process heat required in industry as a function of temperature has two peaks, one between 200 and 400°C and a second peak between 800 and 1 400°C. In the whole temperature range large quantities of waste heat are discharged which if they can be recovered and used, can lead to large energy savings. To that end different heat recovery technologies for industry are being developed. Heat pumps transform waste heat into heat at a higher temperature level where it may be used. They have already been discussed in the previous section. Also different types of heat exchangers are being developed such as heat pipe heat exchangers (<500°C), fluid bed heat exchangers (<1 000°C) and ceramic heat exchangers (>1 000°C). Heat recovery projects in the aluminium, and iron melting industry are carried out. If waste heat can not be used for heating purposes it may be transformed into electricity which can be transported more easily over long distances. For this purpose O.R.C. engines are being developed which, depending on the working fluid, are able to transform waste heat between 100°C and 400°C into mechanical and electrical energy. The energy saving potential of *heat storage* systems in industry was shown to be 1% of the energy use in industry.

Industrial processes

Energy savings by improved combustion and heat recovery may be applied in a large variety of industrial processes. In this chapter we will discuss projects which investigate energy saving opportunities specific for a particular industrial process. Although the market for these techniques is considerably smaller than for combustion or heat recovery, a large number of economically attractive possibilities do exist.

In the metallurgical sector four projects in the steel and aluminium industry investigated a technique, where liquid metal is cast directly in the final forms (e.g. gear box parts for cars, semi-fabricated rolled products) without an intermediate phase of cooling and reheating the metal. The potential for energy savings is 15-25% and the properties of the product were in most cases satisfactory. Furtheron it was investigated whether blast furnace slag can be used as a raw material in the cement industry; this work was not yet successful. Better results were obtained using it for the production of a glass-ceramic material which may be used as lining in pipes which transport corrosive material.

Two projects in the cement-industry investigate the feed regulation and preheating of the feed. Fluctuations in the composition of the raw material fed to the kiln must be compensated by over baking which leads to energy losses and a lower quality of the product. A new method using tracers is being developed which improves the mixing process. Also cyclone heat exchangers by which the feed is preheated with exhaust gases before it enters the kiln, are being improved.

In the textile industry, dying processes are being developed which avoid the energy intensive intermediate drying process normally required after bleaching. Furtheron the energy use in the textile industry is being diminished by developing techniques such as catalysed bleaching and steam purging.

A study is carried out to explore energy saving possibilities in bakeries and a systematic study of the soya bean industry lead to the identification of several energy saving possibilities which may lead to energy savings of 25%.

A number of contracts was grouped under the heading chemical industry. Three projects deal with fuel treatment. A method where scrap tyres are transformed into heavy oil by depolymerization in aromatic oil at high temperatures, turned out to be successful and economically attractive. Another study showed that the potential for fuel production from waste products by anaerobic fermentation is significantly below 3% of the total primary energy use in Europe. Finally an economically attractive method was developed to recover spilled coal in coke ovens.

Projects on a reduction of the overvoltage in chlor-alkali electrolysis, selective removal of H_2S from gaseous mixtures and improvement of cracking furnaces gave encouraging results.

In future, production of oil or gas from coal will become increasingly important and catalyst research will play a crucial role. In two projects catalysts are being developed which in the transformation from syn gas ($CO_2 + H_2$) to petroleum, gasoil or alcohols (e.g. methanol, ethanol) are much more selective for a particular hydrocarbon product than the product distribution with current processes. Also catalysts for hydrogenation of asphalt (oil residuals) into petroleum or diesel oil are being studied.

Heating with microwaves has not been generally introduced due to the high cost of electricity and the often low efficiency of the microwave equipment; heating with gas fired systems is mostly more attractive. In some cases however microwave heating is attractive such as vulcanization of rubber which has a bad thermal conductivity and food processing. In this programme three areas of applications are being investigated: treatment of plastic, wood and concrete drying and drying of coated paper.

A start has also been made with energy optimization studies. Three studies are presently being carried out for an electromechanical factory with a large number of buildings, for an industrial site with different industries and for a large industrial region.

Transport

The transport sector consumes about 18% of the total primary energy in the Community. The fuels used are for 85% petroleum based. As the energy conversion efficiency of internal combustion engines is still very low the potential for energy saving is considerable.

Projects in the E.C. programme to improve existing petrol engines deal with air/fuel ratio, compression, ignition time and gave good results. For Diesel engines the use of Diesel-water emulsions was studied; here the energy savings are limited to a few percent. In two projects combinations consisting of a Diesel engine and an ORC engine are being studied, where the ORC engine transforms the exhaust heat of the Diesel engine into mechanical energy.

New engine concepts such as a rectilinear engine, Stirling engine and a rotary type combustion engine are being developed. Finally several internationally coordinated projects dealing with three dimensional simulation of combustion processes, composite-metal jointing and combustion of residual oil attracted a considerable interest in industry. These projects have, 5, 8 and 16 participants respectively; mainly from the car, petrol and chemical industry.

Energy Storage

Energy storage is needed when the availability of waste or cheap energy does not coincide with the need for energy. Economic feasibility of these systems depends on factors such as the cost of the storage system, the cost of the available energy and the number of storage cycles per year. In particular expensive storage systems (e.g. flywheels) need a high cycling rate to achieve economic feasibility. Research in the field of energy storage has been subdivided in three groups: heat storage, storage of electricity and flywheels.

Heat storage R & D in the first E.C. Energy Conservation R & D Programme (1975-1979) lead to the conclusion that latent heat storage is much more expensive than simple hot water storage and that the energy density of these systems at 60-70°C is only two times higher. In most cases hot water storage is therefore cheaper and adequate. As a consequence very little work was done on latent heat storage in the second programme. One project tested the economic feasibility of a paraffin heat storage system used for daily heat storage in combination with an electrical heat pump (cheap night electricity) where the climate was simulated with a climatic chamber. The pay back time of the heat storage system turned out to be 25 years.

Seasonal heat storage at 180°C is being investigated in a water conducting sand layer at a depth of 500 m with a natural thermal insulation consisting of clay layers below and above. Heat will be provided by a waste incineration plant and will be used for the domestic heating of 4 000 houses.

A study which explored the heat storage opportunities in industry in the UK identified a limited number of applications which in the UK would lead to energy savings amounting to 1 % of the energy used for process heat. Most suitable were steam accumulators and regenerators. No industrial processes were feasible for thermo-chemical storage systems, mainly because of the rapid heat demand fluctuations which require a too high power density of the chemical storage system.

Research on *storage of electricity* is mainly done on advanced secondary batteries. The main application is believed to be for electrical vehicles. In order for these vehicles to have a range of a few hundred kilometers and have a good acceleration, the required energy density and power density are of the order of 150 Wh/kg and 100-150 W/kg respectively (a lead acid battery has 30 Wh/kg and 50 W/kg). Development of advanced Na/S and Li/S batteries led to energy densities of 200 Wh/kg and 100 Wh/kg respectively. These batteries have the disadvantage that they operate at 350-450°C. Basic materials research was therefore started in parallel, to develop an all-solid battery operating at lower temperatures. This work is carried out by seven laboratories from the UK and Denmark, working together in the Anglo-Danish project, and a French group. Recently an all-solid cell has been developed with a polymer electrolyte, which had a extrapolated energy density of 400 Wh/kg and operated at 120°C. Work on this cell is being continued. Also work on glass electrolytes and electrodes by a French group is making good progress. Furtheron research is executed on an alkaline fuel cell and on the overall optimization of electrical vehicles (e.g. temperature control of batteries, light on board battery chargers, control charging).

Finally *flywheel storage* applications for cranes and trains are being investigated in both cases; the economic feasibility is difficult to achieve.

PUBLICATIONS

About 120 final reports of projects which have been carried out in the First and Second Energy Conservation R + D Programme are now available. These reports can be purchased from the Commission (*).

One page summaries of these reports are given in this booklet for projects in the ongoing programme and in the booklet EUR 7389 for projects carried out in the first programme (1975-1979):

> THE COMMUNITY'S FIRST ENERGY R AND D PROGRAMME — ENERGY CONSERVATION
> Survey of results and Compilation of New Projects — Second Edition.
> Edited by: P. Zegers, CEC, Brussels.
> Published in 1982 by the CEC (*) (DG XII) under No EUR 7389 EN.

Intermediate (10 page) information on projects in the second programme may be found in the proceedings of 25 contractors meetings held between 1981 and 1983. These proceedings are bought together in eight books of which a list is given below:

> ADVANCED BATTERIES AND FUEL CELLS
> Proceedings of the second contractors meeting held in Kelkheim on 20 and 21 April 1982.
> Edited by: H. Ehringer, P. Zegers, G. Hoyaux, J.A.A. Ketalaar.
> Published in 1982 by the CEC (*) (DG XII) under No EUR 8078 EN.

> HEAT PUMPS
> Proceedings of four contractors meetings held in Brussels on 28, 29 April and 13 and 14 May 1982.
> Edited by: H. Ehringer, P. Zegers, G. Hoyaux, J.A. Knobbout.
> Published in 1982 by the CEC (*) (DG XII) under No EUR 8077 EN.

> ENERGY CONSERVATION IN BUILDINGS
> HEATING, VENTILATION AND INSULATION
> Proceedings of the contractors meetings held in Brussels on 14-15 December 1981, 6-7 May, 24, 28 and 30 September, and 21 October 1982.
> Edited by: H. Ehringer, G. Hoyaux, P. Zegers, CEC, Brussels.
> Reidel Publishing Company, 1983, XV + 495 pp. Dfl. 145. ISBN 90-277-1578-5.

> ENERGY CONSERVATION IN INDUSTRY
> APPLICATIONS AND TECHNIQUES
> Proceedings of the contractors meetings held in Brussels on 10 May, 17 June, 1, 7 and 22 October 1982.
> Edited by: H. Ehringer, G. Hoyaux, P. Pilavachi, CEC, Brussels.
> Reidel Publishing Company, 1983, XV + 417 pp., Dfl. 120. ISBN 90-277-1580-7.

(*) Office for Official Publications of the E.C.
P.O. Box 1003 - Luxembourg.

ENERGY CONSERVATION IN TRANSPORT
NEW ENGINES AND FLYWHEELS
Proceedings of the contractors meetings held in Brussels on 21 and 28 October 1982.
Edited by: H. Ehringer, G. Hoyaux, P. Pilavachi, CEC, Brussels.
Reidel Publishing Company, 1983, XII + 240 pp., Dfl. 65. ISBN 90-277-1579-3.

ENERGY CONSERVATION IN INDUSTRY
COMBUSTION, HEAT RECOVERY
AND RANKINE CYCLE MACHINES
Proceedings of the contractors meetings held in Brussels on 10 and 18 June, and 29 October 1982.
Edited by: H. Ehringer, G. Hoyaux, P. Pilavachi, CEC, Brussels.
Reidel Publishing Company, 1983, X + 164 pp., Dfl. 75. ISBN 90-277-1581-5.

FLUIDIZED BED SYSTEMS
Proceedings of the contractors meetings held in Brussels, 12-13 October 1982.
Reidel Publishing Company, 1983, XV + 277 pp., Dfl. 90. ISBN 90-277-1616-1.

ADVANCED BATTERIES AND FUEL CELLS
Proceedings of the third contractors meeting held in Bordeaux on 25-27 April 1983.
Edited by: H. Ehringer, P. Zegers, G. Hoyaux.
Published in 1983 by the CEC (DG XII) under No EUR 8660 EN.

NEW WAYS TO SAVE ENERGY - BROCHURE IN SERIES:

- HEAT EXCHANGERS FOR INDUSTRY
- HEAT PUMPS
- RANKINE CYCLE ENGINES
- COMBUSTION (in preparation)
- TECHNOLOGIES AND APPLICATIONS IN INDUSTRY (in preparation)

Other publications made in the framework of or dealing with this programme are:

SYSTEM SIMULATION IN BUILDINGS
Proceedings of the International Conference held in Liège on 6-8 December 1982, Doc. XII/425/83-EN.

ACHIEVEMENTS OF THE EUROPEAN COMMUNITY'S FIRST ENERGY R + D PROGRAMME
J.C. McMullan and A.S. Strub
Martinus Nyhoff for the Commission of the European Communities, 1983, ISBM, 90-247-2511 g.

LIST OF PROJECTS (CONTRACTS)

		Contract number
1.	**ENERGY SAVING IN BUILDINGS**	
	Heating systems and Ventilation	
1.1	Selection of boiler installations from the energy conservation point of view	EE-A-1-001-NL
1.2	The effect of upgraded insulation on heating systems and control	EE-A-1-002-UK
1.3	The performance of various heating systems in a matched pair of houses	EE-A-1-007-IRL
1.4	Air distribution methods for low temperature domestic air heating system	EE-A-1-010-UK
1.5	Plastic water/air radiator for domestic heating operation at 50° c	EE-A-1-003-F
1.6	Heat meter without rotating parts	EE-A-1-011-D
1.7	Heat meter based on Lorentz force	EE-A-1-012-I
	Heating Control Systems	
1.8	Transmission of signals for heating control using existing electrical wiring	EE-A-1-004-D
1.9	Electronic control of combustion and of the total heating system	EE-A-1-005-I
1.10	Heating control in apartment buildings and schools	EE-A-1-009-I
1.11	Use of a microprocessor in an office building to reduce energy consumption for lighting and cooling	EE-A-1-006-NL
	Insulating material	
1.12	Fire resistant insulating materials for buildings using a phenolic resin of the type NOVALAQUE in the form of reinforced foam	EE-A-2-013-F
1.13	The use of bituminous materials to make insulating materials in granules and fibres waterproof	EE-A-2-017-I
1.14	Measures to reduce the deterioration with time of insulating properties in rigid polyurethane foams	EE-A-2-015-F EE-A-2-027-F
1.15	Study of new building materials with a high thermal diffusivity to accumulate heat	EE-A-2-016-I
1.16	Lifetime testing of low cost insulating panels	EE-A-2-014-I
1.17	Improved retrofitting methods for insulation	EE-A-2-023-DK
	Insulation	
1.18	Infrared reflective window coating (heat mirror) by the PYROSOL process	EE-A-2-022-F

1.19	The production of infrared reflective coatings on plastic sheets	EE-A-2-021-UK
1.20	Insulating blinds for windows	EE-A-2-020-UK
1.21	Energy saving by using rolling shutters in houses	EE-A-2-019-NL
1.22	Mobile insulation of windows	EE-A-2-018-DK

Natural Ventilation

1.23	Ventilation control of buildings based on the measurements of the CO_2 content in extracted air	EE-A-5-053-F EE-A-5-061-F
1.24	Fresh air exchange rate and ventilation in air tight houses	EE-A-5-052-DK
1.25	Development of an air infiltration measuring methodology in large and complex buildings	EE-A-5-050-GB
1.26	Air infiltration in large buildings: development of two new tracer gas detection methods	EE-A-5-051-UK
1.27	Analysis of the factors influencing pressure differences on houses in relation to natural ventilation and energy consumption in low cost houses	EE-A-5-063-NL

Characteristics of houses

1.28	Energy saving in low cost houses making optimum use of gratuitious energy	EE-A-5-057-B
1.29	Heating systems and their integration in houses	EE-A-5-056-B
1.30	Building characteristics of low cost houses in view of energy savings for heating	EE-A-5-060-B
1.31	Extension of the ESP energy simulation model for thermal behaviour of buildings	EE-A-5-059-UK
1.32	Improvement of industrial building design, on the basis of an investigation carried out on existing plants	EE-A-3-172-I
1.33	Development and experimental verification of a computer model which simulates the thermal behaviour of houses	EE-A-5-054-IRL
1.34	Bioclimatic design for building system components	EE-A-5-058-I

Domestic Appliances

1.35	Energy saving in the commercial catering market	EE-A-3-026-GB
1.36	Development of energy efficient electrical household appliances	EE-A-3-025-DK
1.37	Development of a low temperature washing machine with formation of oxygen by electrolysis of the washing liquid	EE-A-3-024-I

2. HEAT PUMPS

Domestic compressor heat pump systems

2.1	Compression heat pumps operating with non azeotropic fluid mixtures for space heating	EE-A-4-045-F

2.2	Study of capacity control and the influence of lubrification oil on system and evaporator design, in heat pumps with rotary sliding vane compressors	EE-A-4-028-GB
2.3	Study of a high performance 30 kW heat pump with an oil free single screw compressor	EE-A-4-029-F
2.4	Installation and operation of heat pumps in an existing apartment building where the existing radiators are used	EE-A-4-046-D
2.5	Design, optimization and testing of a variable speed heat pump for application in space heating	EE-A-4-048-F EE-A-4-064-F
2.6	Optimization of oil or gas engine driven heat pumps of 20 kW for domestic heating	EE-A-4-038-D
2.7	Optimized operation of a frozen air heat exchanger and use of a micro computer controlled expansion valve	EE-A-4-049-D
2.8	Control system for an internal combustion engine driven heat pump	EE-A-4-062-F
Domestic absorption and other advanced heat pumps		
2.9	Development of a monovalent absorption heat pump which delivers heat at 70°C for space heating	EE-A-4-039-GB
2.10	An absorption-resorption heat pump for space heating; investigation of solute pairs	EE-A-4-042-F
2.11	Investigation of working fluid pairs for single and multiple-stage absorption heat pumps	EE-A-4-031-D
2.12	Development of a cheap and efficiently adjustable solvent pump for absorption heat pumps	EE-A-4-030-D
2.13	Periodically operating absorption heat pump	EE-A-4-065-D
2.14	An ORC driven heat pump of 10 kW for use in a domestic environment	EE-A-4-043-UK
2.15	Thermo-electric heat pump for domestic heating	EE-A-4-044-F
Ground as a heat pump heat source		
2.16	The use of soil as a heat source and heat storage medium for heat pumps	EE-A-4-032-DK
2.17	Space heating with heat pumps using soil and an energy roof as a heat source	EE-A-4-037-B
2.18	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 house	EE-A-4-033-NL
2.19	Solar assisted absorption or motor driven compressor heat pumps with earth seasonal storage	EE-A-4-047-I
Industrial heat pumps		
2.20	Study and realization of an industrial Brayton-cycle heat pump for high temperatures (150-300°C)	EE-B-1-119-F
2.21	Industrial application of a high temperature gas engine driven heat pump	EE-B-1-147-UK

3. ENERGY CONSERVATION IN INDUSTRY

Combustion

Heat exchangers

Fluidised bed heat exchangers

Heat recovery

3.16 Energy recovery from cast iron melting furnaces — EE-B-2-162-I, EE-B-2-1-163-I

Energy cascading and ORC machines

3.17 Industrial waste heat recovery by use of Organic Rankine Cycles (ORC) — EE-B-1-108-D

3.18 Medium temperature 100 kW ORC engine for total energy systems — EE-B-1-131-I

3.19 Optimization of a multi-vane expander (MVE) as the prime mover in an Organic Rankine Cycle — EE-B-1-121-GB

3.20 Confirmation of the advantages of a thermodynamic cycle using sulphur with the help of an experimental facility — EE-D-3-341-F

3.21 Energy cascading combined with thermal energy storage in industry — EE-B-1-145-UK

Metallurgy

3.22 Saving energy in the manufacture of steel forgings — EE-B-1-115-F

3.23 Development of bainitic nodular iron for the construction of speed gears for the car industry — EE-B-1-149-I

3.24 Lubrication of the continuous casting of steels by slags — EE-B-1-117-F

3.25 Energy saving by applying new thermal cycles to castings removed from the mould in the hot state immediately after the solidification stage — EE-B-1-120-F

3.26 Reduction in energy requirements for converting liquid aluminium to semi-fabricated rolled products — EE-B-1-102-GB

3.27 Composite metal jointing technology for vehicle weight reduction — EE-C-4-261-UK

Cement and glass ceramic industry

3.28 Using tracers to investigate the transfer parameters in the system regulating the chemical constitution of the feed to the cement kilns in order to achieve optimum efficiency — EE-B-1-141-F

3.29 Cyclone heat exchangers: development of a method of defining and improving performance — EE-B-1-106-F

3.30 Study of the treatment of oxygen steelworks slag with a view to using it in cement-making — EE-B-4-183-F

3.31 Ceramic materials from molten blast-furnace slags by direct controlled cooling — EE-B-4-184-GB

Textile industry

3.32 Industrial application of continuous wet-on-wet treatment of fabrics — EE-B-1-139-N

3.33 Low energy preparation processes for textiles — EE-B-1-140-UK

Food industry

3.34 Energy saving in the bakery by improving efficiency and heat recovery — EE-B-1-148-N

3.35 Energy saving in the soya bean extraction industry by reducing the steam consumption for desolventizing-toasting and drying extracted beans EE-B-1-138-N

3.36 Energy saving in edible oil processing plants, by application of a total-energy (TE) system EE-D-1-303-N

Chemical industry

3.37 Modification of cracking furnaces in existing plants to increase yields of valuable products and to reduce fuel consumption EE-B-1-109-I

3.38 Selective removal of H_2S from gaseous mixtures containing CO_2 EE-B-1-130-I

3.39 Energy conservation in the chlor-alkali industry EE-B-1-111-UK

3.40 Thermal depolymerisation of waste tyres by heavy oils and conversion into fuels EE-B-4-182-F

3.41 Critical evaluation of anaerobic fermentation of waste products (management study) EE-B-4-180-UK

3.42 Recovery, treatment and utilization of solid bearing effluents emanating from coke ovens EE-B-4-181-UK

Microwaves

3.43 Application of microwave heating and hot air for the continuous production of plasticized PVC sheets EE-B-1-112-L

3.44 Application of microwave heating to the production of construction materials EE-B-1-135-B

3.45 Development of microwave applicators to dry thin structures EE-B-1-137-B

Energy management

3.46 Reducing energy consumption in a works manufacturing heavy electrical equipment (ACEC) EE-B-3-170-B

3.47 Economic study of the energy exchange between factories in an industrial site EE-B-3-171-B

3.48 Modelling the total energy supply and demand of a region EE-B-3-173-B

3.49 Estimation of energy and cost savings arising from rationalisation of milk assembly operations EE-C-4-266-EIR

4. ENERGY CONSERVATION IN TRANSPORT

Improved internal combustion engines

4.1 Reduction of fuel consumption by thermodynamic optimization of the Otto-engine EE-C-1-203-D

4.2 Operation of automotive diesel engine with water in oil emulsion EE-C-1-201-I

4.3 Optimum matching of internal combustion engines fuelled by means of gas generators EE-D-2-323-B

4.4	Development and testing of an operating method using exhaust heat (bottoming cycle) and capable of reducing the fuel consumption of a diesel engine	EE-C-1-204-D
4.5	Utilization of waste heat from vehicle engines	EE-C-4-265-D
4.6	An investigation of the confined combustion properties of residual fuels used in marine and industrial diesel engines	EE-C-1-209-UK
4.7	Development and evaluation of three-dimensional models of cold flow in internal combustion engines	EE-C-1-210-UK

New engines

4.8	Experimentation of a mobile platform powered by a rectilinear engine associated with electric wheels of programmed movements	EE-C-1-202-F
4.9	Design and construction of a 3 kW sealed Stirling engine test model	EE-C-1-301-F EE-D-1-305-F
4.10	Two-cylinder two-stroke internal combustion engine of the reciprocating piston design	EE-C-1-207-D
4.11	New simple rotary-motion internal combustion engine of high efficiency and low manufacturing cost	EE-C-1-208-GR

Maritime transport

4.12	Design of sailing bulk carrier	EE-C-4-263-B

5. ENERGY PRODUCTION

Fluidized bed combustion

5.1	Design and development of a small-scale fluidized bed boiler with automatic control	EE-D-1-302-IRL
5.2	Production of hot gas for drying processes using fluidized bed combustion of coal	EE-D-2-322-UK
5.3	Further experimental development of circulating fluidized bed combustion for application in steam boiler furnaces using low-grade fuels and coal	EE-D-3-342-D
5.4	The burning of refuse derived fuel and industrial waste in fluidized bed industrial boilers	EE-D-3-343-UK
5.5	Operation and optimization of a furnace for the economic burning of low calorific value gases	EE-D-2-325-UK

Catalysis

5.6	New routes for producing alcohol (motor fuels and basic materials for hydrocarbon substitution) from synthesis gas	EE-D-2-326-B
5.7	Fischer-Tropsch synthesis of hydrocarbons in the gasoil range	EE-D-2-327-B
5.8	Making the best use of asphalts by very intense hydrogenation on an entrained catalyst	EE-B-1-122-F

Coal and Peat

5.9	Desulphurization of bituminous coal by biological leaching	EE-D-2-324-I
5.10	Peat harvesting machinery for operation on smaller bogs	EE-B-5-190-EIR

6. ENERGY STORAGE

Electricity storage

6.1	Development and testing of a β" alumina electrolyte to be used in a Na/S battery	EE-E-2-422-F
6.2	Secondary batteries with a high energy and power density with a molten salt electrolyte	EE-E-2-427-D
6.3	Advanced battery development (Anglo-Danish project)	EE-E-2-421-UK EE-E-2-429-DK
6.4	Investigation of glass materials for new solid electrolytes and their associated cathodes: Study and realization of new batteries	EE-E-2-425-F
6.5	Hydrogen fuel cell with an immobilized liquid electrolyte using a porous matrix	EE-E-2-428-F
6.6	Development of a modular electrochemical energy storage system for road electric vehicles	EE-E-2-423-I EE-E-2-426-DK
6.7	High frequency power supply for both battery charging and motor field control for electrical vehicles	EE-C-2-221-UK

Heat storage

6.8	Short term heat storage based on the melting of paraffin and coupled to an electrical heat pump for domestic heating	EE-E-1-402-F
6.9	Seasonal heat storage at temperatures above 100°C in a 500 m deep confined aquifer: a preliminary theoretical and experimental feasibility study	EE-E-1-403-F

Flywheels

6.10	Design study for retrofitting of flywheel units under the car body of existing commuter trainsets	EE-E-3-441-NL
6.11	Development of a flywheel energy storage system for a crane driving gear	EE-E-3-442-D

SHORT DESCRIPTION OF THE PROJECTS

The summaries have been written completely or in part by the editors. On top of each abstract the name and address of the firm is given together with the name of the project leader. Also the contract number and the final report number (if available) are indicated.

Sector 1

ENERGY SAVING IN BUILDINGS

Preliminary investigation of boiler plants from the viewpoint of low energy conservation 1.1

TNO Heating and Refrigeration
Engineering Division
P.O. Box 342
NL — 7300 AH Apeldoorn

M. KIEL

Contract number: EE-A-1-001-NL

The possibilities were studied of improving the efficiency of boilers for domestic heating (80°C, 100 kW). Calculations show that energy savings up to 26% are possible. Reduction of chimney losses by closing the chimney when the burner is not operating, brings 7-10%. A forced draught burner has a 7% higher efficiency than normal draught boilers with regulation of the secondary air supply. In addition several other modifications bring minor contributions. A computer simulation model is now being developed for a boiler installation which will enable the determination of the fuel consumption of alternative boiler designs. This model will also include cost considerations. It may be considered as a supplement to computer simulation models for the thermal behaviour of houses which are being developed in projects under the chapter "characteristics of houses" (1.28 - 1.34).

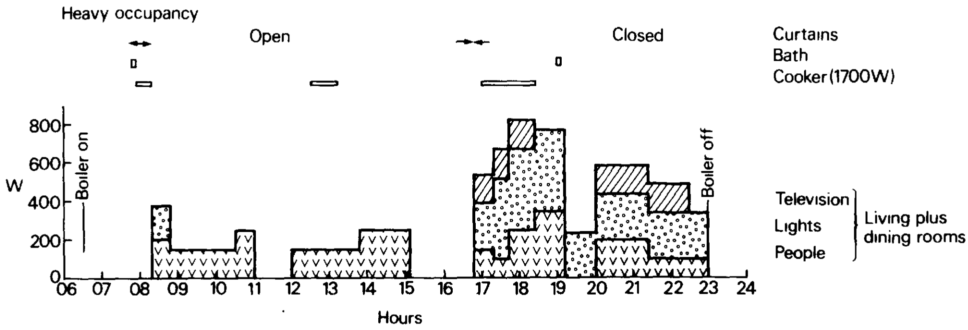


Figure 1.2.1 Simulated occupancy heat gains and times

Heat source	Heat gains/day MJ
People	19.7
Lights	9.0
Electric cooker	
Kettle	15.3
Washing machine	
Refrigerator	5.2
TV (B/W)	2.2
Hot water*	16.9
Total	68.3

* Hot water gain taken as 50% of energy content of run-off.

Figure 1.2.2 Incidental heat gains simulated in the experimental house

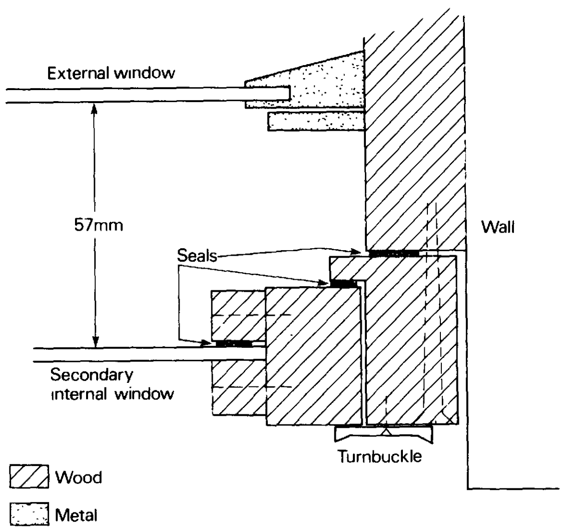


Figure 1.2.3 Schematic diagram of the construction and fixing of the secondary double window

The effect of upgraded insulation on heating systems and control

1.2

B R E
Building Research Station
UK — Garston, Watford, Hertz WD2 7JR

S.J. LEACH

Contract number: EE-A-I-002-UK

This project investigates the performance of domestic heating systems and their control together with the effects of upgraded fabric insulation. Experimental results obtained from specially prepared matched-house pairs will provide data for the verification of an existing computer simulation model. This will produce design guidance for heating installations and their control. Up to now the matched-house pairs have been used to investigate the energy savings obtained from fitting secondary windows. The results demonstrate mean energy savings of 12%. The theoretical reduction agrees well with that measured, only if the air change rate is assumed to have been reduced by about one third.

Presently two pair semi detached and four terrace houses have been prepared for experiments with central heating systems. Some first results on room thermostats have been obtained. For computer simulation of the heating system a simple steady state model was developed by BRE. The simulation of the dynamic behaviour of heating systems will be carried out with an existing package (SYSTEM). The interaction between this model and models for the thermal behaviour of a complete building (see chapter "characteristics of houses") will be investigated.

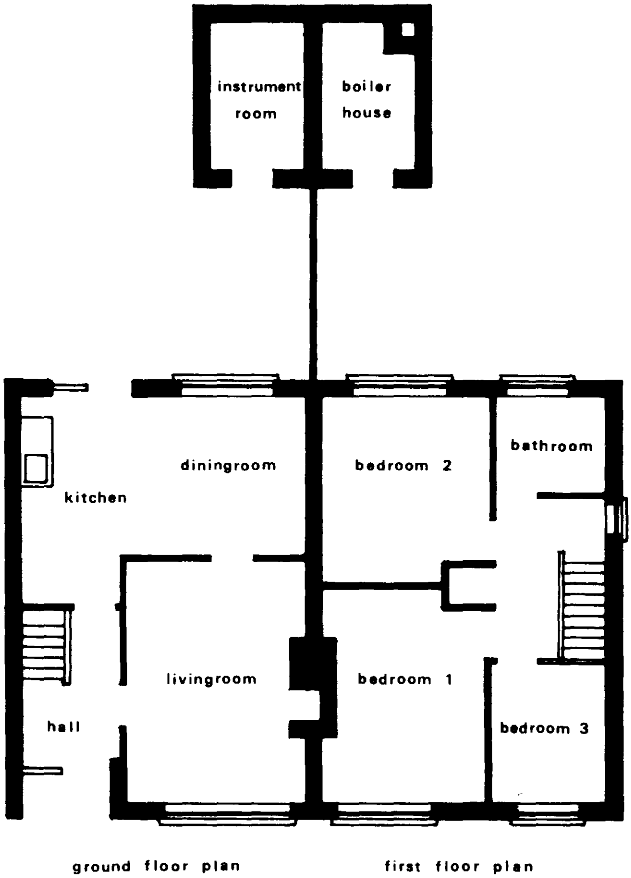


Figure 1.3.1 Test houses and instrument room/boiler house

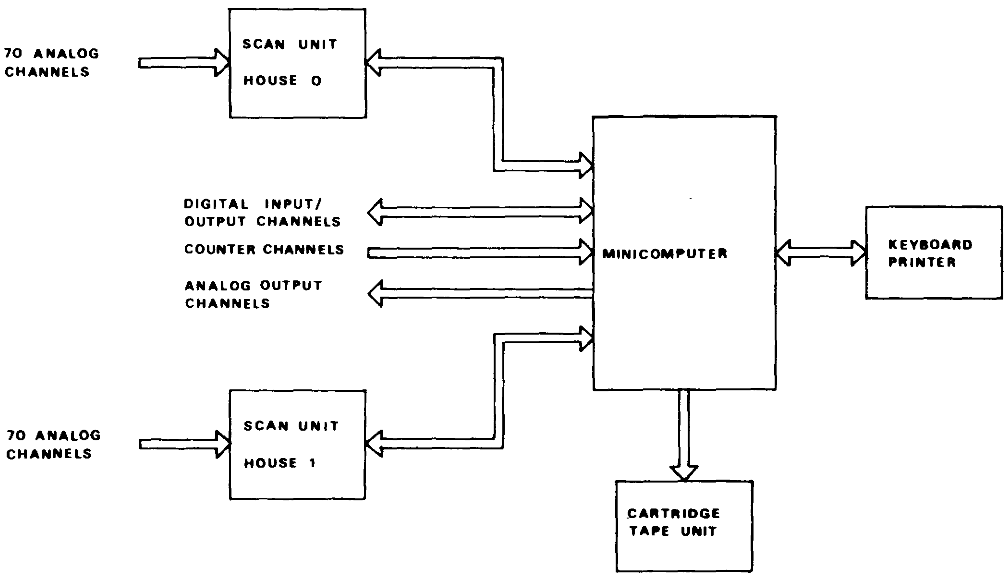


Figure 1.3.2 Datalogging and control system

The performance of various heating systems in a matched pair of houses 1.3

The National Institute for Physical Planning
and Construction Research Ltd.
St. Martin's House
Waterloo Road
IRL — Dublin 4

P.T. PIGOTT

Contract number: EE-A-1-007-IRL

Four different heating systems (oil fired boiler, closed solid fuel stove, solid fuel fired boiler and high output boiler on an open fire) are being tested and compared in a pair of houses. One of the houses is a reference house with electric heating and in the other house the heating system will be tested. The pair of houses has been bought and is now being equipped. The computer system for data collection and treatment has been designed. The following measuring programme is being carried out:

— calibration and possible modification of the houses to ensure that their thermal behaviour is identical

— measuring the efficiency and ability of the four heating systems to meet a variety of heating regimes

— improve the heating systems.

The measured air exchange rate in the two houses was around 1 vol/h. Equipment was installed to simulate the heat gained from occupants, lighting, curtain drawing, cooking, water heating etc.

Presently testing is going on during the whole heating season 1982/1983.

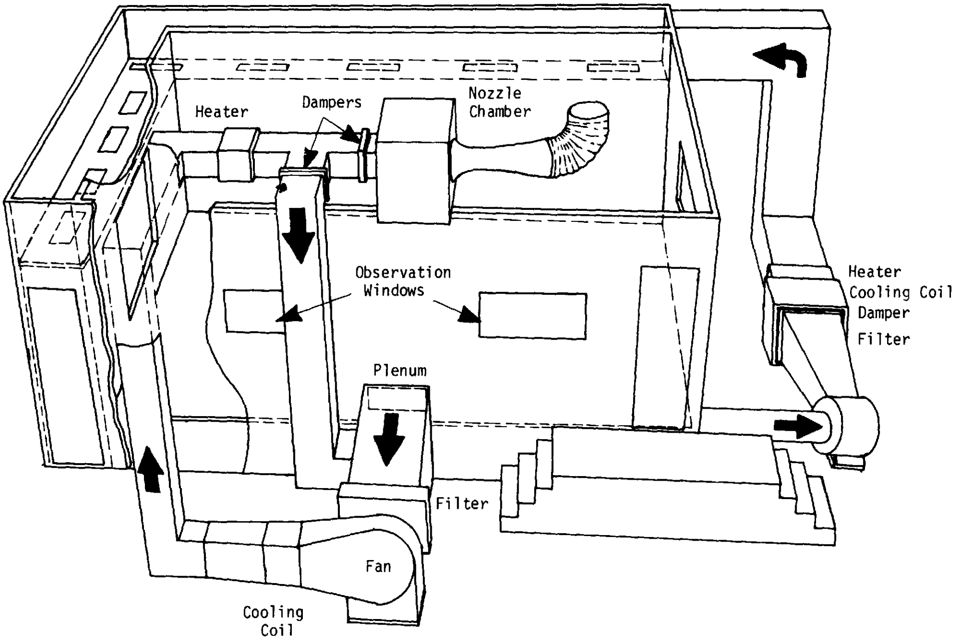


Figure 1.4.1 Test room

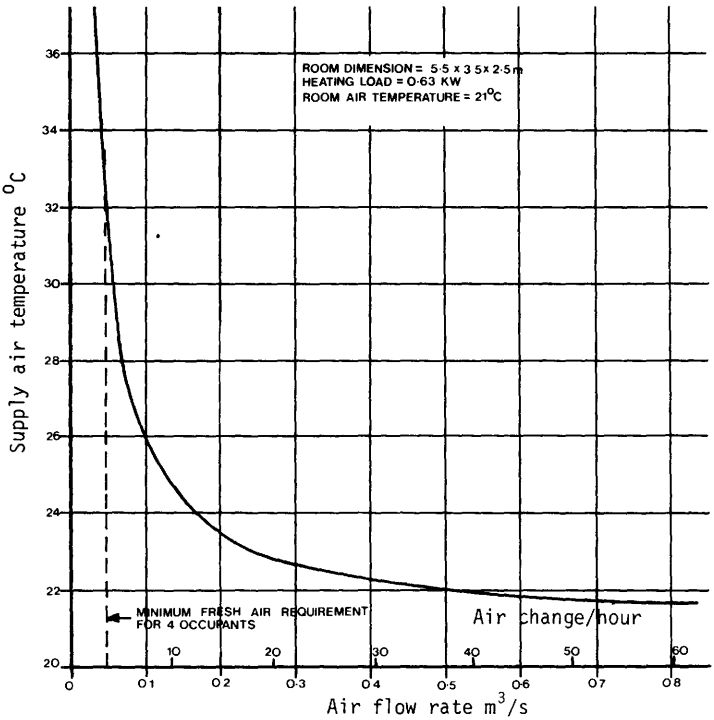


Figure 1.4.2 Variation of supply air temperature with air flow rate for the test room

Air distribution methods for low temperature domestic air heating system

1.4

B S R I A
Old Bracknell Lane
UK — Bracknell, Berkshire RG12 4AH

P.J. JACKMAN

Contract number: EE-A-1-010-UK

In order to know how energy saving is influenced by confort requirements it is important to know what the confort criteria are. A study to that end was carried out. For reasonable confort the dry resultant temperature should be about 21 °C, the humidity between 40 and 70% and the room air velocity smaller than 0,35 m/s. Subsequent air movement studies were carried out in a test room of 5,5 m × 3,5 m × 2,5 m where two perpendicular walls, with a double glazed window of 1,75 m × 1,00 m on the smaller wall, are exposed to temperatures between 1 °C and 20 °C in a climatic chamber. First results showed that conventional low level air inlet systems rarely meet the confort requirements; high level air inlet systems normally do comply.

Fig: a) PLATE WITH WATER CHANNELS

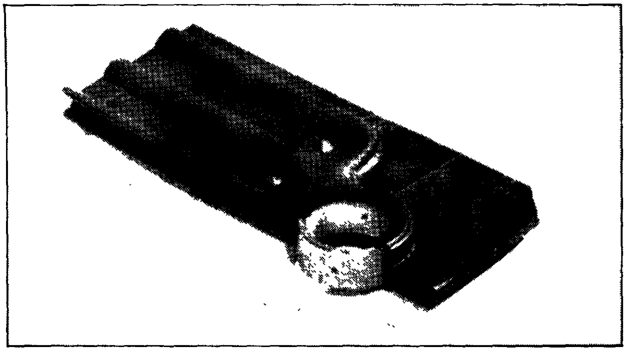


Fig: b) WATER / AIR
HEAT EXCHANGER OF THE 300 WATT MODEL.

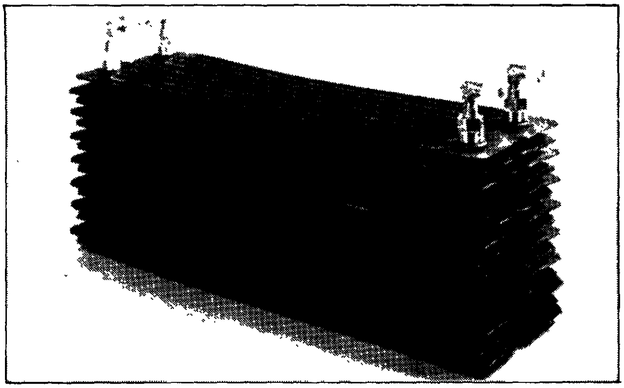


Figure 1.5.1 Plastic radiator

Plastic water/air radiator for domestic heating operation at 50°C

1.5

Laboratoires de Marcoussis
Route de Nozay
F — 91460 Marcoussis

P. DUBOIS

Final report number: EUR 8422 available in French

Contract number: EE-A-1-003-F

A cheap plastic low temperature radiator (50°C) has been developed. Radiator material and production methods have been investigated on a laboratory scale for a plastic with improved thermal conductivity, consisting of a polyethylene matrix with ethylene propylene elastomer and carbon black. Radiator elements have been produced and tested with satisfactory results: a few hundred thermal cycles between 20 and 70°C did not impair the operation of the radiator. The cost of these plastic radiators is 30% lower than for conventional metallic ones. Off factory a 1 kW extruded and heat welded plastic radiator will cost 66 FF and 90 FF respectively. A drawback is the fact that the size is 60% larger than conventional metallic radiators with the same heat output at 50°C.

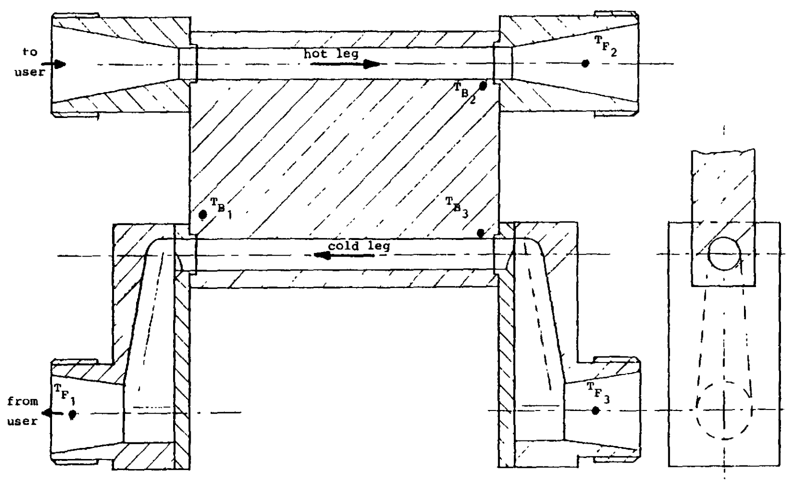


Figure 1.6.1 Design of prototype heat bridge

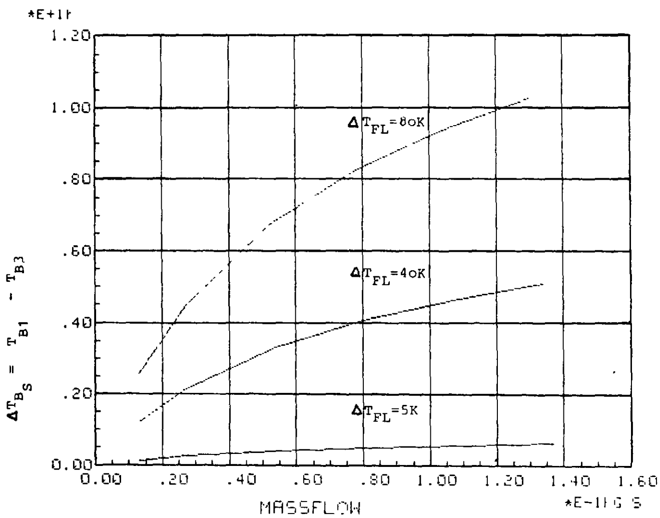


Figure 1.6.2 Temperature difference T_{B1} — T_{B3} as a function of the mass flow in kg/s ($\Delta T_{FL} = T_{B2} - T_{B3}$)

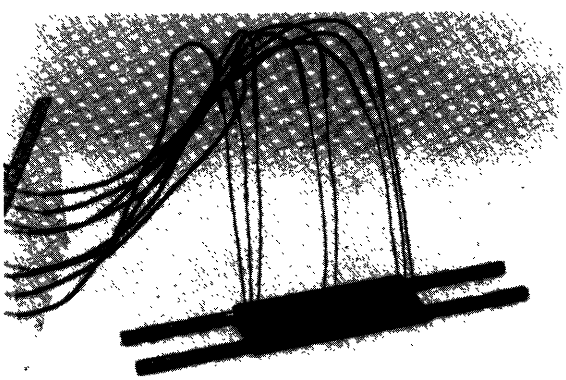


Figure 1.6.3 First heat meter

Heat meter without rotating parts 1.6

Battelle-Institut e.V.
Am Römerhof 35
Postfach 900160
D — 6000 Frankfurt 90

W. GRAMATTE

Contract number: EE-A-1-011-D

Cheap and reliable heat meters are of crucial importance. Up till now heat meters were reliable but expensive or cheap but less reliable. In this and the next project an attempt is made to develop both cheap and reliable heat meters. Generally the heat meter measures the heat consumed by determining the temperature between the incoming and outgoing water and the mass flow of the fluid. The difficult part of the heat meter is the determination of the mass flow. It is mostly measured with moving parts such as rotors which often cause difficulties due to fouling etc. Both methods developed in the EC Programme are therefore based on the determination of the mass flow by static methods.

In this project a heat meter is being developed where a small amount of heat is extracted from the incoming hot water and transferred to the outgoing cold water via a well defined copper slab. This heat flow can be determined from temperature difference of hot and cold water $T_{B2} — T_{B3}$, the heat transfer coefficient (K) of copper and the dimensions of the copper slab. This heat flow equals the heat added to the outgoing cold water which is given by $\mathring{m}\ C_w\ (T_{B1} — T_{B3})$; where $\mathring{m}$ is the mass flow which has to be determined. C_w is the specific heat of water and T_{B3} and T_{B1} are the temperatures of cold water before and after heat is added by the copper slab. With the measured values of T_{B1} and T_{B3} and the given constants C_w and K the mass flow can be determined. This installation is now being tested. A drawback of the system is the fact that temperature differences as small as 0,05°K have to be measured with a 2% accuracy this is at the limit of technical feasibility. Another problem is the non linearity of $T_{B1} — T_{B3}$ as a function of the mass flow.

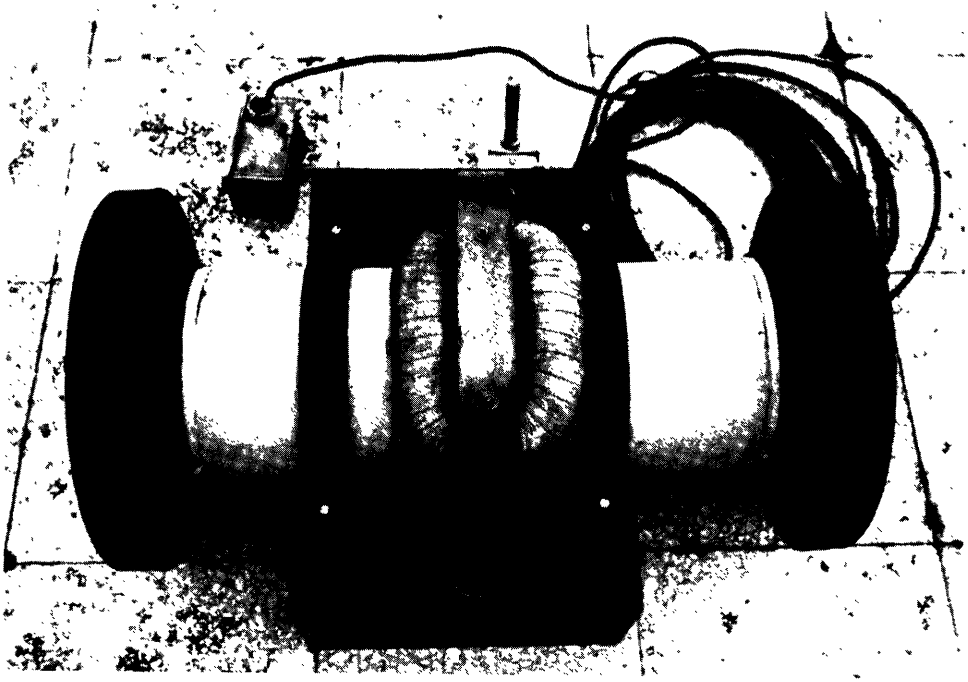


Figure 1.7.1 Heat meter for a four inch tube

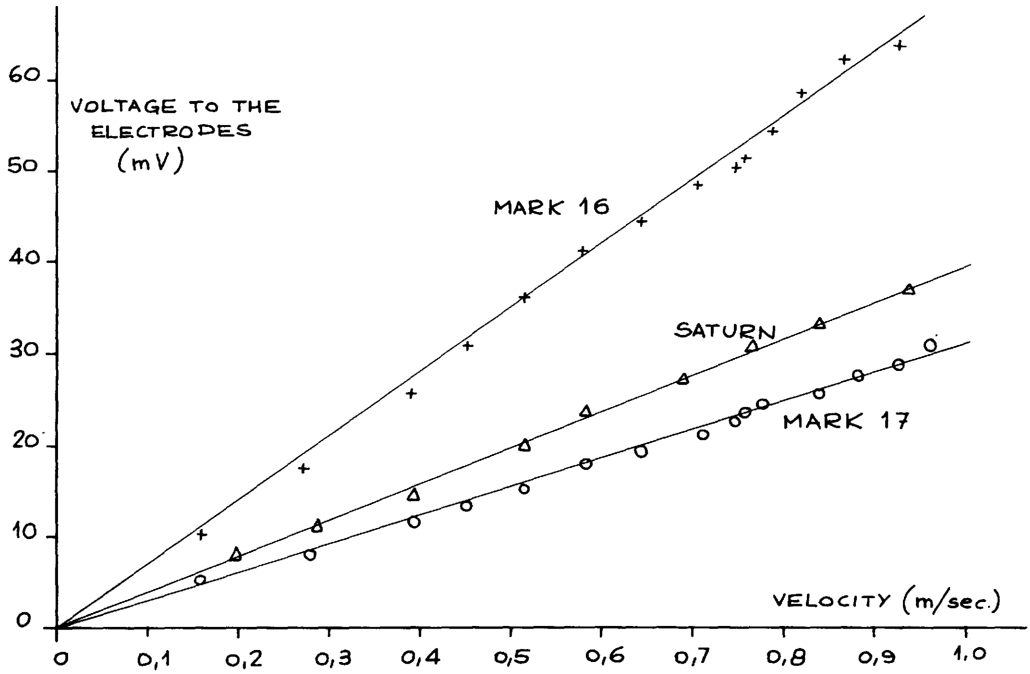


Figure 1.7.2 Performances of three prototype heat meters

Heat meter based on Lorentz force 1.7

Ottico Meccanica Italiana SpA
Via della Vasca Navale 79
I — 00146 Roma

R. LEOPARDO

Contract number: EE-A-1-012-I

Another heat meter is being developed which is based on the Lorentz force. In water normally a small quantity of ions is always present. In a flow of water which is subjected to a magnetic field perpendicular to the water flow direction, these ions experience a force which is perpendicular to both the magnetic field and the flow direction (Lorentz force). With electrodes, one will be able to detect a small current. In this heat meter an electric field opposed to the Lorentz force is regulated in such a way that it compensates this force resulting in a zero current. The electric field is then a measure for the velocity of the mass flow and the mass flow can now be determined if the magnetic and electric field are known. First measurements show a very satisfactory operation in particular at low flow values (0-0,5 m/sec) where most other flow meters are less accurate. The heat meter is now being integrated in a micro processor based control unit which is capable of implementing complex control logics.

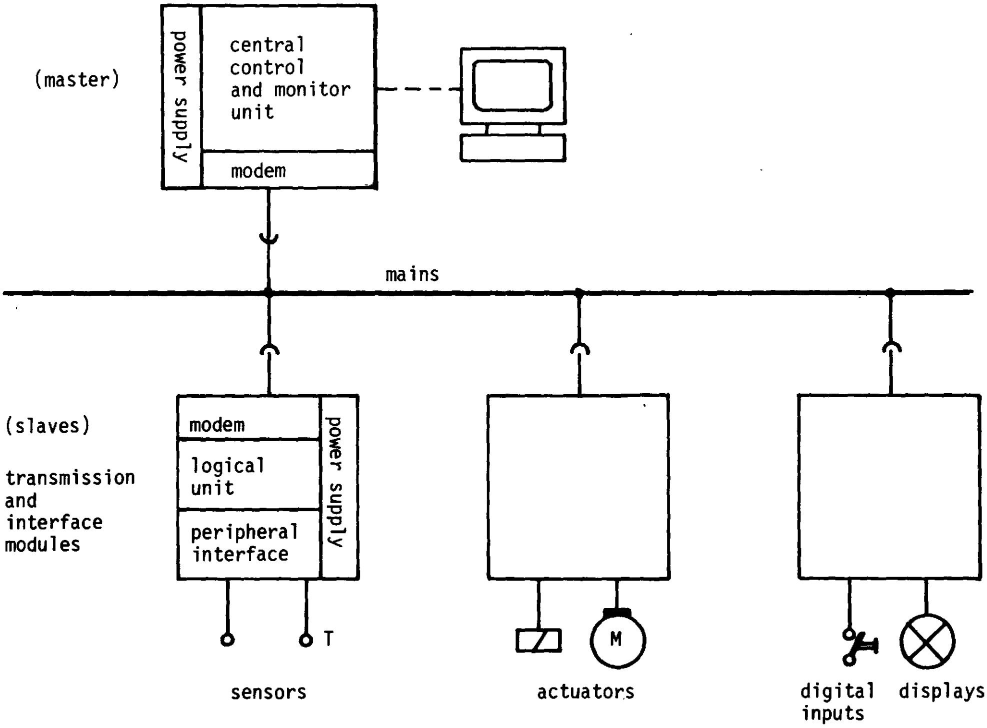


Figure 1.8.1 System concept

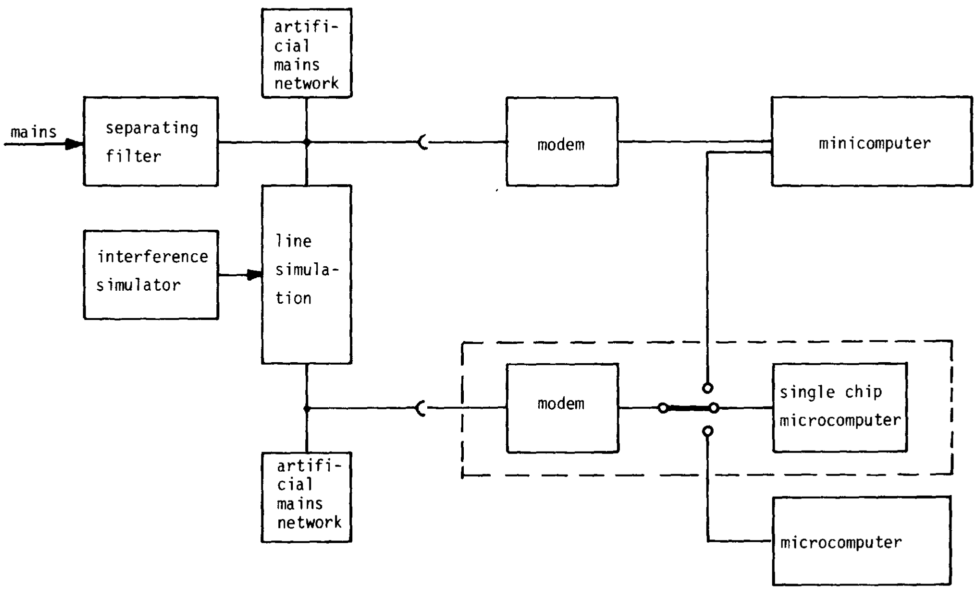


Figure 1.8.2 Experimental arrangement for signal transmission via the electrical house wiring

Transmission of signals for heating control using existing electrical wiring 1.8

Periphere Computer Systeme
Pfälzer-Wald-Strasse 36
D — 8000 München 80

H. RADDE

Final report number: EUR 7939 available in German

Contract number: EE-A-1-004-D

Heating control is a difficult and an expensive part of the heating system. In particular when such a system is retrofitted in existing houses, wiring may be very expensive. It has therefore been investigated whether existing electric wiring could be used for signal transmission. A data transmission system which uses the electrical power wiring has been developed for a small building. It operated satisfactorily: the bit error probability is similar to data transmission via a telephone line and the system response is sufficient for thermal processes as used in a heating system. However due to the long pay back times, the system is commercially not yet attractive. In large buildings with longer distances, with more equipment to be controlled and more devices connected for power use, the control system will not work satisfactorily.

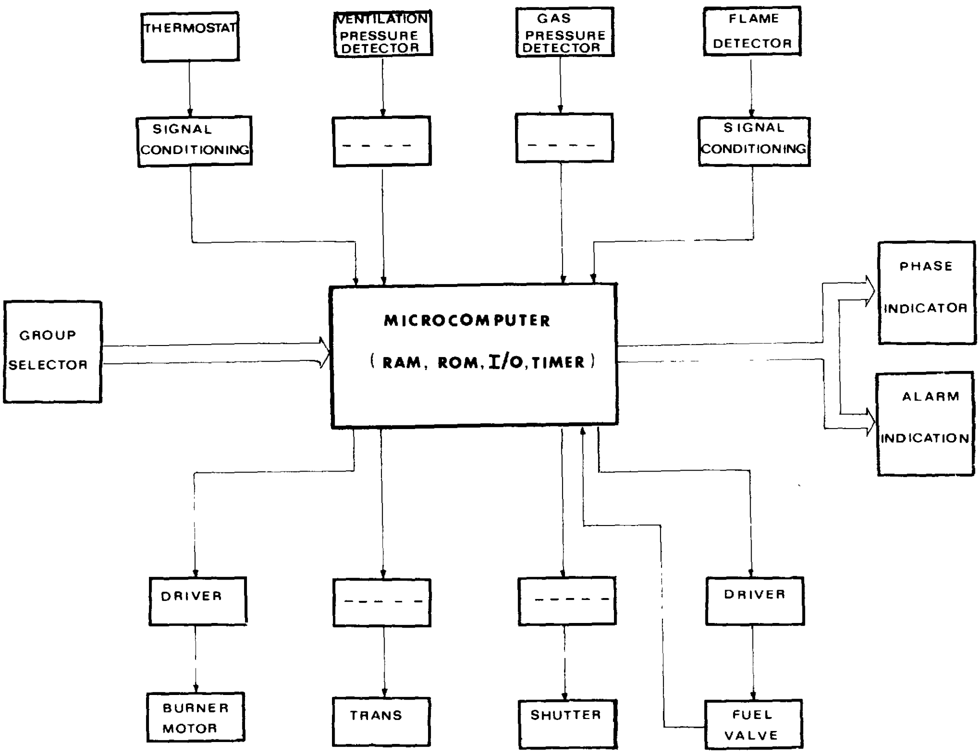


Figure 1.9.1 Block diagram of HECOS 1

Electronic control of combustion and of the total heating system 1.9

Adriatica Componenti Elettronici SpA
Viale della Repubblica, 12
I — 67039 Suimona

F. FONZI

Contract number: EE-A-1-005-I

A heating control system is being developed with electronic control of the burner, thermoregulation and a switch board regulation for the user which allows to determine the desired heating level for a maximum of 15 days. Three control systems are now being developed: HECOS 1 which serves for the control and stochiometric combustion of the burner, HECOS 2 which brings about thermoregulation of the central heating system and HECOS I which is used for an autonomous heating system. The systems are based on a micro processor.

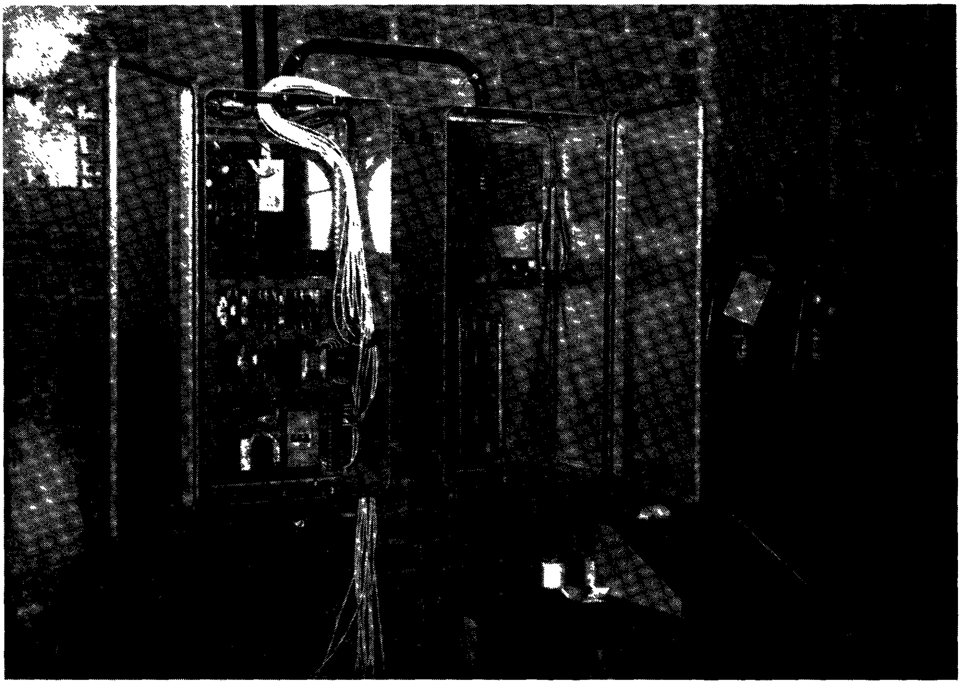


Figure 1.10.3 Central computer

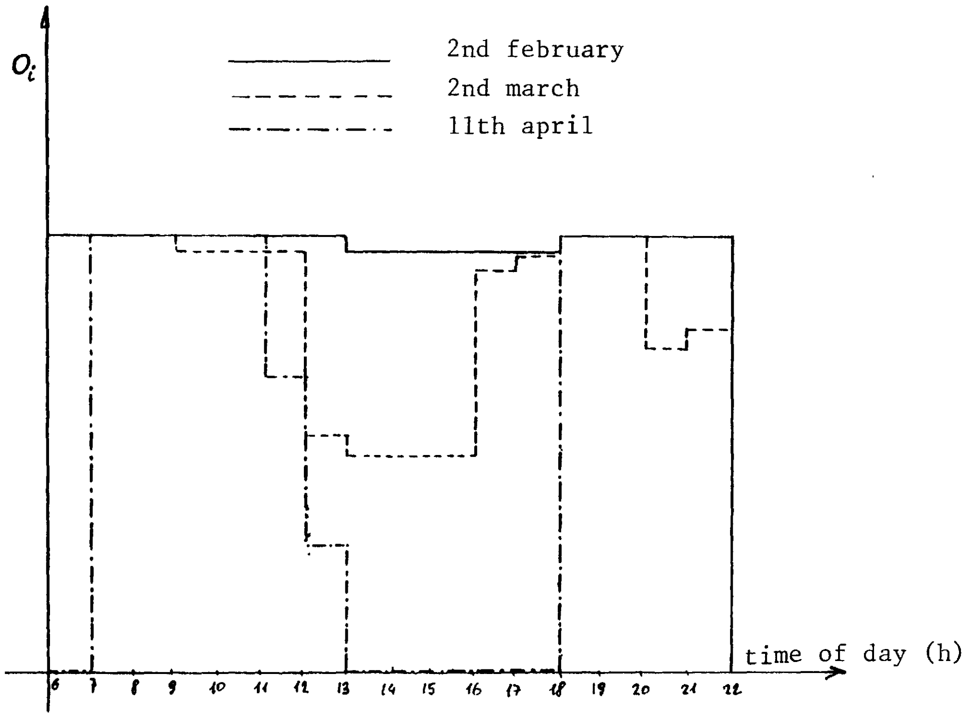


Figure 1.10.4 Learning curves of the computer for occupant behaviour

Heating control in apartment buildings and schools 1.10

CSEA
Via Ventimiglia 201
I — 10127 Torino

G. PAPA

Final report number: EUR 7826 available in Italian and English

Contract number: EE-A-1-009-1

Work by CSEA, a consortium of 23 small and medium sized electronic manufacturers in Italy showed that heating control in apartment buildings and schools can bring energy savings of 20 to 30%. In an existing apartment building with 14 apartments, a control system was installed consisting of a central computer and 14 local micro-processors. This system regulates the temperature in the apartments, taking into account the outside temperatures and the users' requirements. It learns the habits of the users and switches off the heating in an apartment when the users are not present even when they forget to put the heating off. This system of learning was very efficient in reducing the energy use. Also the operation of the boiler is optimized and the whole system is checked regularly to facilitate maintenance. This brought energy savings of about 20%; the pay back time for new and existing buildings is 6 and 10 years respectively. For a school the pay back time was found to be even shorter (2.2 years). The installation of such a control system costs from 600 to 800 ECU per apartment. It is believed that this system is too expensive for single houses. Problems arose with the heating bills which were established with help of computer data. Often users did not agree. Finally the system turned out to be very reliable.

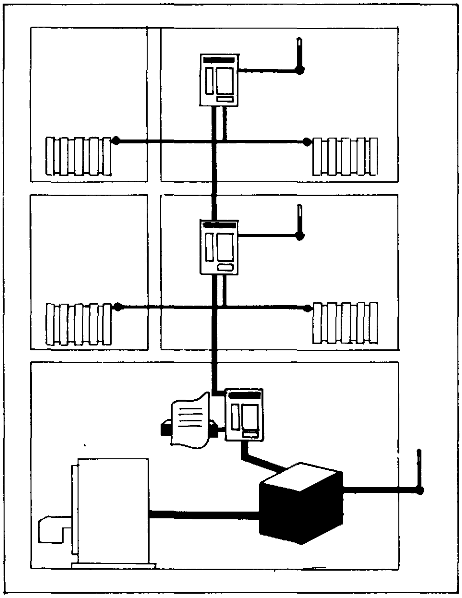


Figure 1.10.1 The system

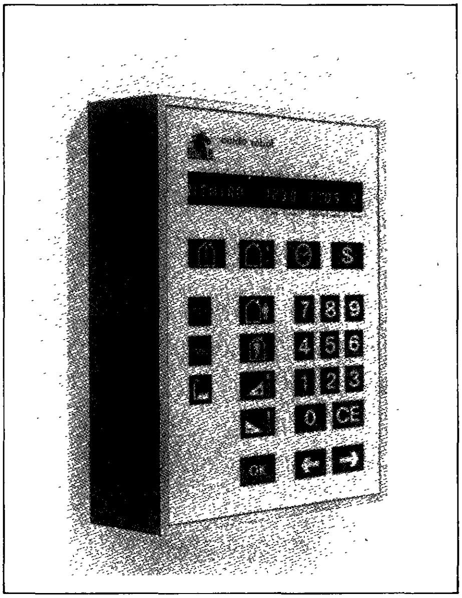


Figure 1.10.2 Microprocessor

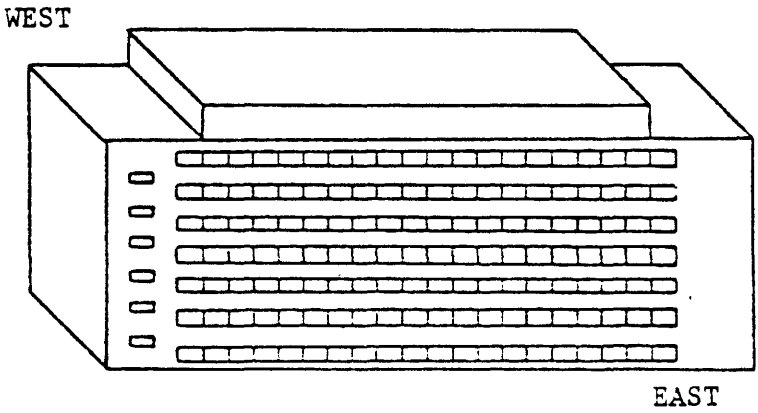


Figure 1.11.1 The 7 storey building which was investigated

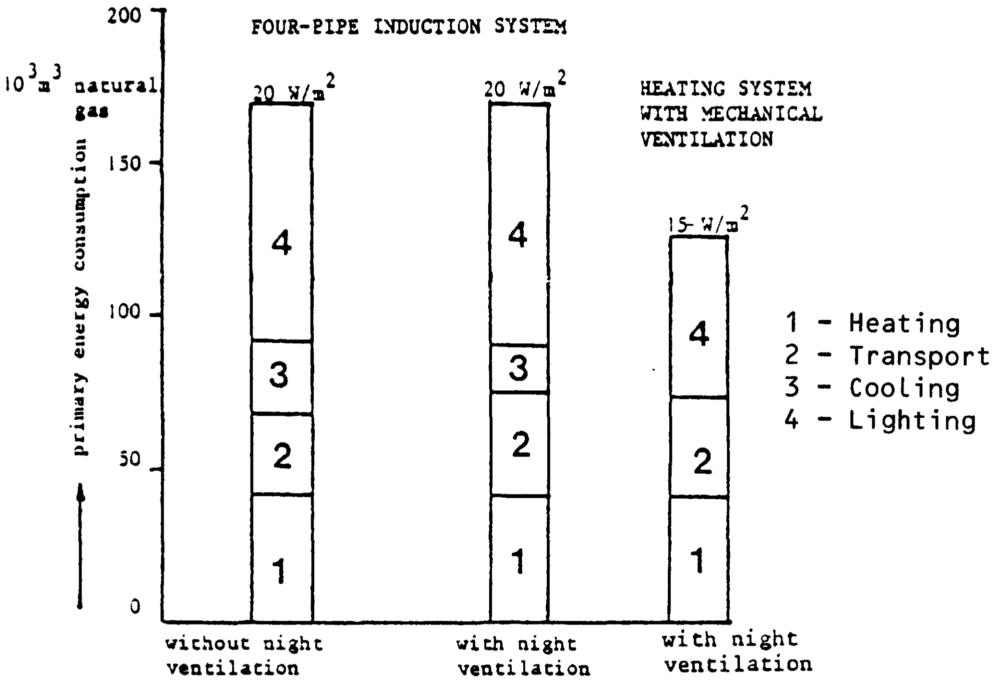


Figure 1.11.2 Energy consumption with and without night ventilation

Use of a microprocessor in an office building to reduce energy consumption for lighting and cooling

1.11

TNO — TH
Technische Physische Dienst
P.O. Box 155
NL — 2600 AD Delft

P. EUSER

Contract number: EE-A-1-006-NL

The reduction of energy use for cooling and lighting in an office building was studied. The building has a volume of 24 000 m^3, double glazing, 40% glass area and inside blinds. The influence was investigated of mechanical ventilation (not cooling) during off office hours, shading and a reduction in lighting on the cooling requirements of the building. It was found that no energy was saved with mechanical ventilation as the energy consumed by the fan was about equal to the decrease in energy use for cooling. On the other hand a reduction of lighting from 20 W/m^2 to 15 W/m^2 brought considerable energy savings ($\pm$ 25%) due to the fact that cooling was no longer required and the energy for lighting was reduced. The reduction of lighting will be brought about by a control system which switches off the light when the day light level is above 700 Lux. To this end a light sensor was selected; a light dependent resistor which is very cheap. Measurements were made to find relations between the sensor signal and the day light level in different parts of the room. Also human behaviour and acceptable lighting levels are being studied. The remaining time will be spent on the development of a control system which integrates the air conditioning plant and the regulation of lighting.

Fire resistant insulating materials for buildings using a phenolic resin of the type NOVOLAQUE in the form of reinforced foam 1.12

Laboratoires de Marcoussis
Route de Nozay
F — 91460 Marcoussis

P. DUBOIS

Contract number: EE-A-2-013-F

Many insulating materials are already commercially available on the market but problems still exist. Most of these insulation materials are inflammable, prone to humidity and water vapour and their insulation properties deteriorate with time.

The problem of inflammability was tackled by MARCOUSSIS, France which developed a non-inflammable, glass fibre reinforced, insulating foam of the type NOVOLAQUE (phenolic-resins). This foam is produced without acid catalyst (thus avoiding corrosion) and can be produced in a continuous process. Different properties (density, porosity, thermal conductivity, mechanical properties) of NOVOLAQUE have been tested as a function of different additives. The best material up till now had a density of 80 kg/m^3 and a thermal conductivity of 0,04 W/m^{o}K. The material was inflammable only under very extreme conditions. The cost per m^3 of phenolic foams with a density of 80 Kg/m^3 is 1,25 higher than polyurethane with a density of 40 Kg/m^3 and 5 times higher than polystyrene which normally has a density of 20 Kg/m^3. To improve economic feasibility phenolic resins will have to be developed with a lower density.

The use of bituminous materials to make insulating materials in granules and fibres waterproof

1.13

Industria Italiane Petroli SpA
Piazza della Vittoria 1
I — 16121 Genova

V. CASTAGNETTA

Contract number: EE-A-2-017-I

Another problem is the deterioration of the thermal insulating properties of polystyrene due to humidity and polluting agents in the air. A method was developed to solve this problem by coating the granular polystyrene with an impermeable and protective bituminous binder, which also binds the particles together into panels. Two methods were used: a hot method where polystyrene granules were mixed with hot bitumen and a cold method where granules of polystyrene were mixed with a bituminous emulsion at room temperatures. Both methods gave very satisfactory results. The cold process is here of particular interest as it uses less energy and causes less air pollution than the hot process. Bituminous board uncovered and covered with aluminium paper gave a thermal conductivity of 0,040 and 0,044 Kcal/hm°C against 0,036 Kcal/hm°C for normal polystyrene. The sound insulation improved from 22 dB for normal polystyrene to 39 dB. Aluminium paper covered bituminous polystyrene board is self extinguishing in two minutes whereas normal uncovered polystyrene is very inflammable. Different aging tests did not change the thermal properties of the bituminous board. (500 hrs exposure to salt spray and weather-o-meter, five 24 hrs cycles of exposure to sulfurous anhydride, 160 hrs exposure to urban gases (CO, NO_2, SO_2, Cl_2) and hydrocarbon vapours (xylene, n-decane). The manufacturing process should now be tested in a pilot plant.

Measures to reduce the deterioration with time of insulating properties in rigid polyurethane foams **1.14**

CSTB
24, rue Joseph Fourier
F — 38400 St-Martin-D'Hères

G. ROUX

Contract number: EE-A-2-015-F

Also for polyurethane the insulating properties deteriorate with time. CSTB/CENG, France found that after 14 days of accelerated aging at 70° and with a humidity of 95%, the thermal conductivity increased by 20-30%. (density ± 25 Kg/m^3.) The influence was investigated of different types and quantities of raw material for the production of polyurethane (7 catalysts and 12 tensioactives). Unfavorable combinations resulted, after weathering, in a value for the thermal conductivity of 35 mW/m°K whereas a suitable combination of catalysts and tensioactives gave, after weathering, a much better thermal insulation (25 mW/m°K). The water content in the mixture does not influence the cell geometry nor the thermal conductivity but has a marked influence on reactivity, density and dimensional stability of the foam. The dimensional stability decreases when the water content goes from 0% to 4%. Finally in preliminary tests it was investigated whether it is possible to decrease the gas diffusion through cell walls by adding a reactive additive; a compound with hydroxyl groups which reacts with isocyanate.

Contract number: EE-A-2-027-F

This follow-up contract further investigates how the thermal conductivity of the foam can be further decreased by influencing the diffusion of gases through the cell walls with help of chemical compounds with hydroxyl groups.

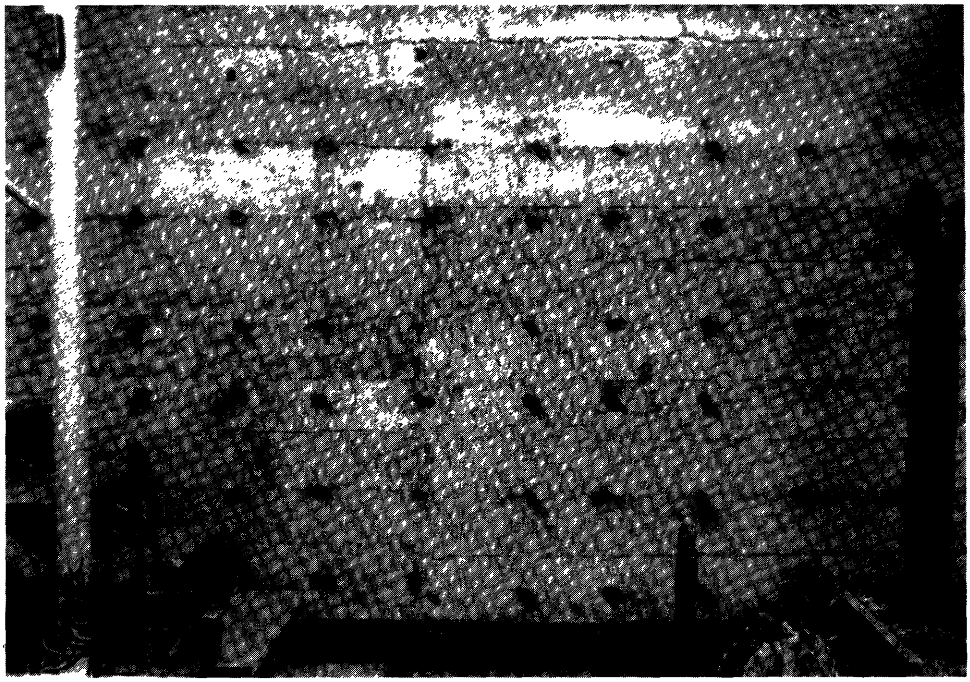


Figure 1.15.1 Detail of the lower wall with heat conducting rods

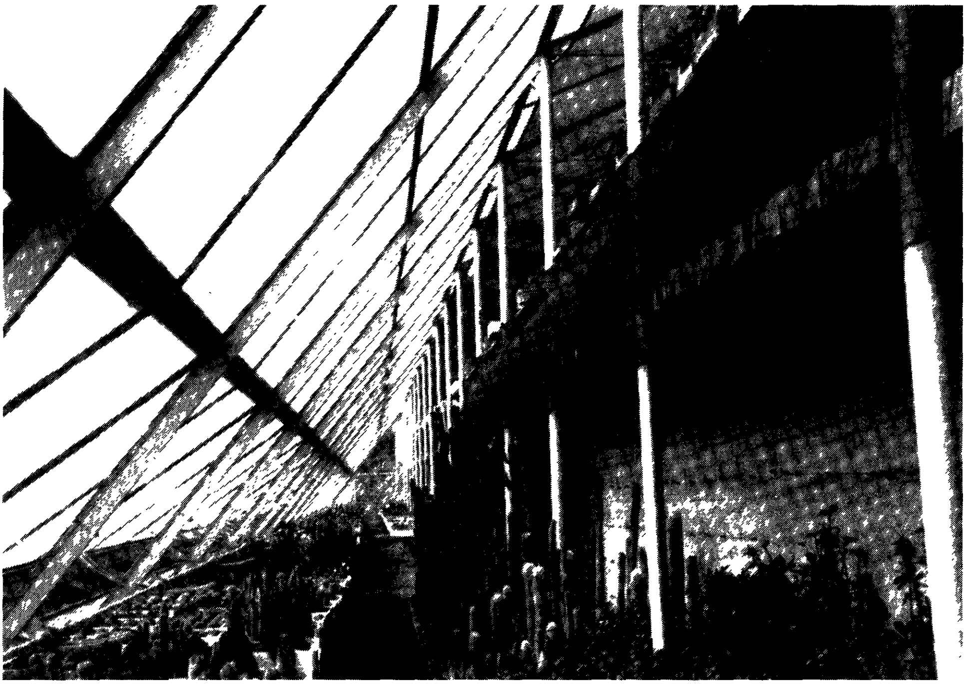


Figure 1.15.2 Internal view of a greenhouse with heat storing walls

Study of new building materials with a high thermal diffusivity to accumulate heat   1.15

Luigi Rossi — Arco Srl.
Viale Romagna, 14
I — 20133 Milano

A.M. TONELLI

Contract number: EE-A-2-016-I

Transverse thermal diffusion of conventional walls can be increased by inserting metal rods perpendicular to the wall surface. On the basis of this assumption new building materials have been proposed; this in order to increase the amount of heat that can be stored in the wall. A part of the research deals with the computer simulation of the thermal behaviour of the new building elements. To this end a computer simulation model was developed which allows an optimization of the wall geometry and of the distribution of metal rods, in order to achieve the highest possible heat storage. This computer model is now being experimentally validated. Four large heat storage walls of concrete and iron have been built inside two green houses in order to obtain experimental data and to investigate the suitability of the applied materials.

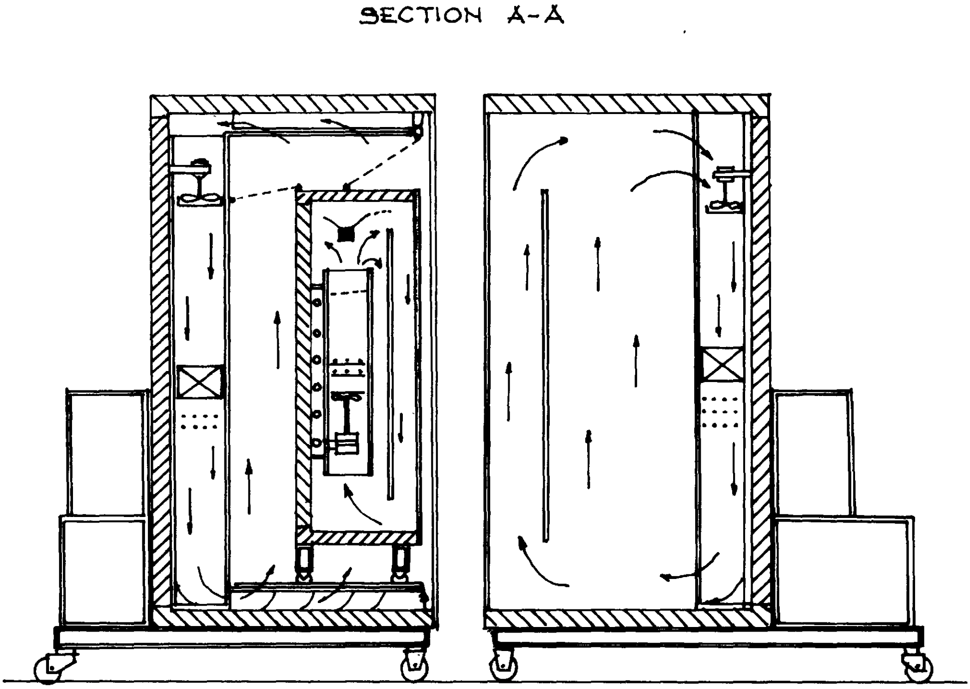


Figure 1.16.1 Thermoregulation group

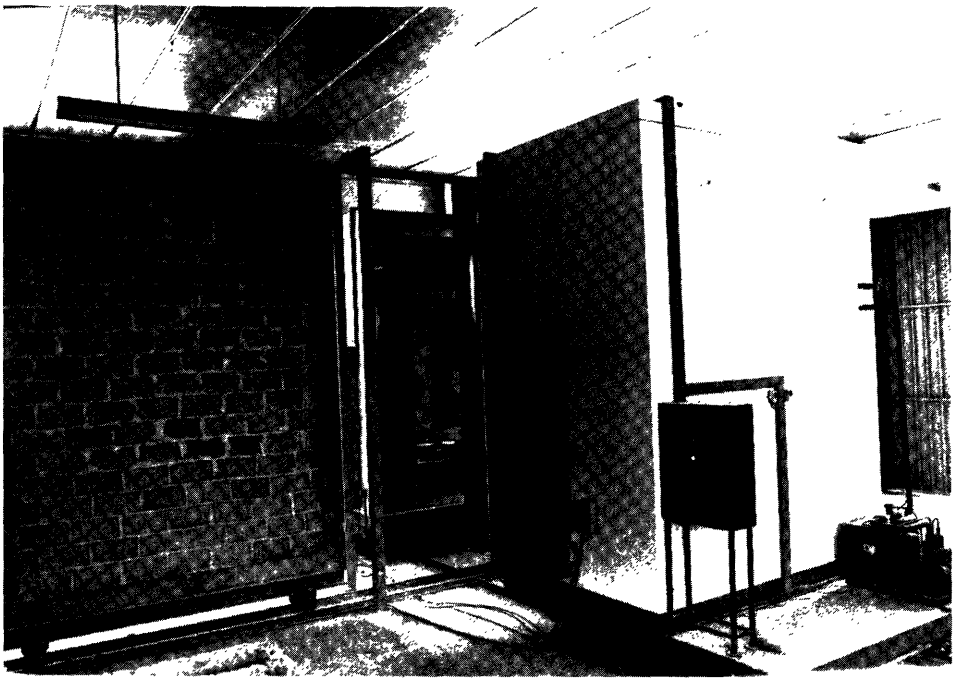


Figure 1.16.2 Thermoregulation group

Lifetime testing of low cost insulating panels 1.16

Instituto Sperimentale per l'Edilizia
P.O. Box 7237
I — 00100 Roma Nomentano

D. FONTANA

Contract number: EE-A-2-014-I

The effect of accelerated aging and vibrations on insulation in different types of walls is being studied. Aging is simulated by a series of cycles with a sudden climb of the wall temperature to 70°C, which is then kept constant for 3 hours and is followed by rapid cooling to 15°C. Vibrations are induced vertically and simulate the spectrum and intensity of vibrations caused by road traffic. The following types of walls are being investigated:

- Heavy concrete with insulating material (fibrous or expanded plastic foam panels).
- Lightweight concrete with insulating material (fibrous or expanded plastic foam panels).
- Clay brick with insulating material (fibrous or granulated or expanded plastic foam panels) or without insulating material.
- Porous clay brick with insulating material (fibrous or granulated or expanded plastic foam panels) or without insulating material.
- Two different types of insulated metal paneling.

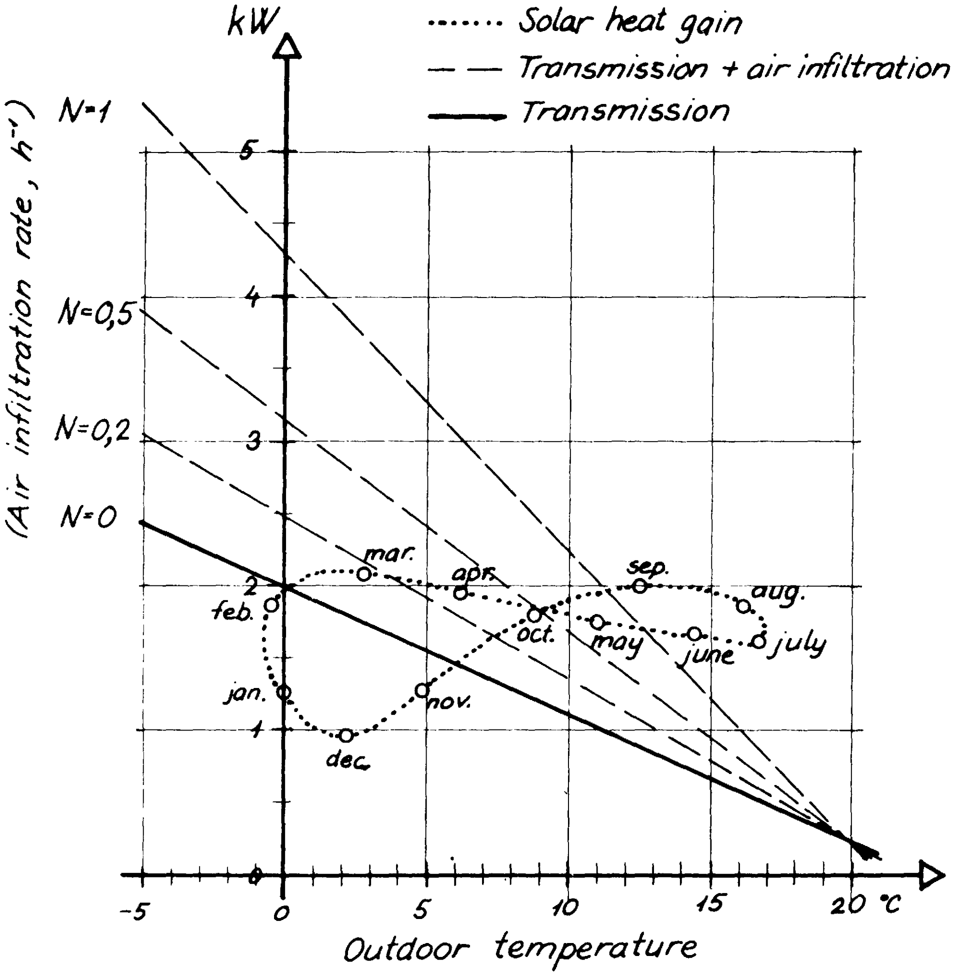


Figure 1.17.1 Powerconsumption and solar heat gain in a well-insulated house:

Area	125 m^2
Glass-area	12 m^2
Volume	337 m^3
Indoor	t = 20 °C
Ground	t = 8 °C

U-values	
Outer walls	0,13 W/m^2 °C
Windows, doors	2,6 W/m^2 °C
Roof	0,10 W/m^2 °C
Floor	0,17 W/m^2 °C

Improved retrofitting methods for insulation 1.17

Byggeteknik
Technological Institute
Department for Building Technique
P.O. Box 141
DK — 2630 Tåstrup

P.F. COLLET

Contract number: EE-A-2-023-DK

The objectives of this project are:

— Development of a measuring methodology with which the "Building Energy Signature" (BES) can be determined. The BES will be determined before and after post-insulation of 50 existing houses in order to check the efficiency of post-insulation.

— Development of cheaper post-insulation methods.

— Improvement of methods for cavity wall insulation.

A simple steady state computer simulation model was developed, taking into account: air infiltration, transmission losses and gratuitious energy from solar irradiation. With this model it was shown that solar radiation gives a considerable contribution. The BES of a house can therefore not only be given by the outdoor temperature and the working period of the heating system as a function of time, but should also include solar data. A computer controlled measuring system CAREN is now being developed which is able to determine all required parameters for BES determination. Measurements in the 50 houses will be carried out in the winter 1983/1984.

In collaboration with two insulation manufacturers post-insulation of roofs is being investigated, measurements will be carried out in the winter 1983/1984.

In order to check the quality of insulating material a method has been developed by which the insulation properties can be determined. They depend on the average cell size and the percentage of the volume which is occupied by air. These data can be determined with a microscope.

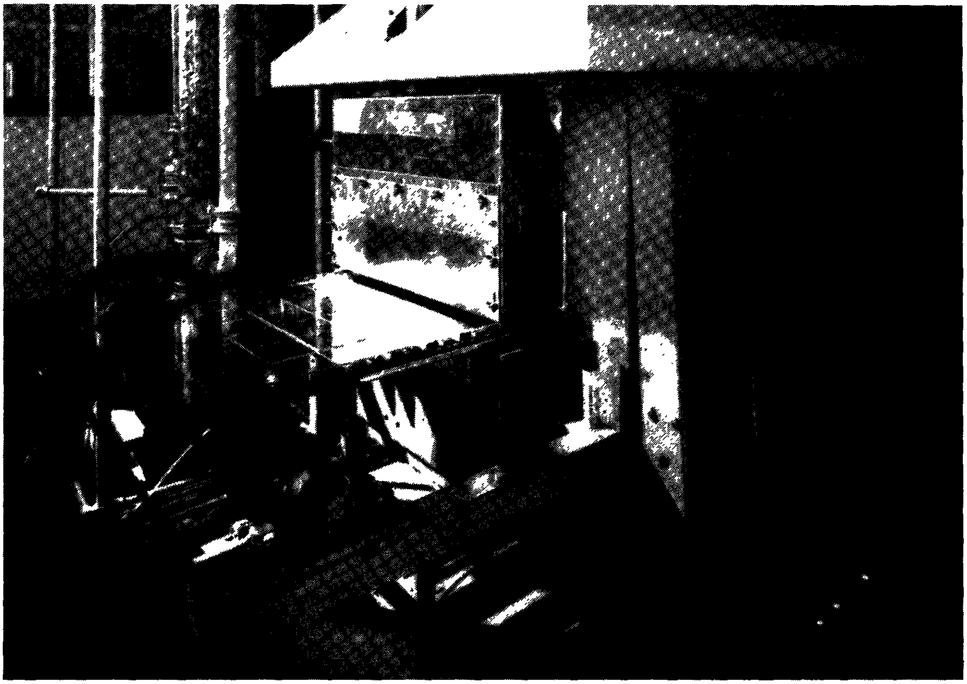


Figure 1.18.1 Glass pane inserted in the PYROSOL glass coating machine

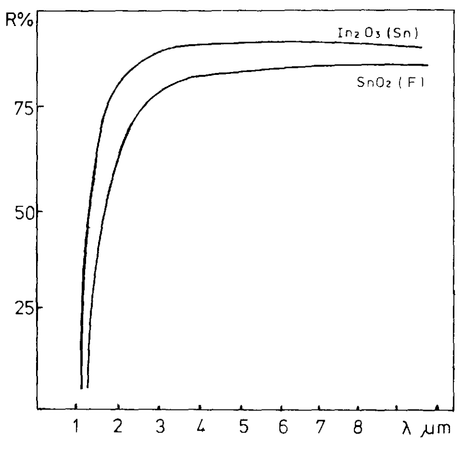


Figure 1.18.2 Infrared reflection of selective coatings

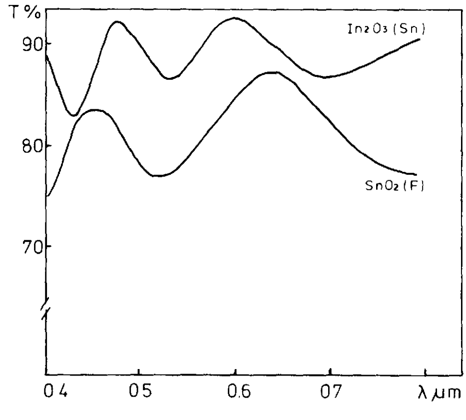


Figure 1.18.3 Selective coatings optical transmission in the visible range

Infrared reflective window coating (heat mirror) by the PYROSOL process 1.18

C E A
CENG/SEM/LEMM
85 X
F — 38041 Grenoble Cedex

G. BLANDENET

Contract number: EE-A-2-022-F

The CENG, France developed a process (PYROSOL) by which glass-panes are coated with layers which are transparent for visible light and which reflect heat radiation. In this way heat is kept in the house and the heat insulation of a single window pane with this type of coating equals roughly that of a double window. In this process tin oxyde and indium oxyde are used. A drawback of indium oxyde is the high cost and for tin oxyde the low performance. In order to reduce the cost and improve the performance, mixtures of indium and tin oxyde (ITO) were investigated. Both tin oxyde and ITO coatings have been tested on a double window where the external glass-pane was coated on the inside (see table). The cost of this process is rather high but there is good hope that a considerable reduction is possible by using cheaper solvents.

	Tin oxyde (E = 0,2)	Indium Tin oxyde mixture (E = 0,15)
Heat transmission coefficient	2,2 W/m^2°C	1,9 W/m^2°C
Transmission for visible light	69%	75%
Cost (now)	38 FF/m^2	55 FF/m^2
Estimated future cost	4 FF/m^2	10 FF/m^2

Properties of a double window where the external glass-pane is coated on the inside and the cost of window coating.

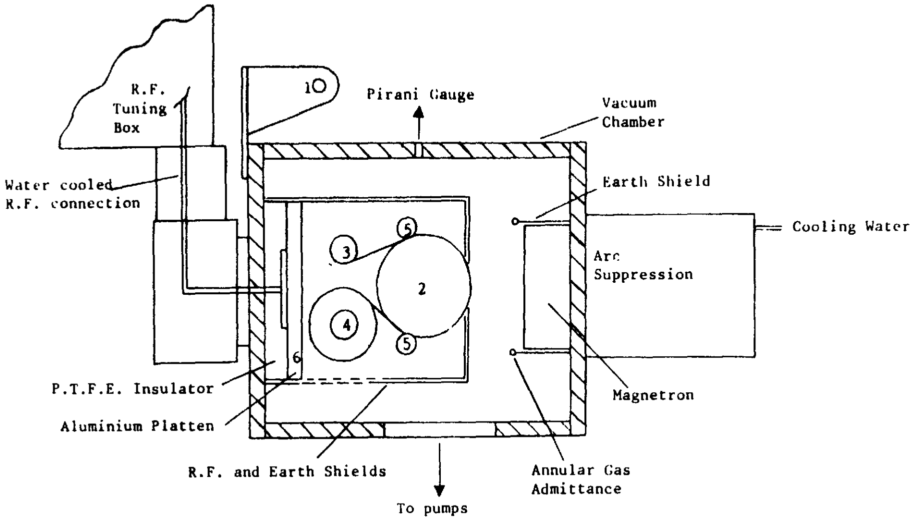


Figure 1.19.1 The roll-to-roll coating apparatus detail and vacuum system showing the magnetron source in position

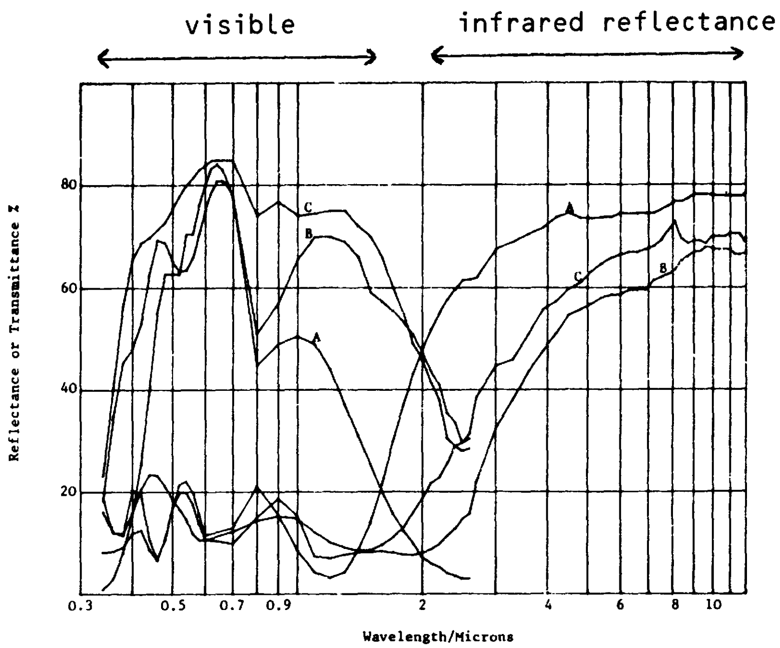


Figure 1.19.2 The selective optical properties obtained with (A) indium 10% tin oxide, (B) indium oxide and (C) cadmium 2:1 tin oxide

The production of infrared reflective coatings on plastic sheets

1.19

University of Technology
Department of Physics
UK — Loughborough Leicestershire LE11 3TU

R.P. HOWSON

Contract number: EE-A-2-021-UK

Window coating can only take place in the factory. In existing houses therefore complete window panes have to be replaced. This is expensive and in order to avoid this problem it was decided to develop coated plastic sheets which can be easily fixed on windows. R and D by the UNIVERSITY OF LOUGHBOROUGH, United Kingdom resulted in a technique for coating plastic sheets. A problem was the low transparency for visible light which was only 60% for $TiO_2/Ag/TiO_2$ coatings but which was improved to 75% using mixtures of cadmium and indium oxydes. It was also found that single windows, with a coated plastic sheet, reflect the heat radiation so well that they remain cold and are covered with condensation water which is opaque for heat radiation and spoils the effect of the heat reflective layer. Coated plastic sheets are therefore not very efficient heat mirrors when they are fixed on single windows. They may however be used as second windows. A combination of a glass-pane with a coated plastic sheet at a distance of 20 mm has a heat transmission coefficient of 2 $W/m^{2o}K$. Such a window has the advantage of being light and cheap. (The cost of coated plastic is 1-1,5 ECU/m^2). As the coating is resistent against scratching it may also be used on rolling blinds.

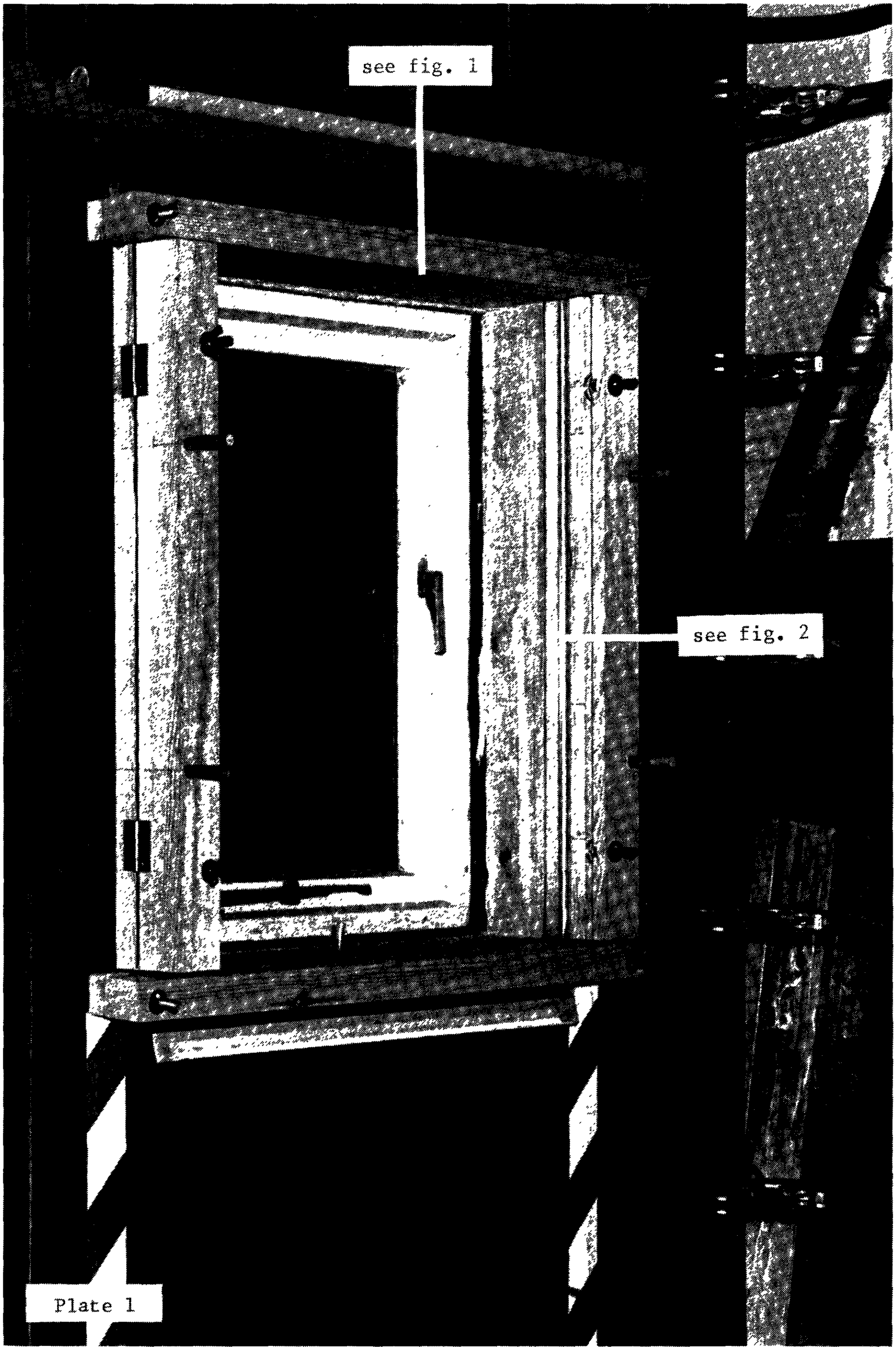


Figure 1.20.1 Test window

Insulating blinds for windows 1.20

The Polytechnic of Central London
35, Marylebone Road
UK — London NW1 5LS

J.G.F. LITTLER

Contract number: EE-A-2-020-UK

Another way to reduce heat transmission through windows is the use of shutters or blinds during the night. Here however human behaviour plays an important role: if the handling of the shutters is not very simple the shutters or blinds will not be used. The blinds or shutters should also be suitable for retrofitting in existing houses. In this project a roller blind is being developed which can be drawn down at the inside of windows and which consists of a few millimeter of insulating material. Computer simulation showed that for a simple window with a rolling blind a heat transmission coefficient of 1 $W/m^{2o}K$ may be expected. This included the assumption that the blind is coated with heat reflective layers. The blind will be designed in such a way that the edges are sealed when the blind is completely drawn, so that air infiltration in the house is also considerably reduced (a 40% reduction for average U.K. houses). Different types of seals have been tested using a plastic film as a blind. Magnetic and EDDM synthetic rubber seals turned out to be most effective. A prototype blind is now being constructed.

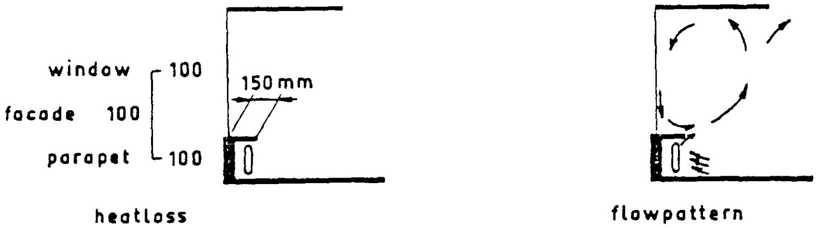


Figure 1 : Reference situation

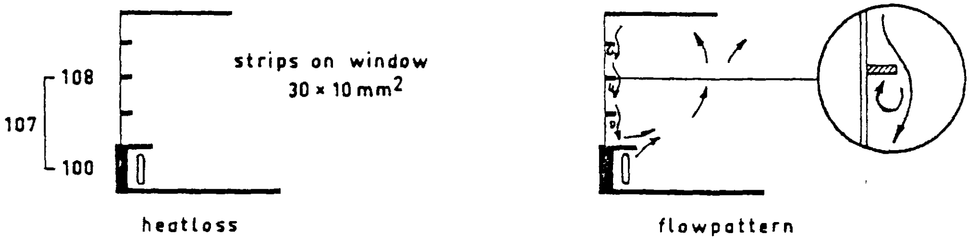


Figure 2 : Horizontal disturbance on the window

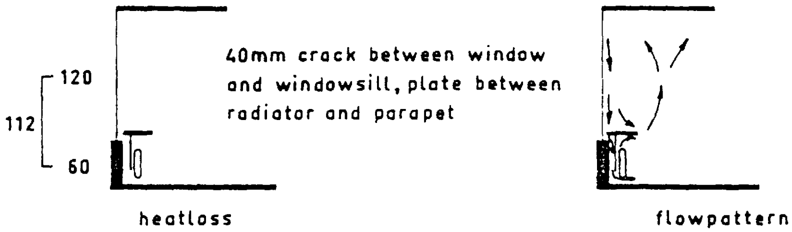


Figure 3 : A part of the cold air from the window flows along the parapet and the radiator

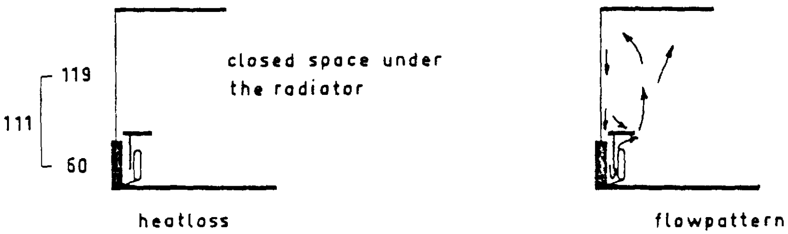


Figure 1.21.1 Some of the situations investigated

Energy saving by using rolling shutters in houses 1.21

T N O
Research Institute for Environmental Hygiene
P.O. Box 214
NL — 2600 AE Delft

M. DUBBELD

Contract number: EE-A-2-019-NL

In this project different combinations of curtains, roller blinds, windows, window-sill and radiators have been studied. The results of experiments carried out in a test room at TNO are:

— Horizontal strips which disturb the cold draft along the window don't bring energy savings.

— An opening between the window and the window-sill above the radiator give considerable energy losses, in particular if the curtain above the window-sill is closed. Such an opening must be avoided.

— The use of reflective material on the parapet (U value ~ 1 $W/m^{2o}K$) gives a decrease in heat loss through the parapet of 20-25%.

In the BRONSWERK AIRCONDITIONING RESEARCH CENTRE, 26 different shutterwindow combinations have been investigated in a testroom. For a single glass window without and with a rolling shutter, the U values were 4,8 W/m^2K and 3,49 $W/m^{2o}K$ respectively. For a double window these values were 2,3 $W/m^{2o}K$ and 2,07 $W/m^{2o}K$, and for a rolling shutter which has a reflecting surface, the U values for the combination with double windows decreases to 1,74 $W/m^{2o}K$.

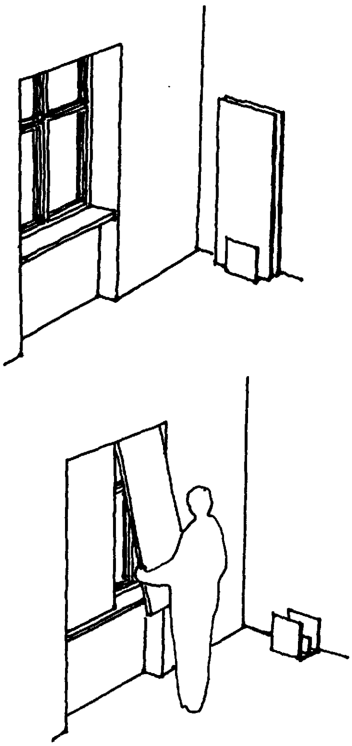


Figure 1.22.1 Internal shutters for existing buildings

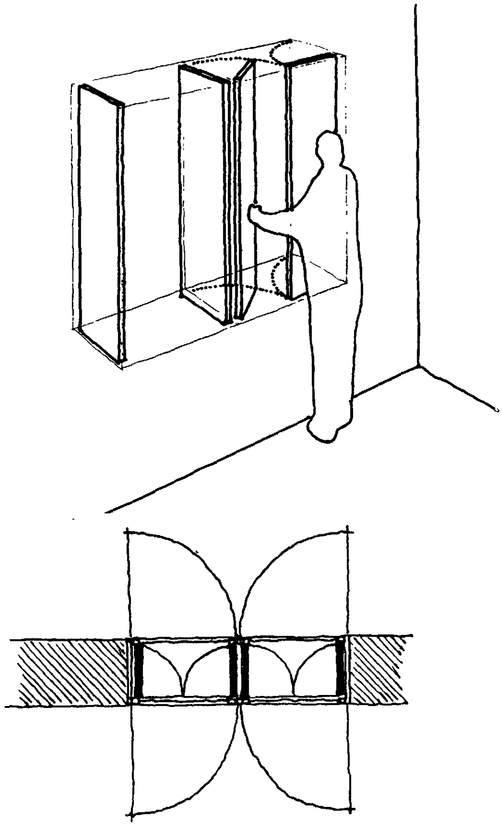


Figure 1.22.2 Internal shutters for new buildings

Mobile insulation of windows **1.22**

The Technical University of Denmark
Building 118
DK — 2800 Lyngby

M. BYBERG

Contract number: EE-A-2-018-DK

The final prototype design for two types of shutters—one for existing buildings and one for new buildings—is now finished. The shutters are now being constructed and consist of polyisocyanurate cellular plast foam (PIR) which has a very low thermal conductivity. Special attention has been paid to the joints around the shutters to secure a high level of air-tightness. Both shutters have to be removed during daytime. For the new buildings the U values of the window during day and night are 2,3 $W/m^2{}^\circ C$ and 0,83 $W/m^2{}^\circ C$ respectively. The annual energy saving in an everage Danish house (window area: 20 m^2) will be around 1 400 kWh. For the existing building the day and night U values are 2,9 $W/m^2{}^\circ C$ and 0,68 $W/m^2{}^\circ C$, and the corresponding energy saving will be 2 300 kWh (120 m^2 house with 20 m^2 window area). The shutters used in the existing house have the drawback that the handling of the shutters is not simple and that space must be available for the shutters during the day. Testing of the shutters will be carried out in a cold/warm test box; these tests will include durability tests.

Contract number: EE-A-5-061-F

In this follow-up contract it will be experimentally established whether the calculated energy savings can be achieved by regulating the ventilation in such a way that the CO_2 content or the water vapor content are kept below a certain value. Experiments will be carried out in a very tight house of 100 m^2 equipped with controlled mechanical ventilation.

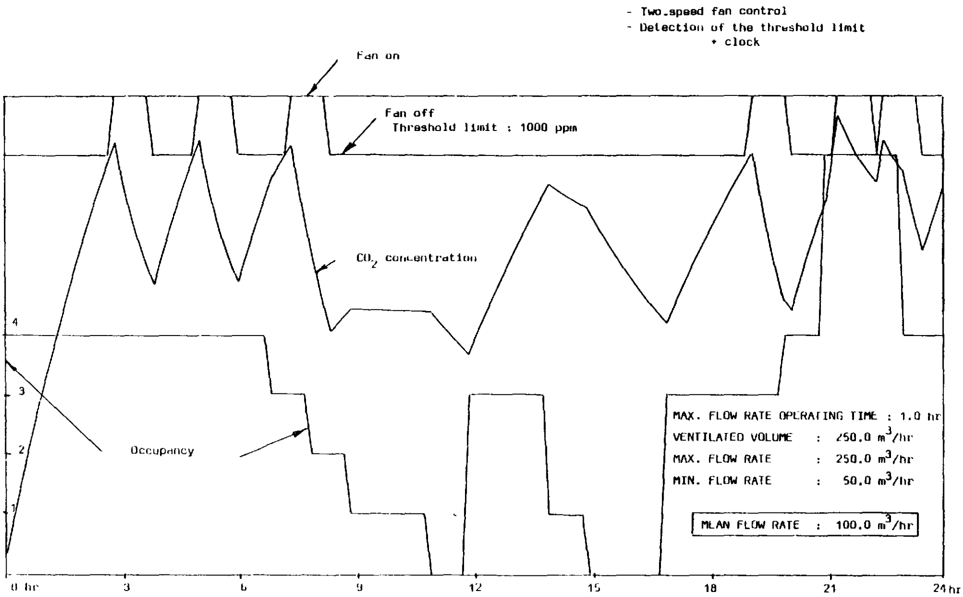


Figure 1.23.1 Computer simulation of CO_2 controlled ventilation in an apartment of 100 m^2

Ventilation control of buildings based on the measurement of the CO_2 content in extracted air 1.23

Société Bertin & Cie
Division Energétique
Boîte Postale 3
F — 78373 Plaisir

O. SOUPAULT

Final report number: EUR 8461 available in French

Contract number: EE-A-5-053-F

If transmission losses have been reduced by insulation of walls, roofs and windows, air infiltration which normally already accounts for 30-40% of the heat losses in a house, will play an even more important role. Air infiltration losses can be reduced by making houses so tight that heat losses are considerably reduced. Much however depends on the behaviour of the persons living in a house; if they open windows and doors frequently, the effect of a tight house is spoilt. Moreover for health reasons the exchange rate of air is not allowed to be lower than 1/2 to 1 volume changer per hour. Under these regulations reduction of heat losses by air infiltration is only possible if the house is made as tight as possible and air infiltration occurs by controlled ventilation where incoming air is heated by outgoing air via a heat exchanger. In smaller houses this again will not work due to human behaviour, and also the cost will be too high.

A still different approach is being developed by BERTIN, France. It starts from the assumption that an air exchange rate of 1/2 to 1 h^{-1} for health reasons is a rather arbitrary measure. When nobody is in the room the air exchange rate may well be much lower. A better measure could be the CO_2 content in the different rooms. The control of the CO_2 level with a CO_2 detector which is coupled to simple ventilation holes, which may be opened and closed, would allow to keep the CO_2 level below an acceptable value ($<$ 1 000 ppm). With such a control system the buildings can be very tight and a considerable amount of energy may be saved. Such a system may be suitable for large buildings such as conference buildings. (In domestic buildings humidity may turn out to be a problem and the control of the water vapor content could be another way to regulate the ventilation).

Several techniques for measuring the CO_2 concentration have been investigated in order to select a low cost CO_2 sensor; this study led to the conclusion that the infrared absorption technique is able to meet the requirements. Computational simulation showed that CO_2 based ventilation control could lead to a pay back time which is only half the pay back time of an air-in/air-out exchanger system. An inquiry amongst CO_2 sensor manufacturers has shown that a CO_2 sensor can be made for the acceptable price of 200 $.

Fresh air exchange rate and ventilation in air tight houses 1.24

Byggeteknik
The Technological Institute
Department of Building Technique
P.O. Box 141
DK — 2630 Tåstrup

P.F. COLLET

Contract number: EE-A-5-052-DK

In a Danish study, the influence of exhaust ventilation and small ventilation holes was studied in very tight houses with a natural air exchange rate of 0,1 to 0,2 h^{-1}. This was done for different types of houses. It was shown that in these houses with a mechanical exhaust, an air exchange rate of 0,5 h^{-1} can be obtained with an under pressure in the house of 5 Pa. The distribution of air in the different rooms is no problem when the doors between the rooms are open. Several ventilation holes, which can be opened and closed, with a total surface of 300 to 400 cm^3 for each apartment, are needed in order to have sufficient natural air exchange in the summer.

Development of an air infiltration measuring methodology in large and complex buildings 1.25

B R E
Building Research Station
UK — Garston, Watford, WD2 7JR

M.D.A.E.S. PERERA

Contract number: EE-A-5-050-GB

It is very important to develop good measuring techniques for the measurements of air infiltration in buildings. Normally this is done by mixing the air in a building with a tracer gas and measuring the tracer gas level as a function of time. Especially in large buildings this is not a simple problem: the local ventilation rate may vary significantly from one part of the building to another; temperature gradients in rooms with high ceilings may induce recirculations; mixing of the tracer gas is often imperfect. After giving a theoretical basis for tracer gas techniques for large buildings, various experimental procedures to carry out multi-cell air infiltration measurements have been reviewed. Three systems have been designed: "grab" sampling, multiple tracer measurements, avarage air change rates over long periods. These methods will be experimentally tested and are now being prepared. Improved gas analysers will be used for tracer gas detection.

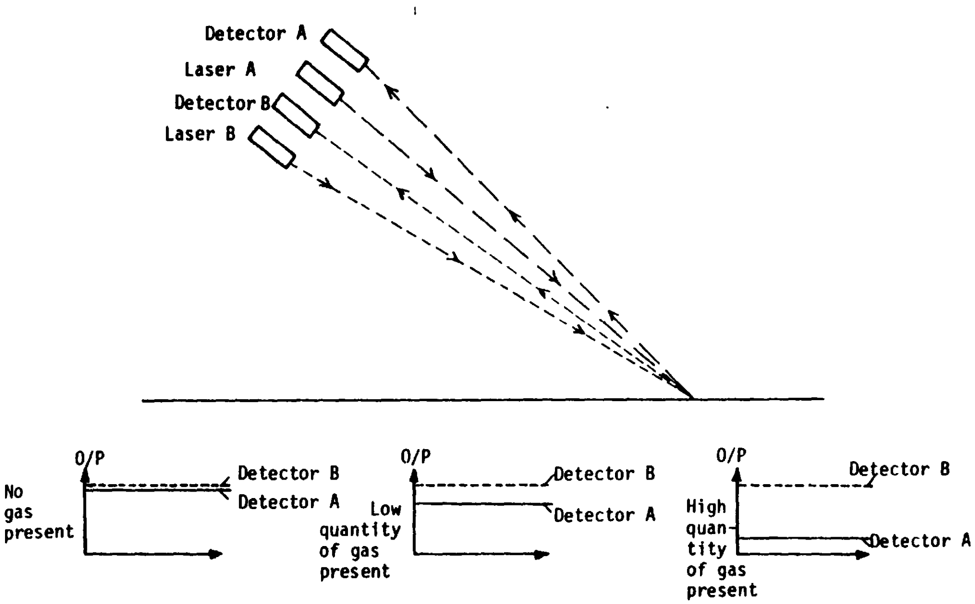


Figure 1.26.1 Principle of laser gas detection technique where laser A has a frequency which coïncides with the peak absorbtion frequency of the tracer gas. Laser B is the reference laser where the frequency is slightly off-tuned from the peak absorbtion frequency so that no light is absorbed.

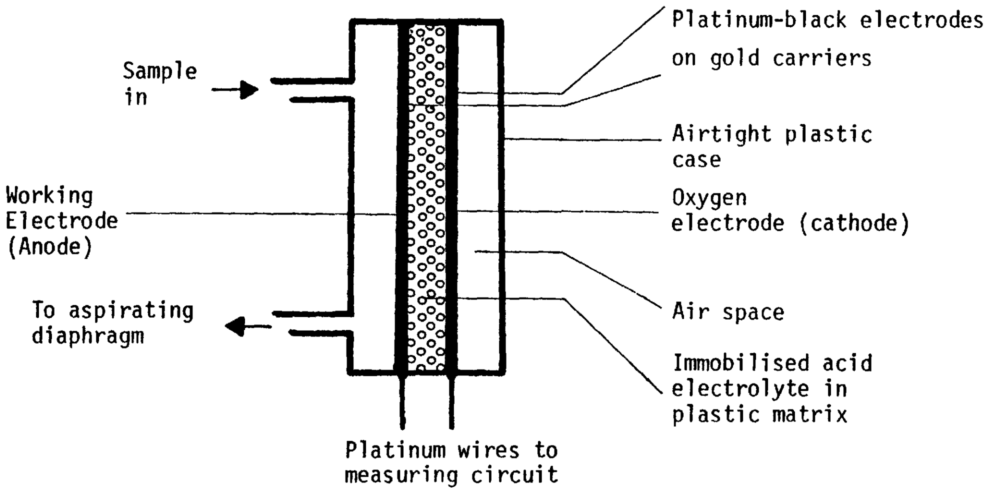


Figure 1.26.2 Schematic of fuel cell sensor

Air infiltration in large buildings: development of two new tracer gas detection methods

1.26

B S R I A
Technical Division
Old Bracknell Lane
UK — Bracknell, Berkshire RG12 4AH

P.J. JACKMAN

Contract number: EE-A-5-051-UK

The measurement of air infiltration is normally done by bringing tracer gas in the building and measure the tracer gas level as a function of time. The tracer gas detection method which is most often used, is infrared gas analysis. Here samples of air are taken to a gas analyser to determine the amount of tracer gas. In large buildings a large number of detection stations is required due to locally varying infiltration, temperature gradients which cause recirculation of air, bad mixing of the tracer gas etc. This results in long and complicated ducting between the sampling stations and the central gas analyser. Moreover each measurement takes about 2 minutes this means for the case of 10 sampling stations that each station is served only once in 20 minutes. Other detection methods have therefore been explored and a systematic study resulted in the identification of two detection methods.

The first method deals with the absorption of laser light (A) of a certain frequency by the tracer gas which is detected and compared with the reference signal of a laser (B) which is slightly detuned so that for this frequency no absorbtion takes place. This system gives the average tracer gas concentration along the laser beam. This method is very suitable for large single cell buildings. A drawback is the cost of the system which amounts to £ 50 000. The apparatus which is presently being constructed will use methane as a tracer gas.

The second detection method is a fuel cell analytical detector. Here the tracer gas is ethanol. It serves as a fuel in the fuel cell and gives an electrical current which is a measure for the ethanol concentration in the air. Concentrations as small as 1 ppm can be measured. This method is very suitable for large multicell buildings. The tracer gas concentrations can be measured rapidly so that many detectors can be served in a very short time. The installation with 10 detectors costs around £ 15 000. The testing of the fuel cell detector is presently going on.

Analysis of the factors influencing pressure differences on houses in relation to natural ventilation and energy consumption on low cost houses

1.27

T N O
P.O. Box 214
NL — 2600 AE Delft

W.F. de GIDS

Contract number: EE-A-5-063-NL (pending)

The aim of this study is to study and quantify the effect of obstacles near buildings on turbulence and pressure distribution around and on air infiltration in the building.

Energy saving in low cost houses making optimum use of gratuitious energy 1.28

C S T C
41, rue du Lombard
B — 1000 Bruxelles

J. UYTTENBROECK

Final report number: EUR 8370 available in French
Contract number: EE-A-5-057-B

In this project computer models have been developed which simulate the thermal behaviour of buildings. Basically three simulation models have been made:

— Simple steady state models for one and multi zone problems (LPB 3 and LPB 4 respectively).

— A simple dynamic model LPB 5.

— Detailed dynamic models LPB 1 and LPB 2.

In these models the concept of a "temperature without heating" t_{WH} was introduced which takes into account the gratuitious energy such as solar radiation. t_{WH} is a very important characteristic of a building and is needed to calculate the energy demand of a building. A formula has been developed by which t_{WH} can be calculated from climatic data. The agreement with experimental data was very satisfactory.

A second concept used in these models is the "equivalent degree-day" which is $\Sigma\ t_{NH} - t_{WH}$ where $t_{NH} = t_i - \Delta t_{OCC}$. In this formula t_i is the in-house temperature of a heated house and Δt_{OCC} the temperature increase in the house due to occupants, domestic appliances etc.

A practical steaty state method has been developed to estimate the heating energy demand through tables of equivalent degree-days (LPB 3 and LPB 4), taking into account external temperatures, wind, direct and indirect solar radiation. This steady state model was experimentally validated in two real houses and twelve testboxes of 1 m^3.
The simple dynamic model LPB 5 has been developed and experimentally verified. Detailed dynamic behaviour of testboxes was studied with LPB 1 and LPB 2.
The testboxes have been shown to be a very useful analytic tool. A limited set of standardized testboxes could also be used as a reference in order to define experimentally the climate in various locations in Europe.

Finally practical guidelines are being developed for the energy saving design of buildings in collaboration with the University of Liège (see 1.30).

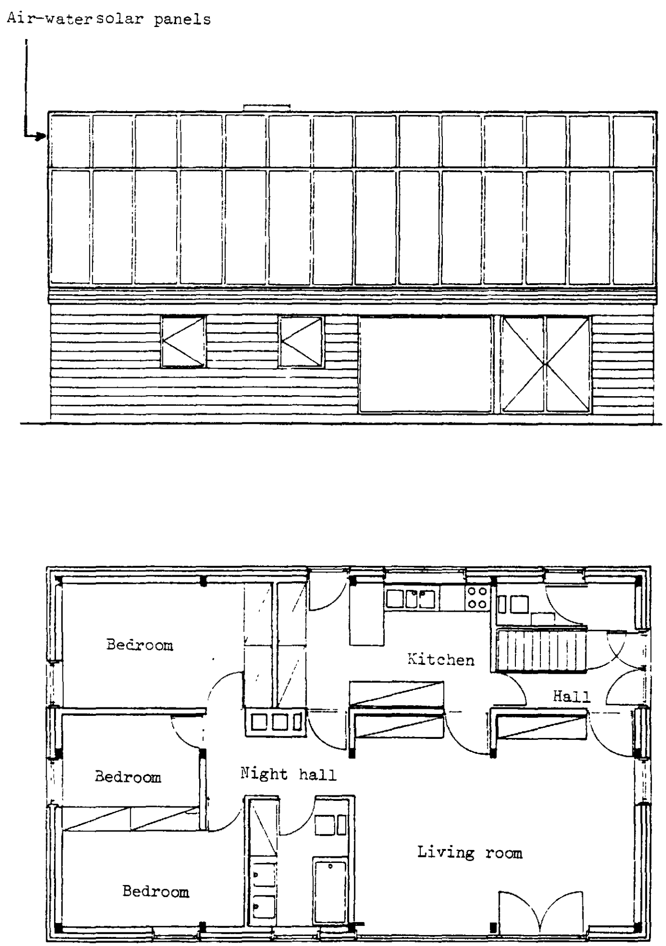


Figure 1.29.1 South facade and ground plan

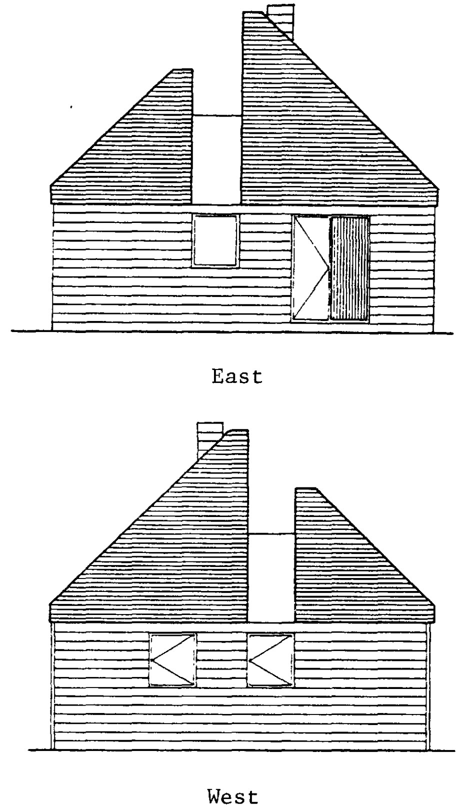


Figure 1.29.2 East and west facades

Heating systems and their integration in houses

1.29

C S T C
Avenue Pierre Holoffe
B — 1342 Limelette

J. UYTTENBROECK

Contract number: EE-A-5-056-B

The computer models discussed in the foregoing project (see 1.28) calculate the heat demand (Q) for a building which is kept at a well defined temperature taking into account heat transfer and air infiltration losses, gratuitious energy, wind etc. The amount of heat (Q′) needed to satisfy this demand depends on the efficiency (η) of the heating installation which in its turn depends in a complex way on the efficiencies of its components (boiler, radiators and the control system). Not much is known about the relation $Q' = \eta Q$ and the aim of this project is to

— develop a methodology for measurement of performance of integrated heating systems;
— develop guidelines for the design of integrated conventional and advanced heating systems;
— optimize the performance of these systems.

The experiments are being performed in two identical houses of 107 m^2, built according to the design guidelines developed by the University of Liège (1.30). In one house heat pumps (seasonal COP = 2,3) and solar collectors (25 m^2) are tested in combination with floor and air heating. The other house is used for a conventional boiler (14 kW) and radiators (90°C/70°C). The occupation of the houses is simulated. Construction of the house is ready, measuring equipment has been installed and experiments are now being carried out.

Building characteristics of low cost houses in view of energy savings for heating 1.30

Université de Liège
Laboratoire de Physique du Bâtiment
Bâtiment D 1
15, avenue des Tilleuls
B — 4000 Liège

A. DUPAGNE

Contract number: EE-A-5-060-B

In collaboration with CSTC, Belgium, TNO, Netherlands and BRE, UK a pratical energy saving design methodology, based on a steady state simulation model for the thermal behaviour of houses (LPB 3-4, see 1.28) has been developed in the First Energy Conservation R + D Programme (1975-1979). This methodology has been used for the design and construction of eight houses. The aim of this project is to validate the existing steady state model and to improve the design methodology by including simulation of the dynamic thermal behaviour of buildings (LPB 5, see 1.28) and by developing a conversational computerized version of the design guidelines. Also the investment, operating and maintenance cost will be included.

The detailed design of the houses is now finished and the construction has started. Simultaneously the design methodology is being computerized. After completion, measurements will be carried out in five of the eight houses, for the validation of the improved computerized model. Comparisons will be made with other computer models (e.g. ESP, see 1.31).

The simple design methodology was also used for the design of the two identical houses used for investigating heating systems (under 1.29) and by an Irish team which performs research work (see 1.3).

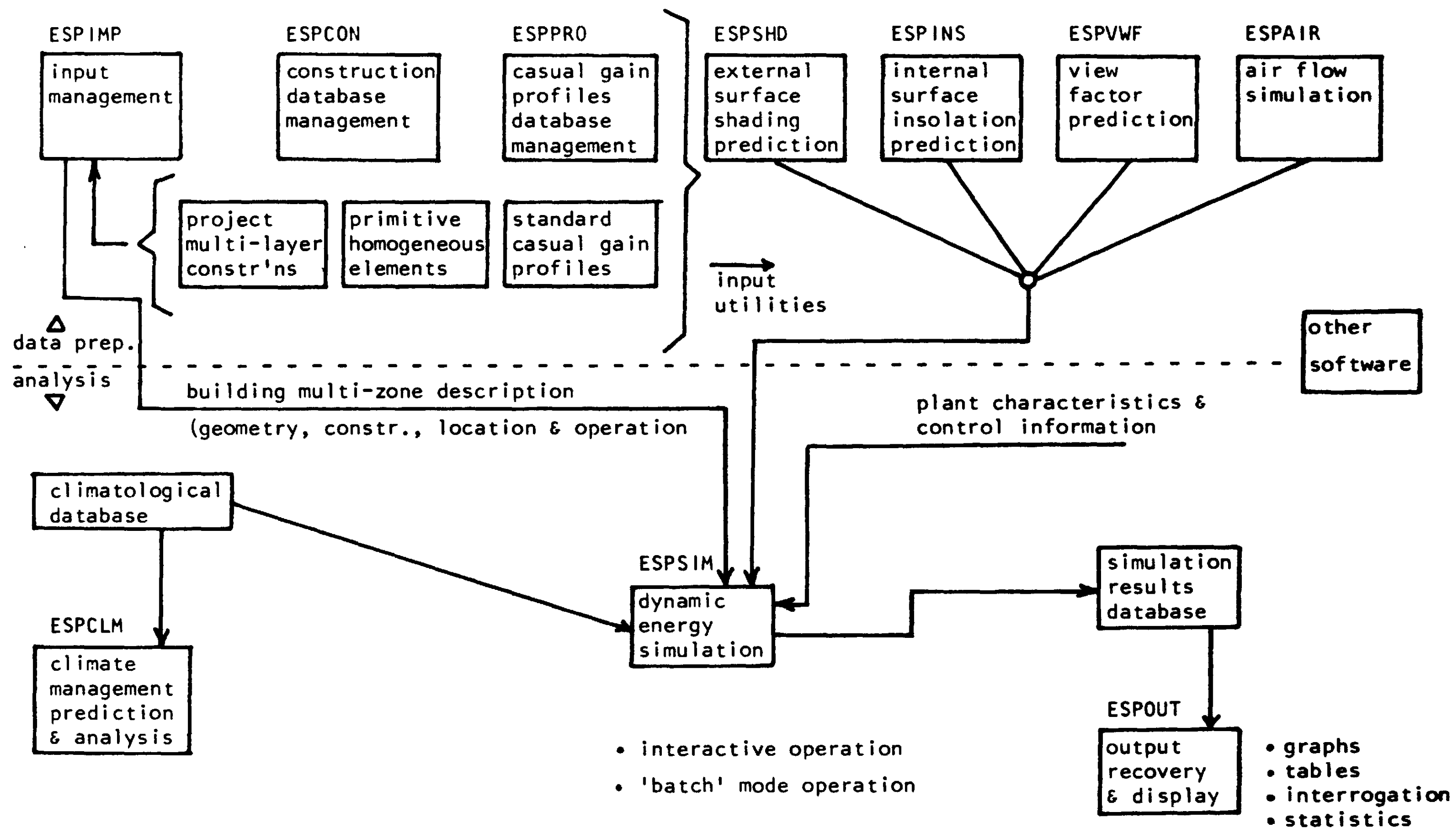


Figure 1.31.1 The ESP System

Extension of the ESP energy simulation model for thermal behaviour of buildings 1.31

ABACUS
Department of Architecture and Building Science
University of Strathclyde
131 Rottenrow
UK — Glasgow G4 ONG

J.A. CLARKE

Contract number: EE-A-5-059-UK

Another model describing the dynamic behaviour of buildings is being developed by ABACUS, UNIVERSITY OF STRATHCLYDE, United kingdom. The ESP (Environmental System Performance) model simulates the energy transfer within, outwith and between a number of zones linked together to form a building. The model allows detailed modelling. It takes into account different climatic factors such as temperature, solar radiation and wind. The ESP model was developed between 1975 and 1980. From 1981 this project was partly funded by the CEC, this lead to further developments.

A range of extensions which enhance the models range of applications, ease of use and relevance to design problem solving. Sub-programmes taking into account shading, air flow in the building, insolation, have been made and integrated in the ESP model.

Development of a simple technique for assessing the dynamic energy implications of housing location and design. This was done by bringing together different climatic factors (e.g. wind, temperature, solar radiation) in one parameter: The Climate Severity Index.

ESP was also implemented on a small computer so that it is more accessible to designers. It was decided to implement ESP on a VAX 750 running the UNIX operating system. This system is now operational.

For the development of a system simulation model which integrates the thermal behaviour of the building and the heating installation, detailed specifications have been made for a number of heating plant components such as: pumps, fans, cooling and heating coils, ductwork, etc.

Improvement of industrial building design, on the basis of an investigation carried out on existing plants

1.32

Fiat Engineering SpA
Via Belfiore, 25
I — 10125 Torino

M. GOFFI

Contract number: EE-B-3-172-I

At present, energy consumption for space heating of industrial buildings is an important amount of the total energy balance in the industrial countries. Several energy saving investigations carried out on industrial plants emphasized important inefficiencies in space heating.

These inefficiencies may be reduced through a better design of the "building-systems". Comparative and critical collection of data on the actual behaviour of the "building-system" are not available. This investigation aims to determine criteria both for design of new industrial buildings and for retrofit on existing ones. It will examine the "building-systems" performances for the most significant type of industrial buildings making use of mathematical models.

The information obtained will be used to indicate ways to limit and rationalize energy demand for space heating both in new industrial buildings and in existing ones.

Development and experimental verification of a computer model which simulates the thermal behaviour of houses

1.33

The Agricultural Institute
Economics and Rural Welfare
Research Centre
Hume House
Pembroke Road
IRL — Dublin 4

F. O'FARRELL

Contract number: EE-A-5-054-IRL

The aim of this project is the study of the effects of external climatic factors on the heat demand. The concept of an in-house "temperature without heating" (t_{WH}) will play a very important role (see also 1.28). With help of temperature measurements in an unheated and unoccupied house and recorded climatic data (solar radiation, wind, outdoor temperature) formulae will be established by which the t_{WH} can be determined from climatic data. The heating demand can then be established with a computer programme (SOLHET). Measurements of climatic data and t_{WH} for a 112 m^2 bungalow have now been carried out for a five month period, for the following cases: single windows, double windows. With these data regression equations have been established by which t_{WH} can be predicted in future from climatic data. Also the heat demand in the houses was calculated with SOLHET on the basis of the obtained values for t_{WH}. Presently the influence of a windbreak near the house is being investigated. A preliminary conclusion is that the external temperatures and solar radiation have a decisive influence on the t_{WH}. The influence of windspeed and direction is slight.

Bioclimatic design for building system components 1.34

Agip Nucleare
Casa Postale 13038
I — 20100 Milano

G. ZACCARIA

Contract number: EE-A-5-058-I

This project is developing a design system which enables the definition of building components and building systems which bring energy savings at a short payback time for a multi-store building. This goal will be pursued with passive and active solar systems which can be integrated in conventional heating and cooling systems.

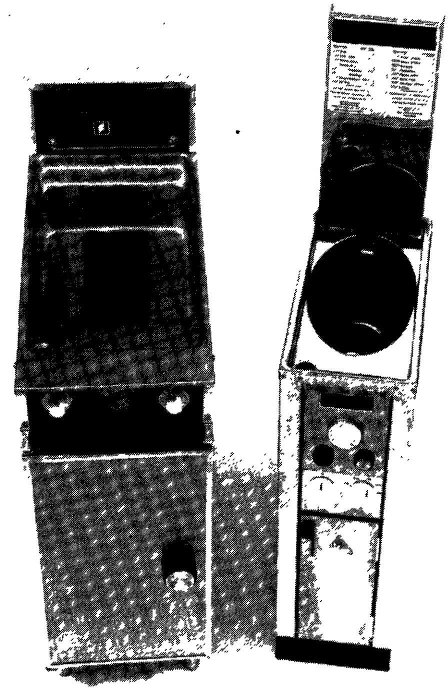


Figure 1.35.1 Typical deep fat fryers studied (gas heated on left and electric on right)

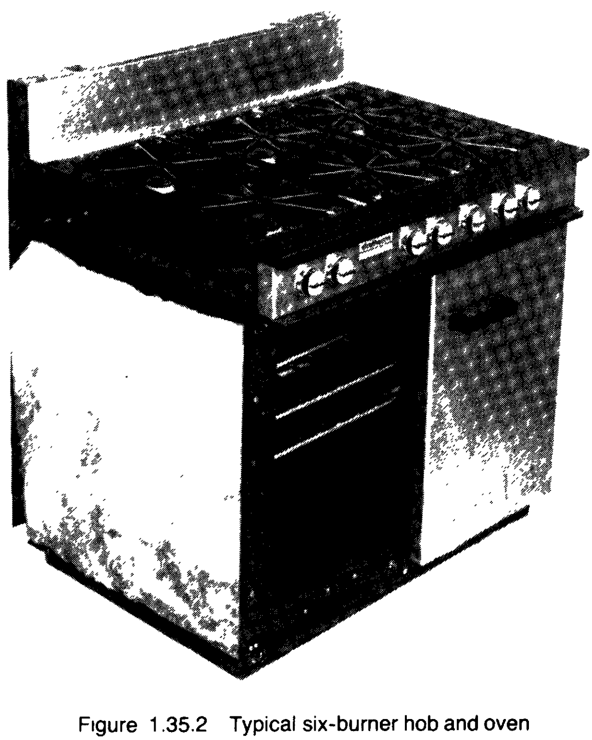


Figure 1.35.2 Typical six-burner hob and oven

DOMESTIC APPLIANCES

Energy saving in the commercial catering market 1.35

British Gas Corporation
R and D Division
Watson House
Petersborough Road
GB — London SW6 3HN

N.C. ROSS

Contract number: EE-A-3-026-GB

In the catering sector very little attention was paid to energy efficiency. A modest saving of 10% in the UK would lead to an annual energy saving of 150 000 TOE. The objective of this project is the investigation of appliance design, with a view to producing cost-effective reductions in energy consumption.

Activities are wide-ranging and include monitoring small commercial dish washers in operation; a survey of potential pan sensing techniques; efficiency studies of deep fat fryers, boiling tables, ovens, grills, solid top tables and griddles. These investigations are progressing at various speeds. At present the dishwasher monitoring exercise has been completed as also has that for the deep fat fryer design.

The main conclusions to date are that dish washing machines operate at only a fraction (25%) of their full capacity and that they should be controlled automatically.

Conclusion for the deep fat fryers are that "cool zones" contribute neither to the life of cooking oils nor to the finished quality of food. Elimination of the "cool zone" could reduce the oil volume of the tank. It is expected that a redesigned tank could lead to energy savings of 10%.

For ovens which are intermittently used a preheating time of 5 minutes is sufficient.

The use of pan sensors on gas hobs can save around 15 000 kWh/a for one appliance. Different pan sensors have been investigated but were too expensive. A micro switch based pan sensor turned out to be promising.

Kitchen monitoring is carried out in four sites. Furtheron, statistical data are being collected for the UK on the energy consumption and the potential for energy saving by different appliances used in different categories of kitchens (snack-bar, pub, restaurant, staff-canteen, etc.).

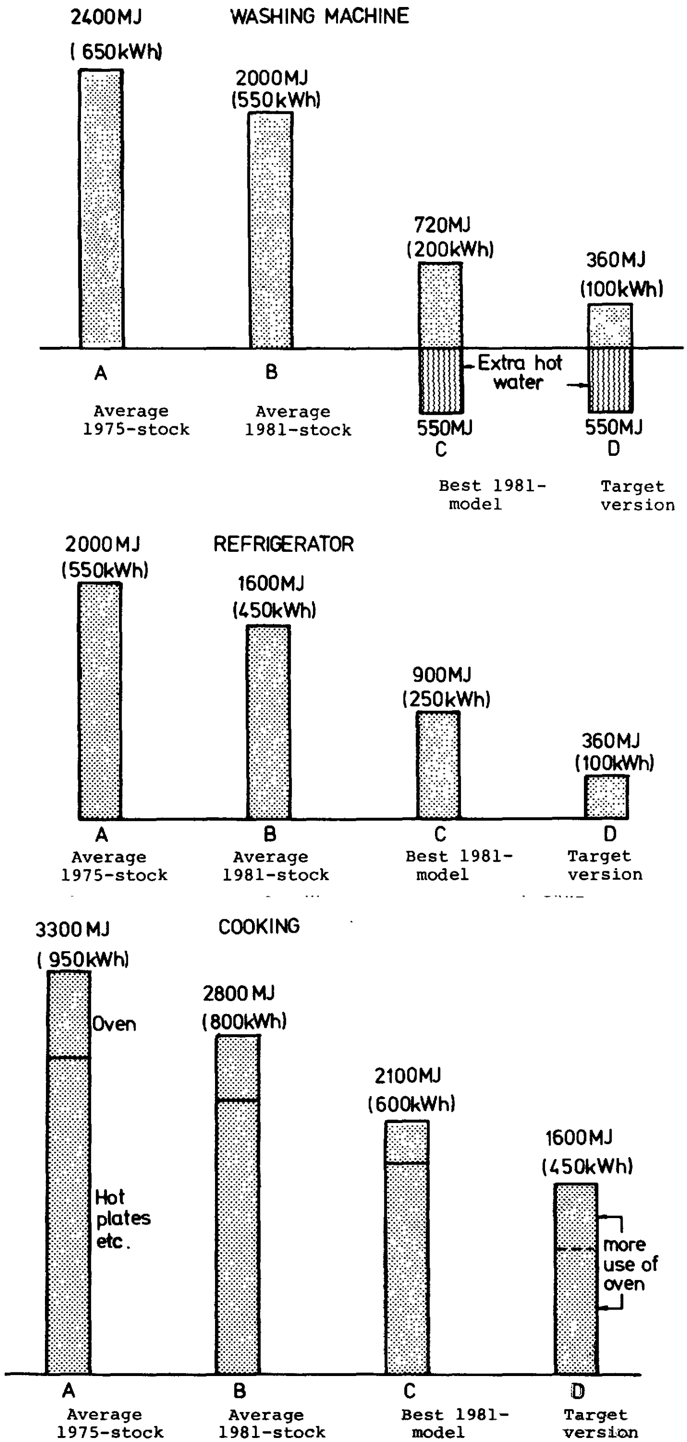


Figure 1.36.1 Target values in Denmark for the annual electricity consumption of washing machines, refrigerators and cooking equipment and their average values for 1975 and 1981

Development of energy efficient electrical household appliances 1.36

The Technical University of Denmark
Physics Laboratory III
Building 309 C
DK — 2800 Lyngby

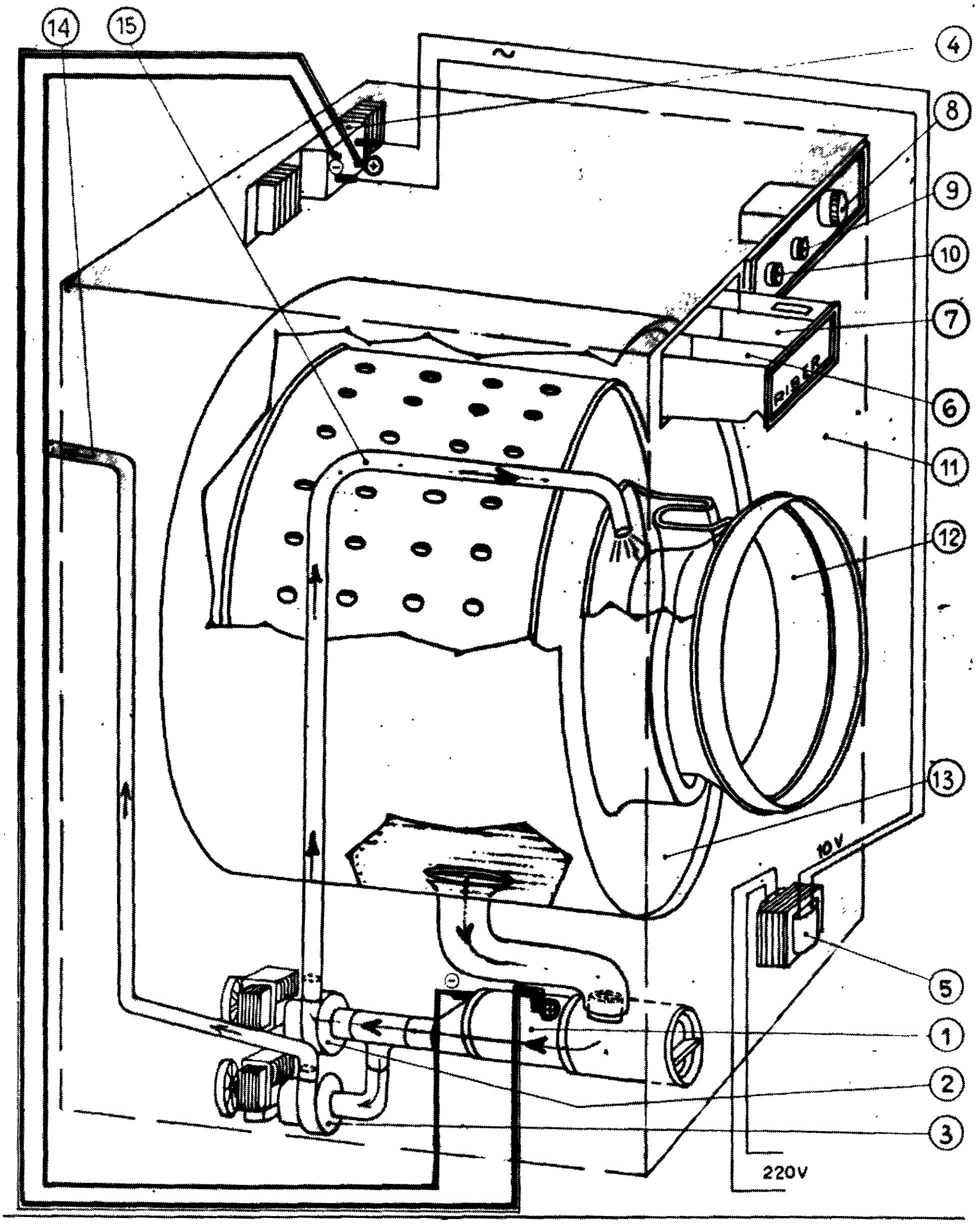
J. NØRGARD

Contract number: EE-A-3-025-DK

The TECHNICAL UNIVERSITY OF DENMARK evaluated the possibilities for energy saving design and construction of refrigerators, cooking pots, ovens and washing machines. The background of this project is an energy analysis for Denmark which included an evaluation of the energy saving potential for household appliances. It was believed that the energy consumption on the average could be reduced to 30% of the energy use by the 1975 stock. The work was carried out in collaboration with manufacturers of these products.

Over the first months a cabinet for a 209 liter refrigerator with a 7 cm thick polyurethane foam insulation has been designed. The refrigerator system was planned to have a COP of 1.5 or more, bringing the annual electricity consumption down to 100 kWh compared with 550 kWh for the 1975-stock and 250 kWh for the best models sold today. Three low energy refrigerators have been built according to this design, by a manufacturer and were equipped with different compressor cooiing systems. The performance of the best refrigerator was very close to the planned 100 kWh/year. The payback time of the additional cost is two years.

Cooking equipment is divided into hot plates and ovens. For the hot plate the investigation has during the last six months focussed on the possibilities of an automatic electronic controller. This device turns off the power before a desired temperature in the cooking pot is reached, but enables the heat capacity of the system to continue the heating of the pot to the desired temperature. The payback time is estimated to be three years. A first version of a small, low energy oven, has been built.



1) Filter-cell - 2) Turbo-pump - 3) Draining pump - 4) Rectifier - 5) Transformer - 6) Salt dispenser (NaCl) - 7) Detergent dispenser - 8) Timer - 9) Thermostat - 10) Electrolysis timer - 11) Cabinet - 12) Port-hole - 13) Tub - 14) Draining Hose - 15) Turbo hose

Figure 1.37.2 Schematic drawing of an electrolytic washing machine

Development of a low temperature washing machine with formation of oxygen by electrolysis of the washing liquid

1.37

RIBER SpA
Via Manzoni, 4
I — 10092 Beinasco

M. MORELLO

Final report number: EUR 8483 available in English

Contract number: EE-A-3-024-I

The objective of research carried out by RIBER, Italy is to develop a washing machine which operates at low temperatures. During the washing process, active oxygen is normally produced from perborates (a detergent component). In order to obtain sufficient oxygen, temperatures of over 60°C are required for a certain period. In this project oxygen is produced from the washing water by electrolysis at room temperatures. A washing machine has been built where prewashing occurs with an electrolyser and is followed by washing between 40-90°C. As compared with traditional washing energy savings of 25-35% are possible with the new washing machine and the washing results are generally better.

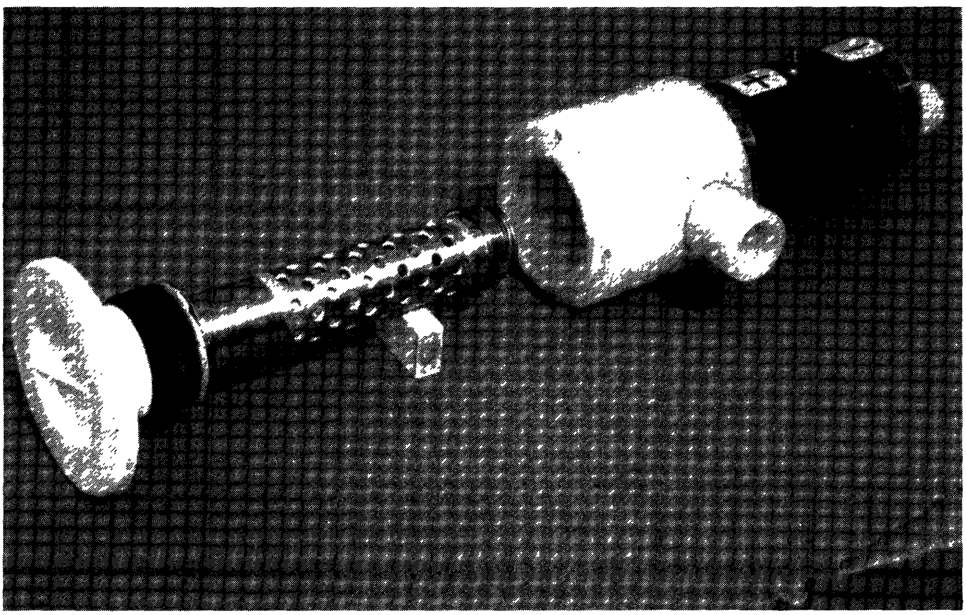


Figure 1.37.1 Electrolyser cell

Sector 2

HEAT PUMPS

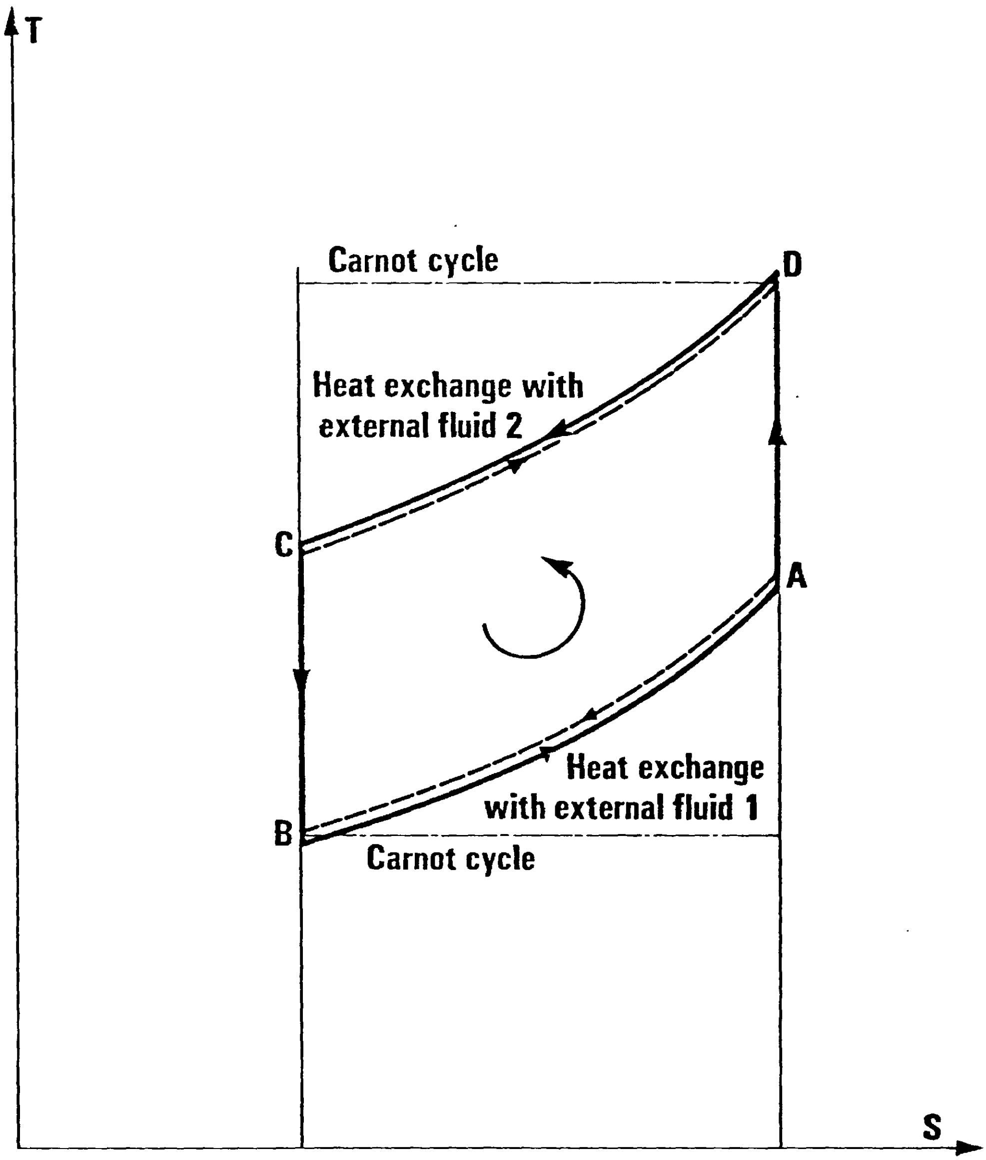


Figure 2.1.1 Temperature variation during vaporization and condensation of a fluid mixture, parallel to the temperature changes of the fluid with which heat exchange takes place

Compression heat pumps operating with non azeotropic fluid mixtures for space heating

2.1

IFP
Boîte Postale 311
F — 92501 Rueil-Malmaison

Leroy-Somer
Département ETH
Zone industrielle de Rabion
F — 16015 Angoulème Cedex

J. DURANDET (IFP)

M. BAGLIONE (Leroy-Somer)

Contract number: EE-A-4-045-F

The thermal capacity and the COP of a compressor heat pump can be considerably improved when instead of a pure fluid, a fluid mixture is used. Contrary to a pure fluid, such a mixture has a temperature variation during the vaporization and condensation stages, which, when parallel to the temperature changes of the fluid with which heat exchange takes place, can lead to a better heat transfer and to a higher COP and/or thermal capacity. The obtained capacity increase reached 28% for water-water units and 24% for air-water units using a fluid mixture of R23 and R22; the COP was in this case also slightly improved. With a fluid mixture of R12 and R21 the COP could be increased by 10,5% as compared to pure R21; the capacity decreased slightly. A choice was made for the further development of heat pumps with R23/R21 mixtures with an increased capacity. For these heat pumps a cost reduction per unit of produced heat of 10% can be realized. Endurance tests gave very good results and presently 20 heat pumps have been installed in houses for the season 1982/1983. This fluid mixture heat pump will be commercialized in near future.

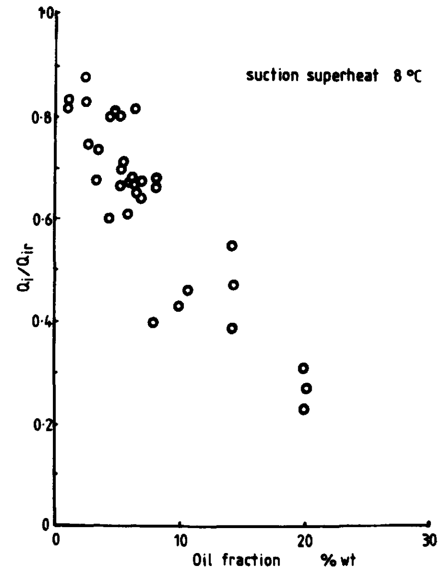


Figure 2.2.2 Extracted heat as a function of the oil concentration in the refrigerant. (Q_{ir} is the extracted heat with a pure refrigerant)

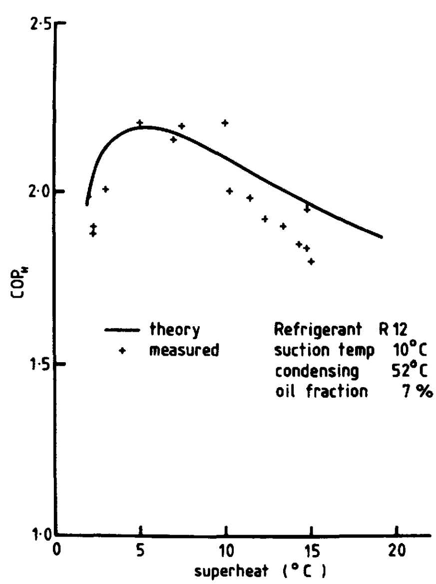


Figure 2.2.3 Comparison of experimental and theoretical COP and its dependence on evaporator superheat (7% oil fraction)

Study of capacity control and the influence of lubrification oil on system and evaporator design, in heat pumps with rotary sliding vane compressors

The New University of Ulster
School of Physical Sciences
Energy Study Group
IRL — Coleraine BT5 1SA
Northern Ireland

J.T. McMULLAN

Contract number: EE-A-4-028-GB

The fact that oil in the compressor dissolves in the refrigerant, results in a less efficient operation of the heat pumps. This problem was studied by the NEW UNIVERSITY OF ULSTER. The fraction of oil dissolved in the refrigerant varies strongly and depends on the type of compressor (e.g. in a sliding vane compressor, often used in industrial heat pumps, 8-15%, reciprocating compressor, often used in domestic heat pumps, 1-2%). It has been shown for a sliding vane compressor that oil can reduce the heat transferred at the evaporator by as much as 30% and that this can have a corresponding effect on the COP. The heat transfer coefficient of the evaporator depends in a complicated way on the oil concentration and the fluid flow conditions. Pressure-enthalpy charts for refrigerant-oil mixtures have been measured and their potential for predicting actual heat pump performance is demonstrated.

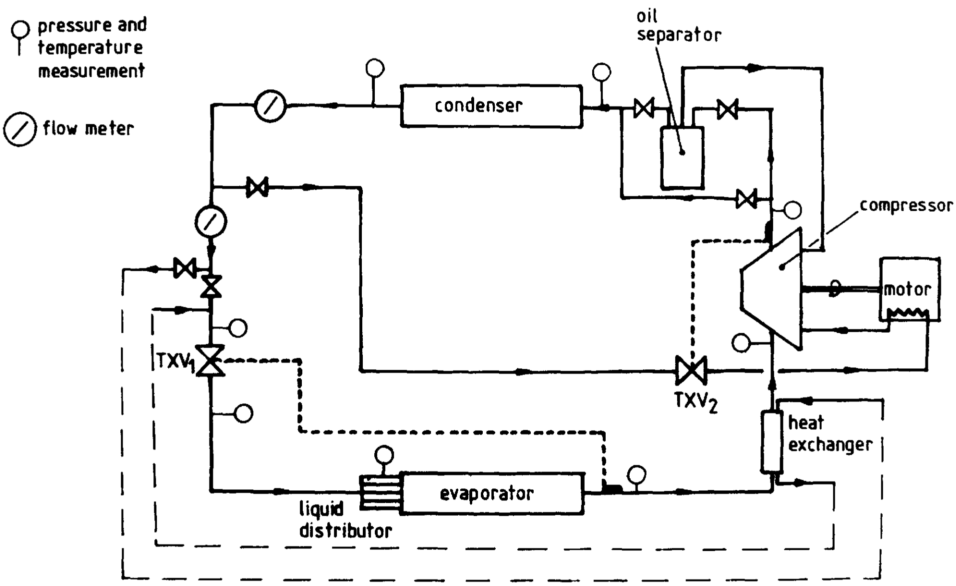


Figure 2.2.1 Rotary sliding vane compressor test rig

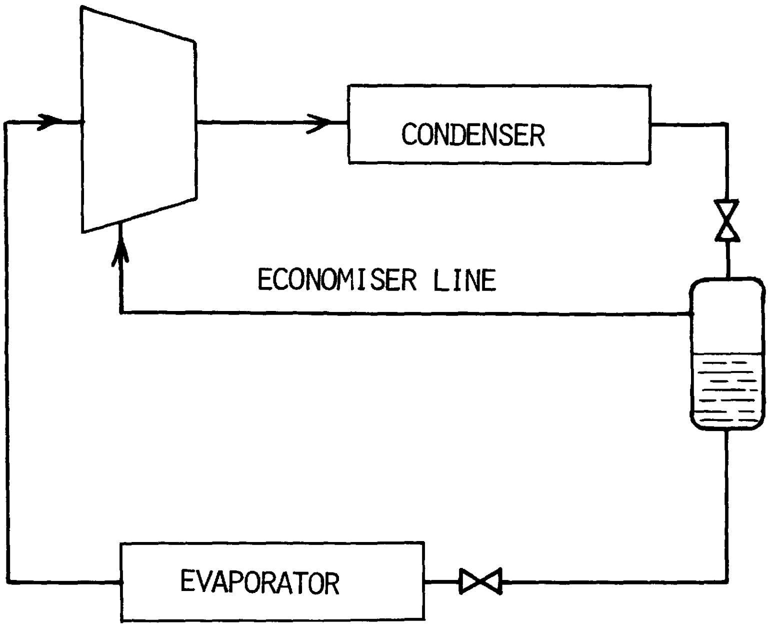


Figure 2.3.2 Principle of economizer

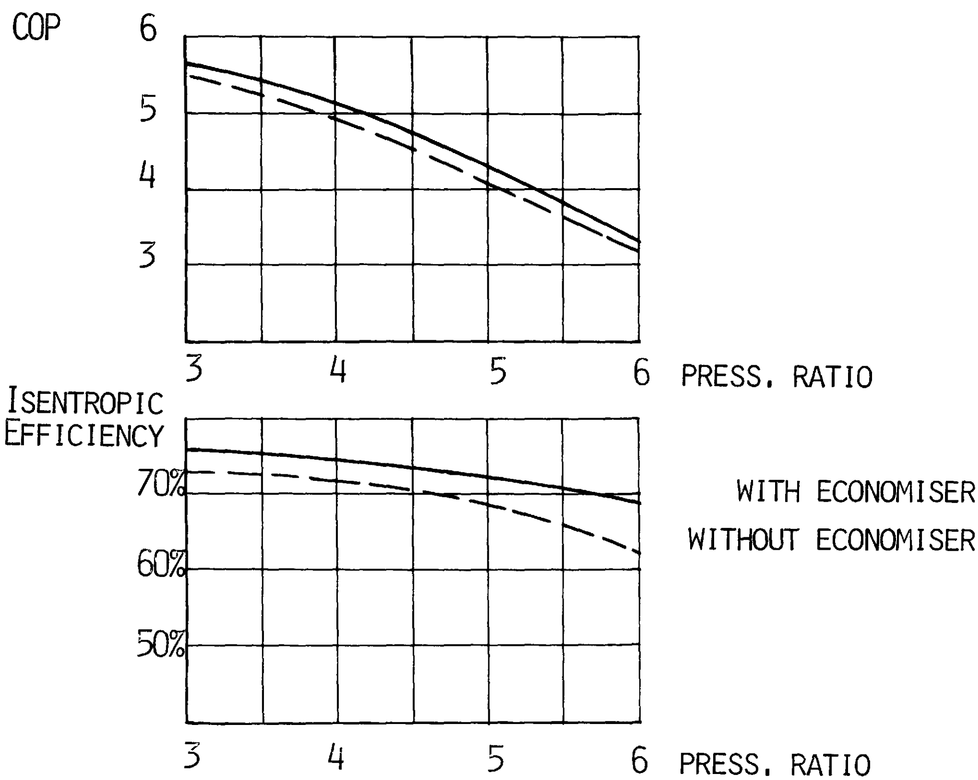


Figure 2.3.3 Effect of economizer at full load

Study of a high performance 30 kW heat pump with an oil free single screw compressor

2.3

Société Omphale
33, rue Godefroy
F — 92800 Puteaux

E. KALLMANN

Contract number: EE-A-4-029-F

A very interesting oil free screw compressor of 25 kW is being developed by OMPHALE, France, which has two additional advantages:

By regulating the mass flow of the refrigerant in the screw compressor the heat output of the heat pump can be regulated down to 50% with a very good part load efficiency.

The second advantage is the use of an "economizer". This device consists of an expansion valve which expands the condensate, formed in the condensor after the compressor, to a lower intermediate pressure. The flash gas is then fed into the compressor, thus increasing the overall efficiency. Normally such an economizer only works at full load. In this project a method has been developed where the economizer is efficient also at part load operation. This method is based on the fact that each of the two gear wheels (see Fig. 1) forms more or less a compressor by itself. One part is kept at the maximum mass flow and is connected with the economizer, in the other part the mass flow regulated.

Efficiencies of 75% have been obtained at full load operation. Endurance tests of over 2 000 hours and stop-start tests (500 cycles) have been carried out to full satisfaction.

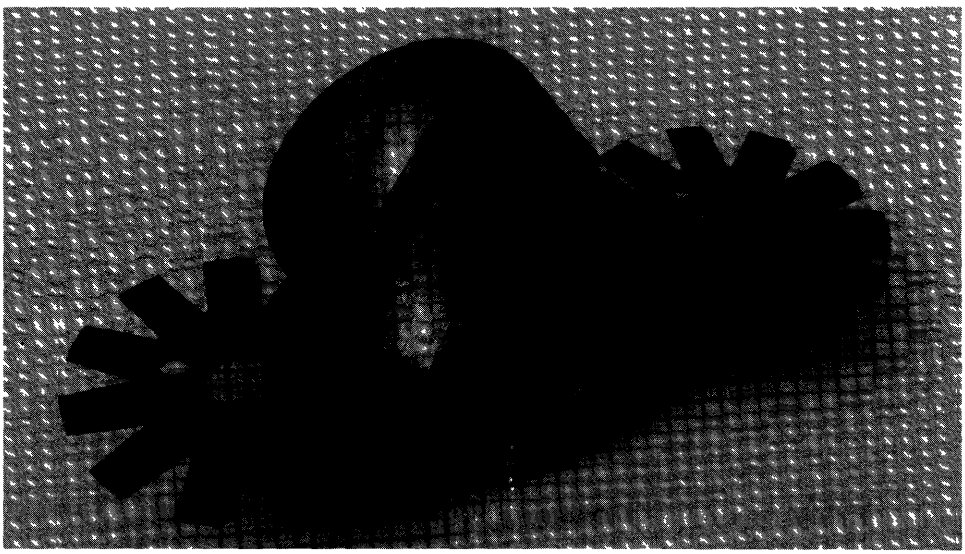


Figure 2.3.1 Oil free single screw compressor

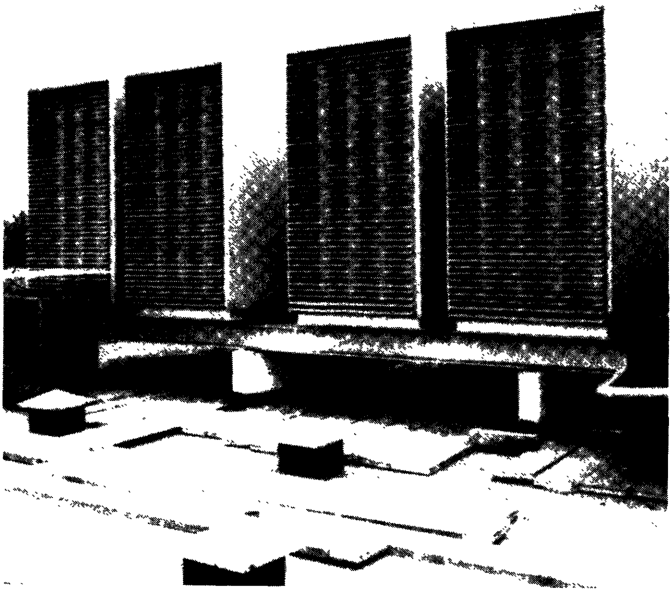


Figure 2.4.1 Air heat exchangers on the roof of the apartment building

Installation and operation of heat pumps in an existing apartment building where the existing radiators are used

2.4

VEW
Postfach 941
D — 4600 Dortmund 1

P. MÜLLER

Contract number: EE-A-4-046-D

The interaction between the heat pump and the building to be heated is very important for the performance of the total system and should be studied. VEW, Germany is investigating this interaction in two existing apartment buildings where electrical heat pumps with air as a heat source have been installed, which use existing radiators for the distribution of heat. The operation of the heat pumps is monovalent and with an outdoor temperature of —12°C the heat is delivered at 48°C. The two apartment buildings have 36 and 44 dwellings respectively and are heated with 4 and 5 heat pumps of 50 kW. A heat storage system has been installed to avoid operation of the electrical heat pumps at peak hours. Presently measurements are carried out to establish the exact heating capacity, the optimum regulation of the heating installation, the noise level, and the maintenance and running costs.

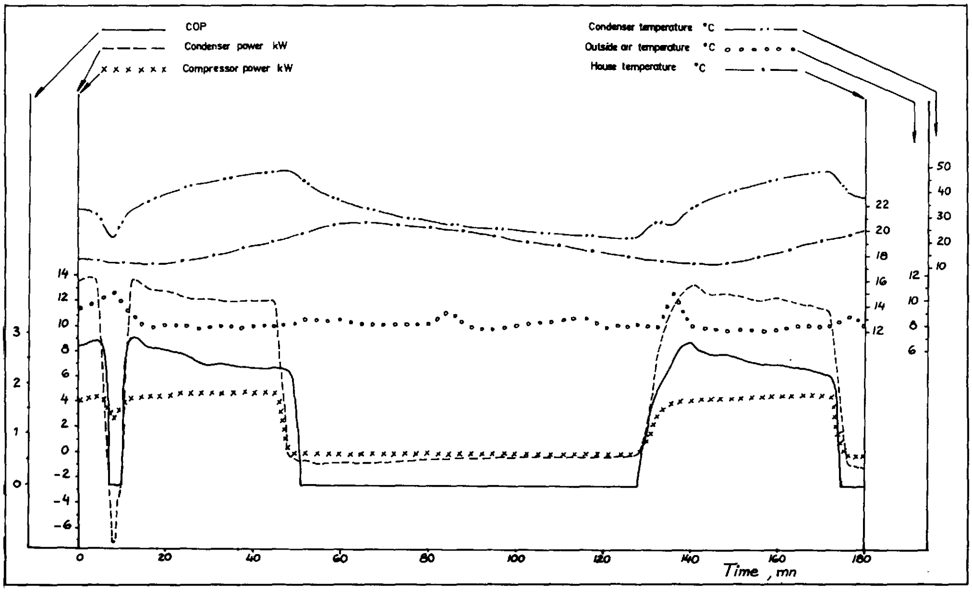


Figure 2.5.1 Conventional regulation with 7°C outdoor temperature

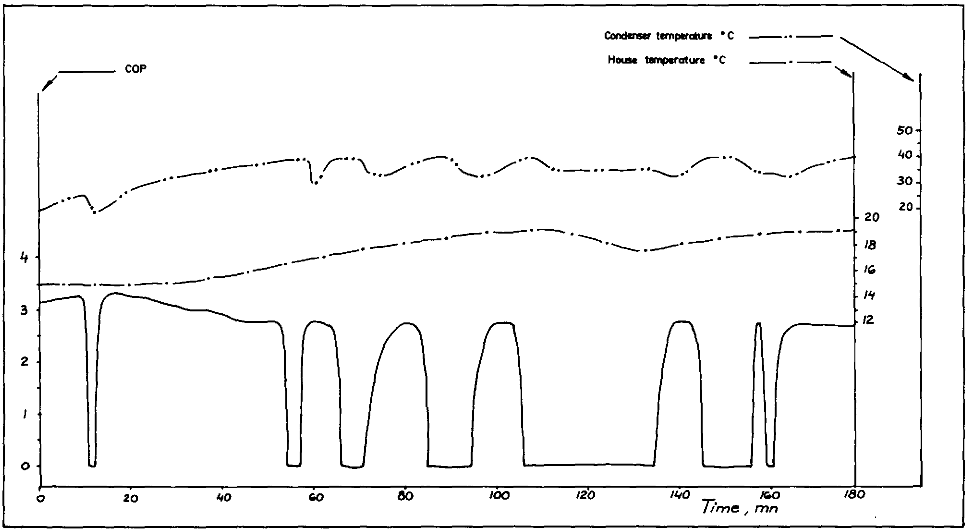


Figure 2.5.2 Regulation of the condensing temperature at 35°C (7°C outdoor temperature)

Design, optimization and testing of a variable speed heat pump for application in space heating

2.5

Société Bertin
Boîte Postale 3
F — 78373 Plaisir Cedex

J.P. PATUREAU

Contract number: EE-A-4-048-F and EE-A-4-064-F

The objective of this project is to identify possible improvements for an electrical compressor heat pump of around 12 kW with air as a heat source. To test the heat pump under different "weather" conditions a test loop has been built which delivers air at the evaporator, at a required temperature and humidity (5 000 Nm^3/hr, —15 to 20°C and 10 to 100% relative humidity). On the condensor side a water circuit with several capacities and heat exchangers simulates the thermal behaviour of a 120 m^2 dwelling.

The major part of the first phase was devoted to the construction of the test loop. Subsequently a commercial domestic heat pump was extensively tested. The instantaneous performance of the heat pump agreed well with the data claimed by the manufacturer. The annual energy saving however was significantly lower due to the following:

— loss of efficiency caused by defrosting cycles;

— loss of efficiency due to inadequate thermal load matching between the heat pump and the house. It was shown that control of the condensing temperature, instead of a conventional control of the room temperature, can bring energy savings of 10%. This could probably also be realized by load matching with a compressor with a variable speed; the heat output range with such a compressor however is limited;

— the inefficient operation of components such as the evaporator and the condensor heat exchangers and the expansion valve (bad regulation caused a too high super heating temperature). Optimization could lead to a considerable improvement. Modifications in the compressor are proposed which may lead to an increase of the efficiency from the present 40-60%, to 60-70%. Decrease of heat pump performance due to compressor oil dissolving in the refrigerant can be neglected for the hermetic piston compressor.

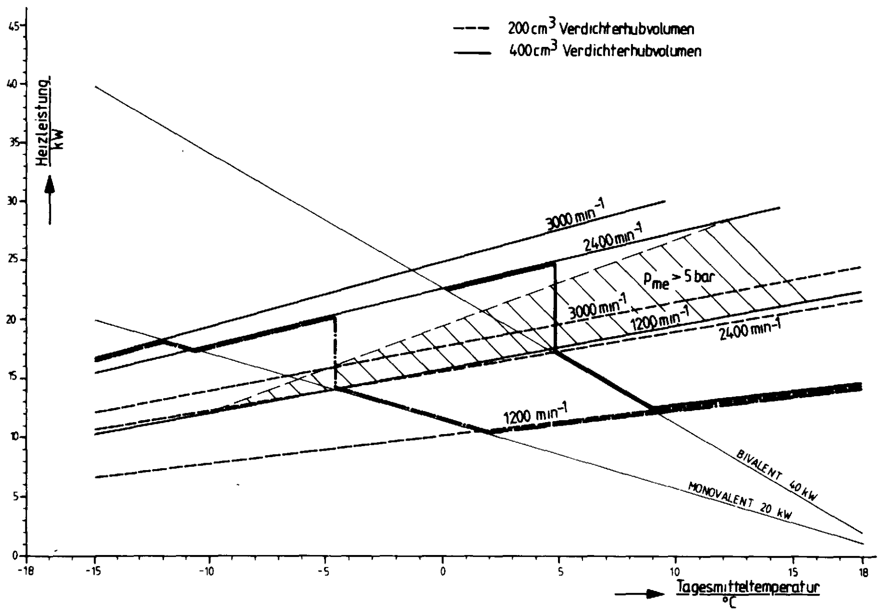


Figure 2.6.2 Heat output as a function of outdoor temperature; regulation of the heat output of an internal combustion engine driven compressor heat pump, by regulating the revolution number and switching on/off a compressor cylinder

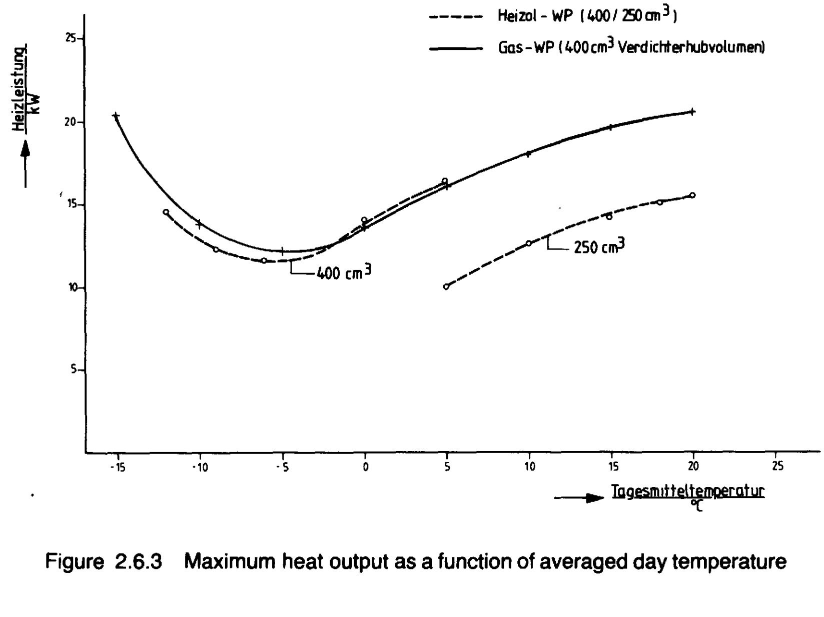


Figure 2.6.3 Maximum heat output as a function of averaged day temperature

Optimization of oil or gas engine driven heat pumps of 20 kW for domestic heating

2.6

Fichtel & Sachs AG
Postfach 1140
D — 8720 Schweinfurt 1

G. BROCKHOFF

Contract number: EE-A-4-038-D

Internal combustion engine driven compressor heat pumps have a higher efficiency than electrical heat pumps due to waste heat recovery from the combustion engine. The heat output can also be varied more easily by regulating the speed of the motor and switching off one or possibly more cylinders of the compressor. The heat output can thus be matched to the heat requirements of the house which leads to energy savings. This type of heat pump was up till now limited to large installations above 100-200 kW. FICHTEL & SACHS demonstrated the technical feasibility of a small 20 kW ICE driven heat pump. The heat output can be regulated by varying the speed of the motor and by switching off one of the two compressor cylinders. This is done with a micro processor which also takes into account the outdoor temperature and the heat demand of the house. Monovalent operation was shown to be possible down to —15°C outside temperatures. The heat is delivered at 80°C which makes the heat pump suitable for retrofitting in existing houses. Eight of these heat pumps have been used in houses and three heat pumps were tested in the laboratory. The maximum operation time is 12 000 hours. From the very limited wear found up till now, a lifetime of 40 000 hours is expected. The cost is estimated to be 20 000 DM and the pay back time 5 years. The coefficient of performance (COP) was 1,2 for —10°C outdoor temperatures and 1,5 for 5°C.

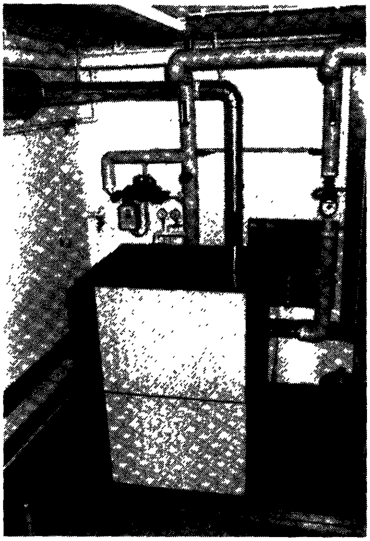


Figure 2.6.1 20 kW diesel engine driven compressor heat pump

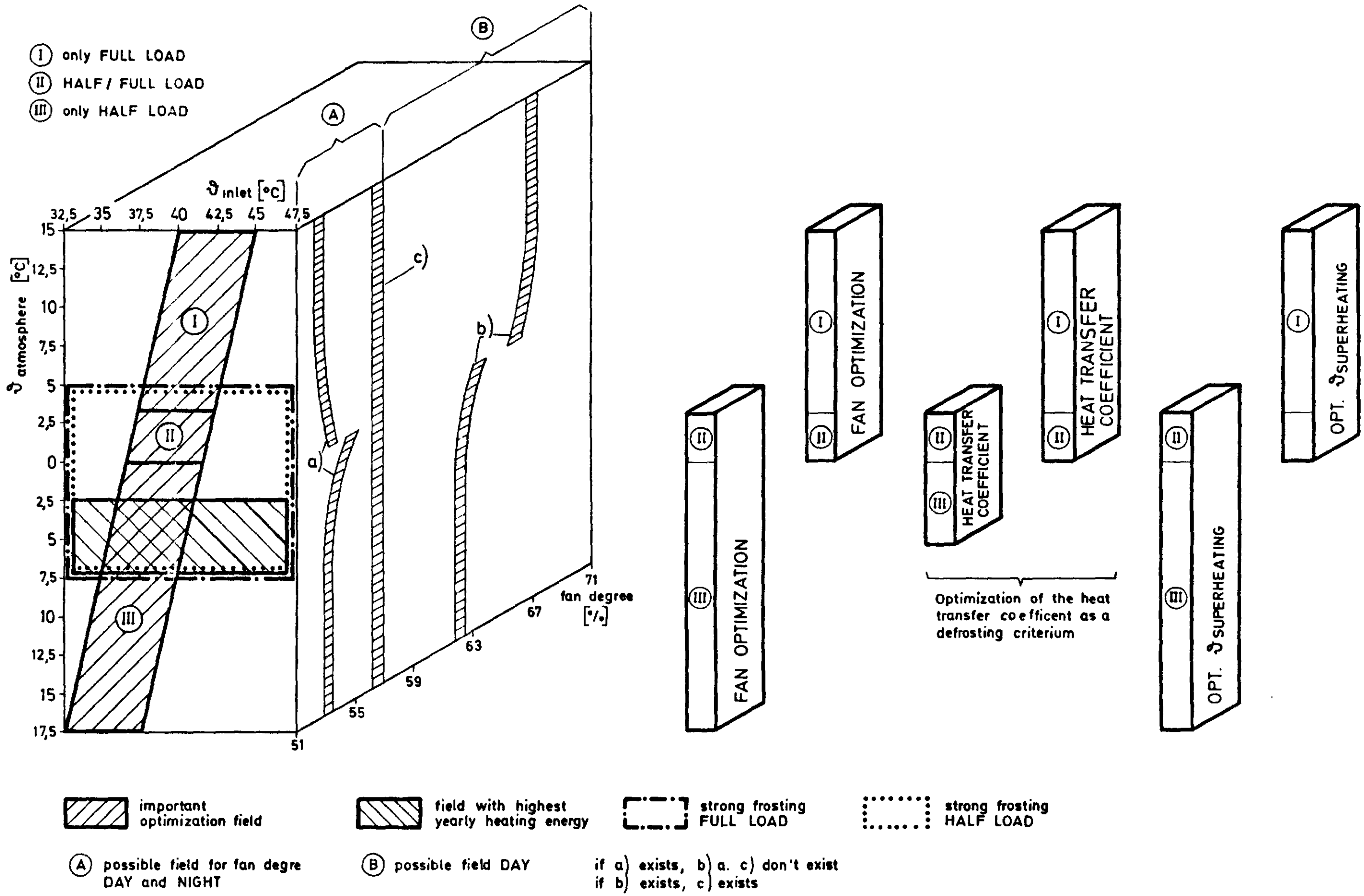


Figure 2.7.1 Heat pump optimization scheme

Optimized operation of a frozen air heat exchanger and use of a micro computer controlled expansion valve

2.7

Institut für Umweltschutz
Universität Dortmund
Postfach 500500
D — 4600 Dortmund 50

R. ISERMANN

Contract number: EE-A-4-049-D

The optimal operation of an electric compressor air-water heat pump with a micro processor was investigated. The various air flow rates obtained by varying the speed of the evaporator fan had no impact on the coefficient of performance. Down to 1,5°C it is however possible to defrost the evaporator by the fan alone. This leads to energy savings. The micro processor controlled expansion valve gave satisfactory results but the cost of this thermo electric expansion valve and its control has not been discussed.

Control system for an internal combustion engine driven heat pump 2.8

Renault
Techniques Nouvelles
147, avenue Paul Doumer
F — 92500 Reuil-Malmaison

A. SARIGNAC

Contract number: EE-A-4-062-F

The objective of this project is to develop a micro processor control system for a gas engine driven water/water heat pump with recovery of waste heat from the gas engine. The engine delivers 31,5 kW and the maximum heat output of the heat pump is 195 kW. The heat exchangers have been built according to a new concept with the sheets in welded stainless steel. The influence of the compression on the performance has been studied and a regulation system has been selected for the control of the rotation speed of the engine. A design was made for heat recovery system. The project has been stopped due to a reorganization of the institute.

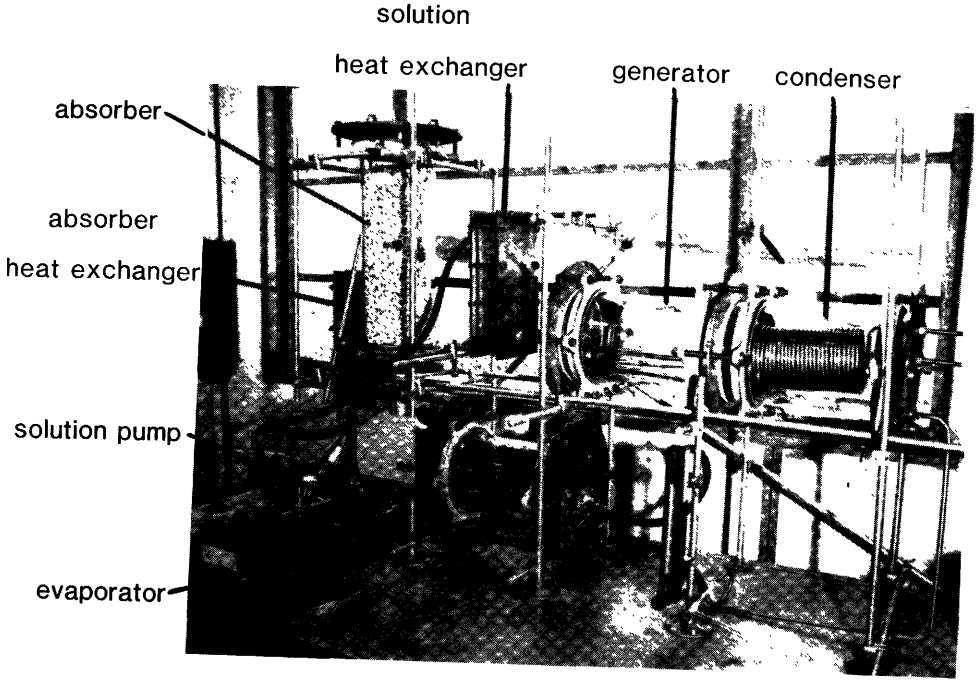


Figure 2.9.1 Experimental set up of the absorption heat pump

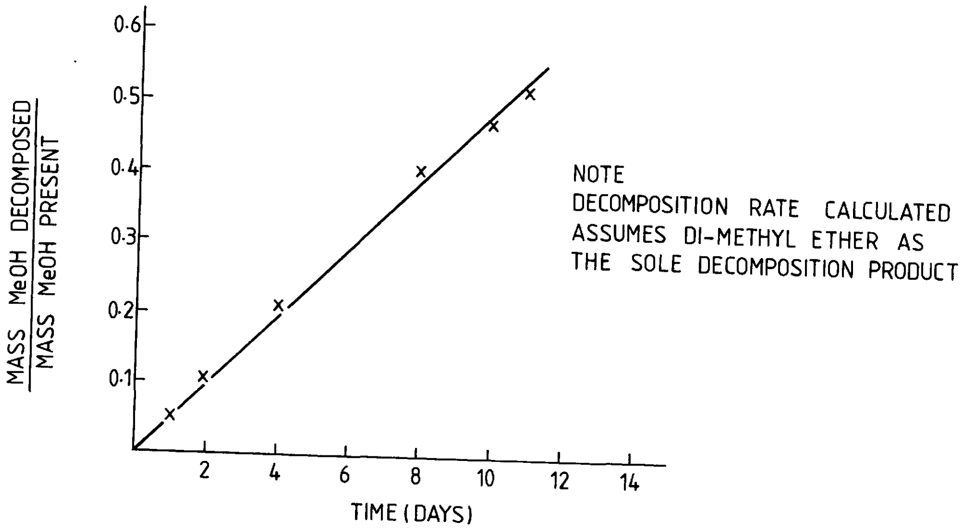


Figure 2.9.2 Decomposition rate of methanol

DOMESTIC ABSORPTION AND OTHER ADVANCED HEAT PUMPS

Development of a monovalent absorption heat pump which delivers heat at 70°C for space heating — 2.9

Cranfield Institute of Technology
School of Mechanical Engineering
UK — Cranfield Bedford MK43 OAL

I.E. SMITH

Contract number: EE-A-4-039-GB

A monovalent absorption heat pump of 10 kW is being developed which will deliver heat at 70°C. This in order to be used with existing radiators in an existing building. A first working fluid pair which was investigated (methanol/mixed bromide) did not operate satisfactorily due to the decomposition of methanol at 190°C. Since then extensive screening tests have been carried out in a search for new fluid pairs. This included water as a refrigerant in combination with salt. Also the working fluids, methylamine and trifluorethanol have been investigated but the last fluid is now considered to have inacceptable high toxicity levels. Apart from toxicity the main criteria are temperature lift and prevention of crystallization. Preliminary results show that water-salt solutions have a potential to be used for a high temperature heat pump. Sodium-hydroxide appears to be the most attractive absorbent but is very corrosive. Solutions for this corrosivity however may be found. Interesting suggestions have been made to avoid crystallization.

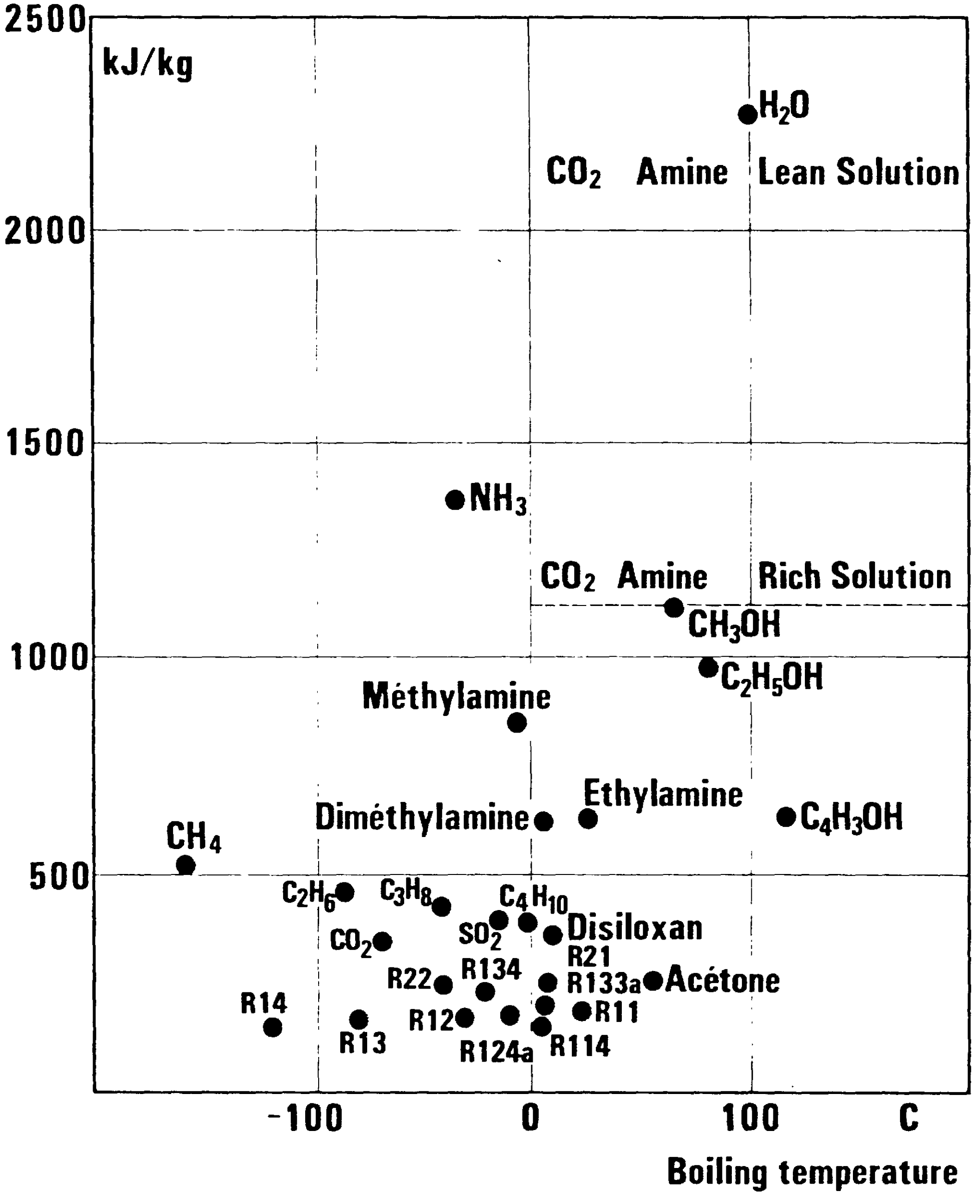


Figure 2.10.2 Vaporization heat and boiling temperature

An absorption-resorption heat pump for space heating; investigation of solute pairs

2.10

IFP
Boîte Postale 311
F — 92506 Reuil Malmaison Cedex

G. COHEN

Contract number: EE-A-4-042-F

A refrigerant, which has very interesting characteristics is CO_2. It is largely available, neither toxic nor inflammable. It has however a low condensation temperature (—78°C) and a high pressure at 10-40°C. This makes CO_2 not very suitable for an absorption heat pump. If however the condensor is replaced by an absorber and the evaporator by a generator (using waste heat), this problem may be solved. Such an absorption-resorption heat pump with CO_2/amine as a working fluid pair has been calculated to have an efficiency of 151% and 187% for diglycolamine and diethanolamine respectively, with waste heat at 0°C, delivered heat between 35-75°C and a generator temperature of 180°C. CO_2/solvent combinations have been investigated both theoretically, with thermodynamical models regarding vapour-liquid composition, and experimentally. The agreement between calculated and measured P-T-x diagrams was very good. Work is now in progress to construct this heat pump.

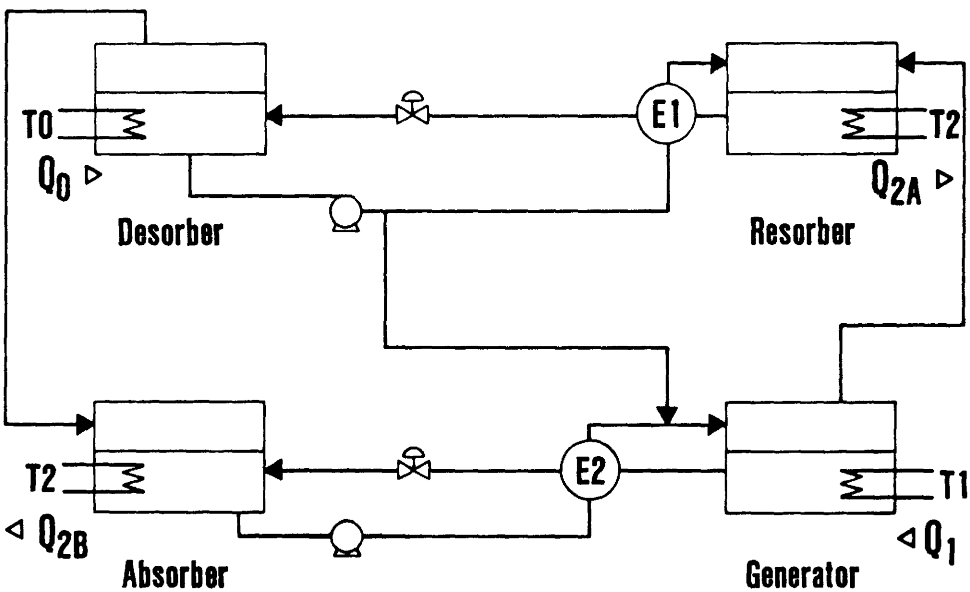


Figure 2.10.1 Absorption heat pump with CO_2 as a refrigerant where due to the low condensation temperature (—78°C) the condensor is replaced by an absorber (resorber) and the evaporator by a generator using waste heat (desorber)

Investigation of working fluid pairs for single and multiple-stage absorption heat pumps

2.11

Universität Essen
Institut für Angewandte
Thermodynamik und Klimatechnik
Postfach 6843
D — 4300 Essen

F. STEIMLE

Contract number: EE-A-4-031-D

All working fluid pairs which are presently used in domestic absorption heat pumps have certain disadvantages. A systematic search for suitable working fluid pairs is therefore being carried out by the UNIVERSITY OF ESSEN, Germany. Alcohols and amines as solutions and different halides, nitrates and thyocyanates as solvents are being studied. Vapour pressure, solubility, viscosity and density measurements are carried out in the temperature and concentration fields of interest. Up till now binary combinations of the working fluids TFE, R123a, R30, R22 and a large number of solvents have been systematically studied. All four working fluids had a remarkable solubility in HMPT but the thermal instability of HMPT excludes the application in absorption heat pumps. However a large number of other promising combinations have been identified. Also ternary combinations have been investigated. Methylamine with aqueous-salt solutions as a solvent were not thermally stable up to 200°C. NH_3 with aqueous-salt salt solutions are now being tested.

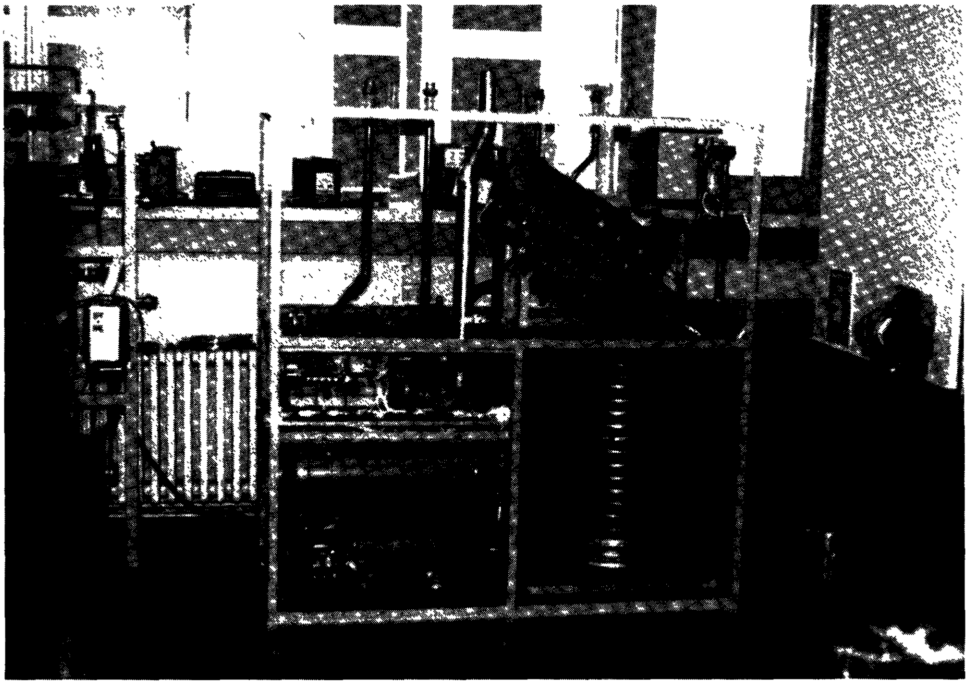


Figure 2.12.1 Water/water absorption heat pump unit for circulation pump testing

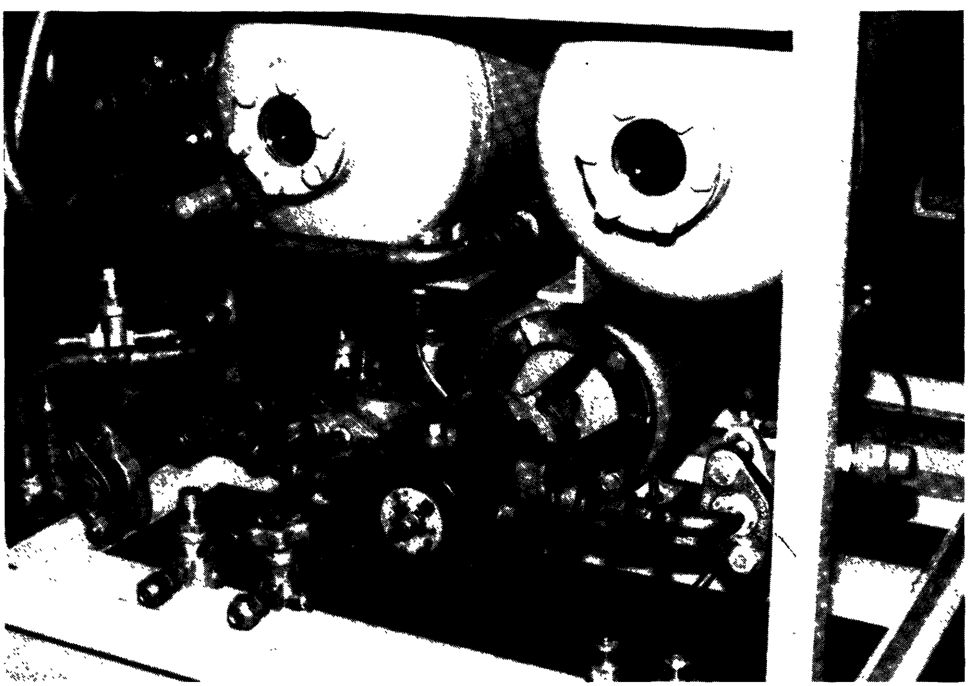


Figure 2.12.2 Annular gear pump with shaft sealing

Development of a cheap and efficiently adjustable solvent pump for absorption heat pumps 2.12

Stiebel Eltron GmbH & Co
Entwicklungsabteilung TE
Dr.-Stiebel-Strasse
D — 3450 Holzminden

K.H. SCHRADER

Contract number: EE-A-4-030-D

Development of a solution pump which is cheap and efficient is another important aim in absorption heat pump research. About four years ago STIEBEL ELTRON, Germany started R + D on the development of a 15 kW absorption heat pump which uses a fluid pair E181/R22. One of the major problems was to find a suitable and cheap (less than 500 DM) solution pump. After systematic testing of different pump types the annular gear pump was found to be most suitable. Two ways were followed to come to an efficient pumping system: In the first solution the pump inside the fluid reservoir is driven by an electric motor outside. Up till now no satisfactory shaft sealing methods were found. In the second solution the electric motor is completely submerged in the working fluid together with the pump (hermetic model). After some time the conductivity in the liquid increased by a factor 100-1000, possibly due to the formation of ions, to values where hermetic operation is not possible. Presently an electric motor is studied with a casing between the rotor and the stator (with electric wires) in such a way that the rotor is in the working fluid and the stator not. R + D on the solution with shaft sealing is being continued.

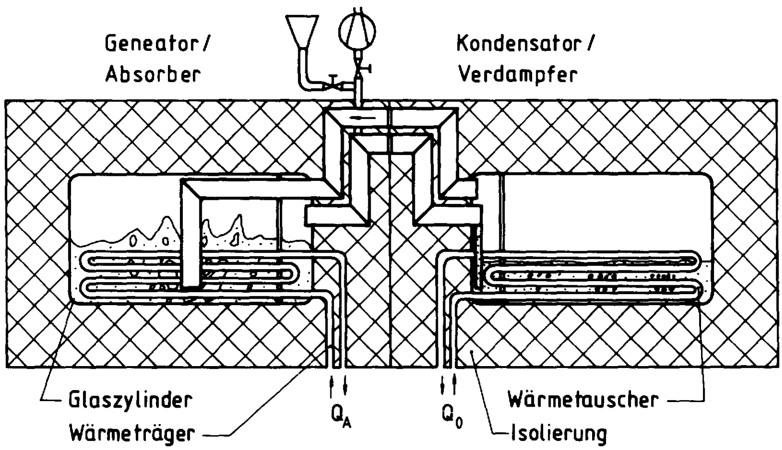


Figure 2.13.1 Periodically operating absorption heat pump

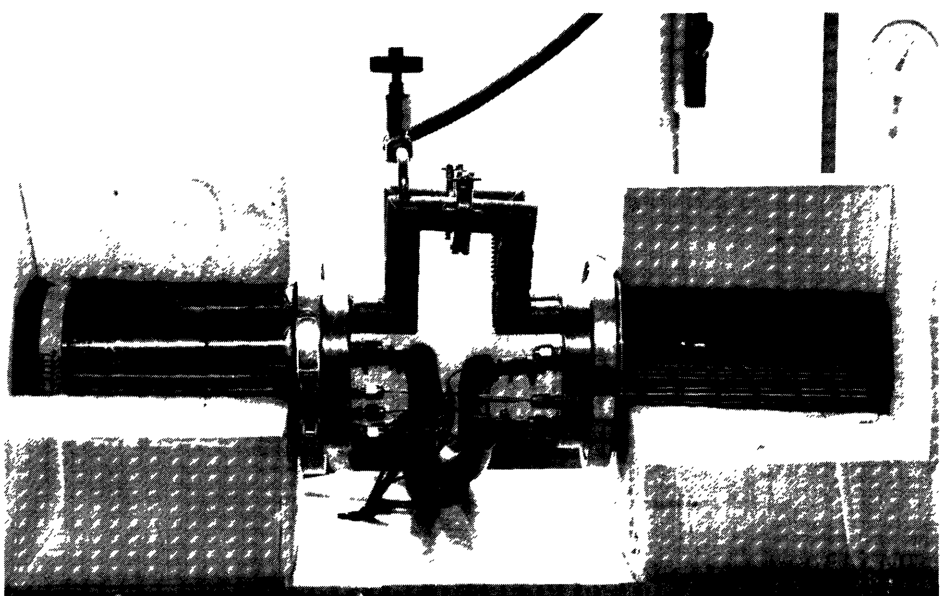


Figure 2.13.2 Experimental set up of a periodic absorption heat pump

Periodically operating absorption heat pump 2.13

Lehrstuhl für Technische Thermodynamik
RWTH
Schinkelstrasse 8
D — 5100 AACHEN

F.K. KNOCHE

Contract number: EE-A-4-065-D

A way to avoid the use of a solution pump in absorption heat pump is to use a periodically operating absorption heat pump. This heat pump consists of two reservoirs where liquids are separated, but where vapours can freely move from one reservoir to another. They are used as a generator and condensor for half a period and as an absorber and evaporator for the other half period. During the generator/condensor phase, heat is given to the generator and vapour is condensed in the condensor where heat is extracted. In the absorption/evaporator phase low grade heat is used to evaporate the fluid which is absorbed in the absorber where now heat is extracted. The cycle time is 1-1 $^1/_2$ hour. COP values of 1,3 have been measured in an experimental set up. Initially the combination LiBr and pure CH_3OH was used. Major problems were mass and heat transfer. By adding water to LiBr/CH_3OH the operation of the heat pump improved considerably. Adding water, shifts the solvability area of the LiBr/CH_3OH mixture towards lower temperatures thus preventing crystallization at room temperatures for salt contents between 0 and 57%. The heat transfer coefficient in the evaporator was found to be very low ($\pm$ 100 W/m^2K). The use of a thermosyphon generator is considered.

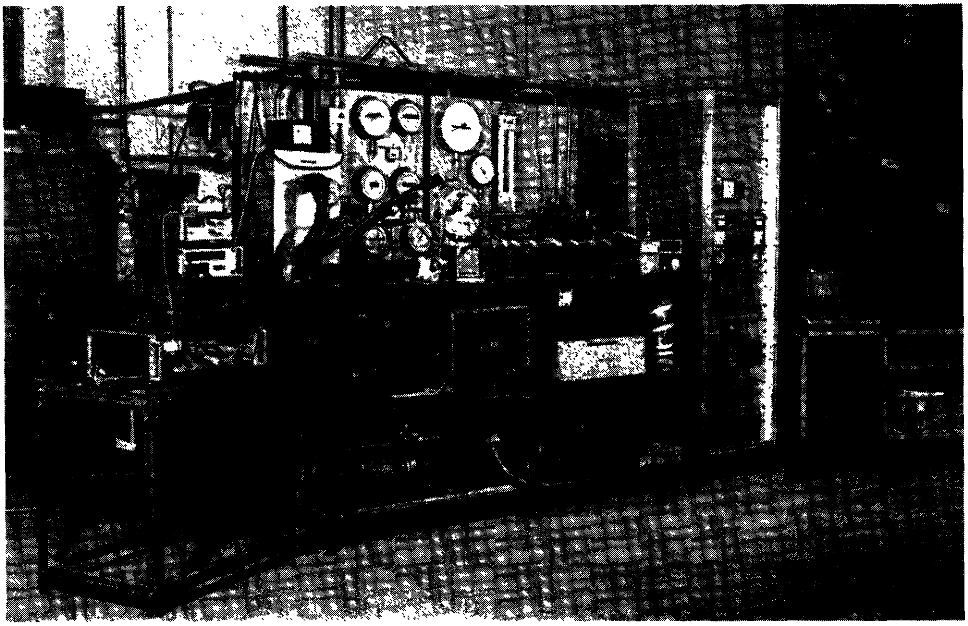


Figure 2.14.1. Main turbomachine test rig

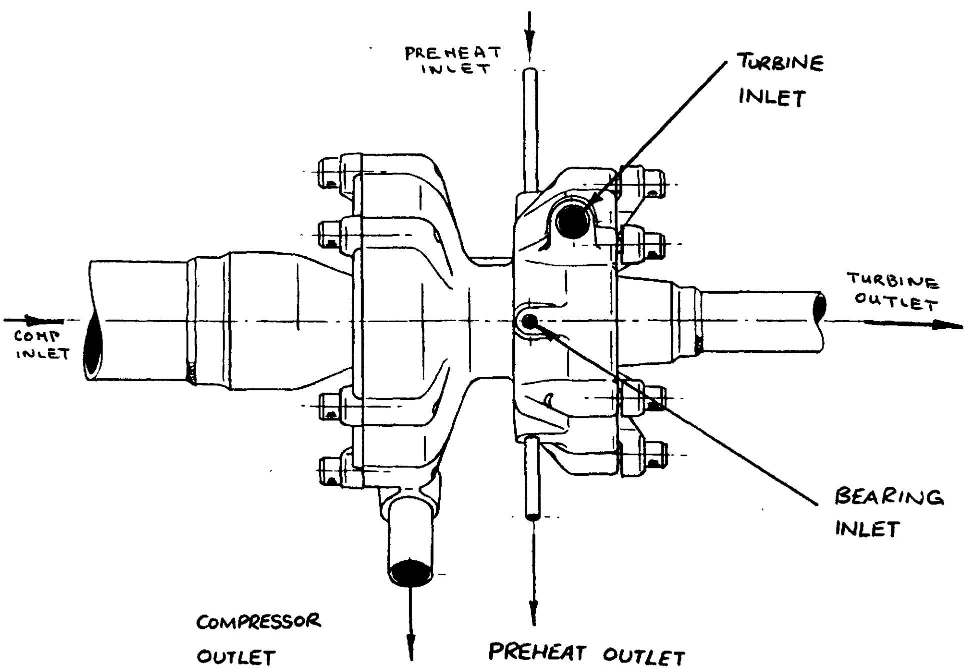


Figure 2.14.2 Proposed production turbomachine

An ORC engine driven heat pump of 10 kW for use in a domestic environment

2.14

Glynwed Group Services Ltd.
Central Resources Unit
15a Cranmore Drive
UK — Shirley, Solihull,
West Midlands B90 4PG

R.A. ATKINSON

Contract number: EE-A-4-043-UK

An ORC engine driven heat pump of 10 kW is being developed by GLYNWED, UK. The ORC turbine and the vapour compression of the heat pump are on the same axis. This heat pump may be fired by oil, gas, wood or waste heat and COP values of 1,2 have been obtained. Problems with rotors and bearings turned out to be insuperable and the project has therefore been stopped.

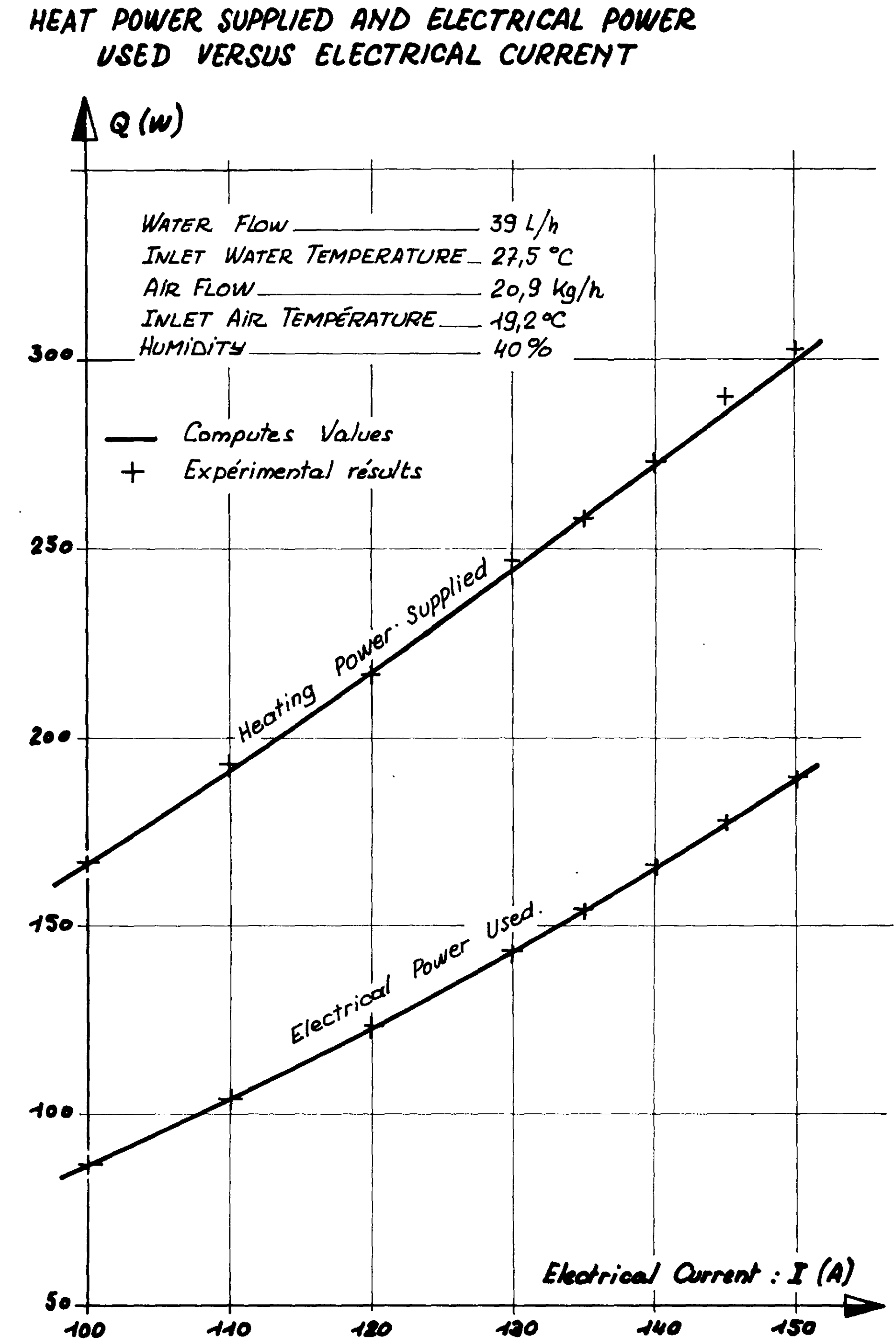


Figure 2.15.2 Heat output and power input for a thermoelectric heat pump as a function of the electric current

Thermo-electric heat pump for domestic heating 2.15

Laboratoires de Marcoussis
Division Energie
Route de Nozay
F — 91460 Marcoussis

P. DUBOIS

Contract number: EE-A-4-044-F

A thermo-electric heat pump has been developed which is based on the Peltier effect. When two different metals form a circuit, a current in that circuit will induce a temperature difference between the two metal interfaces (Peltier effect). Such thermo-elements were produced with two types of pellets where one interface is connected with a heat exchanger which extracts waste heat from exhaust air and the other interface with a heat exchanger by which heat of 35°C is delivered to a water current used for floor heating. Pellets of 170 mm^2, consisting of tellurium, bismuth and antimony (type P) and tellurium, bismuth, selenium (type N), have been developed and were found to operate satisfactorily.

A thermo-electric heat pump of 3.8 kW heat production has been defined where an electric current through a circuit of pellets induces a temperature difference between the heat extraction and heat discharge side. Experiments with a small heat pump module of 17 thermo-electric couples which delivered a maximum heat output of 300 W, showed that the COP value (power→heat) varied between 1,5 and 2,0 for 300 W and 150 W heat output respectively. Though this is not very high, this heat pump has advantages such as silent operation, simple maintenance, and a simple and continuous regulation of the heat output by varying the current in the thermo-element. The cost is approximately the same as for electrical heat pumps of equal size.

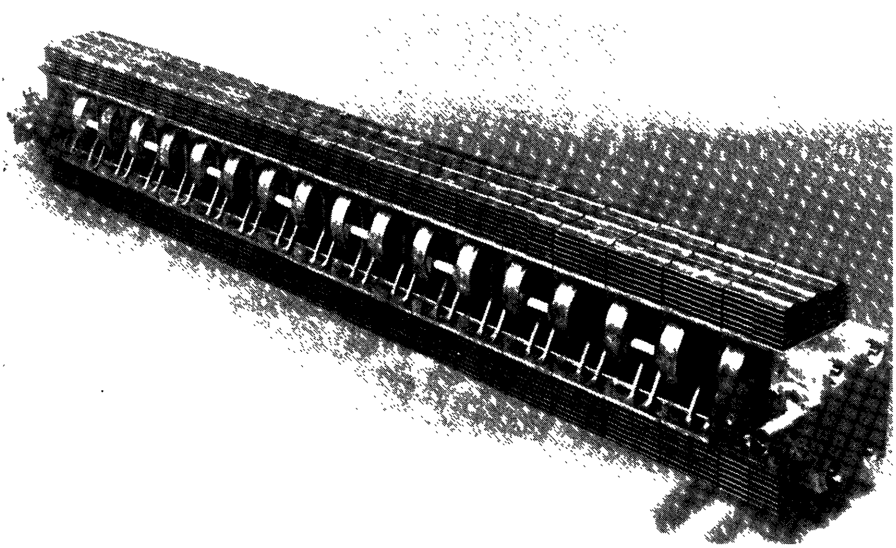


Figure 2.15.1 Small thermoelectric heat pump module of 300 W heat output

The use of soil as a heat source and heat storage medium for heat pumps

2.16

European Heat Pump Consultors
Skovshovedvej 38
DK — 2929 Charlottenlund

M. FORDSMAND

Contract number: EE-A-4-032-DK

The operation of a system with simple unshielded solar collectors (14,2 m^2), a small heat pump for domestic hot water (± 1 kW) and a large heat pump (6 kW, 45°C) for domestic heating via a system of radiators is being investigated. The low grade heat for the electrical heat pump is extracted from the soil with a system of 7-9 tubes of 14-16 m long. Three different drilling methods were studied of which the cost varied from 50 DKR/m to 170 DKR/m. This system has now been installed in a house of 137 m^2 and measurements are being carried out. Up till now COP values of the system varied between 2,7 and 5 with an average value of 3,3. This work is coordinated with work done by TNO, Netherlands (see 2.18).

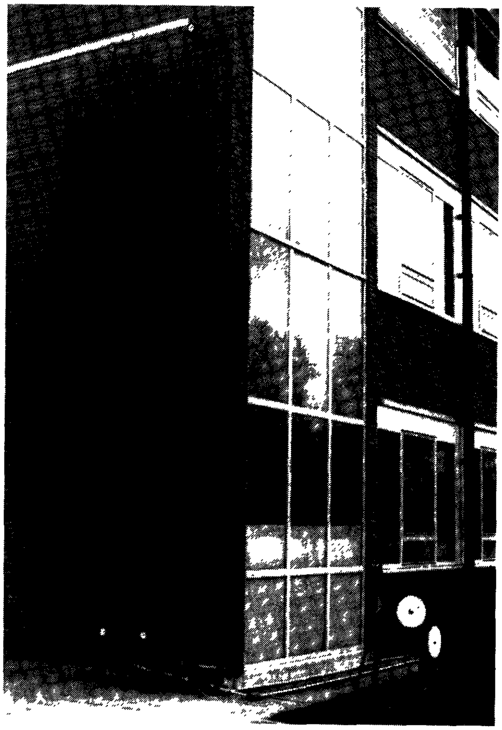


Figure 2.17.2 Energy facade made of copper

Figure 2.17.3 Energy stack as a heat source for heat pumps

Space heating with heat pumps using soil and an energy roof as a heat source 2.17

LABORELEC
Boîte Postale 11
B — 1640 Rhode-St-Genèse

B. GEERAERT

Contract number: EE-A-4-037-B

A systematic investigation of heat sources for heat pumps is being carried out in a 500 m^2 hall heated by three heat pumps using horizontal soil heat exchangers and unshielded solar absorbers as heat sources. The horizontal soil heat exchangers consisted of a two layer system at a depth of 60 cm and 120 cm. The temperature of the tubes could be kept between + 25°C and —2,5°C. Different types of unshielded absorbers, such as copper absorbers and galvanized steel plate absorbers clipped on copper tubes, placed against the walls of the building, were also investigated. The absorption measured, was of the order of 20 W/m^2°K. Also enclosures and stacks made of radiators were tested. They gave a considerably higher absorption: enclosures 35 W/m^2°K and stacks depending on the wind velocity: 20-80 W/m^2°K. An original concept is a Danish stack made of plastic tubes, with small canals in the tube wall where the water/glycol mixture circulates. The cost of this stack is of the order of 130 ECU per kW low grade heat extracted. A disadvantage of all absorber systems is that at low temperatures the efficiency of the heat pump becomes very low. Soil heat exchangers have the advantage to deliver low grade heat at more constant temperatures.

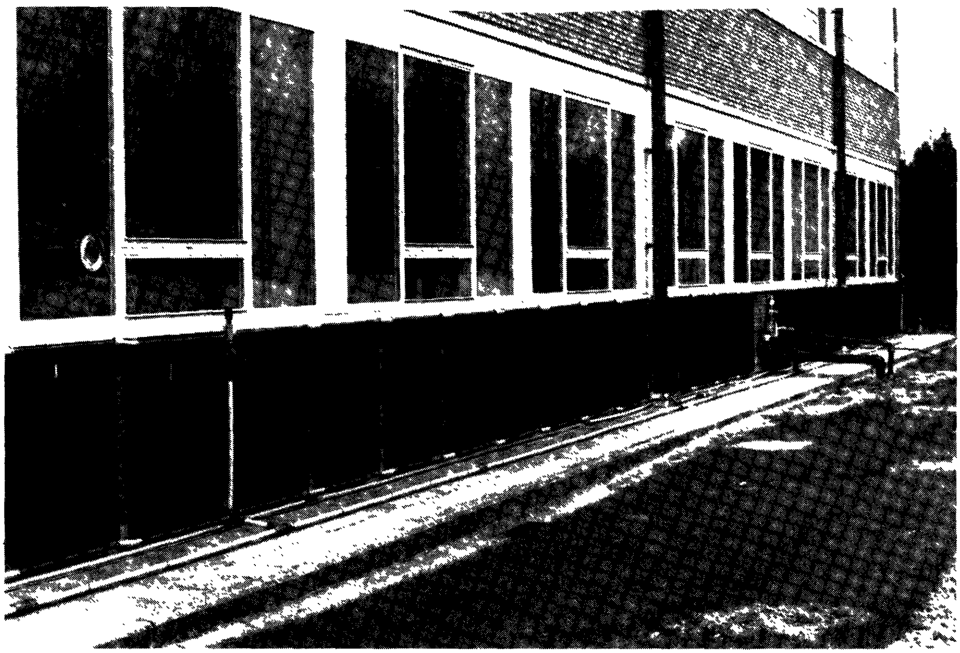


Figure 2.17.1 Energy facade made of galvanized steel as a heat pump heat source

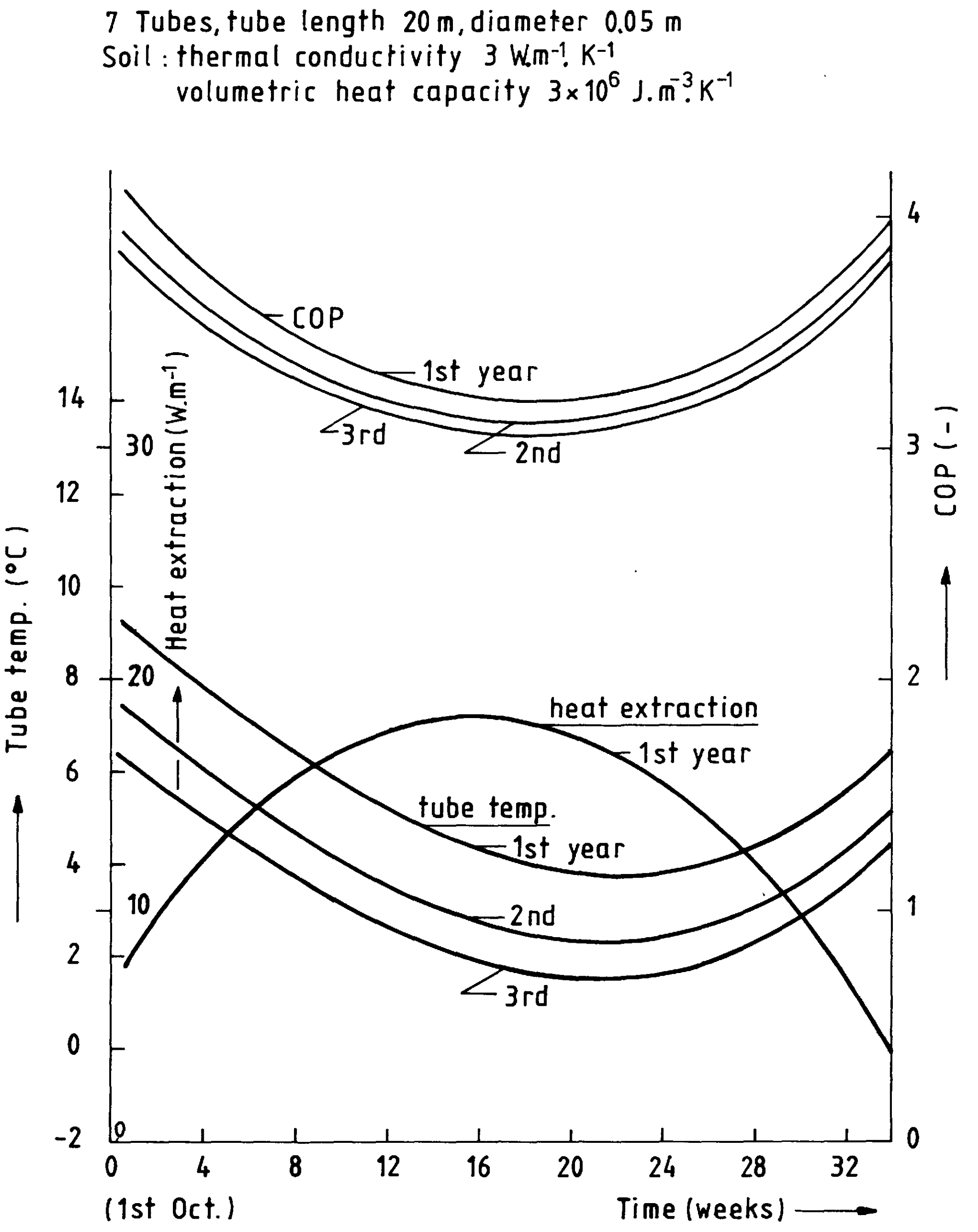


Figure 2.18.2 Calculated performance of a 5,5 kW heat pump connected with a vertical soil heat exchanger consisting of 7 tubes

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 house

2.18

TNO
Postbus 342
NL — 7300 AH Apeldoorn

J.W.J. BOUMA

Contract number: EE-A-4-033-NL

A house of 148 m^2 is heated with a 5,5 kW electrical heat pump delivering heat of 35°C to a floor heating system. Waste heat is extracted from the soil by a system of vertical tubes with a circulation liquid (e.g. water/glycol). Six different methods to sink the vertical tubes were studied. The cheapest method, 9 tubes of 15 m long, extracting 4 kW of low grade heat, will cost 1 000 ECU (200 m of horizontal tubes at a depth of 60 cm will cost 500 ECU). The system is being tested during the winter 1982/1983.

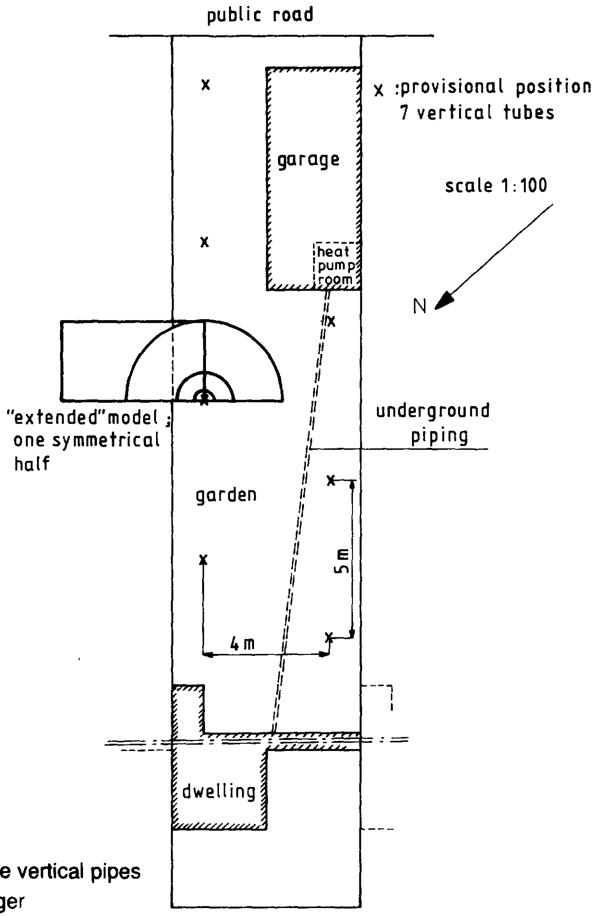


Figure 2.18.1 Siting in a garden of the vertical pipes of the soil heat exchanger

Solar assisted absorption or motor driven compressor heat pumps with earth seasonal storage 2.19

METALUX SpA
Via Triestina, 74
I — 30024 Musile di Piave

D. SARTORELLO

Contract number: EE-A-4-047-I

The aim of this project is to optimize the heating system of a building with a heat demand of 50 000 MJ/year and requiring a maximum heating capacity of 25 kW. The house will be heated with a combustion engine driven compressor heat pump or a 25 kW absorption heat pump with NH_3/H_2O. As a heat source a combination of a vertical soil heat exchanger (± 15 tubes of 15 m) and 14 m × 8,40 solar energy roof will be used. Installation is presently being carried out.

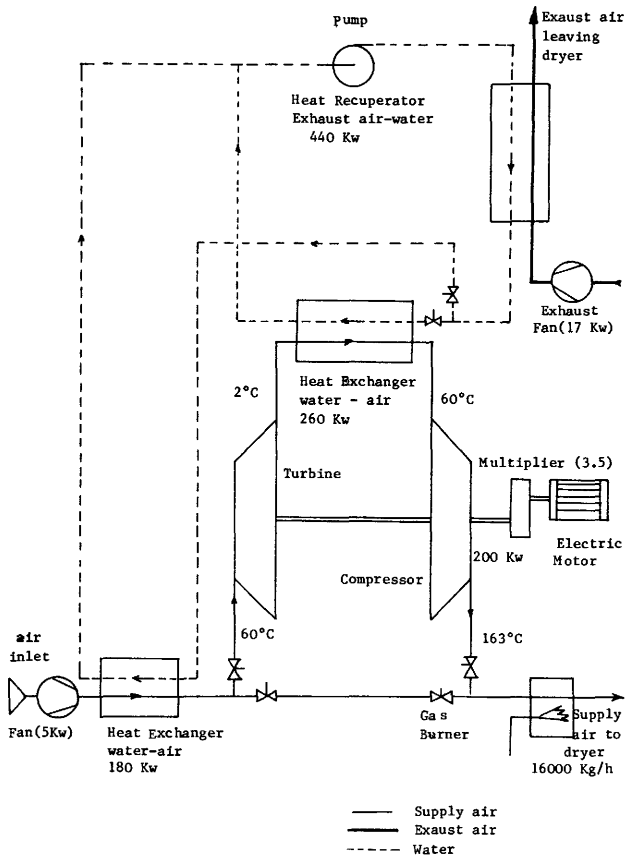


Figure 2.20.2 Schematic arrangement of Brayton-cycle heat pump components

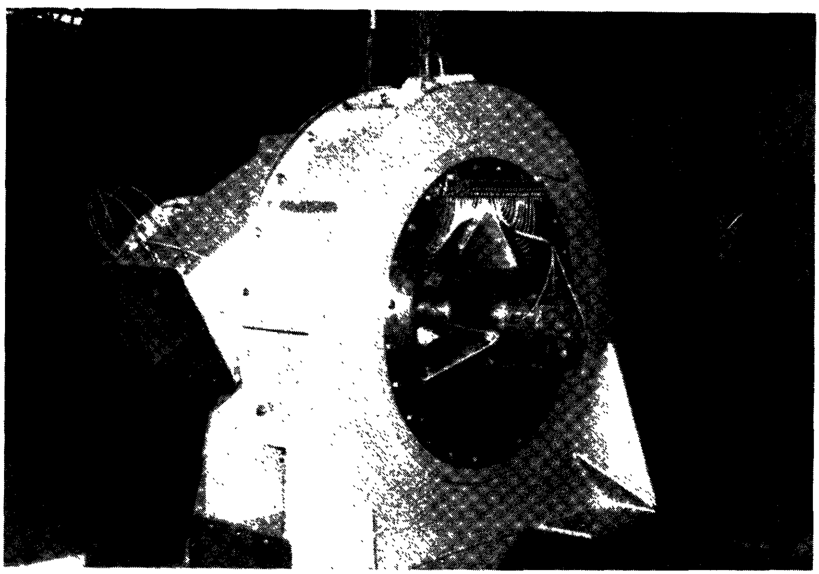


Figure 2.20.3 Turbocompressor unit of an industrial Brayton-cycle heat pump which produces 700 kW at 165°C

Study and realization of an industrial Brayton-cycle heat pump for high temperatures (150-300°C) 2.20

CEM CERCEM
49, rue du Commandant Rolland
F — 93350 Le Bourget

J.P. FLAUX

Contract number: EE-B-1-119-F

Heat pumps in industry mainly serve as a tool to transform waste heat into heat at a higher temperature level where it may be used. With the present state of the art heat pumps can produce heat up to 120°C. Unlike domestic heat pumps where heat has to be extracted from air or soil, the heat source for industrial heat pumps is generally waste heat. The national energy saving potential for industrial heat pumps is not very big (1-2% of the total national primary energy consumption) but can be trebled if heat pumps can be developed which produce heat up to 300-400°C. To achieve this objective much R + D still has to be done.

The only project which has the promise of producing heat at these temperatures is the Brayton-Cycle heat pump which is being developed by CEM, France. Here air of 1 bar is heated with waste heat to 60°C, is expanded in a turbine to 0,5 bar and 2°C and is then heated up to 60°C with waste heat of 90°C and compressed to 1 bar at 165°C. This heat will be used for drying in the production of milk powder. The turbo-compressor will deliver 4 kg/s of hot air at 165°C and consumes 200 kW for a production of 500 kg milk powder per hour. An electric motor has been chosen to drive the turbo-compressor; a combustion engine with heat recovery would give a higher energy efficiency but maintenance is too costly and time consuming. The COP of the heat pump is calculated to be 3,18. The pay back time is 3-4 years. In principle this heat pump concept could be used up to temperatures of 400-500°C. The design phase has now been terminated and construction has started.

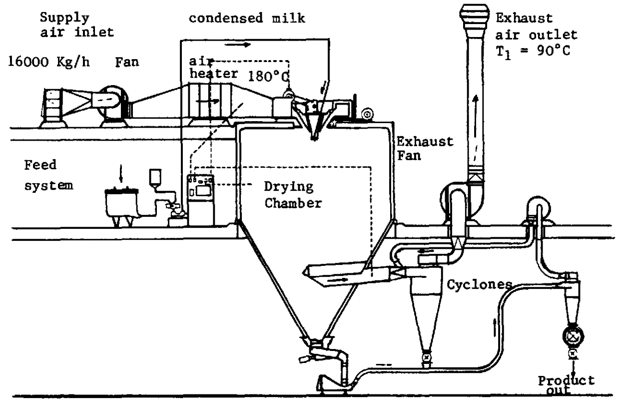


Figure 2.20.1 Conventional spray drying plant

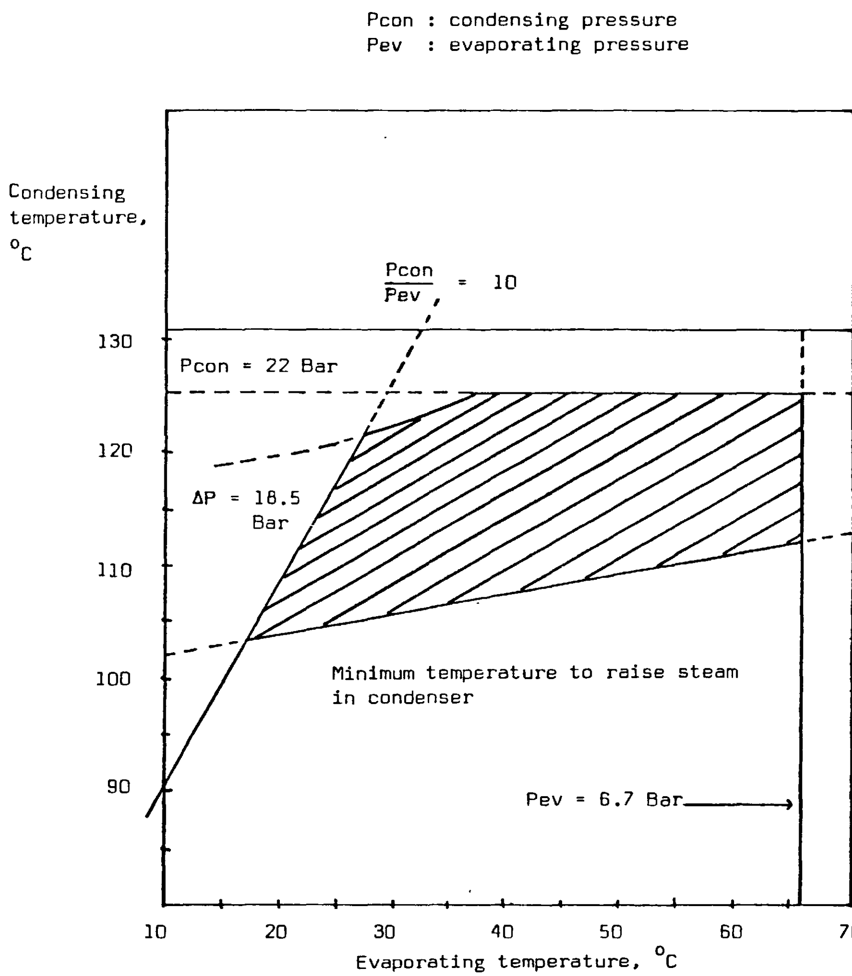


Figure 2.21.1 Limits of operation of a heat pump system imposed by compressor and heat transfer characteristics

Industrial application of a high temperature gas engine driven heat pump — 2.21

IRD
Mechanical Engineering Department
Fossway
UK — Newcastle upon Tyne NE6 2YD

V.A. EUSTACE

Contract number: EE-B-1-147-UK

This contract is a short follow-up contract of work carried out in the first programme. A 330 kW_{th} ICE driven heat pump was developed which produces steam at 110°C; waste heat at 80°C serves as a heat source. The COP value is 1.5. Problems have been encountered with steam flow measurement and compressor oil/refrigerant mixing. In the framework of the C.E.C. Demonstration Programme a demonstration plant is now being built in a chemical industry.

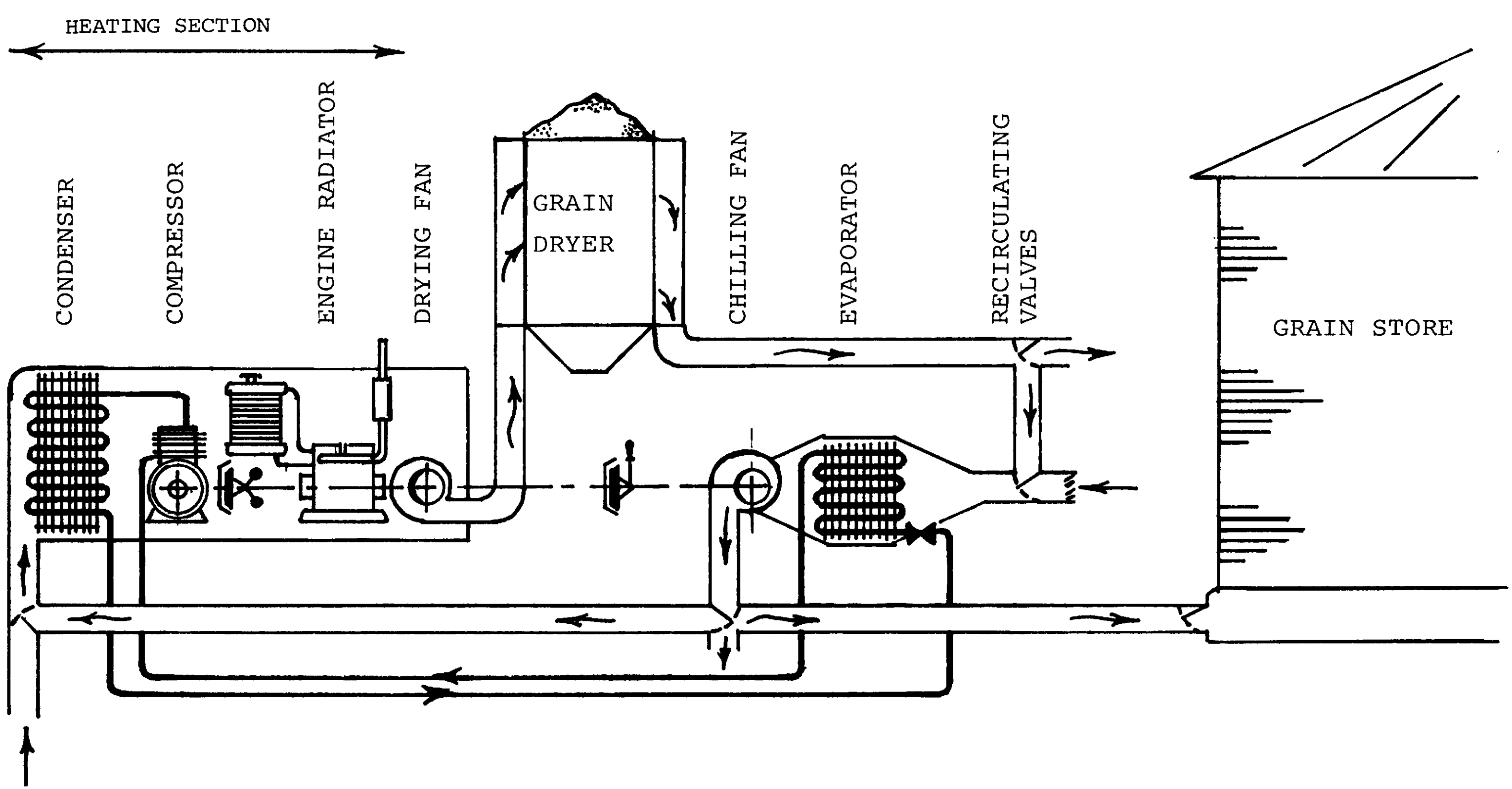


Figure 2.22.1 Schematic arrangement of heat pump chiller/dryer

An internal combustion engine driven heat pump for grain drying combined with refrigerated storage 2.22

The Agricultural Institute
Oak Park Research Centre
IRL — Carlow

B. CUNNEY

Contract number: EE-B-1-125-IRL

An application of a petrol/gas engine driven air source heat pump is believed to be feasible in grain drying in one of its most efficient working modes: simultaneous heating and cooling. The heat pump produces both chilled air of 4-5°C (heat source), which can be used for refrigerated storage of undried grains, and hot air which is used for drying. In this way the grain can be stored for 3-4 months when chilled to 4-5°C. A dryer can then be utilized over a period 2-3 times longer than is typical with current practice. A heat pump which extracts 10 kW low grade heat from air (refrigerating capacity) is driven by a 12 kW petrol/gas engine. Waste heat from this engine is also recovered. A 71 tonne store contains the grain to be chilled and a 6 tonne batch drying unit has been built. After construction both the output and the thermal efficiency were lower than expected. This will however not adversely affect the continuation of the project.

Development of an absorption heat pump for industrial applications

2.23

Katholieke Universiteit Leuven
Departement Werktuigkunde
Celestijnenlaan 300 A
B — 3030 Heverlee

J. BERGHMANS

Contract number: EE-B-1-136-B

In this project thermo-dynamic cycles will be studied for industrial absorption heat pumps which produce heat at temperatures higher than 120°C. Different working fluid pairs will be investigated (e.g. ammonia/water, LiBr/water, methanol/LiBr, Methylamine/water). For promising working pairs lacking data will be measured and the design will be studied of heat pump components.

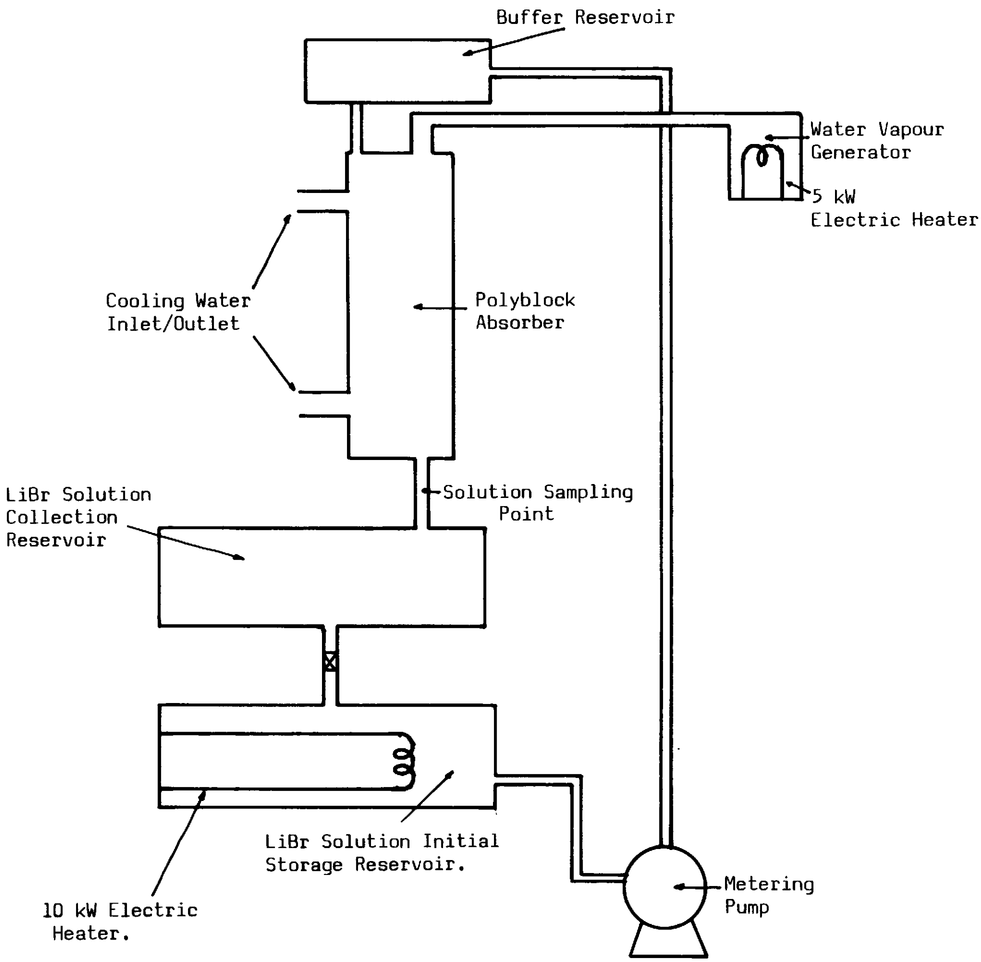


Figure 2.24.2 Schematic of absorber test apparatus

A theoretical and experimental investigation into the performance of absorption cycle heat pumps applied to industrial processes

2.24

IRD
Mechanical Engineering Department
Fossway
UK — Newcastle upon Tyne NE6 2YD

V.A. EUSTACE

Contract number: EE-B-1-146-UK

In this project a design is made for an industrial absorption heat pump of 300 kW with LiBr/H_2O as a working fluid pair. The design of the absorber is believed to be the most difficult problem and a special absorber test rig has been built. A scaled down 10 kW model has been built to gain experience. This heat pump transforms heat of 20-50°C into heat of 60-90°C. To avoid crystallization during periods of non-operation the LiBr is stored at a concentration less than 59%. The sealing of the absorber is a major problem due to the low pressure inside.

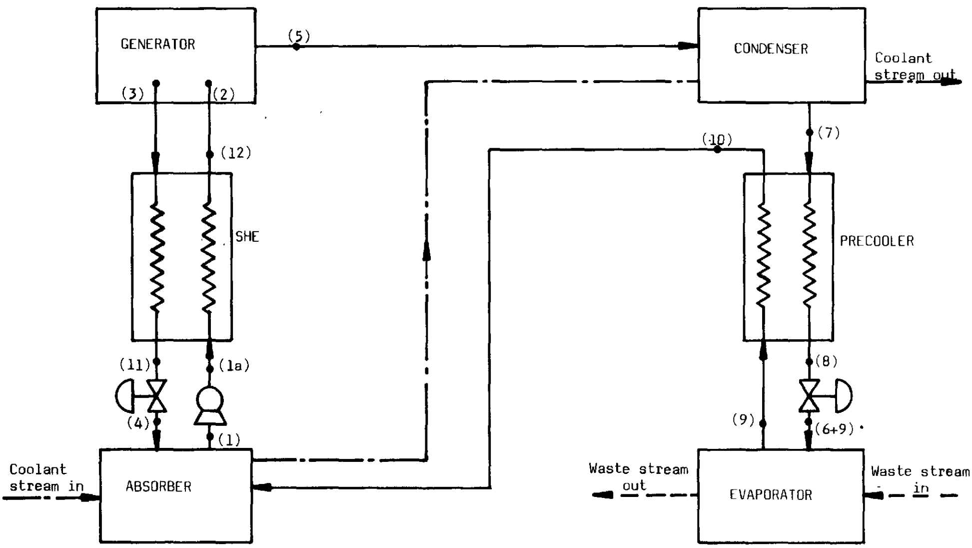


Figure 2.24.1 Schematic diagram of a basic absorption heat pump

R and D on heat pumps for heat recovery from paper dryer exhaust air, producing process steam

2.25

Battelle-Institut e.V.
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D.L. HODGETT

Contract number: EE-B-1-152-D

Different possibilities have been studied to produce heat of 125-145°C for a paper dryer from its waste heat at 80-90°C. A comparison of the possible systems was made regarding technical feasibility, energy saving potential and costs. Three systems (two-staged absorption heat pump with LiBr/H_2O, compression heat pump and thermocompressor) were found to be able to work under the specific operating conditions of the reference paper machine. A computer code for economic assessment calculations (i.e. pay back period) was developed.

Finally the outline design of a two-staged absorption heat pump test rig was made, based on the results of the computer calculations.

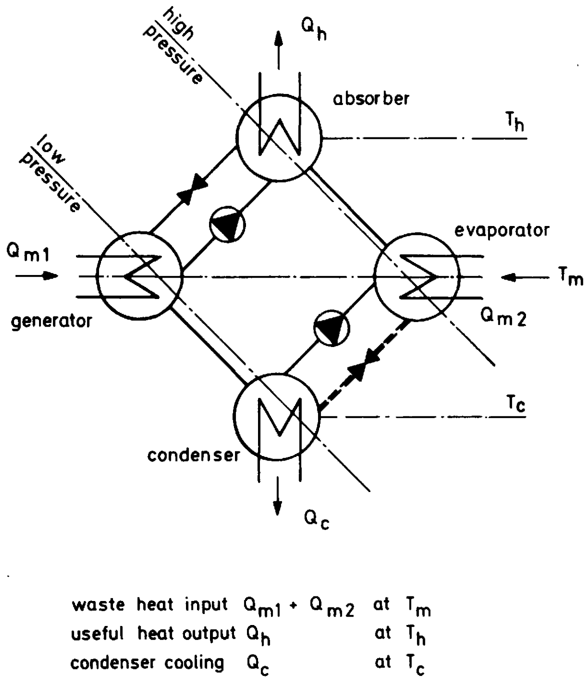

Figure 2.26.1 Schematic diagram of a heat transformer

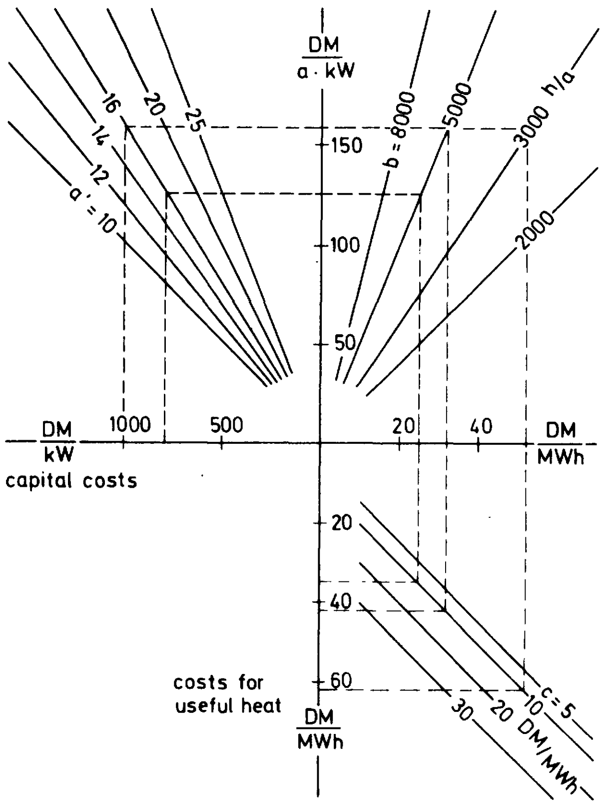

Figure 2.26.2 Economy of the heat transformer

Development of a heat transformer which produces process steam at 130°C 2.26

MAN
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K. MÖTZ

Contract number: EE-B-1-134-D

A 10 kW heat transformer with NH_3/H_2O as a working fluid pair is being developed which will convert industrial waste heat of 80°C in steam of 130°C (3 bar) without further need of fuel or power. A heat transformer is a reversed absorption heat pump. In a normal absorption heat pump high temperature heat is used in the generator, low temperature waste heat is absorbed in the evaporator and medium temperature heat is extracted from the absorber and condensor. In a heat transformer medium temperature waste heat is given to the generator and evaporator, high temperature heat is extracted from the absorber and low temperature heat is discharged at the condensor. The amount of high temperature heat is only fraction of the medium temperature waste heat used in the generator and evaporator. For the heat transformer which is being developed the amount of heat at 135°C delivered by the absorber is about 30% of the waste heat at around 100°C given to the generator and evaporator. Disadvantages of the NH_3/H_2O fluid pair are the high pressures which lead to more expensive tubing and the toxicity of NH_3. The design phase has been finished and construction has started.

Sector 3

ENERGY CONSERVATION IN INDUSTRY

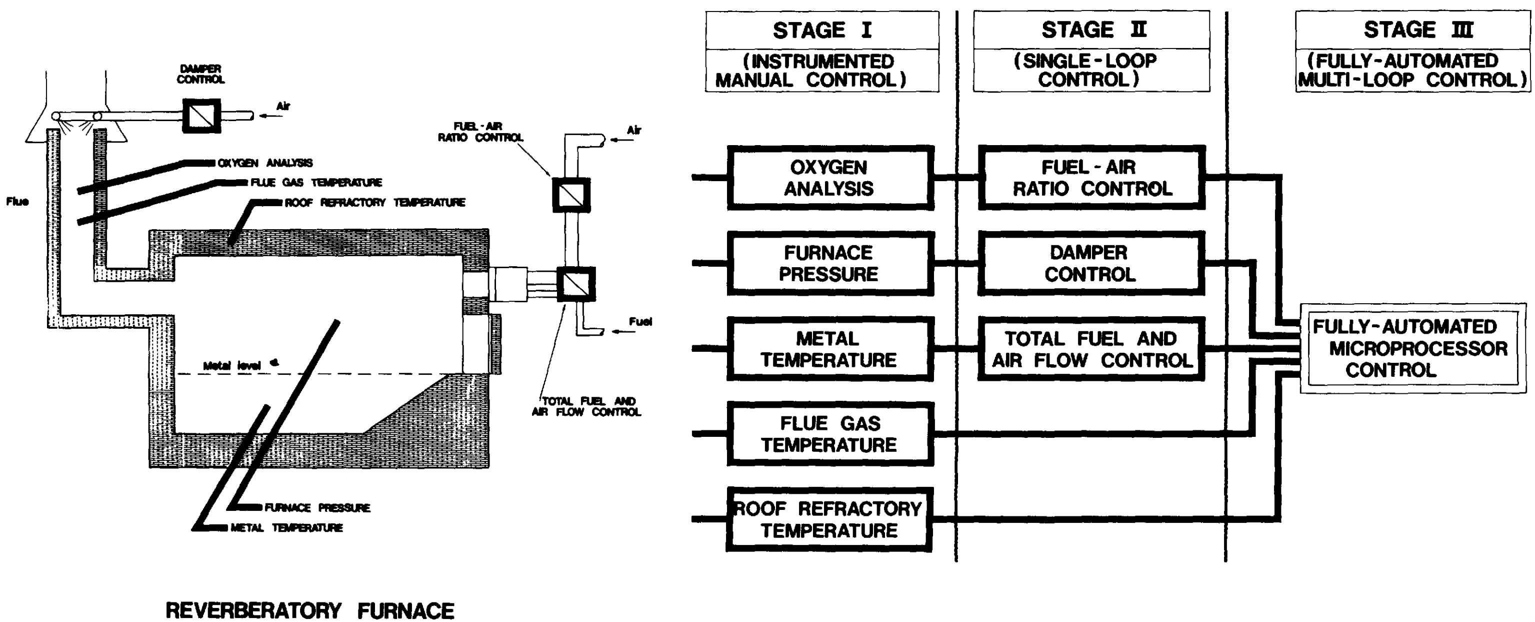

Figure 3.1.1 Automated combustion control system (schematic)

Efficiency of reverberatory furnaces 3.1

The British Aluminium Company Ltd.
Central Engineering Department
Chalfont Park
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V. SUBRAMANIAN

Contract number: EE-B-1-103-UK

In reverberatory melting and holding furnaces (which consume gas or oil) in the aluminium industry the control of combustion conditions is generaly based on manual control by an experienced operator. Consequently, the efficiency of these furnaces tends to be low (10 to 25%). The aim of the project by BRITISH ALUMINIUM is twofold: to improve the manual control of these furnaces by better cost effective instrumentation and to develop a fully automated combustion and furnace control system.

The project was established with the initial aim of being able to develop systems and procedures which would save 15 per cent of the energy used in the company's melting furnaces. To date, the work indicates that double this amount will be saved. This has been made possible by three principal measures: improved burner specifications, particularly increased turn-down ratio, application of new instruments and automated single-loop control of individual parameters.

The estimated savings on the three production furnaces involved in the development to date are £ 70,000 per annum (126.000 ECU) and a pay back period of 6-8 months is anticipated.

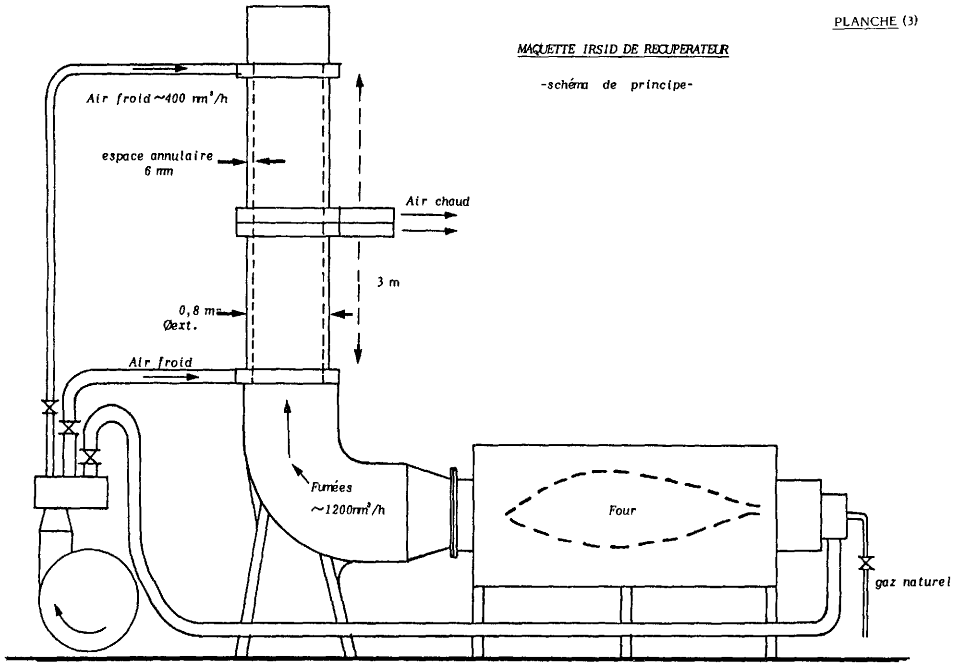

Figure 3.2.1 Model of the IRSID recuperator indicating the principle of improving the heat exchangers which preheat combustion air with exhaust gases of the furnace

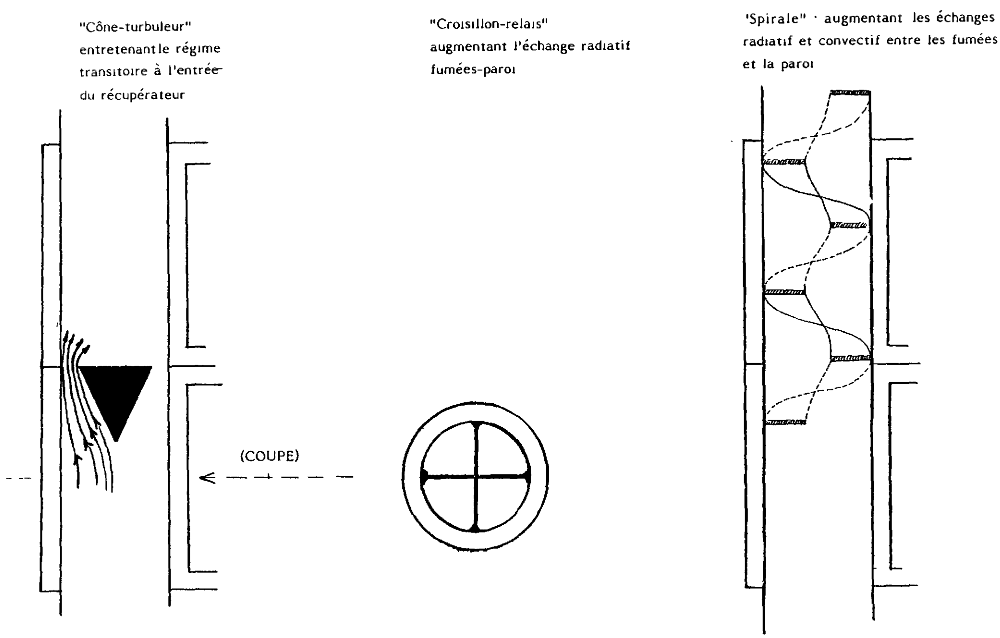

Figure 3.2.2 Suggested proposed techniques to improve the efficiency of radiation heat exchangers

Improvements of heat exchangers associated with steel slab furnaces 3.2

Institut de Recherches de la Sidérurgie Française
(IRSID)
Station d'Essais
F — 57210 Maizières-les-Metz

J.L. ROTH

Contract number: EE-B-1-150-F

Steel produced in blast furnaces is delivered in slabs which are cooled and sent to steel mills for further manufacturing (strips, plates, etc.). Before entering in the steel mills, the steel has to be reheated in furnaces to high temperatures (1200°C). These reheating furnaces are major fuel consumers: a furnace of this type has a yearly consumption of 40,000 to 50,000 toe. (3 or 4 such furnaces are required for the production of 4 million tons of steel per year).

The aim of this study is to decrease this consumption by improving the efficiency of the heat exchangers which preheat combustion air using the exhaust gases of the furnace (at 1000°C). They currently have an efficiency of 25% and their replacement by new and more advanced heat exchangers with an efficiency of 50% could lead to important energy savings (4,000 toe per furnace per year). The pay back time of these investments however is too long. The aim of the present work is therefore to examine ways in which the existing heat exchangers can be improved by simple modifications which have a short pay back time.

The work carried out consists of simulating the heat exchanger with a computer model. This was based on experiments carried out on a 1/5 scale model and on measurements carried out in an industrial plant.

Several construction improvements to the current heat exchangers have been identified (e.g. the introduction of metallic pieces which increase heat exchange) and are being evaluated on the scale model. Errors of heat exchanger feed have been identified and quantified during trials at the plant (fume losses, air leaks) and practical solutions proposed are under study. Although the efficiency of the improvements has yet to be specified by supplementary trials, the approximate gains have been calculated: The proposed actions each lead to yearly energy savings of 400 toe per furnace and are additive. Investment costs are moderate and give a pay back period of 6 months.

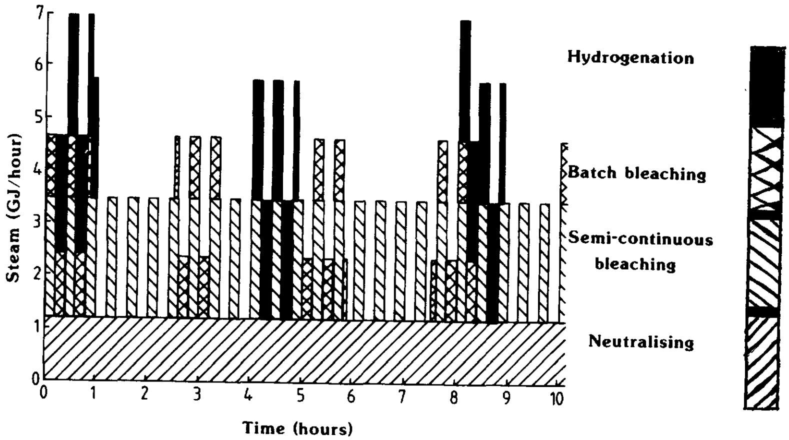

Figure 3.3.1 Calculated steam heating requirements neutralising, batch and semi-continuous bleaching and hydrogenation plants

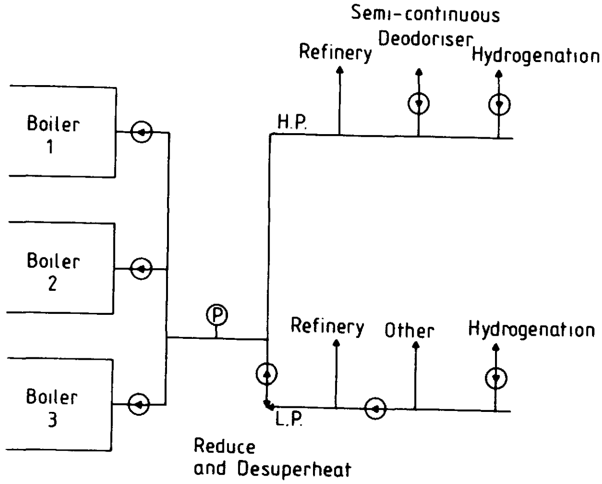

Figure 3.3.2 Steam flow measurement

Improved boiler control in food factories 3.3

British Food and Manufacturing
Industries Research Association
Randalls Road
GB — Leatherhead, Surrey KT22 7RY

W.E. WHITMAN

Contract number: EE-B-1-124-GB

Previous work carried out by LEATHERHEAD FOOD RESEARCH ASSOCIATION (EEC Contract no. 245-77-EE-UK) showed an average fuel consumption of 3.47 MJ/kg of steam produced in food factory boilers. Boiler utilisation was also low (45%). Low boiler utilisation can be traced to erratic and widely fluctuating demand from a number of steam users.

The objective of this work is to study, in collaboration with an industrial partner (PL GROUP (FOODS) LTD), the cost-effective management of steam supply and distribution in a food factory processing edible oil. The industrial partner employs three boilers supplying five major and a number of less important steam users. A micro-computer is to be used in the boiler house to monitor the operations of the steam users in the factory and thence to compute the steam demand some minutes in advance. This information will be used by the micro-computer to control the firing of the boilers so that, as far as possible, steam availability is adjusted to meet peaks and troughs in demand. The micro-computer will be also used to regulate the firing conditions of the boilers, using the "radiation peak-seeking" techniques developed by Land Pyrometers, (EEC Contract no. 396-78-EE-IR).

This project is in its early stages. PL GROUP has installed a computer to log data from steam flow meters and boiler house sensors and to compute boiler efficiencies. The steam meters are operating and a programme of data acquisition and monitoring has started. The beginning of a control strategy exists but is difficult to complete without more quantitative data on steam users and boiler steam production.

Working Fluid		Structural Material			Operating Temperature	Duration[1] /d/	Temperature Differences	
Name	Chemical Formula	DIN	German material-number	AISI-number			$T_1 - T_5$ /K/	$T_1 - T_6$ /K/
Freon R 21	$CHCl_2F$	AlMn	3.0515		80	1430	10-23	16-23
		AlMgSi0.5	3.3206		80	1430	25-30	25-36
		CuNi30Fe	2.0882		80	1430	0-2	0-2
		CuZn28Sn	2.0470		80	1430	2-11	5-16
		CuZn36	2.0335		80	1430	2-3	5-11
		CuZn20Al	2.0460		80	1430	0	0-2
		St35	1.0305		80	1430	0	0
Water	H_2O	SF-Cu	2.0090		150	1450	9-11	8-16
		CuNi30Fe	2.0882		140	1440	0	0
		CuZn20Al	2.0460		150	1440	101-114	104-126
		CuNi10Fe	2.0872		300	30	0-1	0-1
		Ti994	3.7025		300	30	0-1	0-2
n-Octane	C_8H_{18}	St35	1.0305		170	1350	143	144
					230	1350	0	0
		X10CrNiTi189	1.4541	321	200	1350	3	4
					250	1350	0	0
Diphyl[2]	$C_{12}H_{10}$ + $C_{12}H_{10}O$	St 35	1.0305		250	1350	12	14
					270	1350	12	37
		X10CrNiTi189	1.4541	321	270	1350	24	28
					290	1350	28	56
		CuNi10Fe	2.0872		300	30	4-8	4-8
		Ti994	3.7025		300	30	3-5	14-17
Diphyl-O[3]	$C_6H_4Cl_2$	St35	1.0305		220	1360	6-13	6-14
Diphenyl	$C_{12}H_{10}$	13CrMo44	1.7335		350	10	2-3	3-6
					400	10	1-2	1-2
		X2CrNiMo1812	1.4435	316L	350	10	1	1
					400	10	4	7
OM[4]		13CrMo44	1.7335		350	*	-	-
					400	*	-	-
		X2CrNiMo1812	1.4435	316L	350	*	-	-
					400	*	-	-
OMD[5]		13CrMo44	1.7335		350	*	-	-
					400	*	-	-
		X2CrNiMo1812	1.4435	316L	350	*	-	-
					400	*	-	-
Toluene	C_7H_8	St35	1.0305		250	730	0	3-5
		13CrMo44	1.7335		250	730	7	1-12
		X2CrNiMo1812	1.4435	316L	280	600	0-3	0-2
		CuNi10Fe	2.0872		300	90	1-3	2-3
		Ti994	3.7025		300	30	1-3	2-4
Naphtalene	$C_{10}H_8$	St35	1.0305		270	730	1-4	3-7
		13CrMo44	1.7335		270	730	3-7	8-13
		X2CrNiMo1812	1.4435	316L	350	20	4-5	1-6
		CuNi10Fe	2.0872		350	30	0-5	1-6
		Ti994	3.7025		300	30	3	3-4
Silicon Oil XF 218[6]		St35	1.0305		300	80	7-10	12-14
		13CrMo44	1.7335		350	80	9-14	10-18
		CuNi10Fe	2.0872		350	80	11	15
Silicon Oil 200 Fluid 50 cS[6]		St35	1.0305		300	80	90-104	113-122
		13CrMo44	1.7335		350	80	143-108	163-181
		CuNi10Fe	2.0872		350	80	104-109	123-131
Sulphur + Iodine 99 % + 1 % 97 % + 3 %	S (99 %) + I (1 %) S (97 %) + I (3 %)	AlMg 3	3.3535		200	*	-	-
		AlMgSi0.5	3.3206		200	*	-	-
		X2CrNiMo1812	1.4435	316L	450	*	-	-
					500	*	-	-
					550	*	-	-

1) heat pipes: * not in operation
2) binary mixture of diphenyl and diphenyl oxide
3) 1,2-dichlor benzene
4) binary mixture of ortho- and meta- terphenyl
5) ternary eutectic mixture of diphenyl, ortho- and meta- terphenyl
6) trade name of Dow Corning Company

Figure 3.4.1 Results of compatibility tests

Heat transfer, vapour-liquid flow interaction and materials compatibility in two-phase thermosyphons 3.4

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Energiewandlung e.V. (I.K.E.)
Holderbuschweg 52
D — 7000 Stuttgart 80

M. GROLL

Contract number: EE-B-1-133-D

Gravity assisted heat pipes and two phase thermosyphons have excellent heat transport properties. Typically, 1 kW can be transferred through a tube with a diameter of 10 mm. Heat introduced at the "hot" end of the tube evaporates a liquid and the vapour transports the latent heat to the cold end of the tube where it condenses and releases the heat; the condensed liquid returns to the evaporator. In a heat pipe the liquid is returned by capillary forces, typically in a wired mesh lining the inside wall of the tube; in a thermosyphon the liquid returns by gravity.

The objective of the IKE study is to investigate three main aspects of two-phase thermosyphons in order to improve their performance: heat transfer characteristics, vapour-liquid flow interaction and materials compatibility.

Heat transfer measurements revealed coefficients of 10,000 $W/m^{2o}K$ and 100,000 $W/m^{2o}K$ for the evaporator and condenser respectively. The overall thermal conductance of heat pipes was greater than of thermosyphons (this was due to the wick which provided better wetting by the returning liquid from the condenser to the evaporator and enhanced the heat transfer coefficient). Typical axial heat fluxes achievable in heat pipes and thermosyphons were in excess of 1 kW/cm^2. It was also found that high performance thermosyphons were performance limited by liquid-vapour flow interaction, not by boiling.

IKE identified suitable working fluid/material combinations for use in heat pipes and thermosyphons at high temperatures (typically 400°C vapour temperature). While cheap carbon steels may be used as containers for fluids such as naphthalene and toluene at temperatures up to 270°C and 280°C respectively, more expensive materials are likely to be needed if organics are to be successfully used at higher (350-400°C) temperatures.

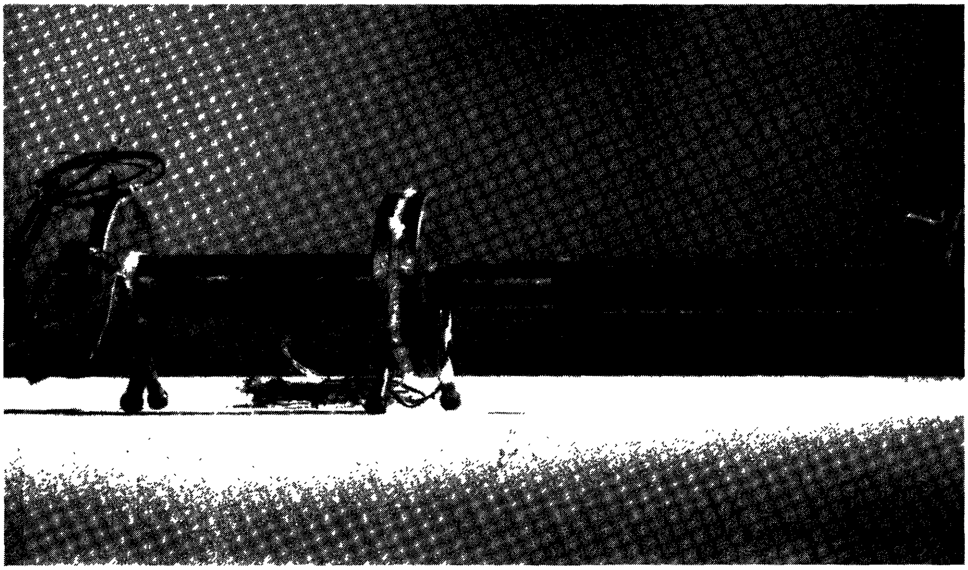

Figure 3.5.1 First metal heat pipe

Figure 3.5.2 Corrosion Coupons after removal from Capsule

Development of a high temperature heat pipe heat exchanger for recovery of residual heat

3.5

AERE HARWELL
Engineering Sciences Division
UK — Oxfordshire OX11 ORA

J.C. RALPH

Contract number: EE-B-1-104-UK

HARWELL, which in the first programme (EEC Contract no. 385-77-EE-UK) successfully developed gas-gas heat pipe heat exchangers for different industrial applications at temperatures between 60°C and 120°C (e.g. paper and laundry industry), embarked on the development of heat pipe heat exchangers suitable for temperatures between 300°C and 500°C; a temperature range where a large amount of process heat is used.

A problem is the very limited number of working fluids suitable for this temperature range since organic compounds degrade above 300°C and metals such as Na can be used only above 500°C (below 500°C the vapour pressure of Na is too low). One of the few suitable working fluids is sulphur and this work was concerned with the testing of sulphur with small iodine additions (which reduce liquid viscosity).

The work programme involved the studies of both the thermal performance and the corrosion behaviour of sulphur/iodine mixtures. Heat transfer tests were carried out on silica and metal heat pipes containing sulphur with 5% iodine. Initial results indicate that gases present in the heat pipe (iodine or inert gases present due to insufficient outgassing of the tube) collect in the upper part (condenser) of the heat pipe, where they hamper the presence of sulphur vapours and their condensation. This leads to less effective operation of the heat pipe.

The main problem, however, was the corrosive nature of the working fluid. Up to now no container material has been found which was not corroded. Results of a series of 1000 hour corrosion tests on some six container materials (metals) indicated that none of them is suitable for long periods of exposure to sulphur-iodine at high temperatures. Those tested included Hastalloys, Fecralloy and stainless steel. HARWELL would like to investigate a number of other materials and to study further the heat transfer characteristics of the system.

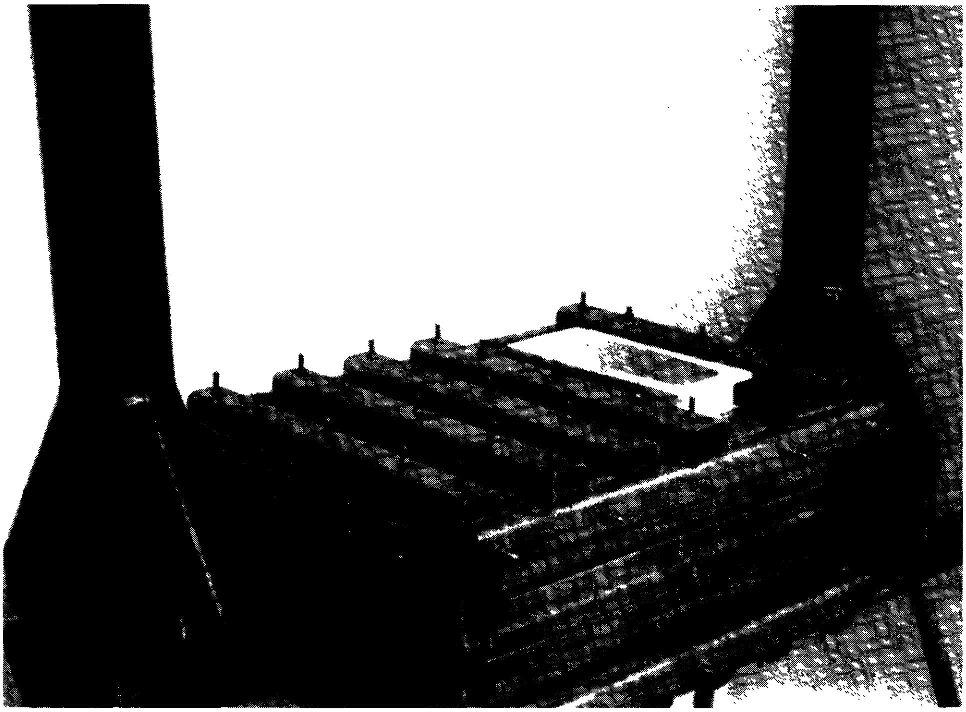

Figure 3.6.2 Ceramic modular heat exchanger within its metal housing

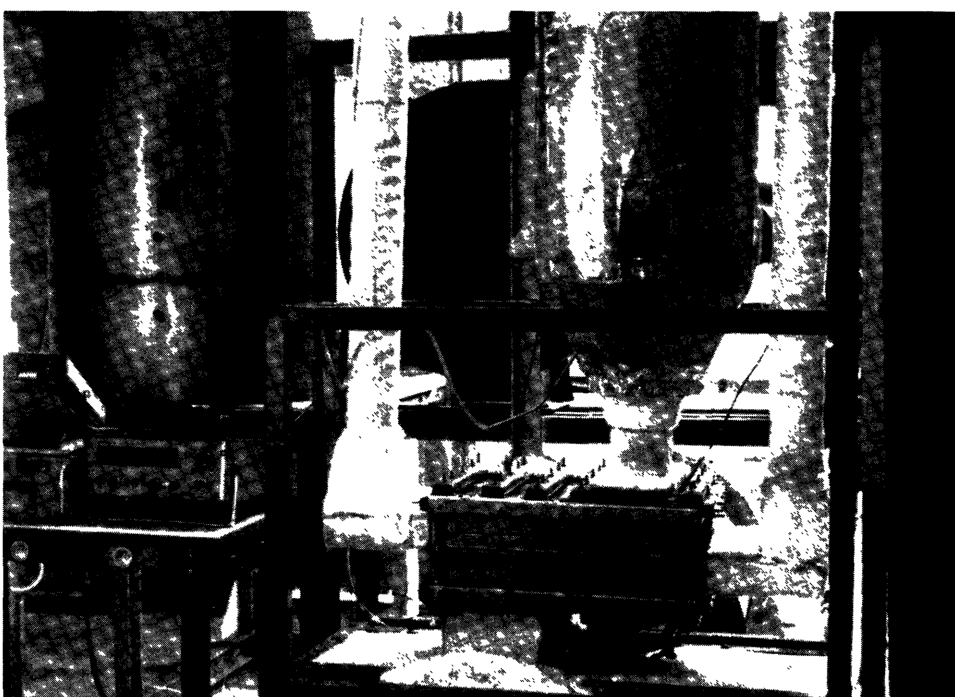

Figure 3.6.3 Experimental test rig of ceramic modular heat exchanger

Design and construction of a novel modular ceramic gas-gas exchanger able to stand temperatures up to 1200°C, for the recovery of energy from industrial furnaces

3.6

Société Bertin
Boîte Postale 3
F — 78373 Plaisir Cedex

S. GALANT

Contract number: EE-B-1-107-F

In the oil, steel, aluminium, glass and ceramic industries there is a need for high temperature heat exchangers suitable for operation between 1000°C and 1500°C. This is a temperature range where much of the process heat is used and where the potential for heat recovery is very large. BERTIN, therefore, developed a gas-gas ceramic (silicon carbide) heat exchanger for use with exhaust gases up to 1200°C (with a future goal of 1500°C).

This heat exchanger can be assembled in the form of modules. It has an estimated cost of 1.700 FF per kWh recovered, which is comparable to metallic heat exchangers currently available for use at much lower temperatures (800°C).

The design of this heat exchanger is optimised both for convective and radiative heat transfer. Forced convection is maximised by using jet impingement (obtained by specially devised slots) within the ceramic perforated plates of the heat exchanger. The turbulence created by the jet enhances heat transfer and this permits overall heat transfer coefficients of the order of 150 W/m^{2}K to be achieved. The module pressure drop is 200 to 300 Pascals (air side).

A single module has been constructed and tested in the laboratory. A second generation of heat exchangers is being designed.

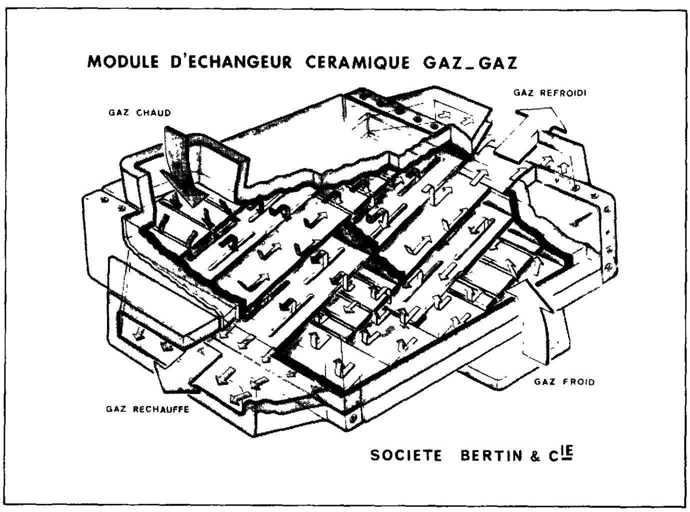

Figure 3.6.1 Modular ceramic gas-gas heat exchanger

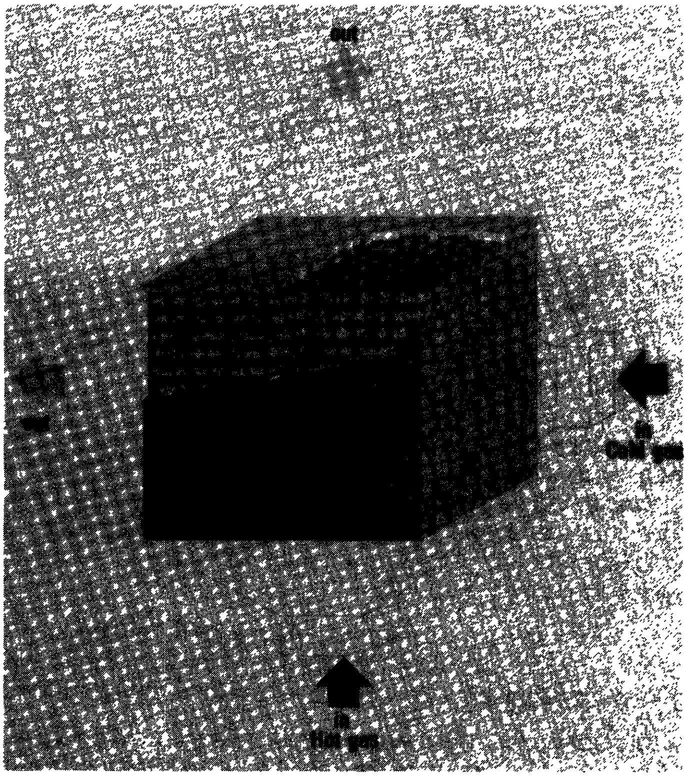

Figure 3.7.1 Compact stacked perforated plate gas-gas heat exchanger. Artist's view

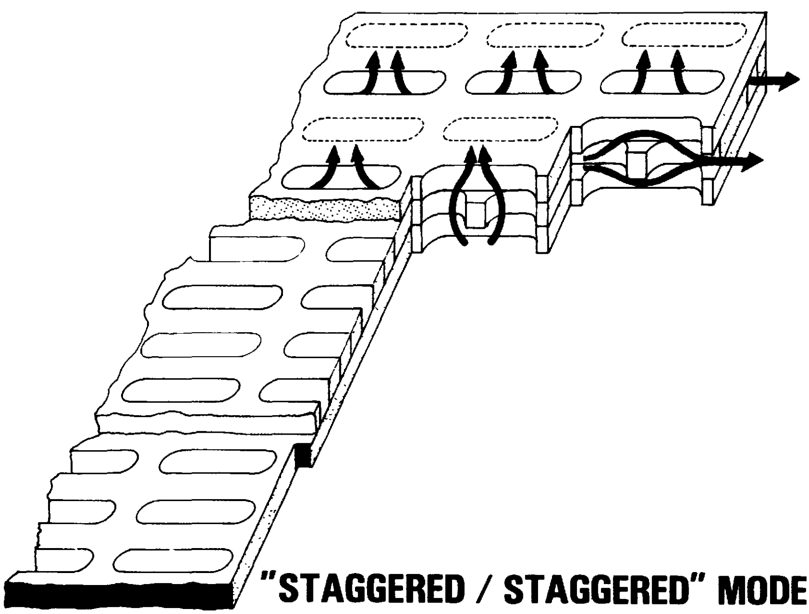

Figure 3.7.2 Compact gas-gas heat exchanger formed by stacking perforated metal plates in such a way, that horizontal and vertical fluid flow passages are formed

Compact gas-gas heat exchanger 3.7

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Direction de Recherche
Physico-Chimie Appliquée et Analyse
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F — 92502 Rueil-Malmaison Cedex

Creusot-Loire
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15, rue Pasquier
F — 75383 Paris Cedex 08

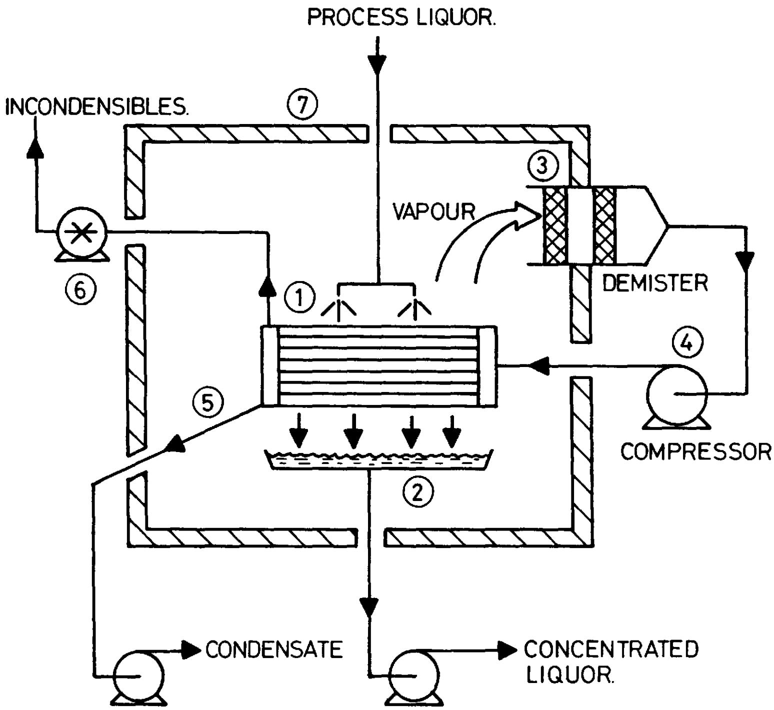
A. ROJEY (I.F.P.)

Mr. TILLEQUIN (Creusot-Loire)

Contract number: EE-B-1-166-F

A market study for gas-gas heat exchangers in the Common Market, carried out by I.F.P., showed that the potential energy savings for preheating of air for furnaces is 2×10^6 toe. (This study did not include the glass, metallurgy and textile industry for which no detailed data were available). Main impediments to installation were lack of space and high installation costs, which can be 1,5 to 4 times the cost of the heat exchanger. With these data in mind, I.F.P. started the design of a modular compact heat exchanger.

The system under development can accept gases up to 400°C and could have a duty of typically 650 kW. It has size advantages over competing systems and its modular construction should lead to lower installation costs. This compact gas-gas heat exchanger is easy to manufacture, has low pressure drops and is easy to clean. The exchanger consists of a block formed by the stacking of perforated metal plates whose apertures create the fluid flow passages. The different plate perforation geometries, tested in the laboratory on small models (exchange area $\approx$ 0,35 m^2) showed the possibility of attaining specific areas of 125 m^2/m^3 and heat transfer coefficients of up to 70 W/m^2 °K. The data obtained from these tests served as a basis for the design of an industrial prototype (exchange area: 12,5 m^2). The tests of this prototype will be carried out on a 1,6 MW boiler, with exhaust gas flowrate of the order of 2000 m^3/h and outlet temperatures of up to 400°C.



1. plastic tubes
2. collector
3. demister
4. compressor
5. condensate
6. purge pump
7. containment vessel

Figure 3.8.1 Essential features of a mechanical vapour recompression evaporator for viscose process liquors

The evaporation of viscose process liquors by low energy means

3.8

Courtaulds Ltd.
Chemical and Development Engineering Centre
P.O. Box 16
345 Foleshill Road
GB — Coventry CV6 5AE

R. THORNTON

Contract number: EE-B-1-101-UK

The research study aims at achieving an alternative means of evaporating water from viscose process liquors (used for viscose fibre production), in order to considerably reduce the energy requirement of the operation. In order to achieve this, COURTAULDS developed a heat exchanger consisting of thin walled plastic tubes. The liquor is evaporated under vacuum from a falling film on the outside of the tubes. This vapour is then brought inside the tubes via demisters, scrubbers and a compressor (mechanical vapour recompression), where it condenses and supplies the condensation heat for the evaporation of the liquor film outside the tubes. In 1980 it was calculated that if this work was to be successful and the resulting technology should be applied to 50% of the viscose production in the EEC (apart from Courtaulds) the energy saving would be around 0.5×10^5 toe/year.

Laboratory investigations have been undertaken to determine the physical properties of the viscose liquors involved, and data on viscosities, specific gravities, boiling point elevations, thermal conductivities and specific heats have been gathered. An examination of the properties of plastic heat exchanger tubes has been executed, with particular emphasis on short and long term mechanical stability, resistance to fouling and wettability.

A bench scale mechanical vapour recompression evaporator has been constructed; heat transfer coefficients of 800-1000 $W/m^{2o}K$ across the tube bundle have been obtained with the viscose liquors.

A research plant to evaporate 100-150 kg/hr water has been designed and construction is in progress. The detailed mechanical design has produced a number of interesting engineering challenges, particularly with regard to the compressor, the concrete vacuum vessel and its corrosion resistant lining and the tube bundle. A strategy to meet these challenges has been formulated.

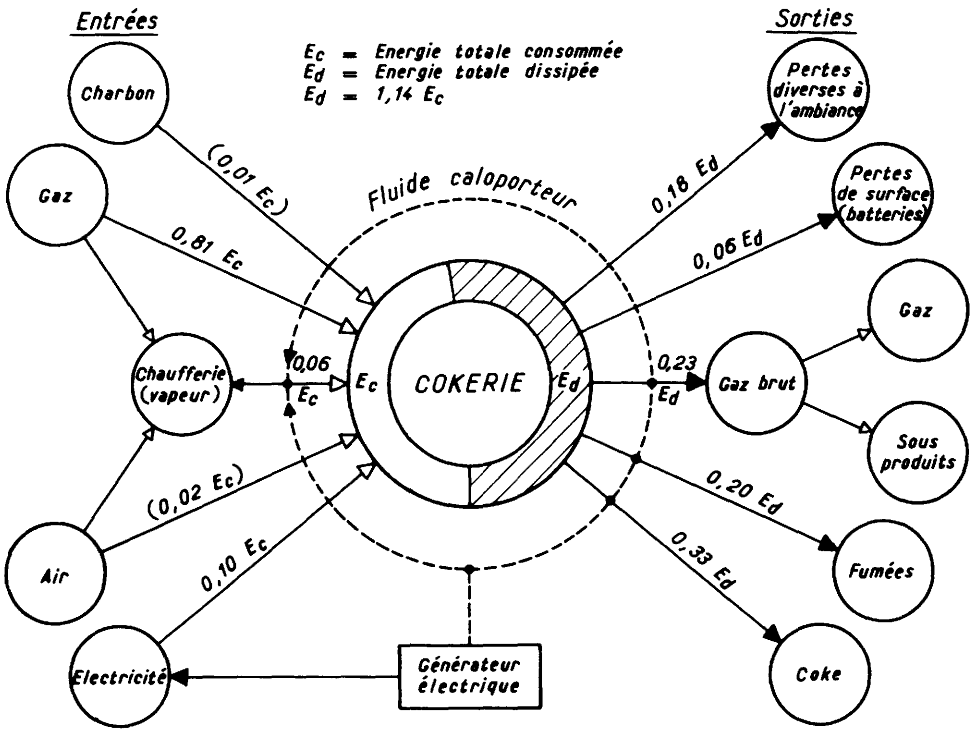


Figure 3.9.1 Energy use in a classical coke industry

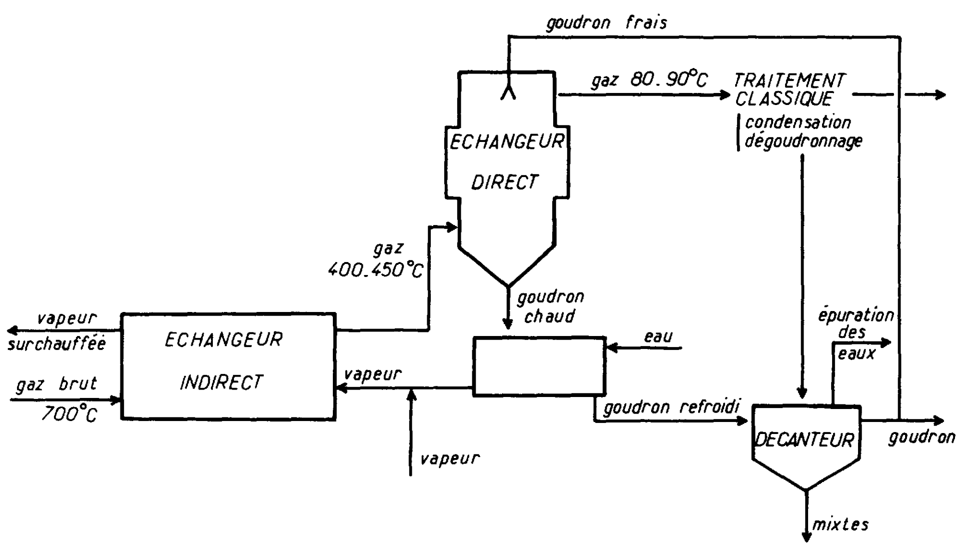


Figure 3.9.2 Principle of heat recovery in the coke industry

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 3.9

Centre d'Etudes et Recherches des Charbonnages de France
(CERCHAR)
Groupe Thermique
Boîte Postale 2
F — 60550 Verneuil-en-Halatte

M. GAILLET

Contract number: EE-B-2-161-F

This is an extension of the work carried out under a previous contract no. 173-76-EE-F. In this contract, CERCHAR studied the possibility of heat recovery in the coke industry. For the production of one tonne of siderurgical coke, on average 1100 kWh is consumed, of which 33% is lost during the cooling of coke, 23% in distillation gases which leave the furnace at 700°C and 20% in exhaust gases. In that contract the possibilities for heat recovery from distillation gases were further developed. 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 used to produce super-heated steam. Designs have been made for a pilot facility for one coke furnace and for an industrial installation working with about 30 furnaces.

The present contract involves testing of a single heat exchanger at the plant to recover sensible heat from distillation gases at 750-800°C. (The set of two heat exchangers is also to be studied but is not included in this contract). Design calculations as well as discussions with the heat exchanger manufacturers have been carried out. The heat exchanger will soon be constructed and will be installed at the Marienau coke factory for testing. It will have a diameter of 0.6 m and a length of 4.5 m and will contain 39 tubes. It is estimated that it will recover 200 kWh per tonne of coke.

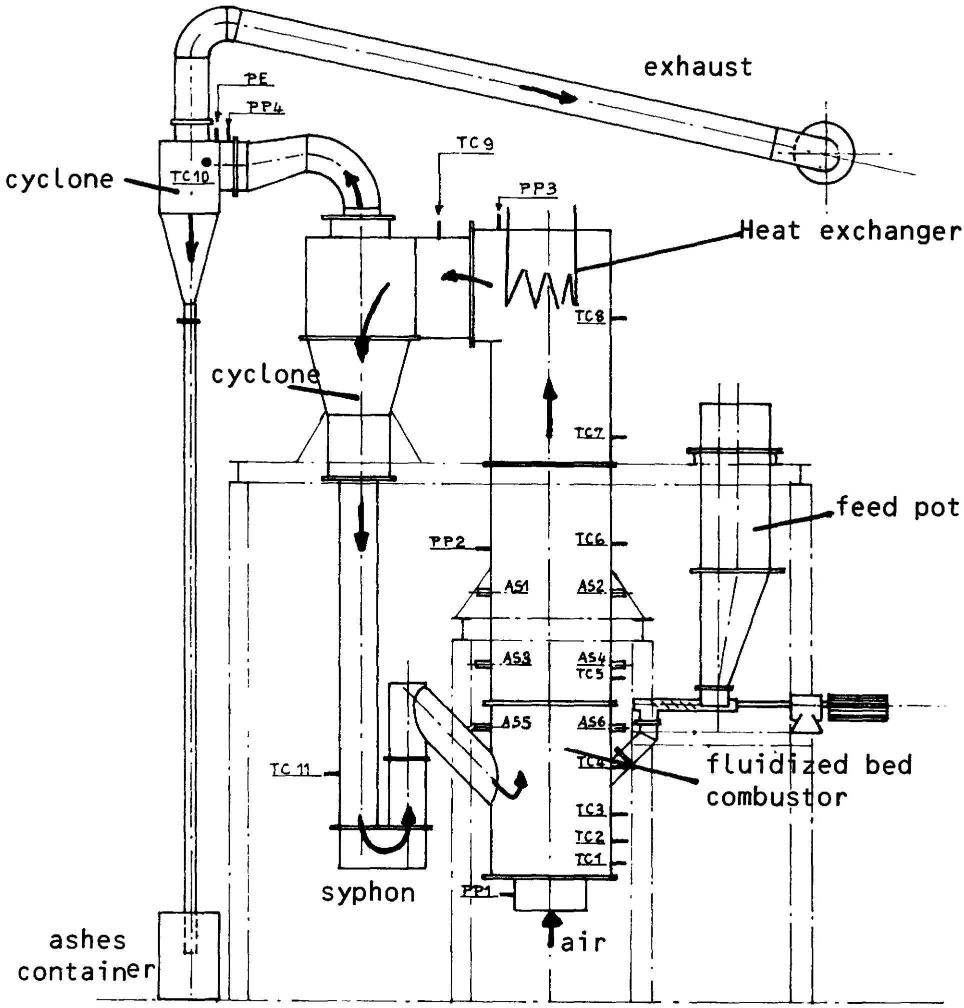


Figure 3.10.1 Experimental circulating fluidized bed

Improvement of thermal exchanges in a circulating fluidized bed combustor 3.10

Creusot-Loire
Division Energie
Section EN/PN/LF
Boîte Postale 31
F — 71208 Le Creusot

G. CHRYSOSTOME

Contract number: EE-B-1-113-F

CREUSOT LOIRE and the UNIVERSITY OF COMPIEGNE are optimizing the performance of a heat exchanger in an external type circulating fluidized bed combustor.

In such a fluidized bed gas velocities are higher than normal, resulting in higher heat transfer coefficients. Another major advantage is the possibility of installing the heat exchanger in the upper part of the combustor, where no combustion takes place, thus separating heat transfer from combustion. Tests are being carried out in a circulating fluidized bed scale model and a 50 cm (diameter) pilot bed.

Subjects of the investigation are:
- — the influence of the overall geometrical configuration of the heat transfer surface on the pattern of solid flow and on the heat transfer coefficient;
- — the influence of the tube shape and the geometry of finned tube surfaces (longitudinal or spiral fins).

The first series of tests showed that instabilities of the two phase gas/solid flow can strongly affect the overall performance of the heat exchanger: suspension flow stability and gas flow friction are the two main criteria used to compare various surface geometries.

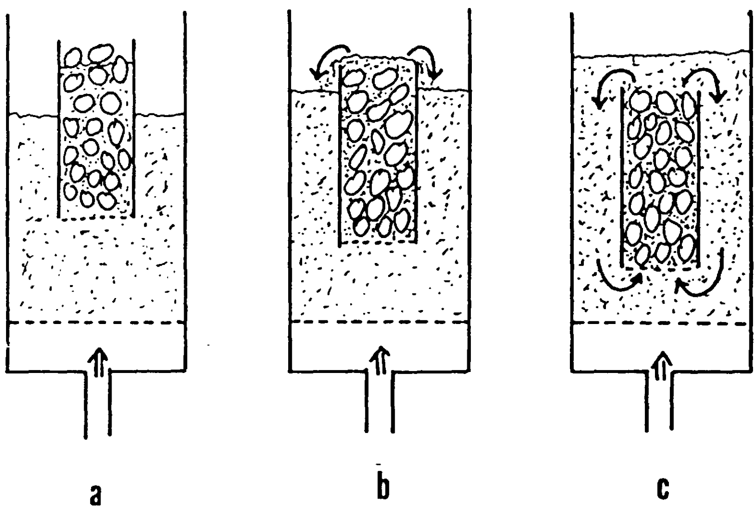


Figure 3.11.1 Self sustained circulation in a fluidized bed

Study of self-maintaining circulating fluidized bed heat exchanger 3.11

Creusot-Loire
Division Energie
Section EN/PN/LF
B.P. 31
F — 71208 Le Creusot

Université de Compiègne
B.P. 233
F — 60206 Compiègne

G. CHRYSOSTOME, Creusot-Loire

J.F. LARGE, Université de Compiègne

Contract number: EE-B-1-114-F

In large fluidized beds, natural circulation occurs with an upward movement in the middle of the bed and downward motion at the sides. In smaller beds such a circulation can be induced by a heat exchanger with horizontal tubes in the centre of the bed. In this study, the effect of the shape of the heat exchanger on the circulation is investigated. Because of the circulation, the tubes can be very close. The heat exchanger is thus very compact and only a small part of the bed is needed for heat exchange. Heat transfer and combustion in the bed are thus separated. By varying the circulation flow the heat output can also be regulated.

One of the aims of this project is to study the geometry of the grate, where the fluidization occurs, so that the circulation effect can be kept under close control. The rate of circulation is varied to suit the relevant application and operating constraints, regardless of the heat exchanger geometry.

Circulation of the solids through the exchanger should give a better coefficient of heat transfer between the fluidized bed and the tubes. This is a result of the faster circulation of particles in contact with the tubes and of the elimination of the layer of motionless particles which otherwise form on the upper surface of the horizontal tube bundles.

The test rig has clearly demonstrated that the self-maintaining circulation starts when a compact heat exchanger is inserted only in the centre of the fluidized bed. Preliminary figures have been obtained for the strength of circulation. A series of experiments is now under way to determine the effect of different variables on the operation. The first experiments gave satisfactory results. Heat transfer and combustion in the bed are more or less separated and by varying the circulation flow the heat output can be regulated.

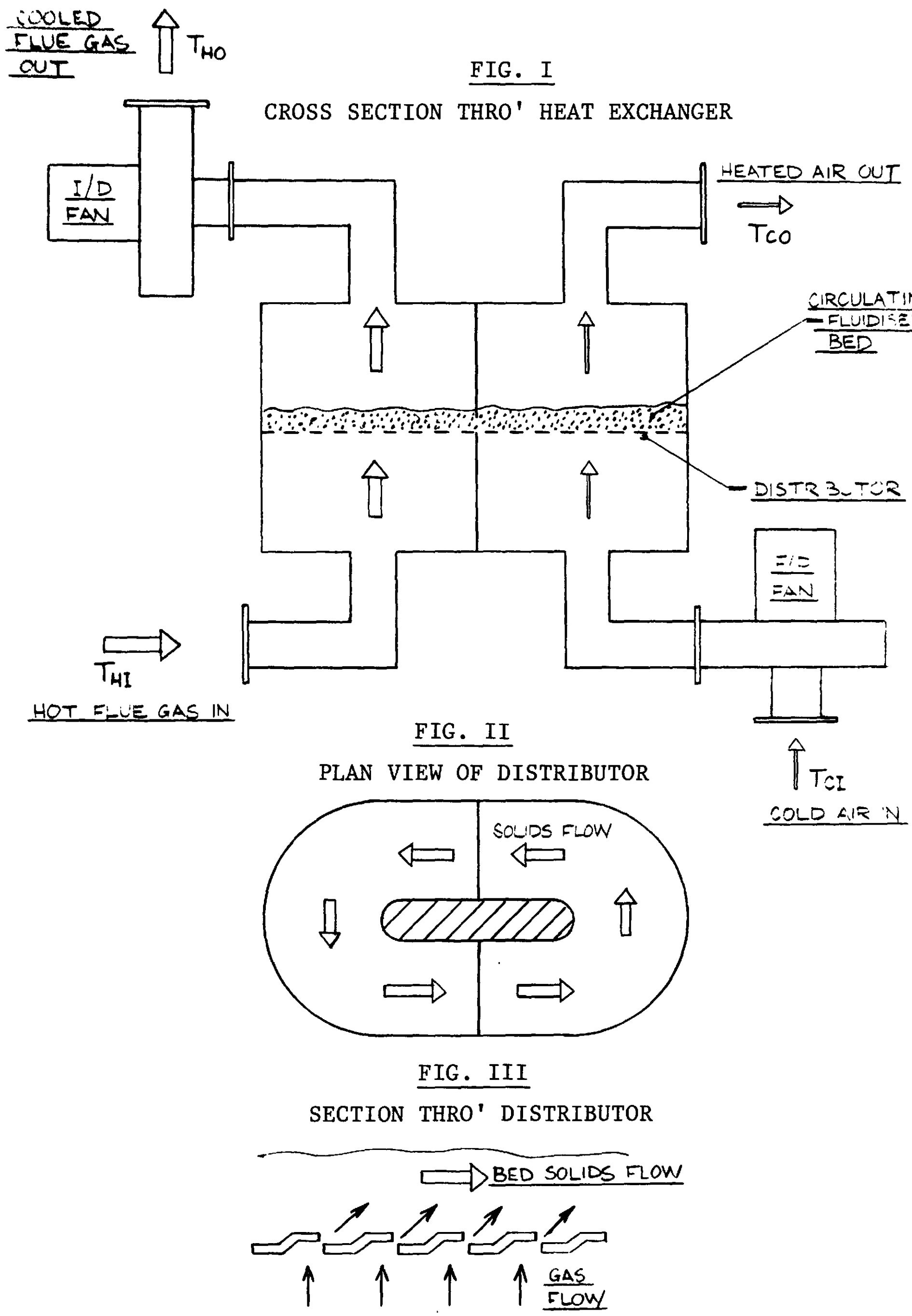


Fig. 3.12.1 Schematic description of a fluidized bed high temperature gas/gas heat exchanger

Fluid bed high temperature gas/gas heat exchangers 3.12

Stone International Limited
Gatwick Road
UK — Crawley West Sussex RH10 2RN

R. BURROWS

Contract number: EE-B-1-142-UK

Currently available high temperature gas/gas heat exchangers have several problems associated with them. For example, some are expensive as they utilize special materials to withstand corrosion and others have unreliable moving seals.

The heat exchanger which is under development by STONE FLUIDFIRE can overcome these problems. It consists of two adjacent fluidized beds. The separating wall between the two beds has an opening at the height of the fluidized bed. This allows the fluidized mass of the two beds to make a horizontal circular movement which is induced by blowing hot gas and cold air through the two respective beds with a horizontal component. The partition plates allow free passage of particles from one section to the other but minimize gas leakage. The heat exchanger operates in parallel flow and has an efficiency of 50%. The fluidized bed will have a total area of 4 m^2 and the unit will recover 530 kW of sensible heat.

Different bed geometries have been tried in small scale prototypes with gas temperatures up to 250°C while testing will continue up to 800°C. The most apparent advantage of this heat exchanger is it simplicity, with gas leakages being controlled within acceptable limits. The potential markets for the heat exchanger are preheating of combustion gas and space heating.

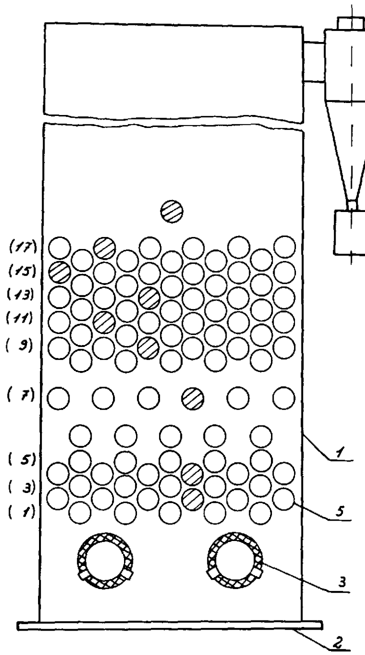


Figure 3.13.1 Experimental equipment. Fluidized bed heat exchanger; 1) Fluid bed column; 2) Column bottom plate; 3) Manifold distributor; 4) Cyclone; 5) One of cooling tubes (numbers in brackets indicate the row number in the array)

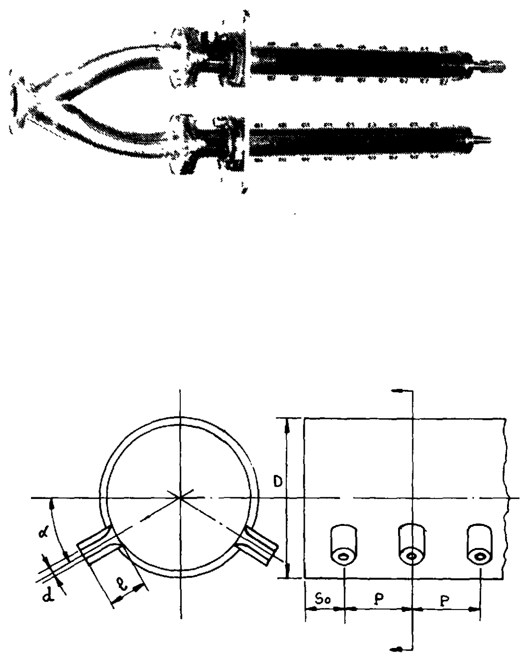


Figure 3.13.2 Distributor:
A = Picture of the distributor with Y shaped joint
B = Detail of the manifold and nozzles
D = 45 mm, P = 40 mm, l = 12 mm
d = 6,5 mm, α = 30°

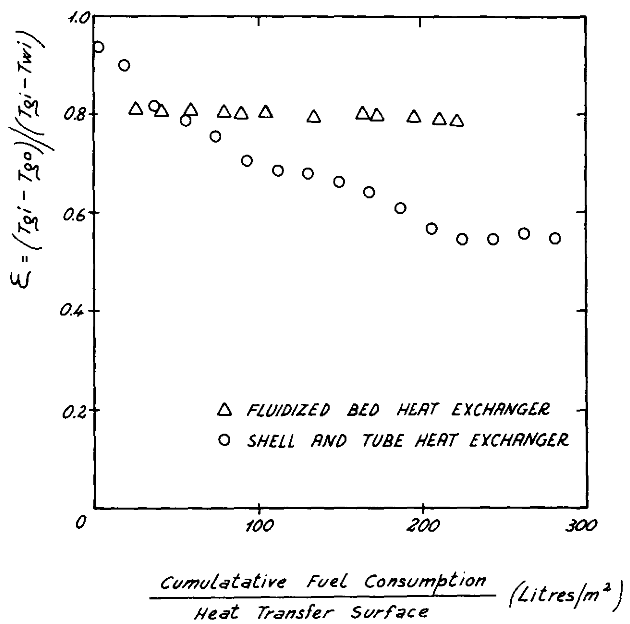


Figure 3.13.3 Exchanger efficiency as a function of ratio between cumulative fuel consumption to heat transfer surface

Fluidized bed heat exchanger filter for waste heat recovery from dirty corrosive gases

3.13

Fiat TTG
Via Cuneo, 20
Casa Postale 500
I — 10100 Torino

G. VIDOSSICH

Contract number: EE-B-1-110-I

This research concerns the application of fluidized bed heat exchangers for heat recovery from dirty and corrosive exhaust gases. Heat recovery from Diesel exhaust gases or, generally, from factory hot flue gases can be difficult because of particles contained in them. In conventional heat exchangers, tube fouling leads to a rapid decrease in heat exchange efficiency, while fluidized bed heat exchangers can overcome this problem.

FIAT designed a semi industrial fluidized bed heat exchanger prototype of 62 kW where the bed is fluidized by soot-bearing exhaust gases at 500-600°C obtained from a Diesel engine. The heat is extracted from the bed by cooling water circulating in an in-bed heat exchanger. The fluidized bed heat exchanger has shown very good behaviour both from the point of view of heat exchange and soot removal. Moreover the engine performance was barely affected.

The study shows that whereas the overall heat transfer coefficient can easily change (due to fouling), the sensitivity of the heat exchanger efficiency to these changes is low. After 30 hours of operation, the efficiency of the fluidized bed heat exchanger falls only by about 3%. Original values of the heat transfer coefficient can be reestablished by inducing tube cleaning by stepping the tube wall temperature up and down.

Experiments showed that soot particles are agglomerated in the fluidized bed at diameters 10-100 times larger than those at the engine outlet. The efficiency of soot removal is strongly improved by this agglomeration while the bed temperature has a small influence on soot removal efficiency. However, the Diesel engine air/fuel ratio strongly affects the agglomeration, and consequently the removal efficiency, of the soot. A higher air/fuel ratio results in better adhesion of the soot to the heat exchanger tubes. This is probably due to the different characteristics of the soot itself and/or to a higher condensable hydrocarbon content.

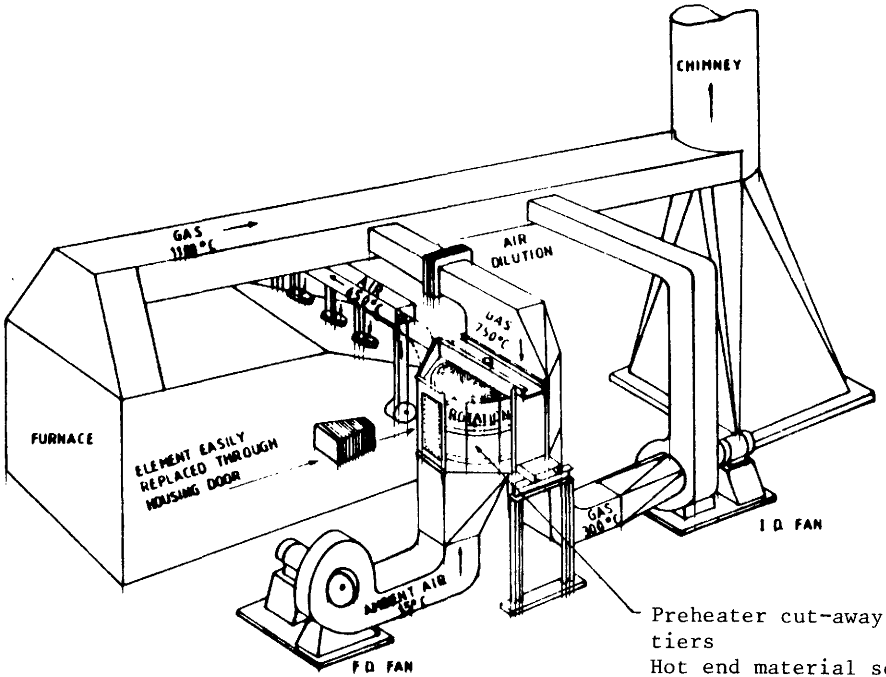


Figure 3.14.1 Typical arrangement of Howden high temperature regenerative preheater on an aluminium melting furnace (expansion joints and control dampers not shown)

Aluminium melting furnace heat regeneration project 3.14

About 50 000 Jungström rotating heat exchangers are in use throughout the world operating at temperatures up to 500°C. The aim of the JAMES HOWDEN project is to extend the application of the heat wheel to higher temperatures. This would be used to recover the waste heat from an aluminium remelting furnace for preheating combustion air. A maximum of 705°C is specified, giving a preheat temperature of 600°C.

The research programme includes the installation of a single trial preheater operating on two aluminium remelting furnaces at Alcan Plate Ltd., Birmingham.

The programme at present has covered the measurement of gas flows, temperatures, gas analysis, dust burdens and flow patterns.

This project has been plagued by the recession in the aluminium industry in the U.K. The original project (No 386-78 EEK) was formally started in 1979 with Alcoa. However, before the hardware was put on order the original user cancelled and closed the furnace. Alcan Plate, the new partner, has cut back production due to low demand from the aircraft industry, and this is delaying work on the current contract.

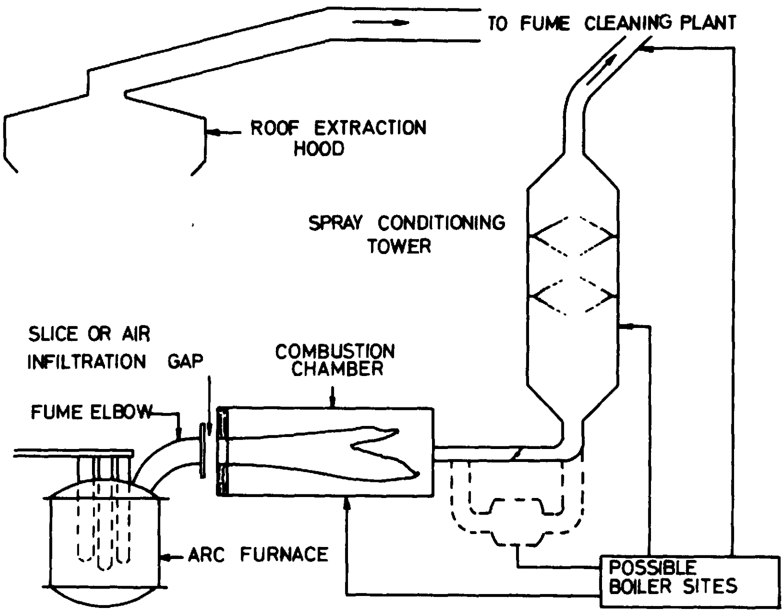


Figure 3.15.1 General layout of electric arc furnace and associated waste gas ducting

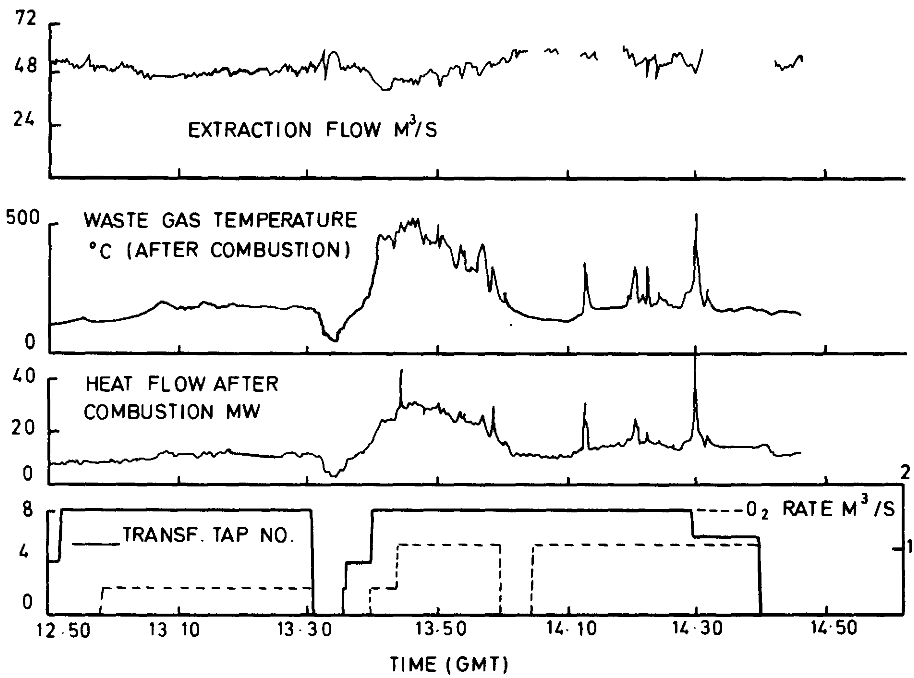


Figure 3.15.2 Waste gas conditions — "E" furnace, Rotherham Works

Design of waste heat boilers for the recovery of energy from arc furnace waste gases

3.15

British Steel Corporation
Sheffield Laboratories,
Fuel and Furnaces Department
Swinden House
GB — Moorgate, Rotherham S60 3AR

J. DIXON

Contract number: EE-B-2-160-UK

At present the electric arc furnace accounts for 30% of the steelmaking capacity in Britain. The cost of electrical energy in steelmaking is therefore a noticeable proportion of the total cost.

A literature survey has revealed a wide area of general interest in methods of waste heat recovery from the electric arc furnace but no waste heat recovery facilities have yet been built.

This project deals with a feasability study for a boiler which will be heated with flue gases from an arc furnace. The 180 tonne arc furnace produces 350 000 tonnes of steel per year and the waste heat available for recovery is 200 kWh per tonne of steel. If this waste heat could be used to raïse steam, thus replacing fuel oil, this would lead to annual savings of £ 0.5×10^6 per furnace. The waste heat temperature varies widely during the process (200°C-500°C). A survey of the steam demand within BSC sites with arc furnaces revealed that specific uses for steam vary from work to work. A large proportion of the heat demand comes from space heating or hot water production. A steam demand exists for 5.5 bars (160°C), 15 bars (200°C) and 45 bars (425°C). The disadvantages for space heating are that the demand is seasonal and for the high pressure steam production that special boilers are required. From the variations in both the amount of waste heat available and the steam usage it must be decided whether to consider several boiler designs for the various circumstances or to concentrate on a specific design for one application.

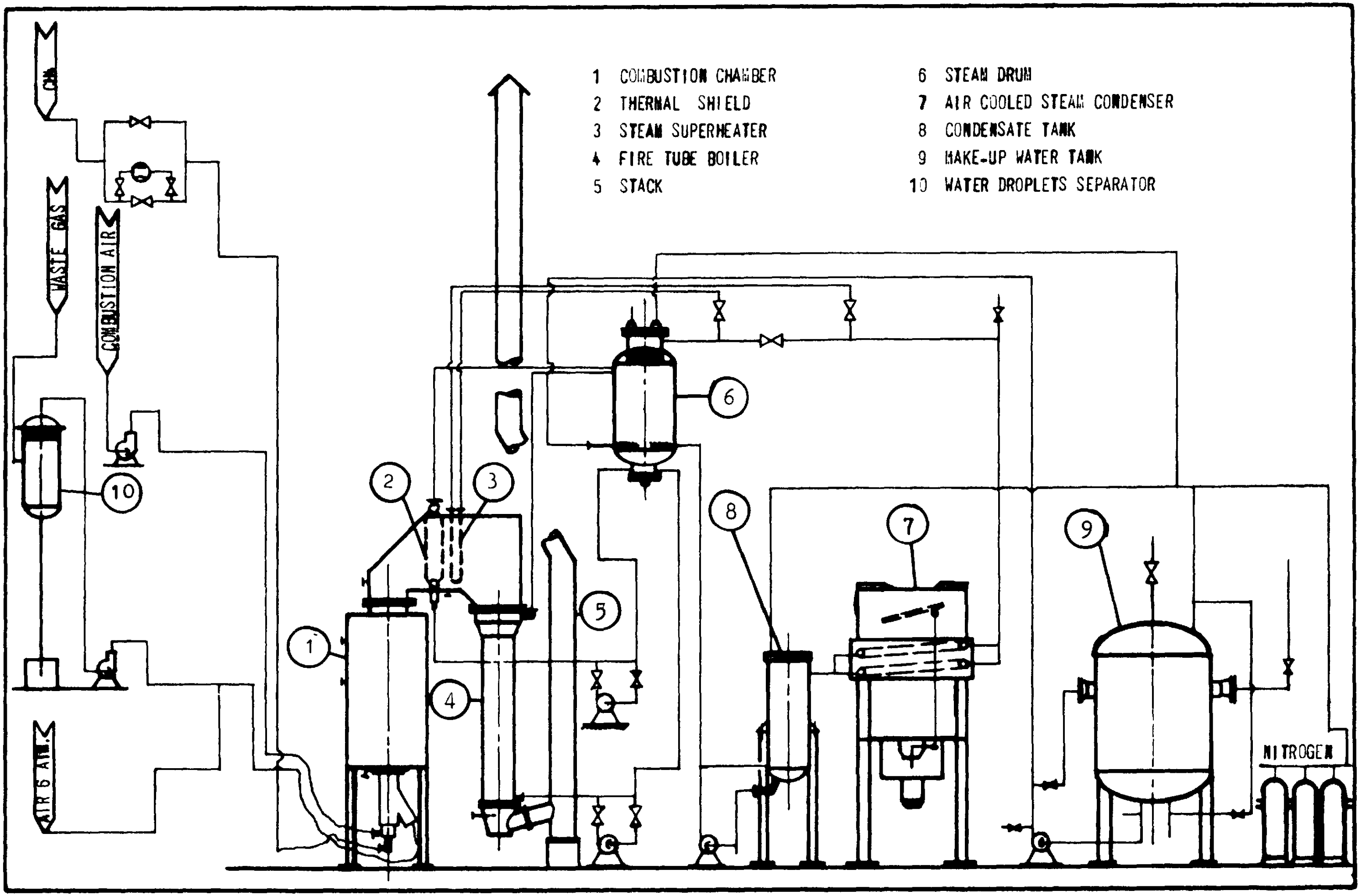


Figure 3.16.1 Pilot plant flow sheet for a cast iron melting furnace with heat recovery

Energy recovery from cast iron melting furnaces 3.16

Teksid SpA
Castek
Divisione Fonderie Ghisa
Corso G. Agnelli, 250
I — 10135 Torino

Costruzioni Meccaniche FBM SpA
Via Lambruschini, 15
I — 20158 Milano

A. CALABRO' (Teksid SpA)

M. MISCHIATTI (Costruzioni Meccaniche FBM)

Contract number: EE-B-2-162-I and EE-B-2-163-I

The possibilities for heat recovery in a cast iron melting furnace were studied by TEKSID. A cupola furnace which produces 40 tonne steel per hour, produces 25 000 Nm^3/h of flue gases which contain 16-22% CO. Taking into account the heat losses at the chimney where fumes are cooled to 200°C the recoverable heat is about $12.4 \cdot 10^6$ kcal/h which mainly consists of combustion heat in CO. This study showed that the heat can be used for the production of electricity, which will be used in the plant. Recovery of 87 kWh of electricity per tonne of steel produced is possible. A steam turbine driven generator of 3.5 MW will be required. The combustion of the low calorific gas (approximately 400 $kcal/Nm^3$) has been studied and gave positive results: wet CO gas can be burnt without addition of methane and preheating of air is not required. The pilot installation of the thermal part of the plant (without turbine and generator) has been built and has been running satisfactorily for several weeks.

Fouling problems have arisen due to the presence of residual dust. It was therefore necessary to complete this research, widening the scope to include unpurified gases (contract EE-B-2-163-I). The aim is to observe the type and the intensity of fouling caused by dust on the gas side heat exchange surface of the plant and to study the most suitable cleaning systems. The frequency of intervention and the maintenance costs as well as the degree of spontaneous separation of dusts would also be examined. In order to carry out the study, the existing heat recovery pilot plant will be connected to the cupola furnace, by insulated and partially fire-proof pipelines (in view of the inflammable gases being carried), with cyclones in the middle. The existing plant will also be modified in onder to incorporate the cleaning systems.

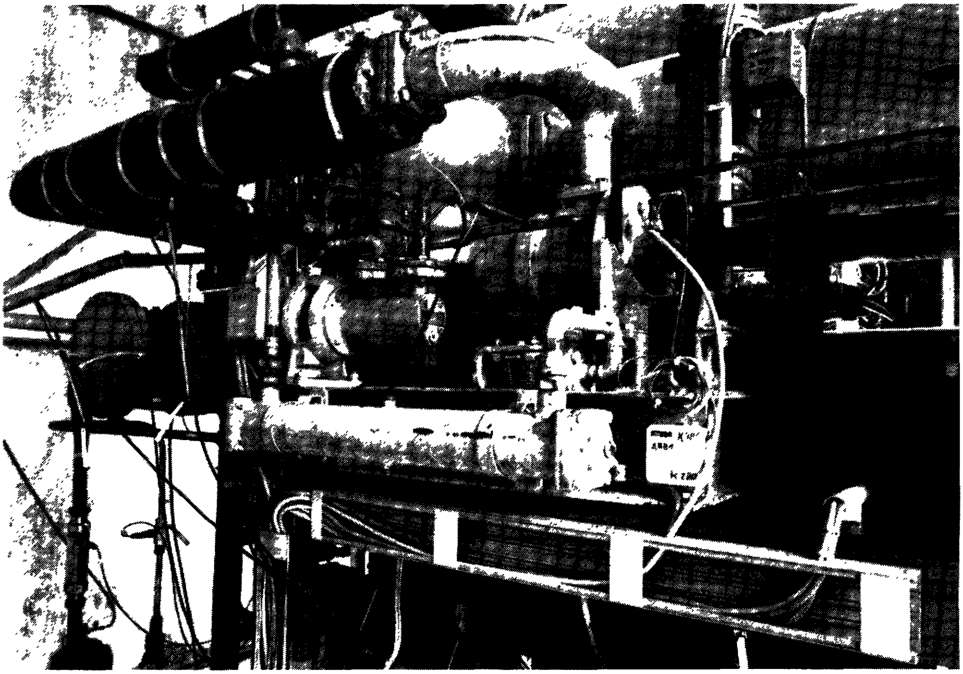


Figure 3.17.2 The screw-expansion unit in operation. To the right the shaft to the generator. In front of the unit the oilpump and below it the oilcooler; to the left the condenser.

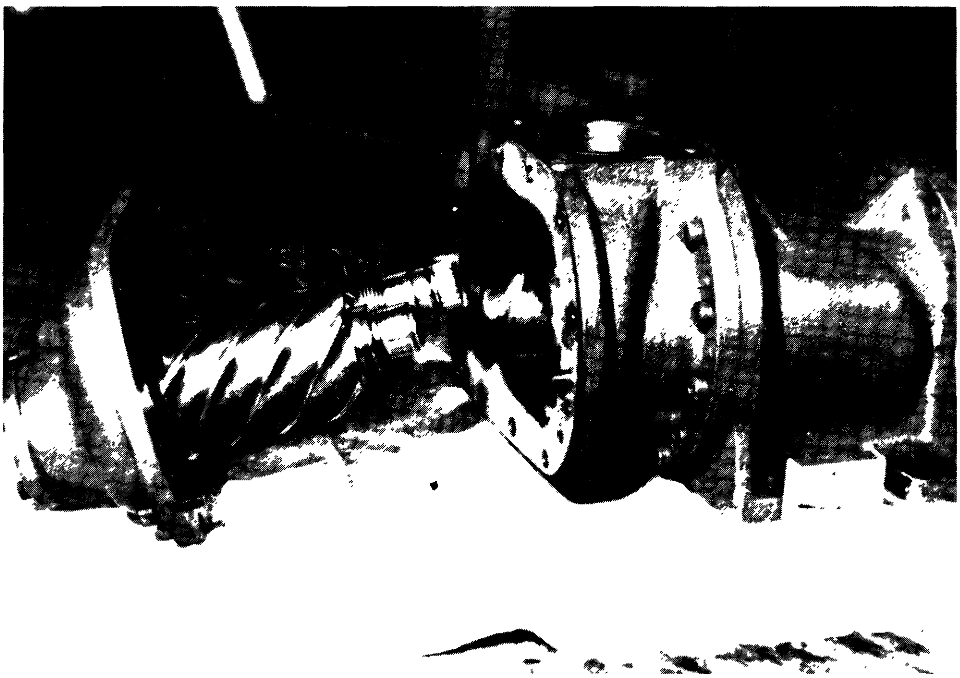


Figure 3.17.3 The screw-expansion unit dismounted

Industrial waste heat recovery by use of Organic Rankine Cycles (ORC) 3.17

Messerschmitt-Bölkow-Blohm GmbH (M.B.B.)
Unternehmensbereich Raumfahrt
Postfach 80 11 69
D — 8000 München 80

H. HOPMANN

Contract number: EE-B-1-108-D

The recovery of industrial waste heat between 200°C and 400°C with an ORC engine cycle using a screw expander is being studied both theoretically and experimentally. The objective is to identify and specify the properties of working fluids which are, at these temperatures, chemically stable and which are cheap enough to make the ORC engine economically attractive.

Using test facilities which exist at M.B.B. realistic dynamic tests are being carried out to investigate the chemical stability of working fluids as a function of temperature and to compare the different types of components. For R114 as a working fluid, it appears that the upper temperature limit of 160°C specified in the literature can be raised to 200°C. Three of the most typical ORC-engine applications in industry are being investigated in more detail. These are in the petrochemical industry, the ceramic industry and the recovery of the thermal energy of diesel-engine exhaust gases.

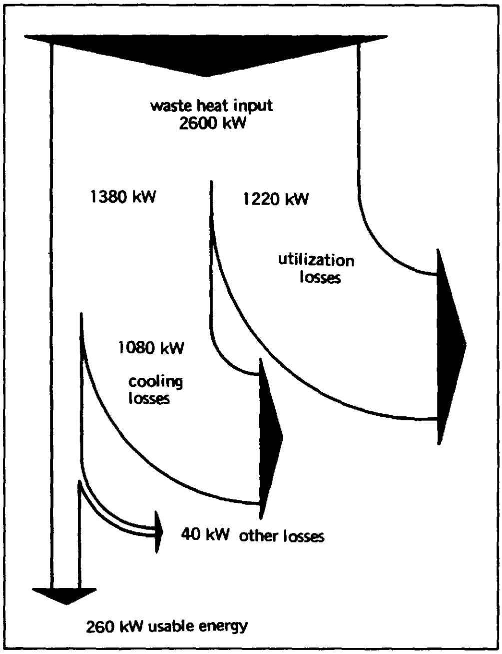
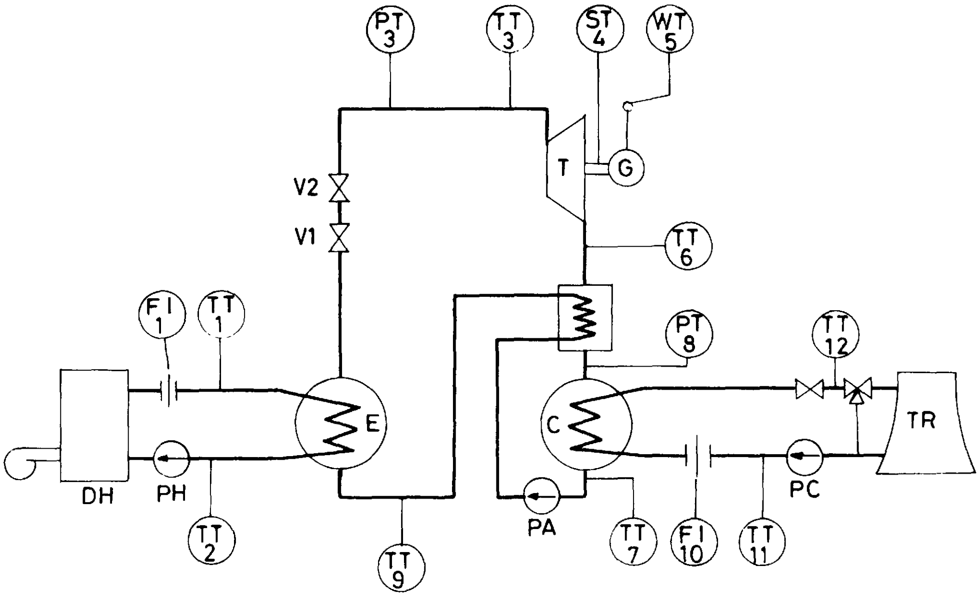


Figure 3.17.1 Flux of energy. Waste heat recovery from a hydrofiner (2,6 MW) by an ORC-engine gives 260 kW electric power output



OH Oil Heater
PH Heat Transfer Oil Pump
E ORC Evaporator
V1 ORC Control Valve
V2 ORC Control Valve

T Turbine
G Electric Regenerator
R ORC Regenerator
C ORC Condenser
PA ORC Feed Pump

PC Cooling Water Pump
TR Cooling Tower

Figure 3.18.1 ORC test installation

Medium temperature 100 kW ORC engine for total energy systems

3.18

Turboden s.r.l.
Via Circo, 1
I — 20123 Milano

F. GAIA

Contract number: EE-B-1-131-I

Several organic Rankine cycle engines for heat recovery purposes have been built for power outputs in the 500 kW range and it is often stated that smaller engines would be too costly for practical use. A previous EEC project undertaken by the contractor (contract no. 198-77-EEI) demonstrated the economic feasibility of ORC engines with a 40 kW power output, operating at low (110°C) evaporation temperatures. It is believed that by utilising the experience gained in the construction and testing of these ORC engines, it is possible to develop small ORC engines which operate at higher evaporation temperatures (approx. 200°C) and which give a better performance than steam turbines.

The aim of the research work done by TURBODEN is to assess the possibility of building an economically attractive 100 kW ORC unit, with a heat source between 200 and 400°C. This unit could be used for industrial waste heat recovery or for cogeneration plants, which discharge heat at temperatures well above those usually required by heat users (as in the case of gas turbines and Diesel engine exhaust gases). O-dichlorobenzene (marketed, for instance, by Dupont de Nemours as Dowtherm E) possesses a good mix of properties (good cycle efficiency, thermal stability, general technical acceptability with respect to toxicity, flammability, etc.) and is to be used as the working fluid.

The performance tests will be carried out at the TURBODEN test facilities near Milan. The design and specification of the engine are finished and construction is almost complete.

	R-11	R-113	R-114	FC-75	FC-88
Cost and avilability	cheapest and available	relatively cheap (∼twice cost of R-11) available	as for R-113	expensive and available	expensive and doubtful availability
Critical temperature (°C)	198	214	146	227	150
Heat transfer rate	average	average	low	high	near low
Pumping requirement	average	average	low	high	average
Rankine efficiency	high	high	average	low	low
Normal boiling point (°C), i.e. at atmospheric pressure	23.8	47.6	3.8	102.6	30.0
Vapour pressure (Nm^{-2}) at 40°C condenser temp.	1.59×10^5	0.76×10^5 (vacuum)	3.17×10^5	0.07×10^5 (vacuum)	1.4×10^5
Thermal stability	up to 120°C in the presence of oil	superior, up to 149°C	?	acceptable, up to 200°C	excellent, up to 176.7°C

A recent communication with the "3M" Company, UK branch, the manufacturer of FC-88, confirmed that this has been withdrawn from the market due to its high cost. Similar chemical compounds, which will be cheaper, will be available under the names of FC-72 and FC-87

Figure 3.19.2 Comparative study of suitable working fluids

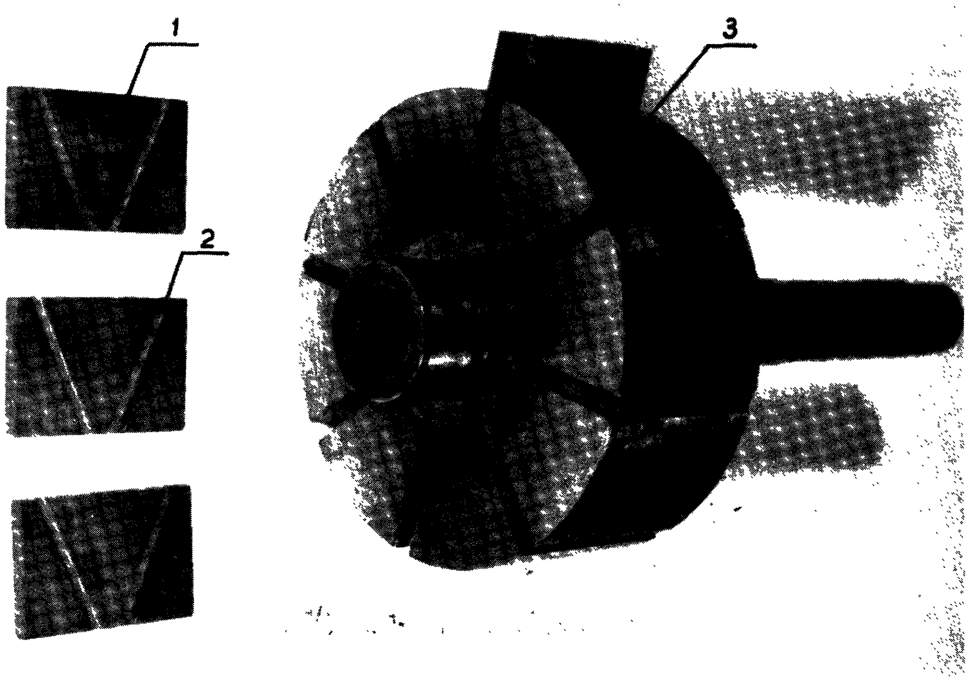


Figure 3.19.3 The rotor
1. Sliding vanes
2. Pressurizing grooves
3. Pressure transducer carriage

Optimisation of a multi-vane expander (MVE) as the prime mover in an Organic Rankine Cycle

Cranfield Institute of Technology
School of Mechanical Engineering
GB — Cranfield Bedford MK43 OAL

P.W. O'CALLAGHAN

Contract number: EE-B-1-121-GB

The work conducted by the CRANFIELD INSTITUTE OF TECHNOLOGY is directed at developing low-cost, robust, quiet and efficient multi-vane expanders (MVE) with a 3-6 kW nominal shaft power as a prime mover in an ORC engine.

Compared to turbines, MVEs have the following advantages: flat operating efficiency characteristics over a wide range of operating conditions (e.g. steam inlet pressure of 10-40 bar); low speeds ($\approx$ 3 000 rpm); and they can expand into the wet region of a working fluid without adverse effects. In addition they have: easy controllability; high power-to-weight ratio; low maintenance requirements; few, easily replacable, moving parts and low lubrification requirements.

Two types of MVE have been extensively investigated using both theoretical and practical approaches. A conventional MVE has been tested using R11, steam and R113 as the working fluid and a lobe MVE has been tested using compressed air. Expander efficiencies of 60% (conventional) and 48% (lobe) have been measured. From computer simulations, realistic target efficiencies of between 70-80% or better should be attainable.

It was concluded that the MVE performance is primarily affected by its design with respect to mechanical friction and leakage. Furthermore, an ORC may be optimised for maximum efficiency once the working fluid and expander characteristics are known; if effective positive internal sealing is employed, high efficiencies can be obtained.

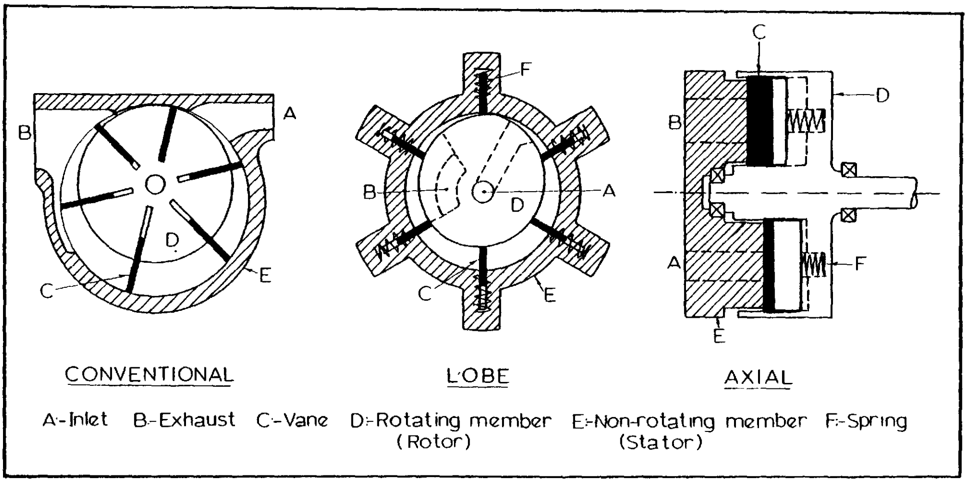


Figure 3.19.1 Three designs of multi-vane expanders

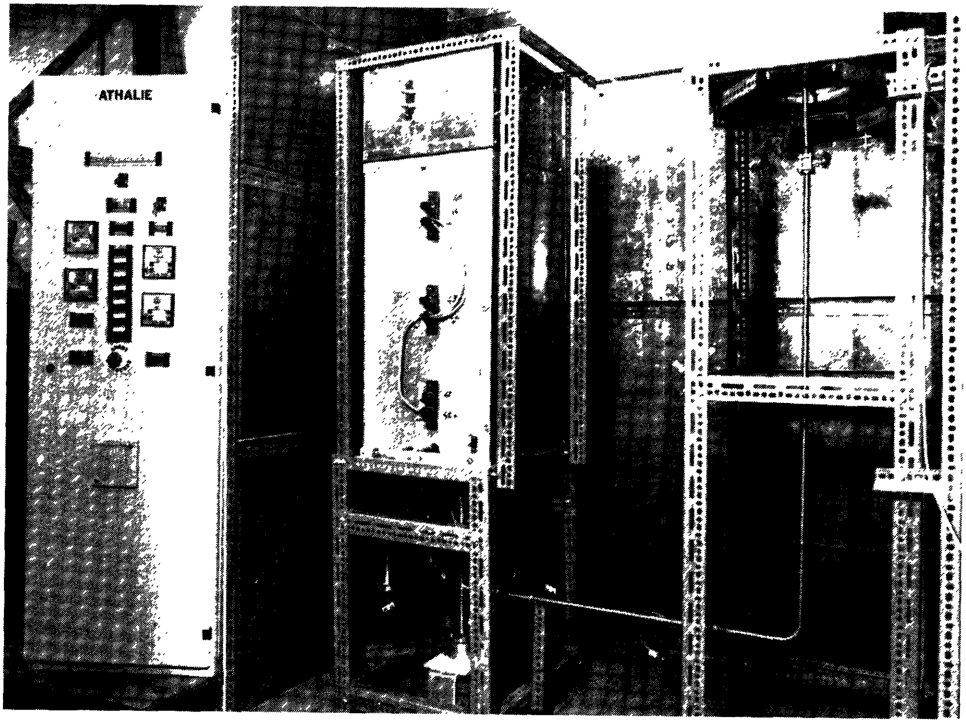


Figure 3.20.1 The experimental loop. To the left the electric cupboard; in the middle the oven; to the right the melter

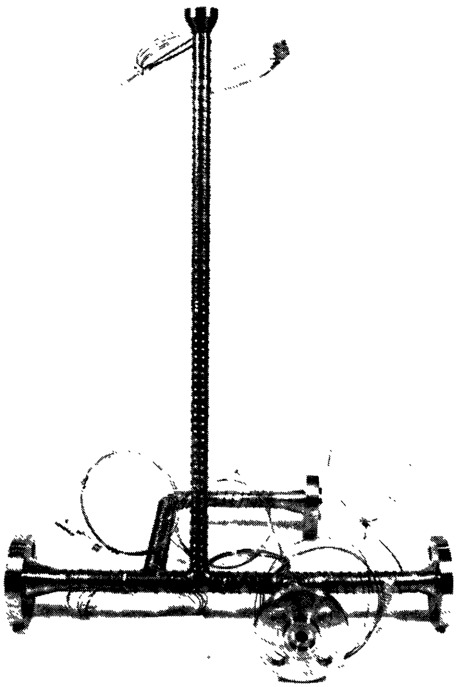


Figure 3.20.2 Tracing of the pipes of the experimental loop. General view during mounting

Confirmation of the advantages of a thermodynamic cycle using sulphur with the help of an experimental facility 3.20

Commissariat à l'Energie Atomique
Centre d'Etudes Nucléaires de Saclay
Département des Etudes Mécaniques et Thermiques
Boîte Postale N° 2
F — 91191 GIF-SUR-YVETTE CEDEX

M. CAIZERGUES

Contract number: EE-D-3-341-F

CEA investigated the technical feasibility of a topping cycle with sulphur as a working fluid (750-600°C) in combination with a conventional steam cycle for the production of electricity. The overall energy conversion efficiency is estimated to be 60%.

This investigation will make use of an experimental installation to study the properties of sulphur as a working fluid in a high-temperature thermodynamic cycle. The programme includes the design, construction and operation of this installation. The problem of corrosion of steel by sulphur at high temperatures had been solved previously (an internal protective coating of alumina is used). The properties of sulphur vapour as a thermodynamic fluid are understood only at relatively low temperature (below 400°C). Above this temperature, the experimental data available are unreliable. Now CEA is in a position to establish the required data for the properties of sulphur at high temperatures (up to 750°C) and to test the behaviour of the materials under real plant conditions in a loop. There are technical difficulties in the construction of the loop and preliminary tests are necessary. There are no problems related to the low temperature part of the loop while a solution with internal protective coating of alumina insulation is proposed for the high temperature part.

The main components of the loop have been ordered and a detailed design study is in progress.

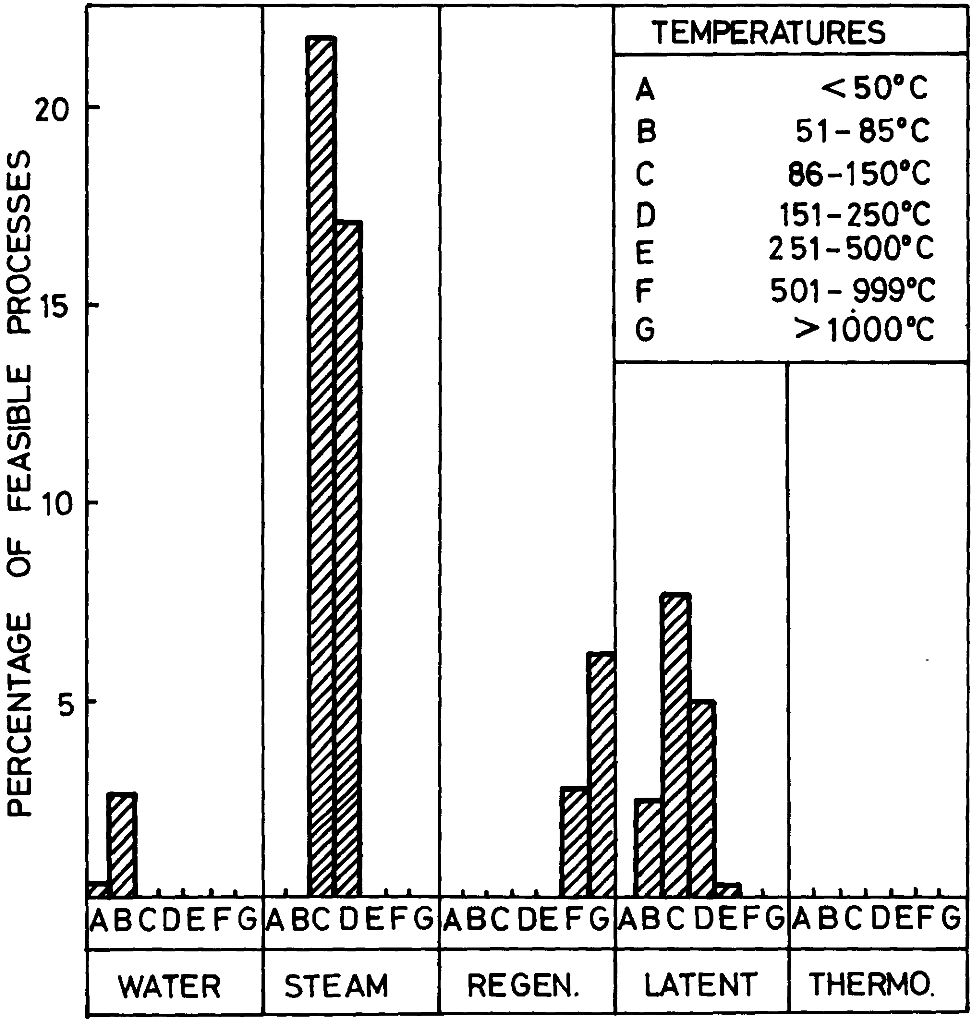


Figure 3.21.1 Histogram of the percentage of processes feasible for storage technology

Energy cascading combined with thermal energy storage in industry

3.21

Cranfield Institute of Technology
School of Mechanical Engineering
UK — Cranfield Bedford MK43 OAL

R.J. WOOD

Contract number: EE-B-1-145-UK

A survey carried out in the USA into the use of thermal energy storage as a means of recovering waste heat has indicated a future energy saving potential of 10^8 GJ per annum for 5 main industrial sectors. If similar savings could be made within the EEC, a potential financial saving of approximately 240×10^6 ECU per annum would be possible. The objective of this study is to evaluate heat storage potential for U.K. industry.

Using technical constraints based on required power densities (100 kW/m^3) and economic constraints based on annual charge cycle frequencies (500 cycles per year), a detailed survey of a representative sample frame of U.K. industry has been carried out. It was shown that the technical and economic potential represents about 1% of the total energy use in the manufacturing sector of the U.K. which is equivalent to $3.9 \cdot 10^7$ GJ per annum. The highest probability of a satisfactory cascade match occurs in the temperature range $100°C \leqslant T \leqslant 250°C$ and above 1 000°C.

Steam accumulators and regenerators appear to be able to contribute most to industrial energy conservation in intermittent processes. New storage technologies are far less significant. In addition the greatest potential for steam storage does not lie in associating it with an industrial process, but in integrating it into the steam service system. No processes were feasible for thermo-chemical storage systems due to the imposed power density constraint.

The practical application of these new cycles requires close cooperation with the forging sub-contractors of R.N.U.R. The first contacts have already been made and the technology of the new equipment developed will be transferred to and controlled by the sub-contractors.

Using these techniques it is estimated that 20% of the energy can be saved. With forged pieces produced within the EEC amounting to 2 400 000 tons/yr this represents 230 000 toe/yr.

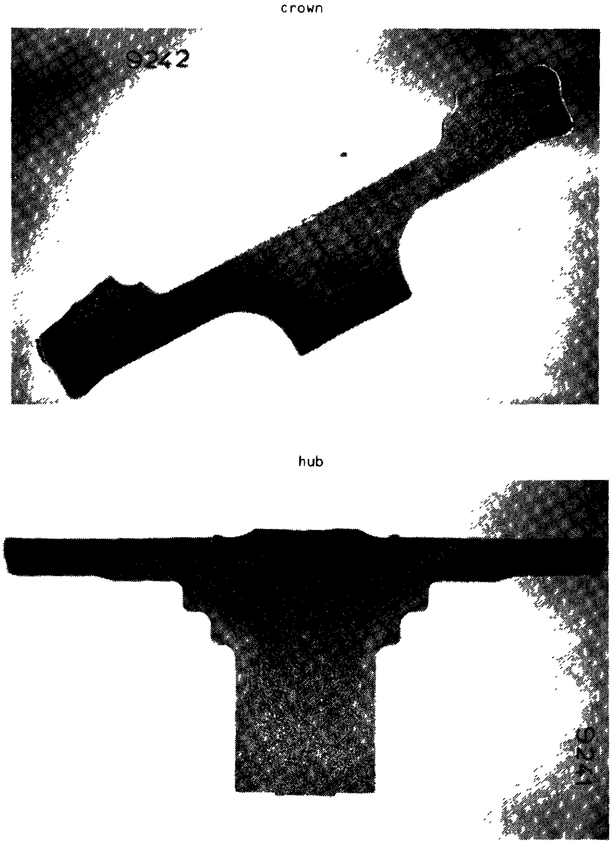


Figure 3.22.1 Directly cast engine parts for cars

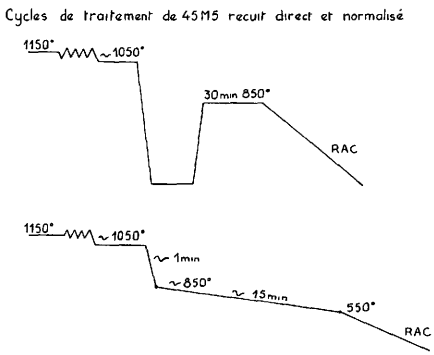


Figure 3.22.2 Treatment of 45 M5 steel for classical and new heating cycles

Saving energy in the manufacture of steel forgings 3.22

Régie Nationale des Usines Renault (R.N.U.R.)
8-10, avenue Emile Zola
F — 92109 Boulogne Billancourt Cedex

Société des Aciers Fins de l'Est (S.A.F.E.)
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R. EL HAIK (R.N.U.R.)

L. Backer (S.A.F.E.)

Contract number: EE-B-1-115-F

The manufacture of machined steel parts for cars involves the use of a considerable amount of material. Each 100 kg of finished part results in more than 200 kg of scrap, this being either discharged as waste or recycled at different stages of the process with a high added value. The consumption of energy is also high. The metal is heated between 4 and 7 times to temperatures varying from 500°C to 1 400°C during the cycle. The order of magnitude of the energy consumption for a given part has been estimated at 800 kWh/100 kg. The length of the manufacturing line explains the high energy cost of parts produced by this technique, which is, in addition, a process offering high levels of performance and reliability.

The aim of the research is to maintain the quality of the parts while at the same time reducing the materials and energy consumption for each operation. Two approaches are being studied:

— Suppression of the rolling process with the parts being directly forged from cast bars. The irregularities in the centre of the cast bars can be reduced by hot working. About four hot working operations are sufficient to obtain satisfactory mechanical properties. Two axisymmetric parts (wheel hub, differential crown wheel) have given satisfying results in endurance tests.

— Reduction or suppression of heat treatment after forging.
Three types of direct treatment after forging are applied in the respective production processes of:
  — Isothermal annealing (for gears)
  — Classical annealing (e.g. for connecting rods)
  — Water quenching (e.g. for steering knuckles)

  Research work enabled the contractors to define cooling patterns for each case ensuring the best compromise between quality (hardness, structure, endurance impact strength) and machinability, as well as to specify the industrial equipment necessary to carry out these treatments.
  Regarding direct isothermal annealing, the relatively coarser grain obtained ensures a substantial gain during machining. The final quality treatment (carbonitriding quenching), enables one to obtain the structure of present mass-produced parts.

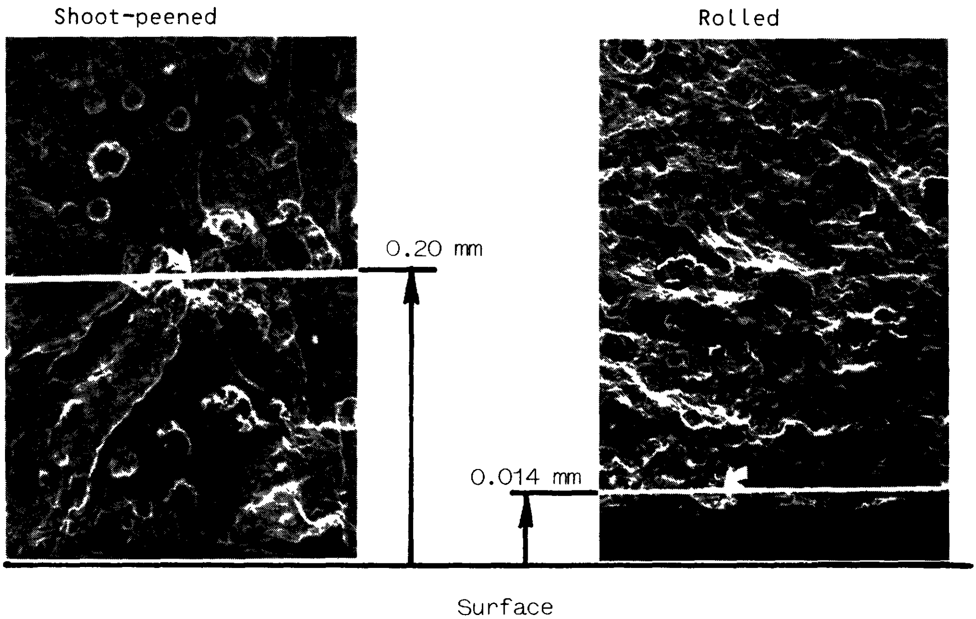


Figure 3.23.1 Scanning microscope analysis indicating that in the shot-peened specimen the crack originates at a deeper level than in the rolled specimen

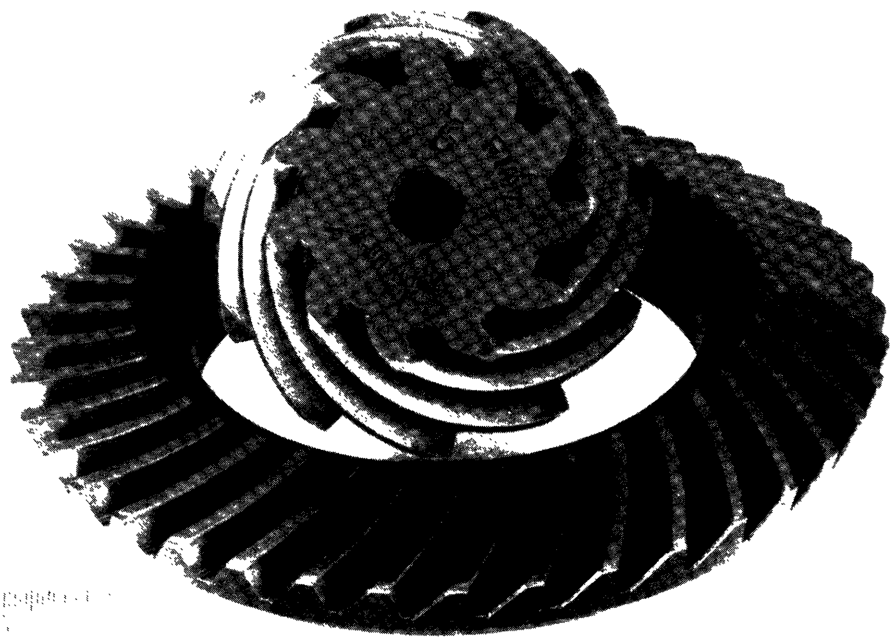


Figure 3.23.2 Bevel gears

Development of bainitic nodular iron for the construction of speed gears for the car industry 3.23

Fiat
Corso G. Marconi, 10-20
I — 10124 Torino

I. MONTANARO

Final report number: EUR 8639 available in English and Italian
Contract number: EE-B-1-149-I

Considerable energy savings could be achieved if bainitic nodular (cast) iron could be used for gear applications (e.g. gear box differential) instead of heat treated 18 Cr Mo 4 steel. The FIAT study intends to analyse the industrial feasibility and to investigate the possible problems connected with the use of cast iron.

In order for bainitic nodular iron gears to have the same mechanical and dynamic characteristics as steel components, it was necessary to treat the machined parts by ferritization, austempering and shot-peening.

The use of bainitic nodular iron resulted in a 75% saving on tool costs in the machining stage. The study indicated that if bainitic iron is to be used for gear applications, further efforts are needed in the areas of heat and mechanical treatment in order to obtain satisfactory characteristics of the new material.

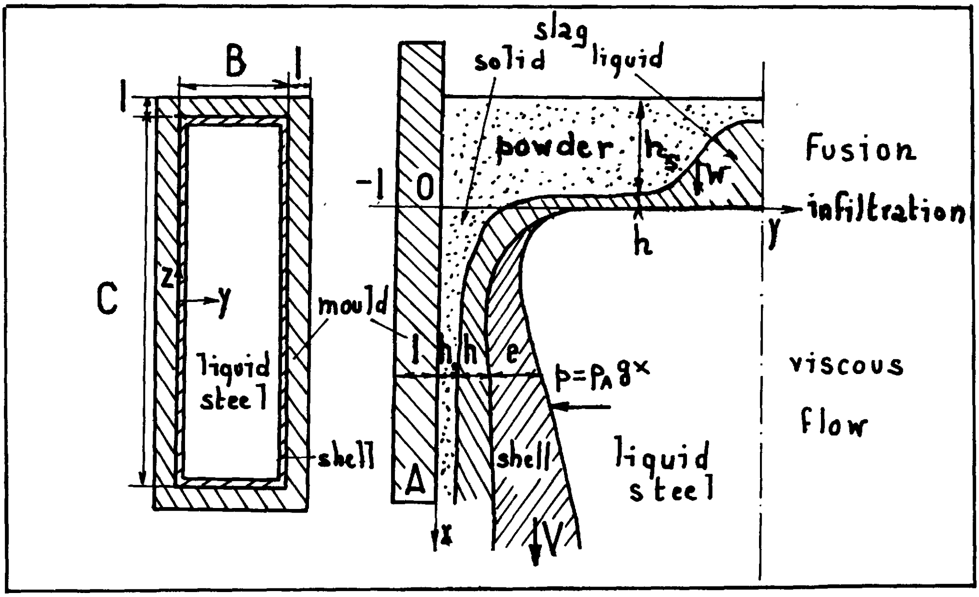


Figure 3.24.1 Geometry of the system

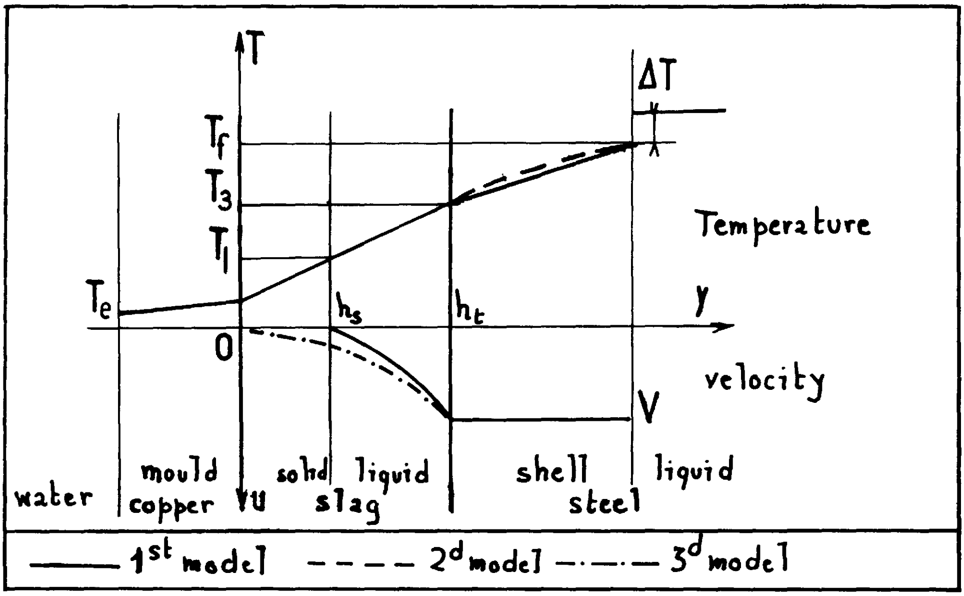


Figure 3.24.2 Schematization of a transversal section

Lubrication of the continuous casting of steels by slags

3.24

Société Armines
60, boulevard Saint-Michel
F — 75272 Paris Cedex 06

E. FELDER

Contract number: EE-B-1-117-F

Continuous casting of steels consumes less energy compared to classical casting routes, including ingot casting and rolling. This project aims to improve the lubrication of the continuous casting of steels.

Present practice is based largely on experience and has generally not been studied under well defined conditions. In a previous theoretical study of the lubrication of continuous casting, made in conjunction with IRSID and CEMEF, the calculated influence of the speed or the viscosity was not in agreement with experimental results.

ARMINES is now building a reliable computer model of the lubrication, using slags, of the continuous casting of slabs by coupling a thermal analysis of the system with a model of the viscous flow of the slag between shell and mould. The model will predict the influence of the slag properties on the heat flux extracted by the mould, the friction between the mould and the steel shell, and the defects of the cast products.

The results obtained with the model are in good agreement with experiments for low viscosity slags. For high viscosity slags, ARMINES will develop the fusion model and analyse the deformation of the solid part of the slag in the lower part of the mould which induces high friction. In addition, they will try to analyse the influence induced by the mould oscillations.

Figure 3.25.1 — Working site for casting and hit-out of samples
— Follow up of thermal cycles on a X-t type recorder

Figure 3.25.2 Fluidized bed ovens used for thermal treatment. Characteristics: useful capacity (dia 600 mm — height 800 mm); electrical heating (45 kW per oven); temperature region between 20°C and 1000°C

Energy saving by applying new thermal cycles to castings removed from the mould in the hot state immediately after the solidification stage

3.25

Centre de Recherches de Pont-à-Mousson (CRPAM)
Boîte Postale 28
F — 54700 Pont-à-Mousson

Institut National Polytechnique de Lorraine (INPL)
Laboratoire de Métallurgie associé au CNRS n° 159
Parc de Saurupt
F — 54042 Nancy Cedex

R. BELLOCCI (CRPAM)

J.M. SCHISSLER (INPL)

Contract number: EE-B-1-120-F

Conventional heat treatment is generally applied to castings removed from moulds at ambient temperature. This research work aims to develop new techniques for heat treating cast nodular pig-iron which has been removed from moulds while hot at temperatures of the order of 1000°C, i.e. the temperature at which the piece has just solidified. This innovation eliminates the consumption of energy currently required to reheat the piece—which has been removed from the mould at 20°C—to a temperature in the region of 1000°C. The project covers both the industrial application of this new technology and the establishment of the relation between the process conditions and the mechanical properties after the new heat treatment.

The first results have shown that the procedure is feasible. Nevertheless the new thermal cycles which yield remarkable energy savings (these have still to be assessed) necessitate optimization of the conditions to ensure that the structures required are in fact obtained.

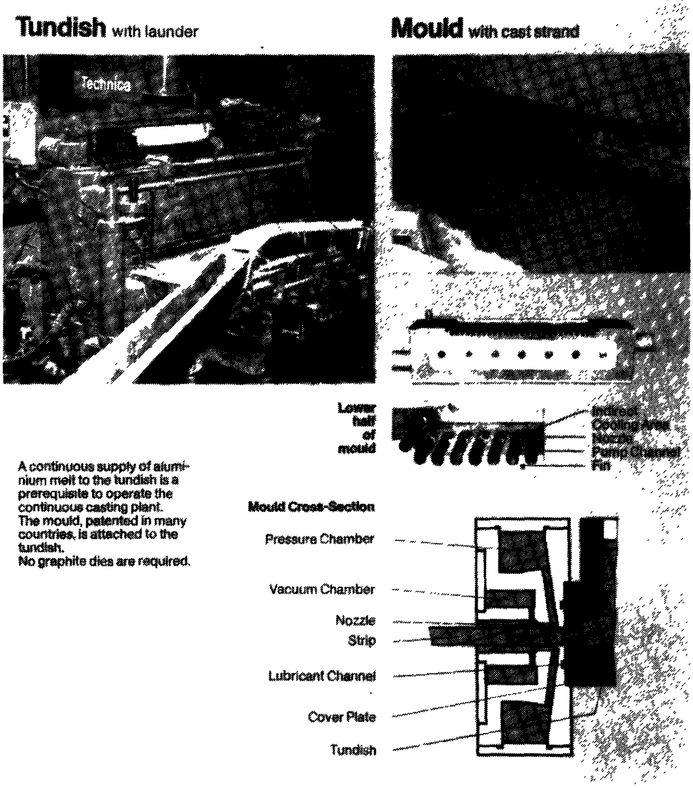


Figure 3.26.1 Fixed mould horizontal DC casting

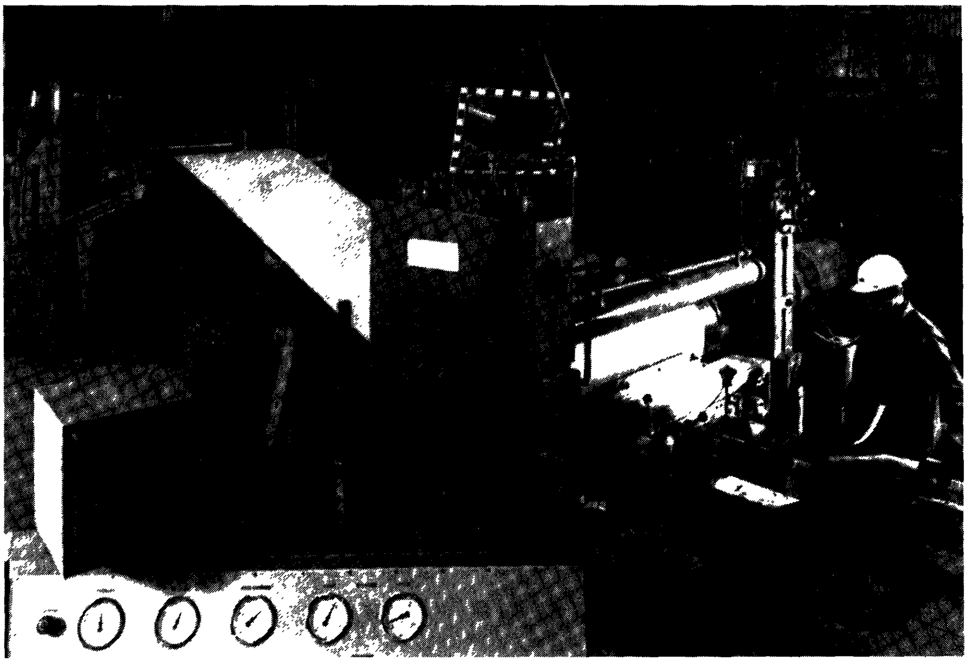


Figure 3.26.2 Alusuisse I. Roll Caster entry side

Reduction in energy requirements for converting liquid aluminium to semi-fabricated rolled products 3.26

The British Aluminium Company
Research Department
Chalfont Technological Centre
Chalfont Park
GB — Gerrards Cross,
Buckinghamshire SL9 0QB

T.J. DENNIS

Contract number: EE-B-1-102-GB

The conventional route for the production of aluminium rolled products involves DC (direct chilled) casting of blocks of 300-650 mm thickness. These are cooled and then heated up again for hot rolling (going through hot rolls while hot), to 2-5 mm for coiling and subsequent cold rolling. To avoid heat losses due to cooling and heating and power losses due to hot rolling, a method has been developed for directly casting liquid aluminium into thin strips. This can be done in different types of strip casting: horizontal DC strip casting, pellet-rolling (compacting and rolling pellets into strips) and spray rolling (compacting and rolling a spray into strips).

A total energy audit of six typical rolled products produced by both routes was undertaken to determine the potential energy savings. It was confirmed that energy savings up to 37% were possible using thin strip casting methods. These savings were less than expected because of increased cold mill passes and long high temperature homogenising annealing requirements. These partially offset the energy gains of eliminating the scalping, preheating and hot rolling operations of the conventional route.

The energy requirements of both processing routes for all six products selected were related to a typical product mix of 40,000 tonnes per annum. It was established that the potential energy saving using the thin strip casting route to achieve this output would be approximately 25% or 3 million therms, equivalent to 315, 517 GJ per annum.

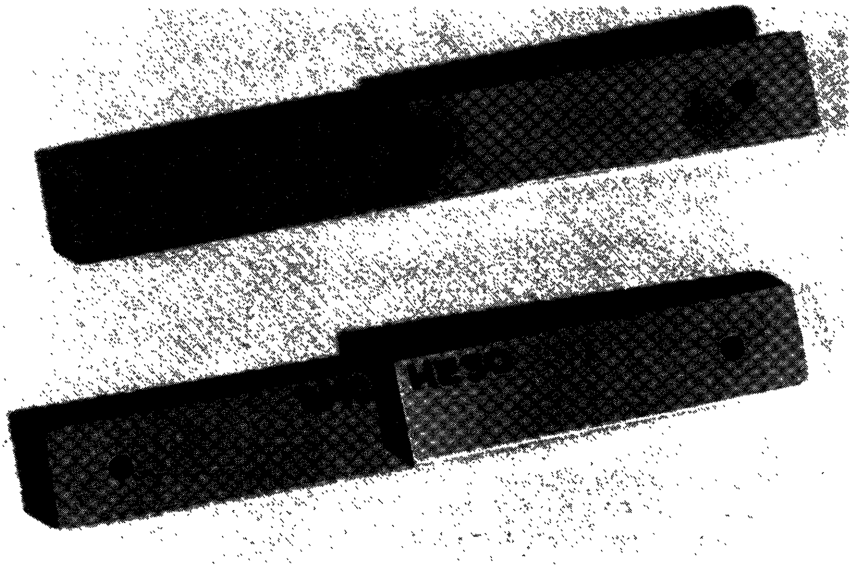


Figure 3.27.1 Composite/metal lap shear coupon specimens

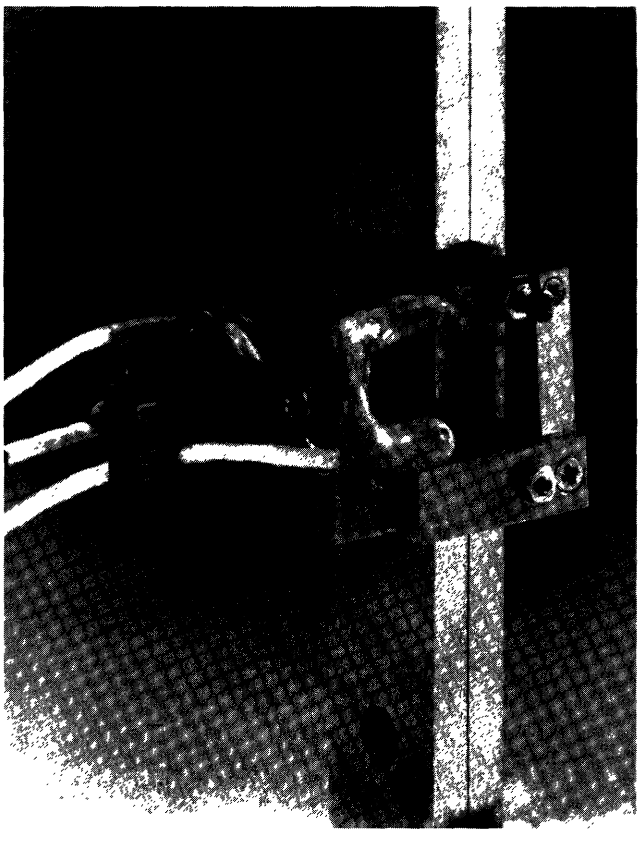


Figure 3.27.2 Thick adherent lap shear specimen with extensometer mounted

Composite metal jointing technology for vehicle weight reduction

3.27

AERE Harwell
Materials Development Division
UK — Didcot, Oxon 0X11 0RA

P. McGEEHIN

Contract number: EE-C-4-261-UK

In the transport sector, one way to save energy is to reduce the weight of motor-vehicles. A clear way to reach this objective is to make more extensive use of composite materials and adhesive bonding techniques. This would provide an improved design leading to a reduction in the weight of vehicles and aircraft, and consequently a reduction in energy consumption in transport.

The aim of the project is to develop design procedures for structural joints between composites and metals with emphasis on adhesive bonding techniques. The project is supported by 15 firms including manufacturers of motor-vehicles, adhesives, and composite materials. The joint geometries and materials being investigated have been chosen because of their potential for applications in the automotive and aerospace industries. Three typical potential applications have been chosen: a torsional joint, a chassis bracket and the hinge attachment of a hatch backdoor. To date, design computer programs have been written and a large programme of materials testing has started (thick adherent shear tests to characterise the mechanical properties of adhesives, lap shear tests to investigate the ageing behaviour of adhesives and interfaces and boeing wedge tests for accelerated environmental durability studies). Test data are currently being used to design the specified joints, and a manufacturing programme is under way which will allow the performance of component joints to be subsequently established, and the design procedures validated.

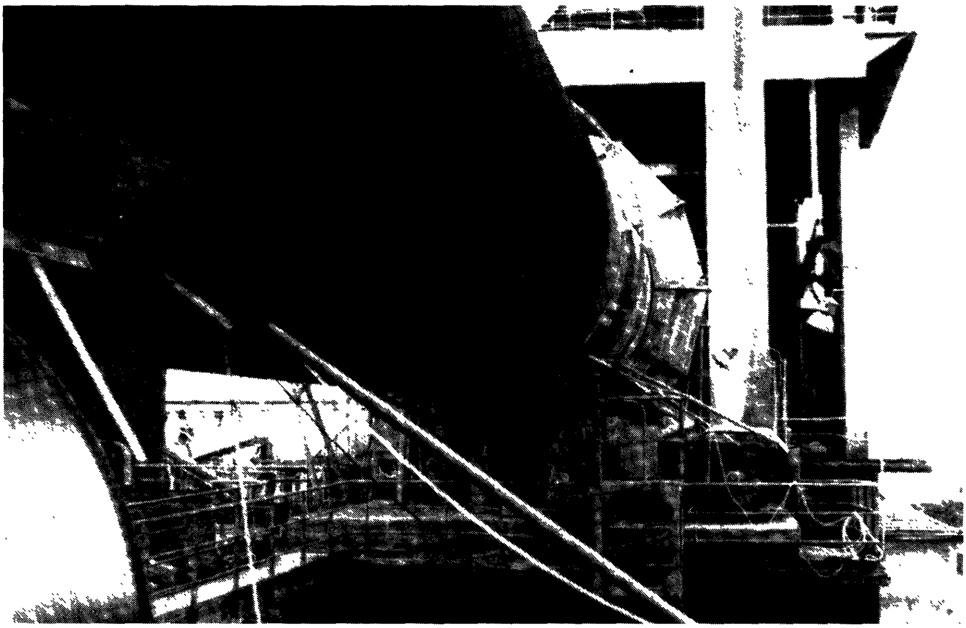


Figure 3.28.1 Cement factory of LE BOUCEAU
View of the rotating oven and of two probes for gamma ray detection, used to study the progression of the charge in the oven

Using tracers to investigate the transfer parameters in the system regulating the chemical constitution of the feed to cement kilns in order to achieve optimum efficiency

3.28

Commissariat à l'Energie Atomique (C.E.A.)
CENG - SAR - LAT - 85 X
F — 38041 Grenoble Cedex

J. GUIZERIX

Contract number: EE-B-1-141-F

In order to produce cement, limestone is obtained from quarries. It is then crushed, mixed with clay and fed to a cement kiln for production of clinker which is milled to cement.

The fluctuations encountered in the composition (due to insufficient mixing) of the raw material fed to the cement kiln must generally be compensated for by over-baking which leads to energy losses. The factory kiln at LE BOUCEAU consumed 850 to 1000 kcal/ton of clinker produced while values of 720 to 800 kcal/ton can be achieved under proper operating conditions. The aim of this project is to determine the parameters which govern the mixing of this raw material so that optimum energy consumption can be obtained.

By developing a new method of marking the raw material with tracers, C.E.A. was able to study the efficiency of the homogenising silos and the passage of the material through the kiln, as well as obtaining a better understanding of the operation of the crusher. In addition the mixing efficiency of the pre-homogenising stockpiles was evaluated. The research is carried out at the cement factory in LE BOUCEAU near BAYONNE.

Results indicate that the crusher is a good mixer. There is a short circuit in the homogenising silo and mixing there needs to be improved. Pre-homogenising stockpile experimental results are not yet available. The average residence time of the material in the kiln is about 1 1/2 hrs. 10% of the materials, however, stays less than 45 minutes while another 10% stays more than 4 hrs. Hence, a part of the material with low residence time will be under-baked while another part with long residence time is heated too long resulting in wastage of energy.

In a second step, C.E.A. will investigate the energy consumed per ton of clinker produced, the quality of the clinker and the hazards of kiln operation. An accurate knowledge of the mass transfer mechanism in the kiln will also be obtained.

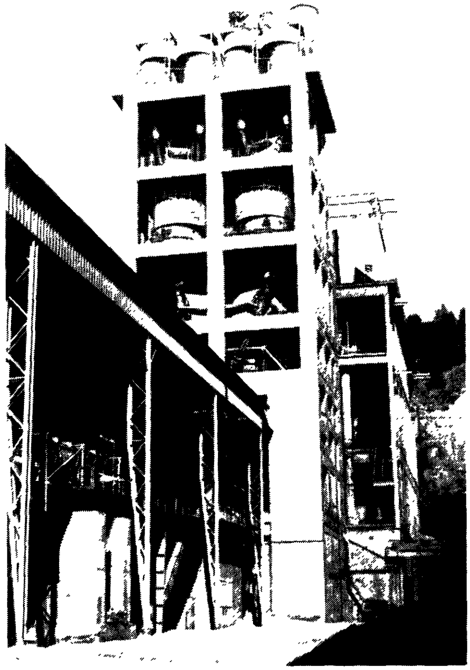


Figure 3.29.1 General view of the clinker baking plant

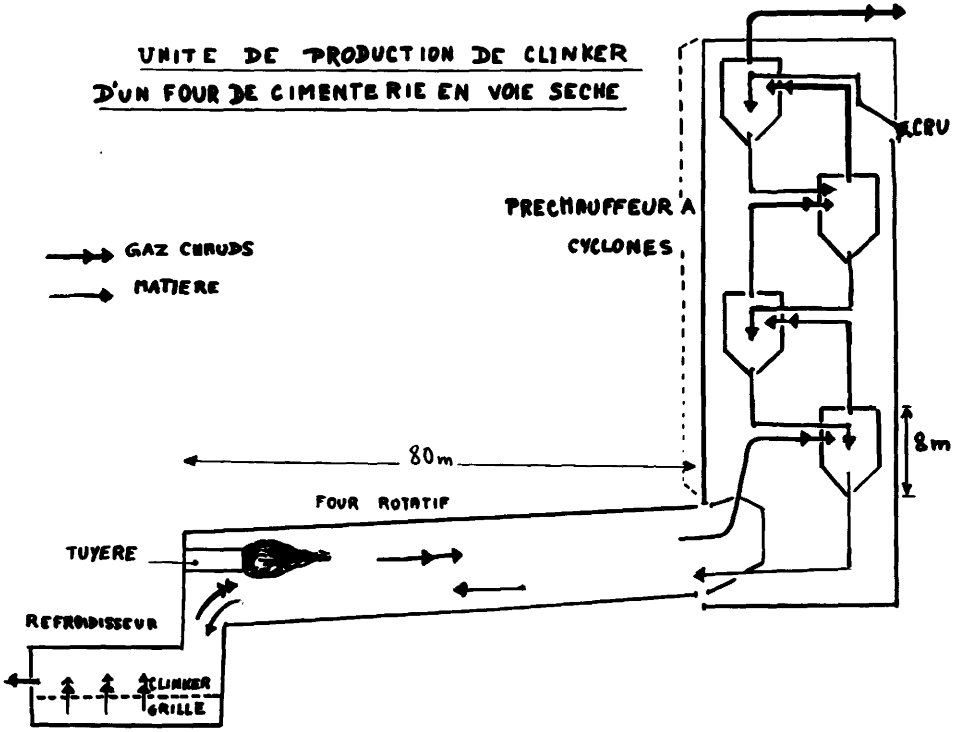


Figure 3.29.2 A unit for clinker production using the dry process

Cyclone heat exchangers: development of a method of defining and improving performance 3.29

Lafarge Coppée Recherche (L.C.R.)
Boîte Postale 8
F — 07220 Viviers-sur-Rhône

Centre d'Etudes Nucléaires de Grenoble (C.E.N.G.)
85 X
F — 38041 Grenoble Cedex

C. DOUVRE (L.C.R.)

R. MARGRITA (C.E.N.G.)

Contract number: EE-B-1-106-F

The cement industry is a large consumer of energy. In order to produce 1 tonne of clinker (product from the kiln which is crushed to produce cement) a wet-process furnace (the older process in which water was added to the clay and limestone feed) consumes about 1400 therms (~ 140 kg of fuel oil) while a dry process furnace consumes about 850 therms (~85 kg of fuel oil). Therefore, in recent years, there has been a major effort to change over from the wet to the dry production unit, but the latter still needs considerable improvement.

A dry production unit consists of three major components, cyclone heat exchangers or preheaters of the feed, a rotating kiln where clinkering of the feed takes place, and a cooler which enables a large part of the heat from the clinker to be recovered. The cyclone heat exchangers are used to preheat the feed to the rotating kiln (from ambient temperature to some 850°C) by counter-current heat exchange between the cold materials and the hot exhaust gases (at a temperature of around 1000°C) before they are discharged to the stack.

The aim of this research is to obtain a better knowledge of the operation of such cyclone exchangers in order to make subsequent modifications enabling heat exchange efficiency to be improved. The purpose is also to reduce the energy consumption in the preheater tower; energy can be saved by diminishing the power consumed by fans and by better use of the heat brought by the gas.

LAFARGE COPPEE RECHERCHE and C.E.N.G. are studying the mechanical performances of the cyclones, i.e. the residence time of the materials, the efficiency of separation, the pressure gradient, etc. Experiments with radioactive tracers have been carried out in order to investigate these parameters. A computer programme has also been written to simulate the cyclones and has been validated by the experimental data. This programme has been used to optimise the cyclone geometry to improve separation efficiency and reduce pressure drop. Results indicate that the benefits are too low to justify any modification of the existing cyclones. However, this optimisation programme should be taken into consideration in the design of new cyclone installations.

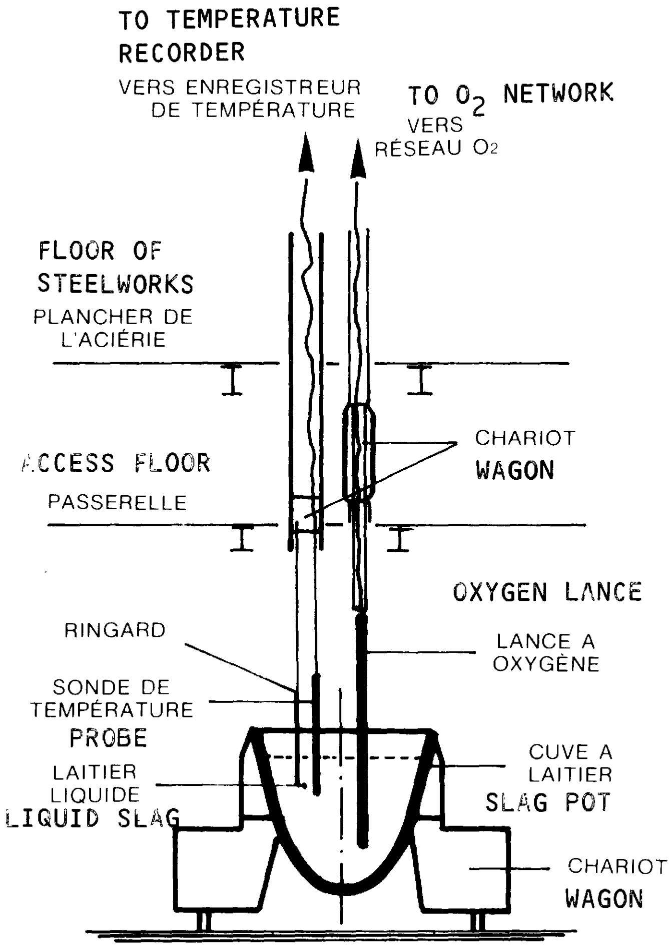


SCHÉMA DE L'INSTALLATION D'INSUFFLATION D'OXYGÈNE

Figure 3.30.1 Schematic of oxygen injection experimental setting

Study of the treatment of oxygen steelworks slag with a view to using it in cement-making

3.30

Institut de Recherche de la Sidérurgie Française (IRSID)
Station d'Essais
Boîte postale 13
F — 57210 Maizières-les-Metz

Lafarge Fondu international (LFI)
157, avenue Charles de Gaulle
F — 92521 Neuilly-sur-Seine

R. PAZDEJ (IRSID)

F. SORRENTINO (LFI)

Contract number: EE-B-4-183-F

Slags from oxygen steel-making (containing SiO_2, Al_2O_3, FeO, CaO, MgO) are waste products which have not yet found many applications; they generally contain between 1 and 2% alumina. If the alumina content could be raised to about 10%, this product would have sufficient hydraulic properties (capacity to absorb water and to permit the setting of cement with good mechanical properties) to be used in the cement industry as an additive to Portland cement.

IRSID and LFI are testing methods of increasing the alumina content of slags produced at the Dunkerque steelworks of Usinor. Alumina is added to the slag in the form of an alumina-containing flux (Camflux) in the convector and by addition of bauxite and aluminium waste in the slag pot, their melting being ensured by oxygen injection. In this way, alumina concentrations greater than 10% could be obtained.

The resulting product however is very hard and difficult to crush. Its hydraulic properties are poor and further studies should be carried out to obtain a better understanding of the mechanisms involved.

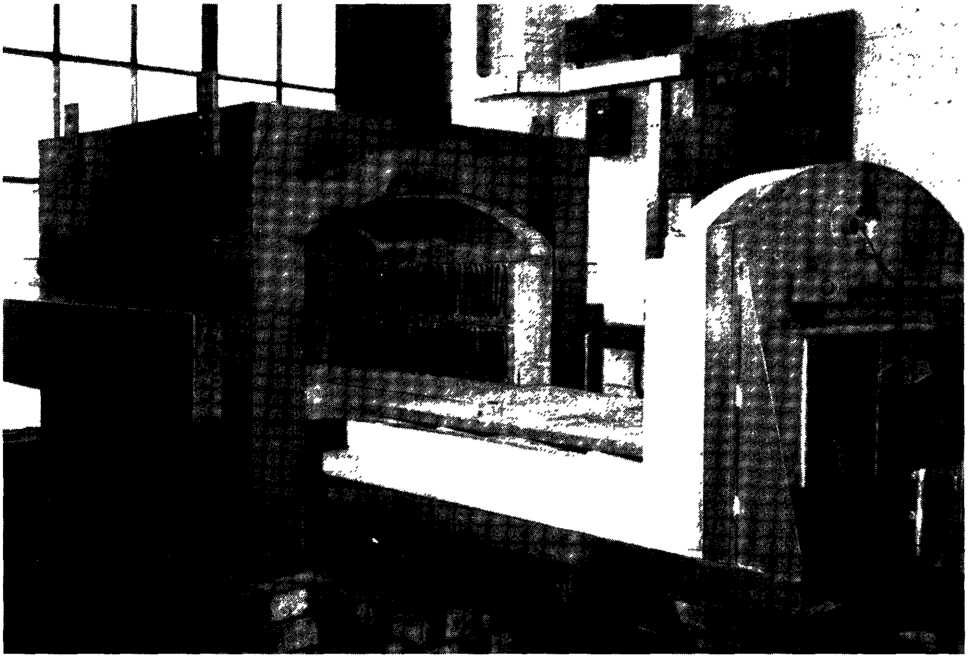


Figure 3.31 Heat treatment kiln

Ceramic materials from molten blast-furnace slags by direct controlled cooling

3.31

Imperial College of Science and Technology
Department of Metallurgy and Materials Science
Royal School of Mines
Prince Consort Road
GB — London SW7 2BP

P.S. ROGERS

Contract number: EE-B-4-184-GB

The resistance to erosion of glass-ceramic material, coupled with the favourable tensile strength and hardness, makes this material particularly useful for industrial applications which involve wear due to erosion.

Convention glass-ceramics are made by cooling a melt to the glassy state and then crystallising it in a controlled manner by reheating. In the USSR glass-ceramics are made in this way, using blast-furnace slag as the chief constituent.

IMPERIAL COLLEGE is developing a novel process for the production of a glass-ceramic material ("Silceram") from molten blast-furnace slag by heat treatment. This involves direct cooling from the melt instead of the two-stage reheating treatment for conventional glass-ceramics. The nucleation and growth of crystals take place during a controlled cooling from the melt, thus avoiding the reheating from cold glass required by the conventional process. It also shortens the heat treatment time leading to additional energy savings.

A pilot-plant for the production of glass-ceramic castings has been designed, constructed and commissioned. This consists of an oil-fored tilting tank furnace capable of melting 100 kg batches, a heat treatment kiln, casting and moulding equipment and facilities for storing raw materials and finished products.

Physical and mechanical property determinations have been made in the laboratory with the new material. The viscosity of the molten mixture used for "Silceram" production has been determined as a function of temperature over a range between 1250 and 1600°C. The data show that the melt has adequate fluidity at 1450°C, but has rapidly increasing viscosity as the temperature falls to that of the heat treatment kiln (900-950°C) which is necessary if the shape is to be retained during crystallisation. (The viscosity at 1350°C is 5.95 Nsm^{-2}). These investigations have shown that the new material is attractive as an erosion-resistant ceramic for industrial applications.

It could be used as a lining for conveyors or pipes which carry erosive gas-entrained solids.

A first series of trials has enabled the best conditions for casting to be established; there is now nothing to hinder continuous production at the pilot plant.

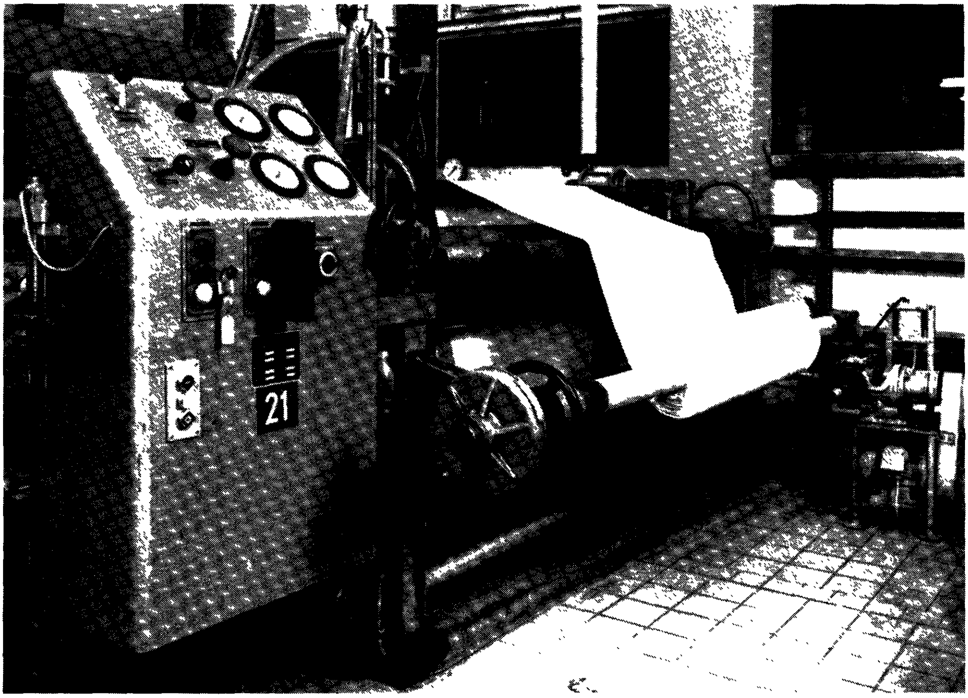


Figure 3.32.2 Full scale pad

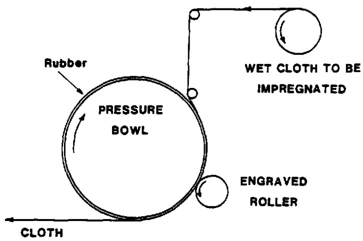


Figure 3.32.3 Diagram of printing with engraved rollers

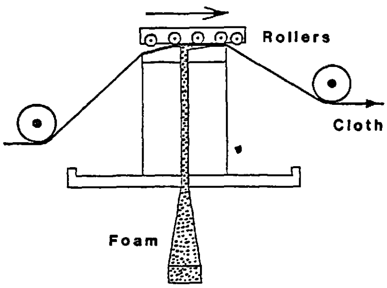


Figure 3.32.4 Foam application with a vertical slit

Industrial application of continuous wet-on-wet treatment of fabrics 3.32

TNO Vezelinstituut
Postbus 110
NL — 2600 AC Delft

R.B.M. HOLWEG

*Contract number:*EE-B-1-139-N

The possibility of impregnating wet tissues directly, thus avoiding the "energy-expensive" intermediate drying stage is being investigated by TNO. (This work was initiated in a previous EEC contract 392-78-EEN). Three methods are now being tested in the laboratory under the present contract:

Experiments on a pad: wet cloth can be impregnated in a pad, the concentration of the solution being adjusted. TNO determined the optimal values of this concentration as a function of impregnating conditions: type of cloth, speed, initial water content of the cloth and type of substance.

Experiments on engraved rollers: Satisfactory results were obtained on a semi-technical printing machine. Initial results indicate that: the effect of cloth speed is small, the amount of solution applied depends on the roughness of the cloth, and the pressure between the printing roller and the cloth is an important parameter.

Impregnation by means of foam: In some textile mills, chemicals are applied to a dry cloth by means of foam. This method could be made suitable for the impregnation of wet cloth. Experiments have been carried out by TNO on a semi-technical installation constructed by TNO-Fibre Research Institute. Applying the foam by means of the vertical slit method, the chemicals were applied fairly evenly across the width of the cloth. Penetration of the chemicals into the interior of the cloth was fairly good. The process conditions should, however, be carefully selected.

Experience gained in the laboratory will enable experiments and applications with a pad and with engraved rollers to be carried out in industrial plants.

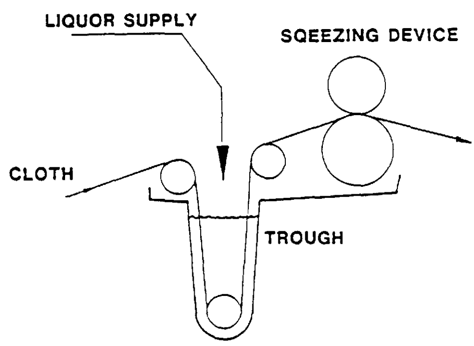


Figure 3.32.1 Principle of a pad

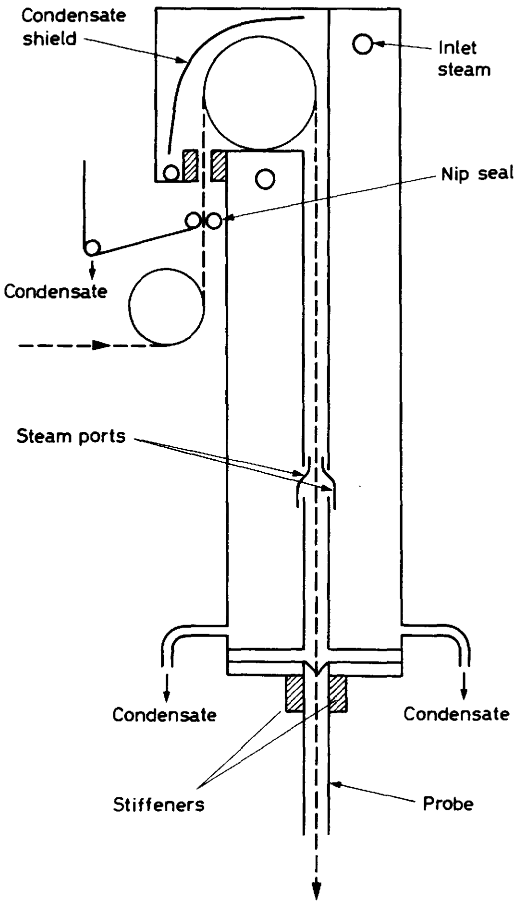


Figure 3.33.1 Model of the steam pad indicating the principle of steam purging

Shirley Institute
Didsbury
GB — Manchester M20 8RX

J.G. ROBERTS

Contract number: EE-B-1-140-UK

Surveys of typical textile processes show that the energy requirement for desizing (removal of polymeric material used to strengthen and lubricate fibres during fabric forming processes), scouring (removing impurities including oils, fats and waxes in a bath) and bleaching is commonly between 10 and 30 GJ per ton of product.

It is envisaged by the SHIRLEY INSTITUTE that processing can be achieved with very low energy consumption—5 GJ per ton—by eliminating the heating during these processes without prolonging processing times. Three lines of experimentation are being followed to reduce energy requirements and still maintain short reaction times: steam purging (removal of air from the fabric by steam for better impregnation); combined desizing, scouring and bleaching; catalysed bleaching (to accelerate reaction times at lower temperatures).

Experimental work has demonstrated the value of the steam purging technique as a means of obtaining rapid full impregnation of loomstate (grey) fabric. This is an essential feature of rapid processing at this stage. Combined desizing, scouring and bleaching (with conventional bleaching solutions) has been achieved with steam purging in a 24-hour reaction period at ambient temperature. The progress of the reaction after 5 hours suggests that accelaration of the three reactions can be obtained. Two separate approaches were tried: a two-stage application of a foamed hypochlorite solution followed by the peroxide bleaching step and a single-stage application of peroxy salts incorporated with the hydrogen peroxide bleach. Further work will be required to obtain the optimum reaction times.

A literature survey has been made of the use of catalysts for bleaching textiles. The more important substances identified were urea and tungstates. Experiments have started to study urea. Initial results suggest that reaction times can be halved, but considerably more work is required.

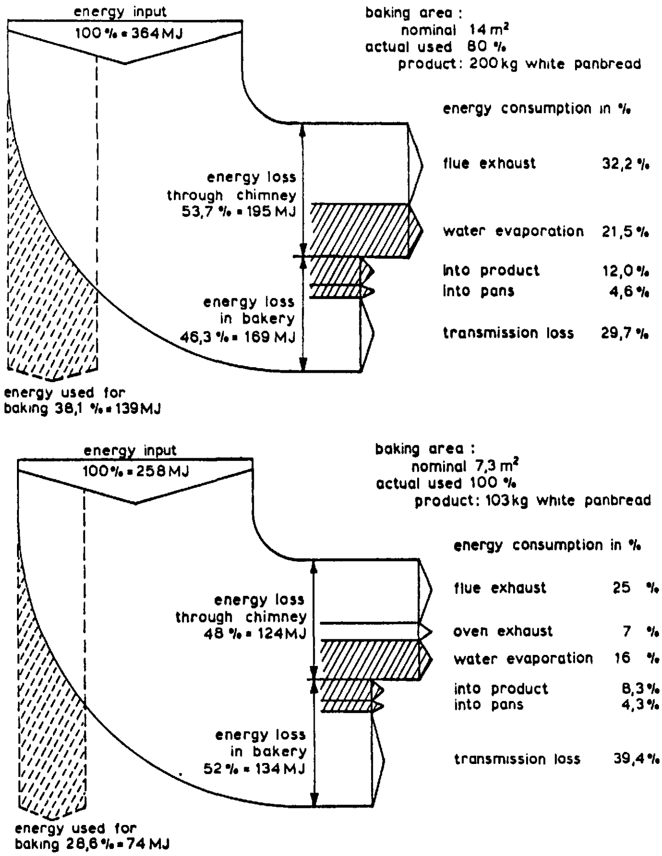


Figure 3.34.1 Energy balance for baking ovens

BAKERY CODE	1	5			8	18	
OVEN NO.	-	1 (3 days)	2 (3 days)	1 + 2	-	1	2
BREAD in kg flour	1461	491	372	1696	2945	1215	1468
CONFECTIONARY in kg dough/batter	100	-	48	422	318	162	179
ENERGY CONSUMPTION OVEN IN MJ	8158	3177	1050	10294	12754	3206	9176
ENERGY CONSUMPTION divided into:							
1. Losses before baking	745	347	192		639	352	1282
2. Baking bread	4648	2162	913		8344	1903	5450
3. Baking confectionary	1119	63	608		1315	335	1054
4. Cooling losses after baking	1646	397	212		2456	616	1390
5. Pilotflame in non-baking period	-	208	173	1030	-	-	-
Energy consumption per 100 kg flour for breadbaking:							
Monday MJ/100 kg	300				289	133	453
Tuesday " "	319				300	134	431
Wednesday " "	281	496	228		257	144	447
Thursday " "	279	468	284		365	117	352
Friday " "	306	382	231		224	212	299
Saturday " "	369				275	188	356

Figure 3.34.2 Energy consumption of baking ovens and baked products per week

Energy saving in the bakery by improving efficiency and heat recovery 3.34

TNO
Institute for Cereals, Flour and Bread
P.O. Box 15
NL — 6700 AA Wageningen

L.W.B.M. de VRIES

Contract number: EE-B-1-148-N

Approximately 175,000 toe are used annually by bakeries in the Netherlands. Half of the bread production is carried out in small bakeries, of which there are 3600 in the country, and an idea of their size can be gained from the fact that only 7% employ more than 10 staff. Few reliable data on energy consumption in bakeries are known. It is therefore important that these bakeries, as well as the larger centralized units, are studied.

Measurements have therefore been carried out by TNO in 7 bakeries with batch ovens, 5 bakeries with continuous ovens and 3 industrial confectioners. 5 bakeries in the first category, representing 50% of the Dutch bread production have already been studied and the work will now concentrate on bakeries with continuous ovens (41% of the total bread production).

In these bakeries, the main source of energy is natural gas, 75% of wich is used in the baking ovens (natural gas is also used for cooking, general heating and water heating). Results indicate that these ovens vary considerably in efficiency, and that each oven has its "good" and "bad" days due to varying degrees of production planning. An efficient day of operation can result in 25-30% less energy usage than days when production planning was less than ideal. It was also shown that 10% can be saved by substitution of pilot flames by spark ignition and 10% by closing the gas exhaust duct in periods in which the burners were switched off. It was also shown that electricity usage was comparatively small, but its cost could be high. Of the total consumption of electricity 30-55% is spent on freezing and refrigeration. A saving of 10-20% is possible in this latter area.

A survey has also been made of the available quantity and composition of the combustion gases from steam-boilers operating with natural gas, fuel oil and coal respectively. The combustion gases of fuel oil and coal contain considerable amounts of hydrocarbons (fuel oil: 300 mg/fuel unit, coal: 150 mg/fuel unit) and fly ash (fuel oil: 2000-3000 mg/fuel unit, coal: 300 mg/fuel unit). Since the soya bean meal and oil are normally intended for edible purposes, this will prohibit the use of these gases for direct heating. It is, however, possible to use natural gas which contains low quantities of hydrocarbons (10-60 mg/fuel unit) and fly ash (10 mg/fuel unit).

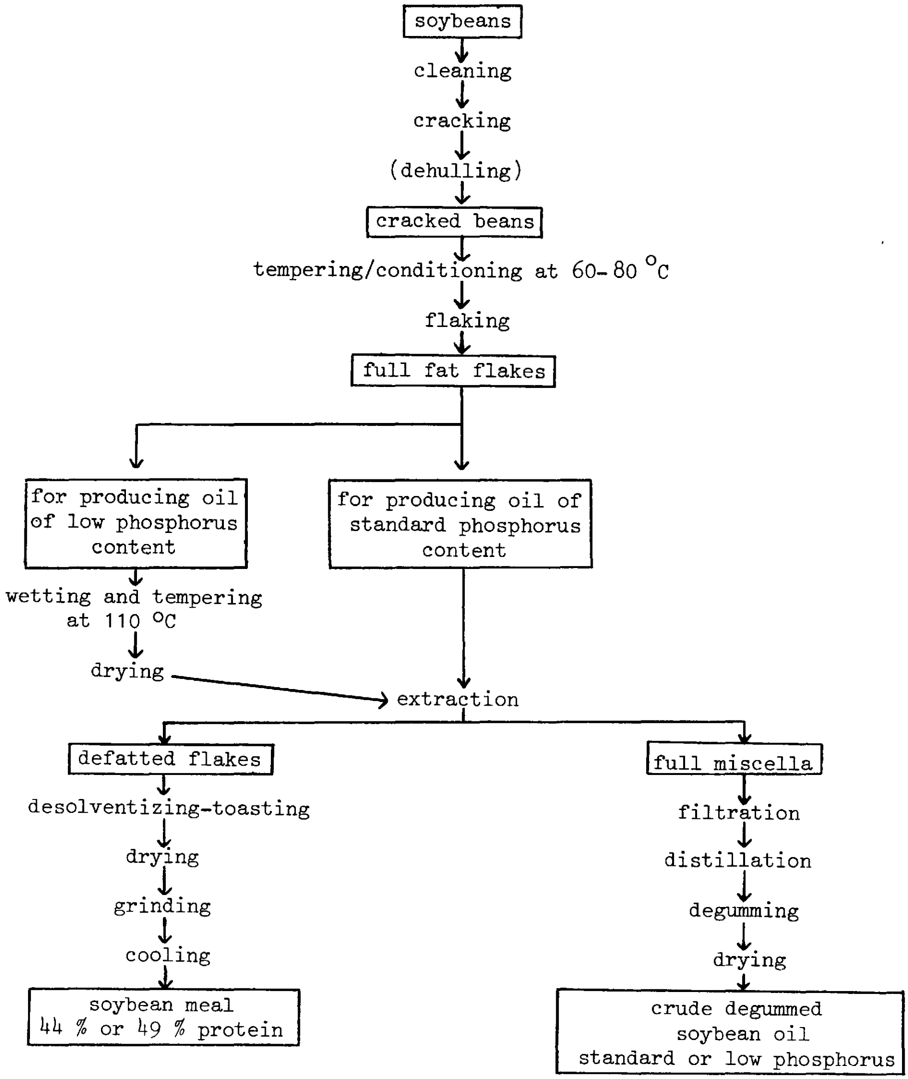


Figure 3.35.1 Flow diagram of a soya been extraction plant producing soya bean meal and crude degummed oil of standard (200 ppm P) and low (20 ppm P) phosphorus content

Energy saving in the soya bean extraction industry by reducing the steam consumption for desolventizing — toasting and drying extracted beans

3.35

CIVO Institutes TNO
Division for nutrition and food research
P.O. Box 360
NL — 3700 AJ Zeist

T.L. ONG

Contract number: EE-B-1-138-N

Five Community countries each processed more than 1 million tonnes of soya beans in 1981, and the total amount processed in the Community was over 10 million tonnes. The soya bean extraction process involves a number of stages. For the production of soya bean oil and meal, soya beans are consecutively: cracked, dehulled (in making soya bean meal of 49% protein), heat-conditioned and formed in flakes from which oil is extracted by means of hexane. The remaining meal (defatted flakes), containing 30-40% hexane, is subsequently desolventized and toasted (to improve its nutritional value) by means of steam. Finally the wet extracted meal is dried by means of air. In the manufacture of low-phosphorus soya bean oil, the flakes (before extraction) are cooked at a moisture content of 16% and at a temperature of about 110°C (to partially deactivate the enzymes) and subsequently dried to about 11% moisture content and cooled to about 60°C. These flakes are extracted in the usual way and (after desolventizing) still have to be toasted to improve their nutritional value. Steam usage required for heat-conditioning, extraction, desolventizing-toasting, drying and for distilling hexane out of the oil-in-hexane solution, is particularly high, and it is here that TNO is investigating energy saving techniques.

The aim of the research is to reduce the steam consumption as follows:

— by combining the toasting operation (which consumes 60 kg steam per tonne of beans) with the heat conditioning step (which consumes 45 kg steam per tonne of beans) and utilizing waste combustion gases for the production of steam, 20 kg steam per tonne of beans can be saved;

— 30 kg steam per tonne of beans can be saved in the drying operation (which consumes about 100 kg steam per tone of beans), by desolventizing the defatted flakes by means of superheated hexane vapour, resulting in soya bean meal of low water content which hardly needs any drying.

In this context the optimum specific energy consumption of the processes concerned has been assessed. It was found that the steam consumption based on 1 ton of beans in the most important operations of the new proposed process will be: 118 kg for heat conditioning at 110°C and toasting, 97 kg for desolventizing defatted flakes (35% hexane) at 80°C and 6 kg (estimated) for stripping residual hexane in the meal. The total steam consumption based on 1 ton of beans is thus 221 kg, which is 106 kg less than that of today's process and considerably better than the envisaged energy savings of 50 kg/ton.

	heat (MJ)	electricity (MJ)*)
cracking		7.2
tempering/conditioning	119	3.6
flaking		36.0
extraction	40	3.6
desolventizing/toasting	297	7.2
drying	158	7.2
grinding		7.2
distillation (including usage of the heat of the vapours from the DT)	79	
pumps, conveyors etc.		14.4
ventilators		14.4
	693	100.8

*) 1 kWh = 3.6 MJ

Figure 3.36.1 Breakdown of the energy consumption in a 1 000 tons per day soya-bean extraction plant — MJ/ton of beans

Energy saving in edible oil processing plants, by application of a total-energy (TE) system

3.36

CIVO Institutes TNO
Division for Nutrition and Food Research
P.O. Box 360
NL — 3700 AJ Zeist

T.L. ONG

Contract number: EE-D-1-303-N

It is well known that in public electricity generation stations only 34-40% of the total energy input is converted into electricity; 60-66% of the energy input is lost as heat. In total energy systems electricity is produced in such a way that heat is discharged at a useful temperature, so that it may be used.

In the past the application of TE-systems was only feasible for capacities of at least 10 MW. Recently, however, reliable smaller TE-units, driven by gas or diesel engines, have become available and their application in smaller plants is now feasible.

TNO made a feasibility study to investigate under what conditions energy saving by means of TE-systems can be implemented in edible oil processing plants. Edible oil processing plants—like extraction plants, refineries, etc.—utilize, in addition to electricity, enormous quantities of low pressure steam (3-10 bar). This makes this industry an interesting candidate for the application of a total energy system.

Provided that the electricity supply authorities are co-operative, the installation of total energy packages at factory sites can be cost-effective. It is necessary to identify the demand for electricity and heat, and to quantify the grade of heat needed and the fuel available on site before deciding on the type of system to be adopted, if any.

TNO is studying three principal production processes, those for soya-bean oil extraction, soya-bean refining, and margarine production. For margarine production TE-systems are not attractive since the heat/power ratio is 0.7. However, for a soya-bean extraction plant (of 1 000 tons per day capacity) the high utilization (6 000-7 200 hours/year) and attractive heat/power ratio of 6.9 (693 MJ of heat and 100.8 MJ of electricity) suggests that the use of total energy plant coult be feasible. Here, it is planned to install a TE-system based on a gas turbine of 1 000 kW.

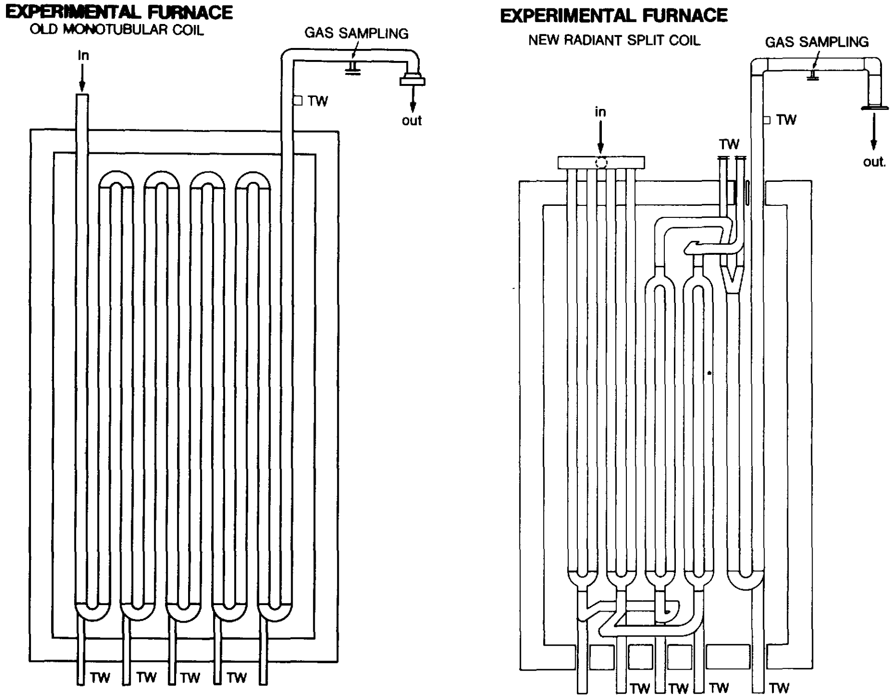


Figure 3.37.1 Comparaison of the old and newly designed coil reactor

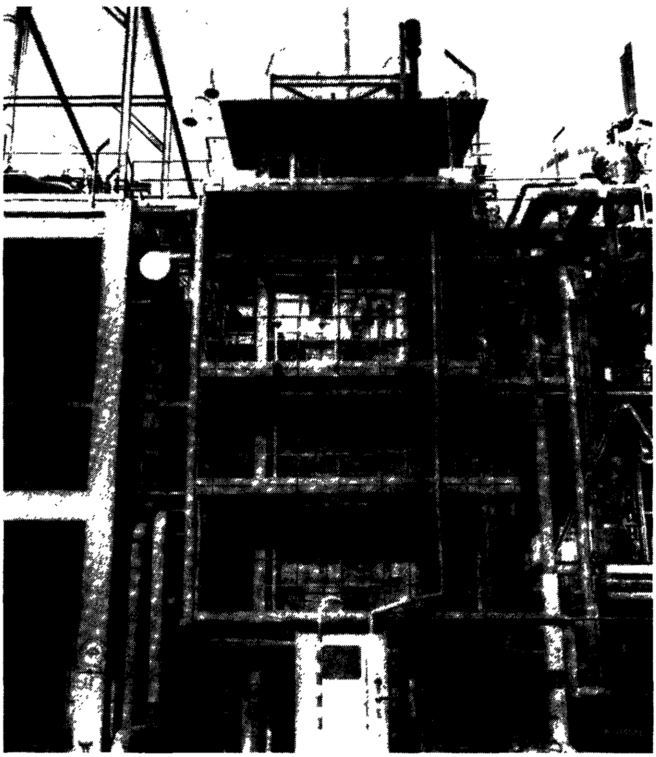


Figure 3.37.2 Front view of cracking furnace

Modification of cracking furnaces in existing plants to increase yields of valuable products and to reduce fuel consumption 3.37

Riveda (ex Montedipe)
Via Moscova, 3
I — 20121 Milano

M. SPOTO

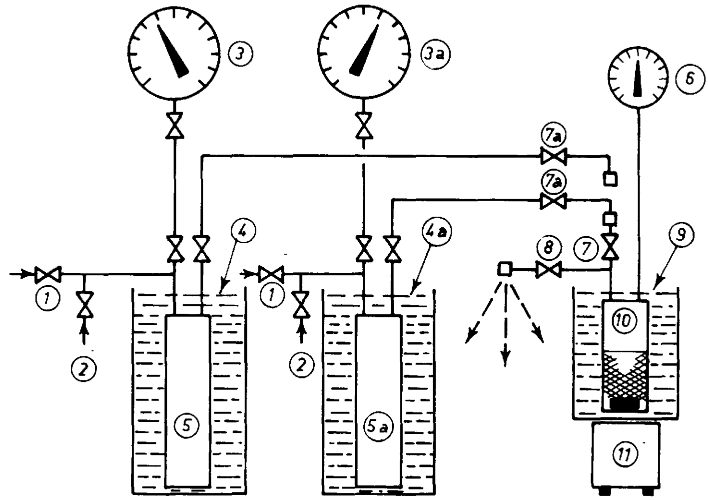
Contract number: EE-B-1-109-I

Up to 1973, the availability of Virgin Naphtha in Europe (light or medium oils distilled from crude oil) was higher than the demand and its price was lower than that of other petroleum products. Therefore, almost all steam cracking plants producing olefinic products were based on Virgin Naphtha as primary feedstock. Many of the existing cracking monotubular reactors, which are the heart of an ethylene plant, no longer comply with the new market constraints, i.e. reduced Virgin Naphtha availability and higher feedstock and energy costs.

The aim of this study is to design a new coil reactor which would increase the yield of olefinic products, reduce the feedstock and the energy requirements per unit of product and give maximum flexibility to the choice of feedstock. It is expected that substantial cost savings can be achieved, especially in view of the rising cost of both raw materials and energy.

By using a computer simulation program ("SPYRO" kinetic model) several coils, designed on the basis of Montepide's experience, have been tested. The coil selected, consisting of a multiple diameter tube arrangement, is more selective in olefinic products than the existing one. The new geometry and the new alloy employed will reduce the fouling rate and it should also consume less dilution steam, at constant olefinic yield and coking rate. This coil will be equiped with instruments to record the temperature profile (feedstock is introduced at 600°C) and coking rate inside the tubes. A special process chromatograph, developed by Montedipe would continuously analyse the gases flowing from the furnace. A pay back period of six months was calculated.

Coil construction is in hand and testing will follow.



1) Inlet valve
2) Outlet valve
3) (sA) (6) manometers
4) (4A) (9) thermostatic baths
5) (5A) Feed autoclaves
7) (7A) Valves for collecting feed autoclaves (5) (5A) to absorption cell
8) Valve to vacuum, for feeding solution and outlet gas from absorption cell
10) Absorption cell with magnetic stirrer
11) Magnetic driver apparatus

Figure 3.38.1 Apparatus for vapour liquid equilibria determinations

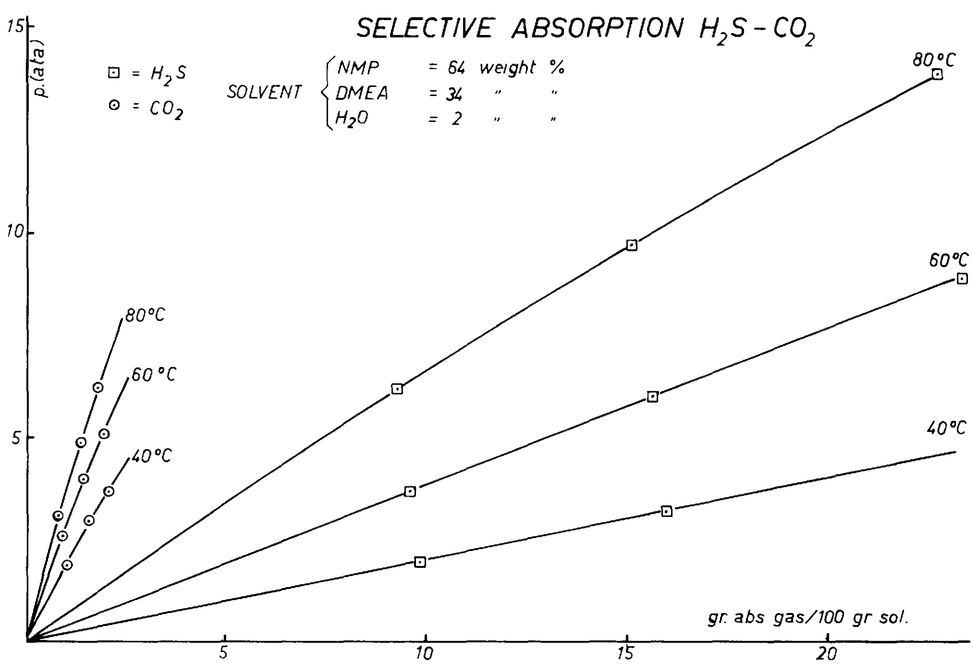


Figure 3.38.2 Selective absorption of H_2S from H_2S - CO_2 mixtures by a solvent

Selective removal of H_2S from gaseous mixtures containing CO_2 3.38

SNAMPROGETTI S.p.A.
Casa Postale 12059
I — 20100 Milano

L. GAZZI

Contract number: EE-B-1-130-I

The selective removal of H_2S from gaseous mixtures containing CO_2 is currently carried out by means of:

- Oxidation processes (Gianmarco, Streetford, etc.);
- Favourable absorption of H_2S with respect to CO_2 in water-Methyl-diethanolamine (MDEA) solutions.

Industrial application of these processes has met with considerable difficulties from both the ecological (industrial waste) and cost (due to selectivity losses) points of view, when complete removal of H_2S is required.

SNAMPROGETTI investigated the selective removal of H_2S by combined amine-solvent absorption system. The solution of the problem lies in the choice of solvents and in the optimization of the parameters involved (concentration of the amine and the solvent, temperature, pressure). Various amine-solvent combinations have been tested and, from vapour-liquid equilibria determination at various pressures and temperatures, a first selection of absorbing media has been made. Interesting results have been obtained by using mixtures of Dimethylethanolamine (DMEA) in Sulfonane (SOL), N-Methylpyrrolidone (NMP) and N-Methylimidazole (NMI) containing ca. 2% w of water e.g. for 64% w SOL, 34% w DMEA, 2% w H_2O, at 40°C, 2 ata, abs. ratio H_2S: CO_2 ~ 10 : 1.5; for 64% w NMP, 34% w DMEA, 2% w H_20, at 40°C, 2 ata, abs. ratio H_2S : CO_2 ~ 10 : 1; for 64% w NMI, 34 % w DMEA, 2% w H_2O, at 40°C, 2 ata, abs. ratio H_2S : CO_2 ~ 10 : 1.

On the basis of the laboratory work, tests will now be carried out in a pilot plant.

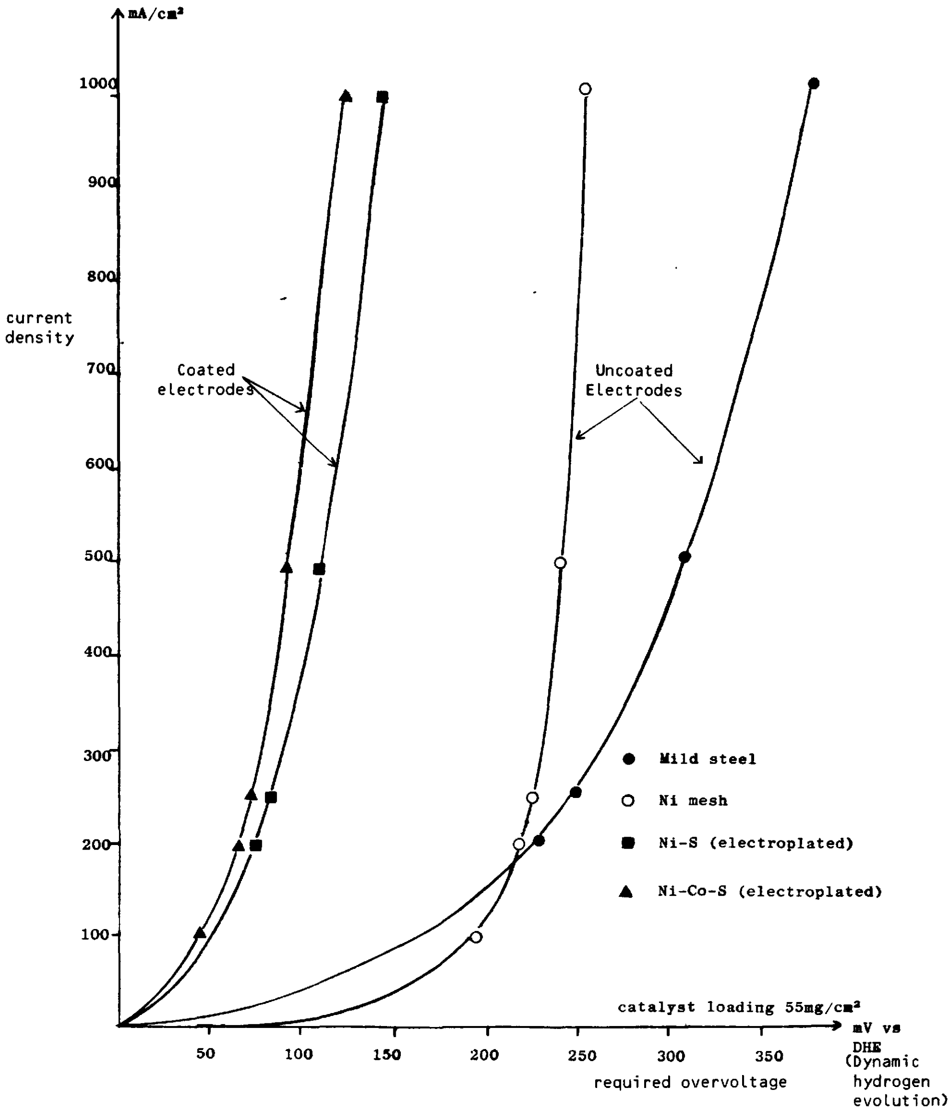


Figure 3.39.1 Effect of electrodeposited coatings on the cathode activity for Hydrogen evolution (corrected values obtained by substracting Ohmic resistance of the 5N NaOH electrolyte at 80°C)

Energy conservation in the chlor-alkali industry 3.39

The City University
Department of Chemistry
Northampton Square
GB — London EC1V OHB

A.C.C. TSEUNG

Contract number: EE-B-1-111-UK

The theoretical cell voltage for electrolysis of brine (NaCl in water) is 2.1 V. However, due to losses and polarization at the electrode, the practical operating potential lies around 3 V. The very large chlor-alkali electrolysis industry is by its nature highly energy-intensive. A small reduction in cell voltage of e.g. 150 mV on 3 V at a given current density represents a saving in electric energy of 5%.

The voltage of the cell is determined by the overvoltages at both electrodes with the main contribution coming from the cathodic overvoltage required for the hydrogen evolution (presence of hydrogen bubbles at the cathode which prevent efficient contact between the ions in the solution and the cathode) and by the ohmic resistance of the electrolyte (and diaphragm or membrane). Applying a catalyst to the surface of the cathode reduces the overvoltage. However, it is necessary that he catalytic activity is stable for a long period under the prevailing cell conditions.

Two types of low overvoltage coatings based on Ni-Co-S for the H_2 cathode have been developed and tested in a chlor-alkali environment. Both electrodeposited and Teflon bonded coatings gave similar results: −99mV and −96mV vs the Dynamic Hydrogen Electrode (D.H.E.) at 300 mA/cm^2, electrolyte 10% NaOH, 80°C, compared to over −350mV for standard steel cathodes.

However, Co is likely to be corroded on open circuit since it will become anodic relative to nickel or iron. One way to prevent this is to ensure that the cathodes are always cathodically polarized by a small cathodic current on open circuit. This may not be always practical in an industrial environment. Therefore, a proprietary cathode catalyst which is immune to corrosion at open circuit at electrolyte 45% KOH, 85°C, has also been developed. In the near future, this catalyst is to be tested under chlor-alkali industrial conditions. In addition, in collaboration with various European chlor-alkali manufacturers, such coatings are to be evaluated in terms of performance, life, susceptibility to poisoning and energy saving.

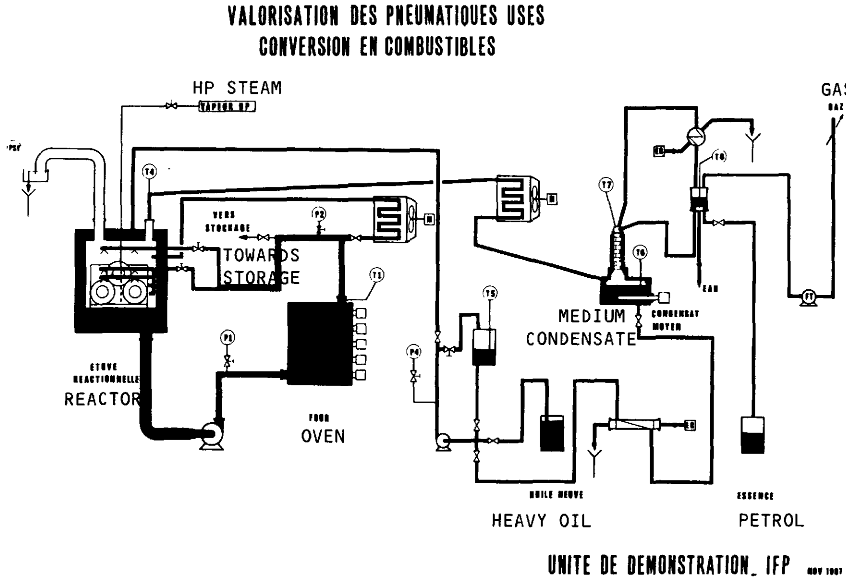


Figure 3.40.1 The pilot plant

Figure 3.40.2 Metallic remains of tyres after treatment

Thermal depolymerisation of waste tyres by heavy oils and conversion into fuels

3.40

Institut Français du Pétrole (I.F.P.)
Boîte Postale 3
F — 69390 Vernaison

F. AUDIBERT

Contract number: EE-B-4-182 F

Used tyres can create an environmental problem but do have a high energy content (7 000 - 8 000 kcal/kg). Many different proposals have been made to reuse old tyres, but these applications cannot deal with the tonnages of waste produced and are rarely economically advantageous. The most attractive solution to dispose of these tyres is to process them thermally. The two main methods of processing are:

— by pyrolysis and

— by dissolution at 300°C - 400°C in the presence of a low grade heavy fuel.

In this contract, the second method was chosen. The reaction leads to the formation of a small quantity of gas and petrol and a combustible liquid which contains carbon black in suspension obtained from the tyres; it corresponds to the specification of heavy fuel oil. This combustible liquid, without any refinement, can be burnt in a furnace.

A significant advantage of this method is that the tyres are processed without the necessity to cut them into slices. Furthermore, the necessary heat for the reaction can be provided by the combustion of the gas and petrol obtained.

The fundamental studies have been carried out at the University of COMPIEGNE while development work is being pursued by IFP. In addition, a multinational tyre manufacturer is contributing towards the cost of developing this process.

The pilot plant has been constructed and the process is carried out in a batch agitated reactor (100 to 300 kg of tyres are put in the reactor with contacting heavy oil representing a total volume of around 600 l).

The pay back period of 3.8 years calculated for an industrial unit processing 4 000 t/year is sufficiently attractive to encourage further development of this process. It is estimated that 100 000 to 200 000 tonnes of tyres (i.e. 10 to 20 million tyres) could be processed in France and about six times this quantity in the whole of the EEC. This is equivalent to energy savings of 0.7 to 1.5 $\times$ 10^5 toe.

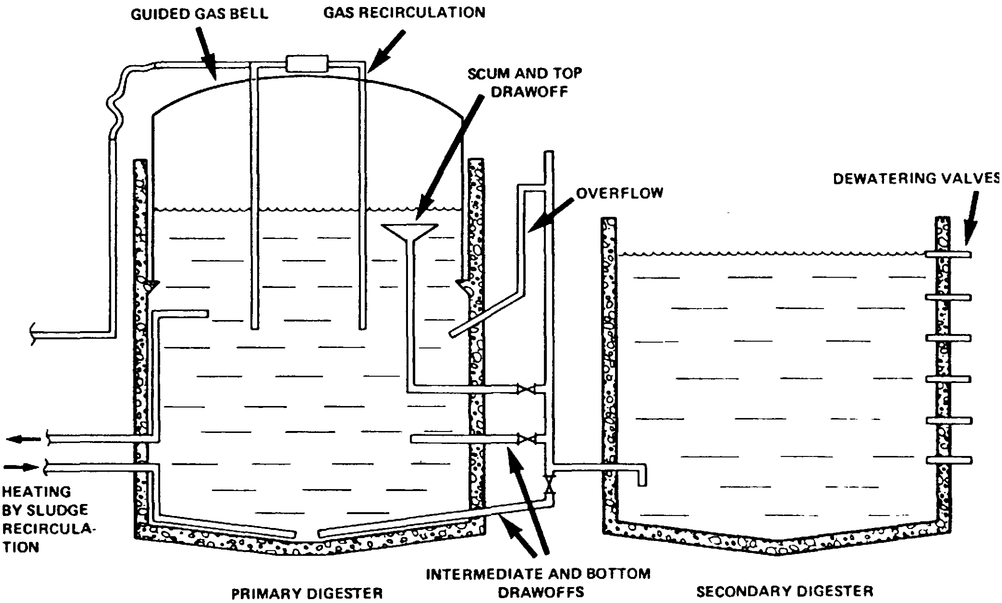


Figure 3.41.1 Simplified layout of proprietary high-rate digestion equipment

Critical evaluation of anaerobic fermentation of waste products (management study) 3.41

International Research & Development Co. Ltd.
Fossway,
GB — Newcastle upon Tyne NE6 2YD

B. FORSTER

Contract number: EE-B-4-180-UK

Considerable research and development has been carried out over the last few years on anaerobic fermentation of organic wastes to produce methane. The work has met with varying degrees of success, numerous papers having been published. The time has come when it is necessary to assess the state of the art of existing technology in order to understand the barriers to the exploitation of the technology in both technical and economic terms.

The aim of this study is to provide the Community with an objective appraisal of all the relevant information which is necessary before new programmes and policies are generated. It covers a study of the current state-of-the-art, the barriers to the technology, the market needs and trends, and a full economic assessment of the use of anaerobic fermentation of waste materials to provide energy whilst satisfactorily dealing with the waste. Health and environmental considerations are also included.

It is hoped that firm information will give a clear picture of the real potential of such a resource of combustible gas. The main conclusions from the study are:

- Almost all European countries allocate significant funds to work on anaerobic fermentation; but little progress has been made recently in basic microbiology and biochemistry;
- For each kg of organic waste treated by anaerobic fermentation there is a yield of 0.3 m^3 of gas;
- The maximum possible contribution of waste products to energy demand is 3% of the Community's energy requirements. It is believed that a figure of 0,5% is nearer reality.
- The economics of the system are influenced by the size of the installation, the volume and nature of the wastes, the transport costs, and especially by the regularity of the flow of wastes;
- The main incentive behind the installation of such a system is the possibility of solving environmental problems; energy saving is of secondary importance;
- In the last 3 to 5 years there has been no substantial progress in anaerobic fermentation processes.

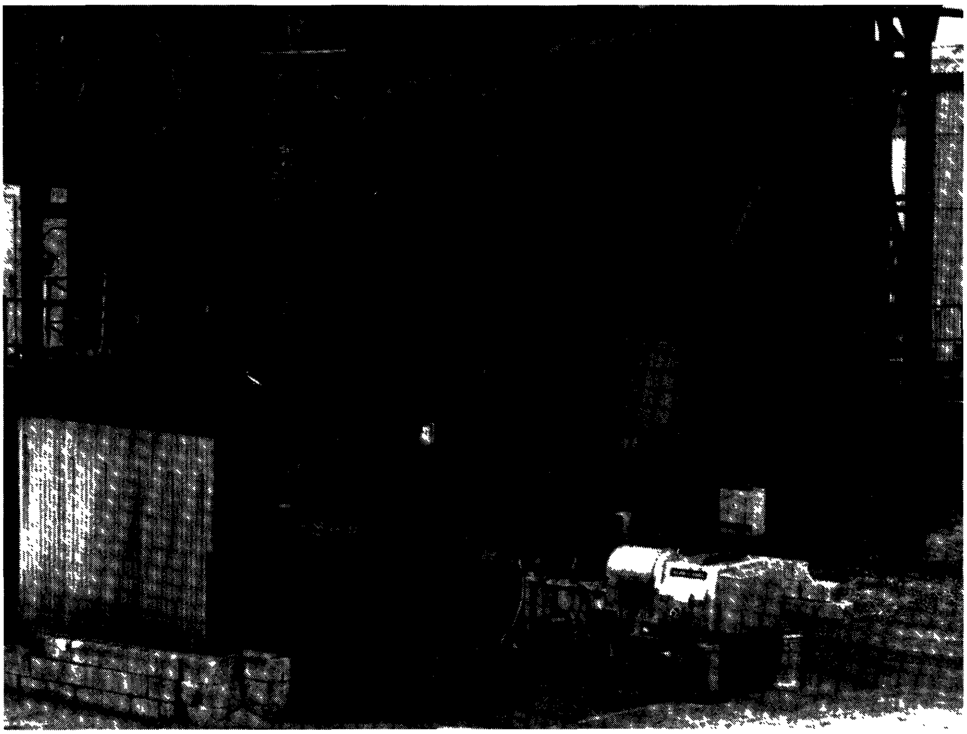


Figure 3.42.1 General view showing: pusher centrifuge, pump thickened slurry tanks, bags filters, thickening tanks and 150 mm conduit pipe from charging main (top of picture)

Recovery, treatment and utilization of solid bearing effluents emanating from coke ovens

3.42

The British Carbonization Research Association
GB — Wingerworth
Chesterfield Derbyshire S42 6JS

V.J. PATER

Contract number: EE-B-4-181-UK

The preparation and charging of preheated coal to the coke oven is associated with significant losses of coal fines (particle size between 4 and 25 μm). These arise from the preheater waste gas, from the oven exhaust gas during charging and where a pipeline system with a bleed-off is used (where hot coal particles are transported to the oven by means of steam) from the steam bleed-off.

The total quantity of carryover can exceed 2.0% of the coal input and thus constitutes a significant proportion of the scarce and expensive material (coking coal) used. Hitherto, operators of plants in the U.K. and abroad where the preheating process is used have not succeeded in recovering this material in a usable condition and have adopted the simple expedient of dumping. Accordingly, there is a considerable loss of energy in the form of valuable raw materials, handling charges are increased, and there is a potentially serious pollution problem.

The project carried out by the BRITISH CARBONIZATION RESEARCH ASSOCIATION is aimed at the recovery, treatment and utilization of these solids—containing effluents emanating from coke ovens. Two types of effluent slurries (containing coal fines) are considered: those coming from the preheater and those coming from the oven during charging.

The charging slurries sometimes contain a high concentration of tar. Handling of these slurries is now possible up to a tar content of 30%. Dewatering of the slurries requires two steps: the first is a flocculation stage and additives are required to speed up dewatering; the second is a mechanical dewatering stage, which brings the moisture content down to 30%. Mixtures of charging slurries and preheat slurries are more difficult to dewater and this results in an increase in the moisture content. As dewatering of these fines was found to be practicable, the investigation is now extended into handling, preparation and utilization of recovered fines.

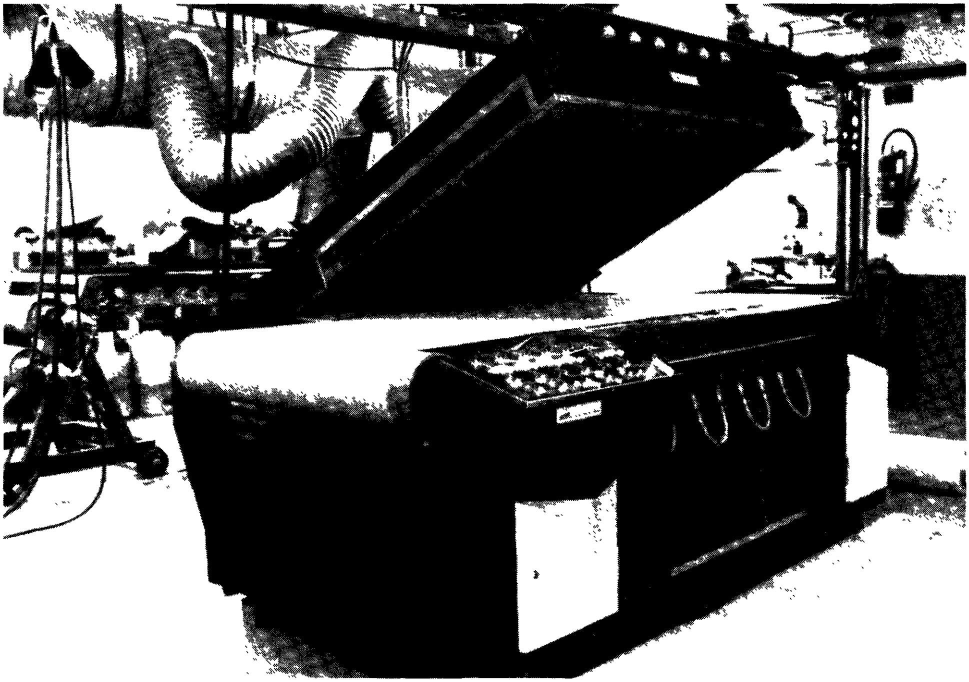


Figure 3.43.1 The microwave oven while open

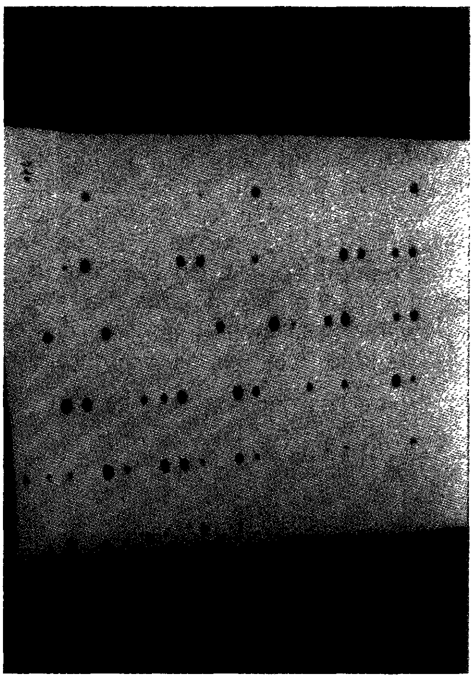


Figure 3.43.2 Non-uniform local burning of a PVC sheet with microwave heating

Application of microwave heating and hot air for the continuous production of plasticized PVC sheets 3.43

Eurofloor S.A.
Boîte Postale 10
L — Wiltz

A. ROUSSEL

Final report number EUR: 8630 available in English
Contract number: EE-B-1-112-L

Work at EUROFLOOR is directed at building and testing a pilot microwave oven for treating PVC floor coverings. These are formed by heating a PVC paste, which then solidifies. Normally this is carried out in a thermal oven at temperatures between 175°C and 210°C at an efficiency of only 5%. Because of the low efficiency, the process seemed to be an ideal candidate for microwaves. In fact the electric characteristics of PVC correspond to the requirements of the process. A smaller equipment size is required compared with a purely air heating system. Heating within the material also provides advantages when foaming is to take place since the regularity of the cells is favoured, thus improving the mechanical properties of the material.

The microwave oven used has a power input of 6 kW and is designed to treat the product at a rate of 20-30 metres/minute. A supplementary hot air source is used to homogenise the surface temperature of the sheet and to maintain it at a sufficiently high level.

While the curing processes of foaming and gelling (hardening) of the PVC can be made to take place rapidly in the oven, results to date have shown that local burning of the material can occur very rapidly due to nonuniformity of the applied energy. It was suggested that the position and thickness of the material could influence the field in an unpredictable manner. it was also found that the hot air increased the sensitivity of the material to microwaves.

EUROFLOOR has shown that a uniform field (with the applicator type used for the (PVC) could be obtained when thick wet paper was treated. Work is under way to attempt to resolve the above difficulties with PVC.

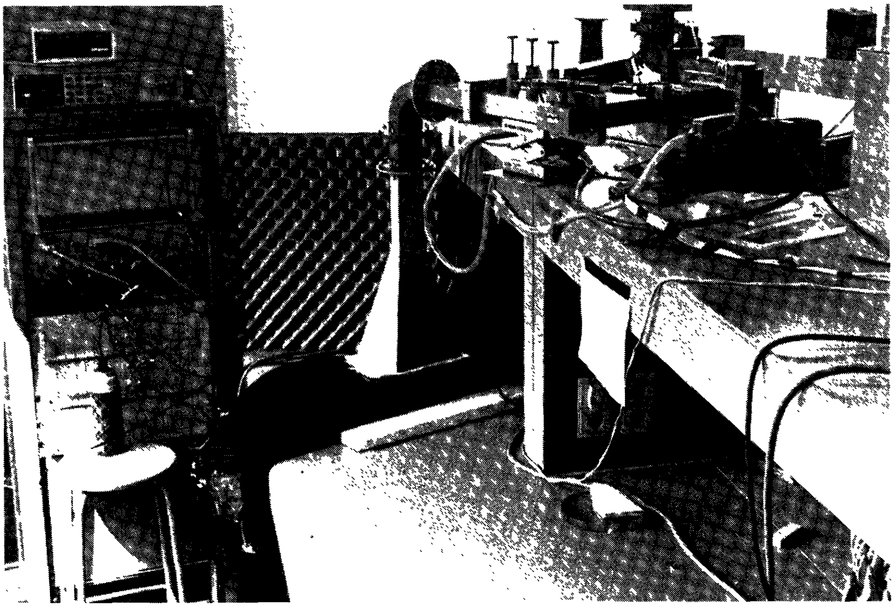


Figure 3.44.1 Microwave irradiation of an industrial layered material and simultaneous automatic temperature measurements by ten thermocouples

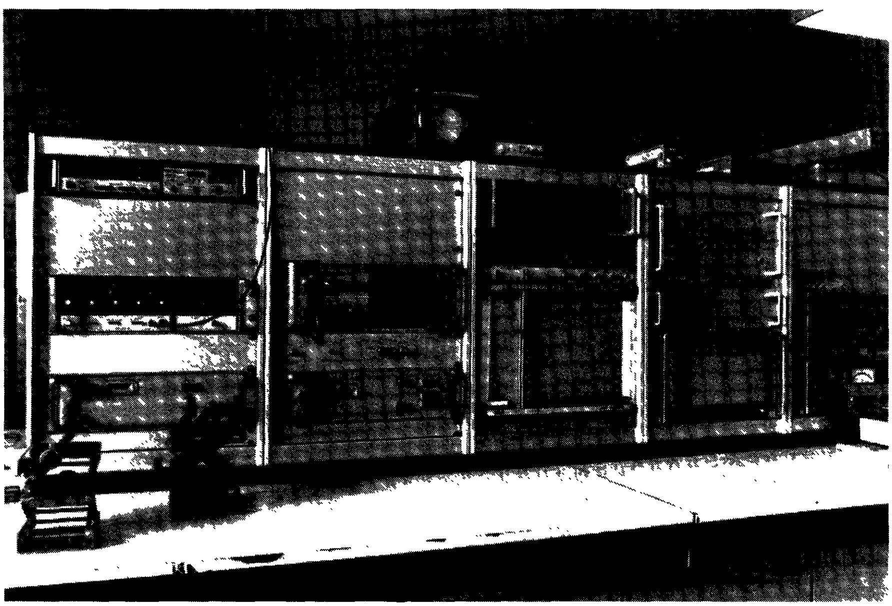


Figure 3.44.2 Computer controlled network analyzer system for measuring reflection and transmission coefficients of industrial applicators

Application of microwave heating to the production of construction materials 3.44

Rijksuniversiteit Gent
Laboratorium voor Elektromagnetisme en Acustica
St. Pietersnieuwstraat 41
B — 9000 Gent

J. VAN BLADEL

Contract number: EE-B-1-135-B

The objective of this work is to study the replacement of classic heating by microwave heating in those industrial processes where this leads to energy saving. In particular building materials such as cellular concrete materials and European woods (they have a moisture content ranging from 9% to 12%) are considered. By using microwaves for these two materials at least 50% of primary fuel can be saved compared to conventional drying methods.

A number of stages are involved in the research programme, including the development of a 5 kW generator (of 80% efficiency) and applicator, the construction of a laboratory microwave oven, and the determination of the microwave and thermal properties of the materials to be tested.

The work to date at Gent has concentrated on the last aspect, the determination of the properties of the materials to be treated. Properties of the material needed are the dielectric constant and the permittivity. The permittivity of both bulk and sheet materials was measured, the latter requiring the development of an automatic system. All the relevant properties of cellular concrete have been successfully measured, and rapid curing experiments have been carried out. It was found that intermittent microwave heating could be used to even out non-uniformities in temperature. Properties of wood veneers have also been determined.

An infra-red device was used to determine surface temperatures of material subjected to microwaves, while internal material temperatures were measured using thermocouples. A computer model using microwave and thermal performance equations may be used to predict the variation in temperature in samples as a function of time and applied microwave power.

The work is now being applied to the design of a microwave oven, into which a microprocessor-based control system will be integrated.

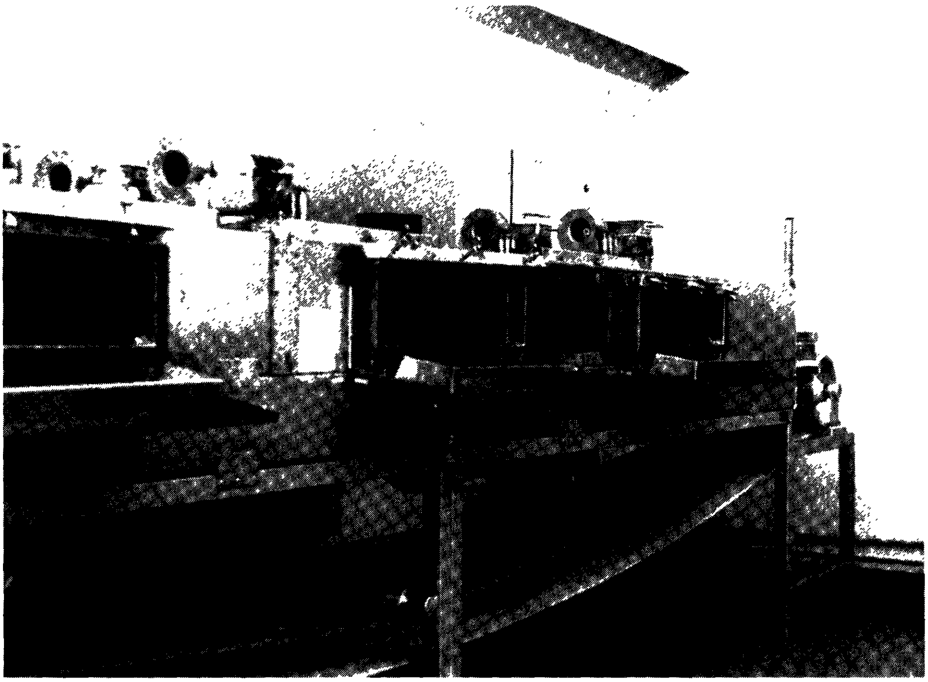


Figure 3.45.1 Side view of tunnel type microwave applicator

Development of microwave applicators to dry thin structures 3.45

Katholieke Universiteit Leuven
Dept. Elektrotechniek M.I.L.
Kardinaal Mercierlaan, 94
B — 3030 Heverlee

P.J. LUYPAERT

Contract number: EE-B-1-137-B

The aim of this study is to develop high power microwave applicators to dry or treat thin layers. These applicators are to be used in all kinds of coating and drying processes. Compared with conventional means, an energy saving of 30 to 40% is expected. The study involves both theoretical and experimental work, leading to a prototype system of 12 kW (power at the applicator) in which samples of coated paper are to be dried.

The efficiency of a microwave heating system depends on a good match between the power which can be absorbed by the sample (which depends on its size and characteristics) and the power applied. If too much power is applied a larger part will be reflected. In order to ensure optimum matching a reflection coefficient meter was developed with the measuring probes connected to a microprocessor. Experiments are now being carried out to test the installation. In addition, experiments are in hand to measure the microwave properties of potential products.

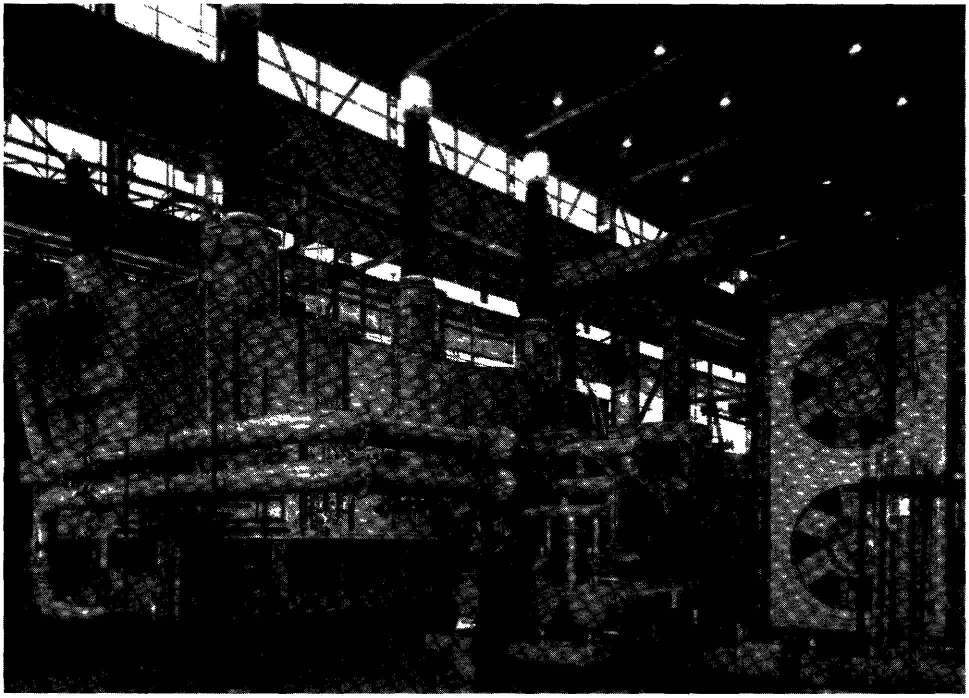


Figure 3.46.1 ACEC Building 26 housing the workshop for transformer production

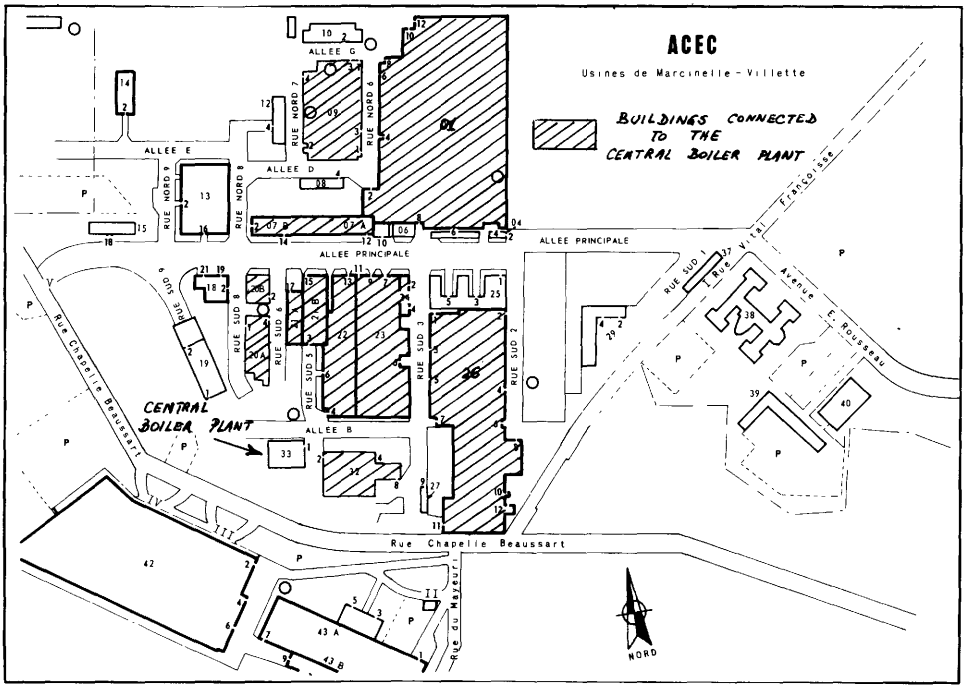


Figure 3.46.2 ACEC Factory of Marcinelle-Villette

Reducing energy consumption in a works manufacturing heavy electrical equipment (ACEC) 3.46

A.C.E.C. («Ateliers de Constructions Electriques de Charleroi»)
Boîte Postale 4
B — 6000 Charleroi

Ph. KIRSCH

Contract number: EE-B-3-170-B

The ACEC premises in Charleroi consist of 43 buildings spread over 2 km^2; a major part consists of workshops of various ages, designs and dimensions, housing different activities. 25 buildings are provided with their own boiler or heating system, the remaining ones—and amongst them the largest workshops—are provided with an array of heat exchangers connected to an internal district heating system.

A comprehensive programme of action has been formulated to reduce expenditure on heating and on electricity consumption. It deals with savings already gained (10% from 1979 to 1981) or expected and comprises the following items:

— Good housekeeping activities such as insulation and heating control;

— Analysis of a particular heating system;

— Development and use of a new micro-computer which controls the entire heating system for the main management building. Fuel savings amounting to 15 to 30% have been measured. In the near future, other buildings will be provided with the same equipment;

— Use of a computer program to calculate the heat losses of buildings of any kind, taking into account the structural characteristics of the building components, rate of change of air, exposure and degrees-days. More accurate results are expected from a second, more complex version of the program, which would include a better assessment of the rate of air renewal and additional input data such as thermal inertia and unsteady conditions;

— Reduction of expenditure on electricity (by reduction of peak demand e.g. lighting);

— Calculations with respect to the central boiler of the district heating system and associated hot-water piping. A first study indicated a possible reduction in the heat losses from the distribution system.

Economic study of the energy exchange between factories in an industrial site

3.47

C.E.N. — S.C.K.
Boeretang, 200
B — 2400 Mol

G. WOUTERS

Contract number: EE-B-3-171-B

The use of computer models correlating the energy needs and exchanges between factories on existing industrial sites, could indicate considerable saving potential. These models could also predict the types of industry which have to be associated with a particular site to ensure optimum energy use. C.E.N. - S.C.K. is developing such a model for the economic assessment of the energy exchange (electricity, steam, etc.) between the ten factories located at the Mol site. These are: a coal power plant, a glass bottle factory, an asbestos cement products factory, a central workshop, a transport and storage company, a factory making ballast material for roads, two sandpits and milling companies, a research centre and a factory for chemical processing of irradiated fuels.

The first step is to collect and classify energy data and to evaluate the possible inter-relations between factories. A mathematical model simulating the industrial site consists of a network in which the nodes represent the energy sources or sinks for each factory and the links between the nodes are the energy carriers for the possible inter-relations between the factories. Economic factors and factory inter-dependence are taken into account.

As a first step, C.E.N. — S.C.K. is undertaking a comprehensive survey of the energy production possibilities as well as studying energy wasted or available in the different factories. The collection of data is nearly finished and the computer input operation is in progress.

Modelling the total energy supply and demand of a region

3.48

Rijksuniversiteit Gent
Onafhankelijkheidslaan 17-18
B — 9000 Gent

M. ANSELIN

Contract number: EE-B-3-173-B (pending)

Development of a model for the energy supply and demand which will be applied to the region of Gent-Terneuzen. This model will include the demand and supply of this strongly industrialized and urbanized region and will help in developing a standardized methodology, which may be applied to other regions in the European Community.

Estimation of energy and cost savings arising from rationalisation of milk assembly operations

3.49

The Agricultural Institute
Economics and Rural Welfare Research Centre
19 Sandymount Avenue
IRL — Dublin 4

E. PITTS

Contract number: EE-C-4-266-EIR

The collection of milk from dispersed farms often occurs in an inefficient way. The objective of this study is to optimize energy and costs savings by using computerized routing techniques and by rationalising the catchment areas in order to avoid duplication and overlap. Computer techniques for deriving an efficient routing system in terms of cost or energy savings are relatively well known and there are a variety of routing packages available. There are however difficulties in applying general solutions to the problem of milk collection where the locations of individual farms are associated with natural barriers such as lakes or mountains.

This study compares these packages in terms of mileage saved, difficulty of operation, etc. A comparison of the cost/energy efficiencies for collections made daily, every two days and every three days is also carried out.

The problem of calculating savings arising from the rationalisation of catchment areas has generally not received the same detailed attention as the problem of routing. However, in this study existing techniques are adpated and in particular a generalized technique will be developed to estimate cost/energy savings from given data in situations where overlap of catchment areas exists.

Sector 4

ENERGY CONSERVATION IN TRANSPORT

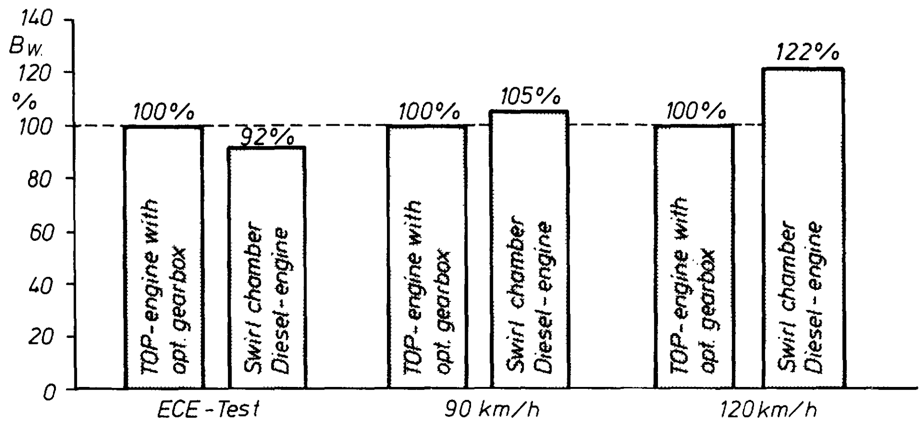


Figure 4.1.1 Comparison of the energy consumption of an Otto and Diesel engine driven Porsche 924.

Exhaust emissions g/test	TOP-engine, production gearbox	TOP-engine, opt. gearbox	Prechamber Diesel-engine *	Swirl chamber Diesel-engine	Exhaust emission standard ECE 15-03	15-04
CO	27,4	21,2	8,2	10,7	87	67
HC_{URAS}	7,0	6,8	2,2	5,7	7,1	–
NO_x	6,6	7,0	5,1	2,9	10,2	–
$HC_{FID} + NO_x$	18,4	18,8	7,0	12,5	–	20,5

Figure 4.1.2 Exhaust emissions of the Otto and Diesel engine driven Porsche 924 in the ECE-Test.

Reduction of fuel consumption by thermodynamic optimization of the Otto-engine — 4.1

Dr.-Ing. h.c. F. Porsche AG
Abteilung Forschung — Vorentwicklung
Motor — Antrieb (EFA)
D — 7251 Weissach

D. GRUDEN

Final report number: EUR 8297 available in German
Contract number: EE-C-1-203-D

This project is directed at improving on the results already obtained in a preceding study, 337-78-1 EED. The intention is to increase further the high fuel economy at part load of the "TOP" engine (thermo-dynamically optimized Porsche 924 Otto engine) in comparison with modern Diesel engines of equal displacement.

In the first instance all investigations carried out were aimed at showing to what extent the fuel consumption of an Otto engine may be reduced by conventional means. By a number of unconventional technical measures, further reductions in the fuel consumption of Otto and Diesel engines could be obtained.

The results presented on the spark-ignition Otto TOP 924 engines show that fuel consumption is 5 to 30% lower than with the 924 engine and that it is possible to obtain at part-load a fuel consumption as low as that of a Diesel engine. It has thus been shown that by adapting this engine by conventional methods (combustion chamber, high compression ratio, high air/fuel ratio (lean mixtures), ignition advance) and by using an appropriate gear box it is possible to substantially reduce the fuel consumption of an Otto engine so that it equals that of a Diesel engine with the same displacement, whilst the essential dynamic qualities (torque) of the Otto engine are maintained.

By a number of unconventional technical measures, further reductions in the fuel consumption of Otto and Diesel engines can be obtained. In Diesel engine development, the introduction of direct injection is considered to be highly promising. Regarding the Otto engine, the thermodynamic optimization in conjunction with an optimized transmission, a reduced engine cylinder volume and the introduction of electronic control systems are of great promise.

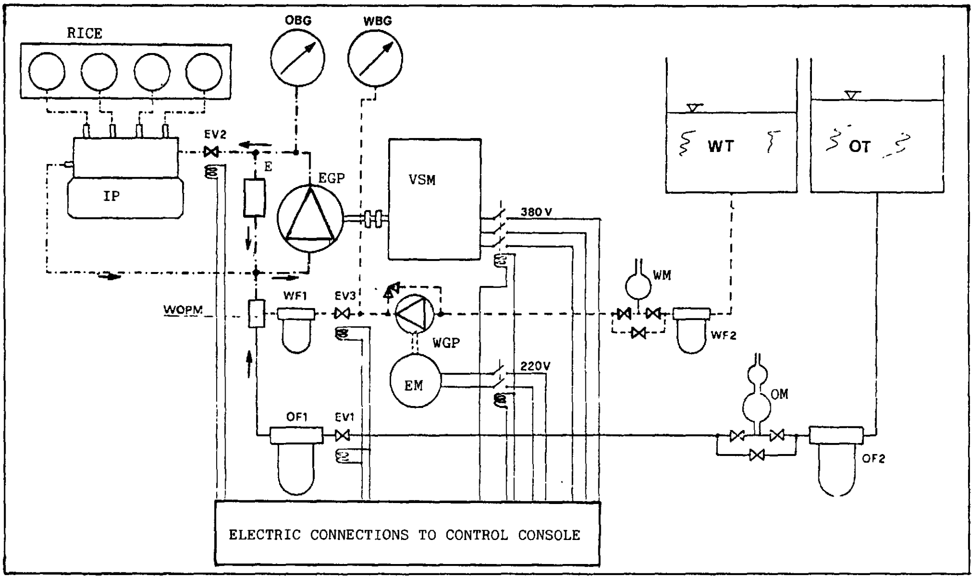


Figure 4.2.1 Water in oil emulsion feeding system for high speed diesel engine on test bench (RICE = Reciprocating internal combustion engine, OM CO2D, 4 strokes, 4 cylinder diesel engine; IP = injection pump, Bosch type; E= emulsifier; WOPM = water oil pre-mixer; EGP = emulsion gear pump; VSM = variable speed motor; WGP = water gear pump; EM = electric motor; OF1, OF2 = oil filter; WF1, WF2 = water filter;OM = oil meter; WM = water meter; WT = water tank; OT = oil tank; OGB, WGB = bourdon gauge; EV1, EV2, EV3 = solenoid valve).

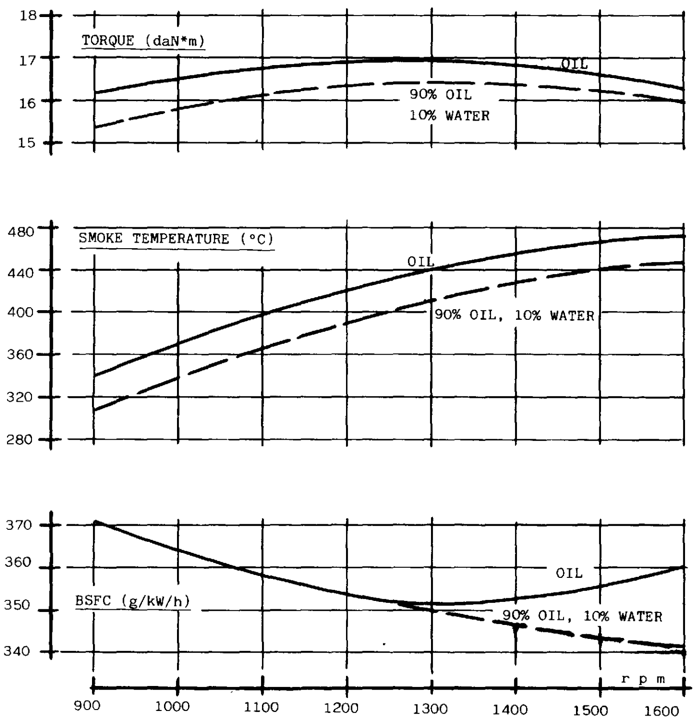


Figure 4.2.2 Torque, smoke temperature and brake specific fuel consumption with oil and water in oil emulsion (rack fixed at 3/4 of stroke).

Operation of automotive diesel engine with water in oil emulsion 4.2

Agip Solar 77
Via del Commercio 1 A
I — 00146 Roma

A. CANTONI

Contract number: EE-C-1-201-I

The introduction of water finely mixed with fuel in the combustion chamber brings about a better atomisation of the fuel itself and therefore a closer mixing with the air; this results in more rapid and complete combustion.

Besides fuel saving, considerable ecological advantages may be achieved due to the fact that nitrogen dioxide (due to lower combustion temperature) and smoke content (due to more complete combustion) in the exhaust gases are drastically lowered. Furthermore, the reduction of the combustion temperature improves the engine reliability due to lower mechanical stresses and may permit reduction of excess air and a rise in the specific power output.

In this study, the behaviour of various diesel engines operating on emulsion under different conditions it tested. The novelty of the proposed emulsifying system is based on the use of a static device of greatly reduced size and higher reliability. The main economic advantages are reduced specific fuel consumption, lower maintenance costs and saving of lubricating oil due to cleaner operation of the engine. Experiments have shown that energy savings of up to 2,5% can be obtained with 14% of emulsified water. Positive preliminary test bench results lead to road tests with urban and highway cycles. The main objectives of these tests were: to investigate system reliability, to set a suitable water-fuel ratio and to learn the drivers' opinion. During the first road tests no serious troubles were found and vehicle driveability was practically unchanged; tests are being continued.

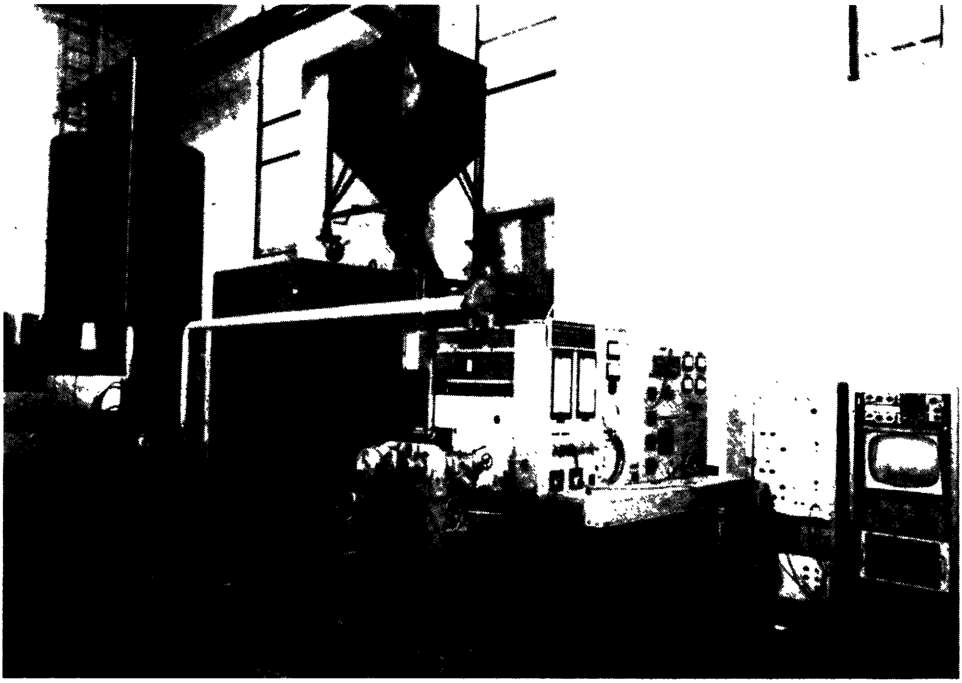


Figure 4.3.1 General view of the test rig.
To the left the gas tank; in the middle (under safety system) the gas generator; to the right the engine.

Optimum matching of internal combustion engines fuelled by means of gas generators 4.3

Université Catholique de Louvain (UCL)
Département Thermodynamique et Turbomachines
2, Place du Levant
B — 1348 Louvain-la-Neuve

J. MARTIN

Contract number: EE-D-2-323-B

The production of gaseous fuels from solid fuels by a gas generator and the combustion of this gas in an internal combustion engine is investigated and optimized. This combination was used during the Second World War and is presently found in developing countries. The objective of the study is to prepare technical instructlions necessary to convert conventional petrol or diesel engines into engines burning generator gas which has a heating value of only 4000-5600 KJ/m^3. The "motor/gas generator" system is optimized, while due allowance is given to environmental constraints and economic feasibility.

The experimental study covered the combustion characteristics of lean gases, which are still not clearly known, in the conditions of operation of internal combustion engines. Also the behaviour of gravity-fed gas generators under various sets of conditions was analysed.

In an integrated system consisting of an engine and a gas generator for laboratory tests, it was shown that unmodified spark-ignition engines, if fed with a gas generator-produced gas mixture, reach efficiencies up to 31% (with a gas generator efficiency of 74% and a total efficiency of 22%). Heat losses must always be compensated for and the fuel-to-air ratio must strictly be matched. Experimental tests on a CFR engine have demonstrated that the auto ignition limits the compression ratio to 11 for air-steam mixtures with gas, and to about 14 for air-gas mixtures. However, the air-steam gas system seems to be more efficient, due to a higher gasification yield and a better engine mechanical efficiency.

Development and testing of an operating method using exhaust heat (bottoming cycle) and capable of reducing the fuel consumption of a diesel engine

4.4

M A N
Neue Technology
Postfach 500620
D — 8000 München 50

K. MÖTZ

Contract number: EE-C-1-204-D

The aim of this study is to convert exhaust heat of internal combustion engines into mechanical energy. For diesel engines this may improve the overall efficiency from 40% tot 50%. In this study a bottoming cycle unit for a conventional diesel engine installed in a long-haul truck (181 kW at 2100 rpm) will be developed, constructed and tested. To this end, different working fluids will be compared. A test rig will be used to measure, test and refine the system for use.

The choice of the working fluid fell ultimately on steam. (The Organic Rankine Cycle technology requires, compared to a steam process, a higher capital investment due to much greater heat-exchanger surfaces, the expensive working fluid and the safety precautions required if the working medium has an inflammable or toxic behaviour). A radial turbine was chosen, while the other components of the Rankine engine were selected according to conventional practice. A gear box will be used to connect the bottoming engine with the diesel engine (lubrication problems of the gear box have been solved). The speed of the turbine would be 107,000 rpm and its useful power approx. 19.4 kW. The steam is heated with waste heat of 400-600°C, is expanded and cooled down to 110°C.

Construction of the test rig should be completed soon and tests will then begin.

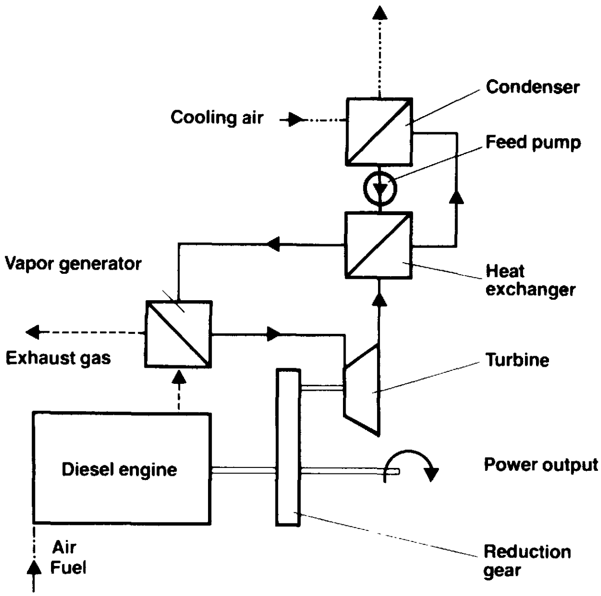


Figure 4.5.1 Diesel-organic Rankine compound engine

Utilization of waste heat from vehicle engines 4.5

Daimler-Benz AG
Postfach 202
D — 7000 Stuttgart 60

D. GWINNER

Final report number: EUR 8505 available in English and German
Contract number: EE-C-4-265-D

Between 60% and 80% of the energy produced in heat engines is lost to the ambient environment as waste exhaust heat. Suitable equipment could turn some of that heat into useful mechanical energy, e.g. an exhaust gas turbine, a Stirling engine or a steam-driven system.

DAIMLER-BENZ AG carried out a feasibility study of the possible application of a Diesel engine coupled with a Rankine bottoming cycle. It is shown that a heavy-duty truck of 206 kW on a long haul can reduce its fuel consumption for the same output by 10% (using the working fluid Fluorinol-50). According to rough estimates this corresponds to approx. 90,000 t of Diesel fuel per year on fuel savings in the Federal Republic of Germany (based on the figures for 1980). The pay back time of this system is however too long under the present technical and economic conditions. This may be improved by using a Diesel engine with thermally insulating ceramic cylinders operating at higher temperatures and efficiency.

An investigation of the confined combustion properties of residual fuels used in marine and industrial engines

4.6

AERE HARWELL
Engineering Sciences Division
UK — Didcot, Oxfordshire OX11 ORA

D.W. DALE

Contract number: EE-C-1-209-UK

Residual fuel oils are widely used in marine propulsion and industrial steam raising.

Residual fuels are low quality residual products of the oil refining process. They vary widely in quality thus posing problems for engine operators,designers and fuel suppliers.

The research project is carried out by AERE HARWELL. It aims to establish links between the physico-chemical constitution of the oils and their combustion performance, particularly in the medium and slow speed diesels used in ships and generating plants.

The programme is being supported by an international industrial consortium comprising ELF, LLOYDS REGISTER OF SHIPPING, LUCAS BRYCE, MIRRLEES-BLACKSTONE, RUSTON DIESELS and WARTSILA.

Development and evaluation of three-dimensional models of cold flow in internal combustion engines 4.7

BL Technology Limited
Gaydon Proving Ground
Banbury Road
Lighthorne Heath
Warwickshire CV34 OBL
England

S.F. BENJAMIN

Contract number: EE-C-1-210-UK

A computer program will be developed which will compute the velocity and turbulence fields during the induction, compression, expansion and exhaust strokes of an internal combustion engine. The program will be restricted to relatively simple but fully three-dimensional geometries. The turbulence will be described using a k-ε effective viscosity model.

The performance of the computer program will be evaluated using flow data obtained by laser Doppler anemometry measurements in motored engines.

The computer program will be written in portable FORTRAN and documented to a high standard. The completed version of the computer program will be supplied to the participating member companies of the Joint Research Committee of Automotive manufactures.

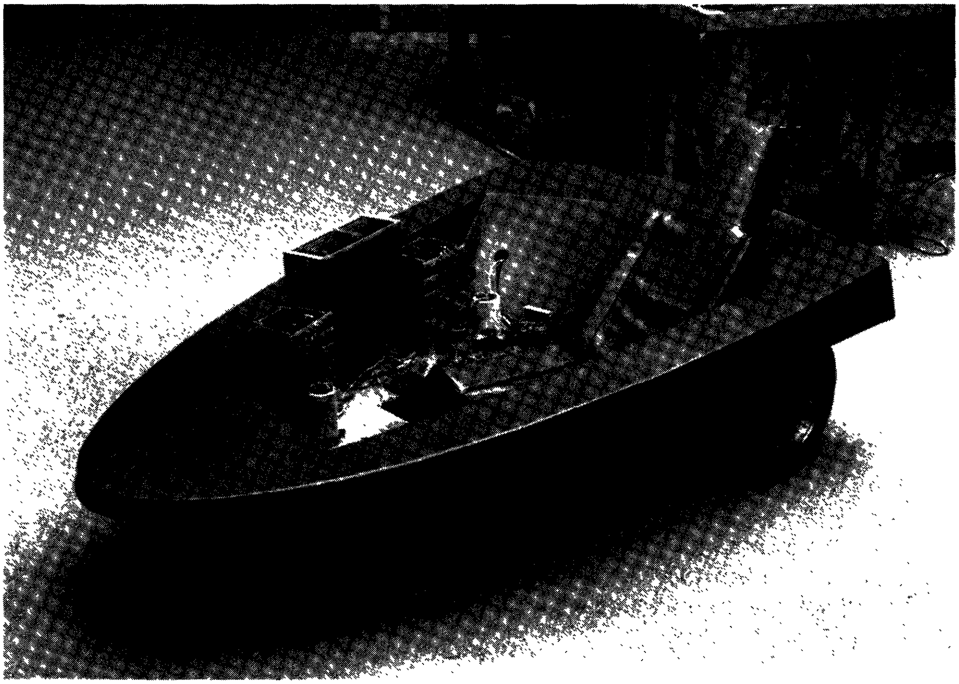


Figure 4.8.1 Experimental platform. The shell, made of stratified material, is mounted on a 3 wheel chassis.
(Steering is obtained by the differential control of the back wheels of programmed motion).

Figure 4.8.2 Experimental 15 kW rectilinear machine

Experimentation of a mobile platform powered by a rectilinear engine associated with electric wheels of programmed movement

4.8

Mothelec
64, rue de Meromesnil
F — 75008 Paris

G. FAUL

Contract number: EE-C-1-202-F

MOTHELEC has in progress the development of an electricity generating internal combustion engine, the rectilinear engine. This engine transforms the mechanical energy obtained by the engine pistons into electrical energy, with an efficiency of 40 to 50% for a power of 40 to 50 kW. A mobile platform, already developed, would be propelled by this engine which produces electricity fed to electric motors on the two back wheels.

The aim of this project is to illustrate that steering can be achieved by regulating electronically the differential speed of the two back wheels; thus reducing the use of mechanical parts. It will also demonstrate the fact that this can be achieved in a very simple way thanks to electronics.

The use of the electric wheels with programmed motion gives the car simple and efficient means for accelerating, braking and steering. It could also lead to cars of higher quality than current models, in terms of ease of driving, safety and economy.

Construction of the mobile platform is almost completed and tests will be carried out soon.

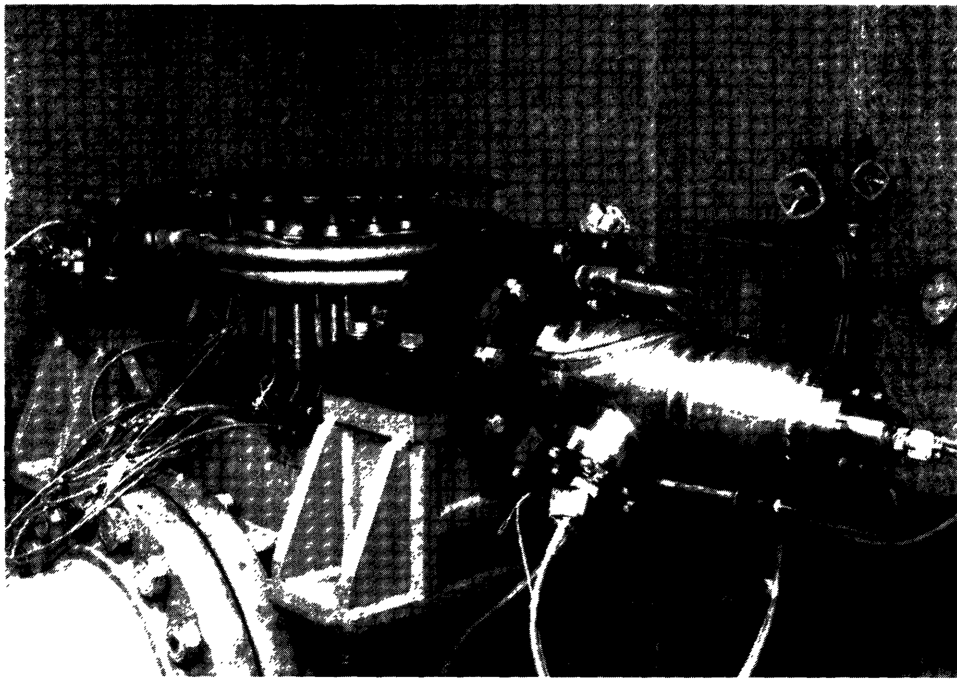


Figure 4.9.1 Stirling engine test model; general overview

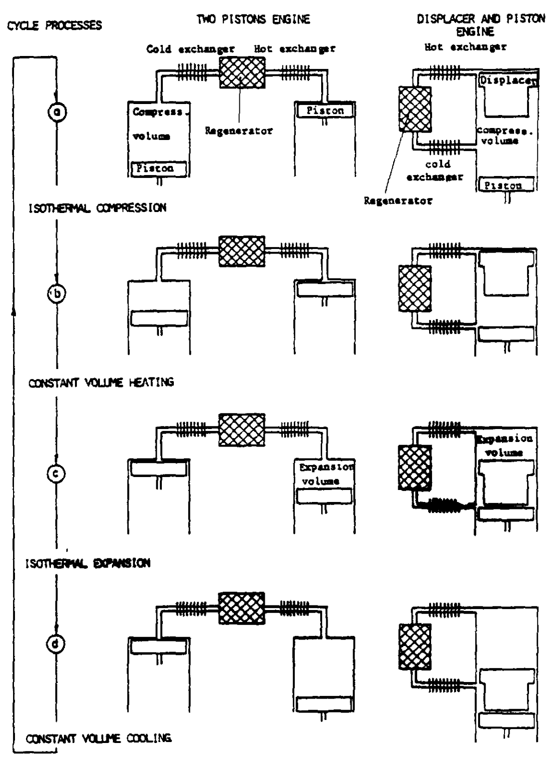


Figure 4.9.2 Piston and displacer motions in ideal Stirling engines

Design and construction of a 3 kW sealed Stirling engine test model — 4.9

Société Bertin
Boîte postale 3
F — 78373 Plaisir Cedex

J.L. BOY-MARCOTTE

Contract numbers: EE-D-1-301-F and EE-D-1-305-F

The Stirling engine is a closed-cycle gas heat engine. The heat source can accept heat of varying origin (fuel, industrial waste heat, etc.).

One of the aims of the development of Stirling engines is to have a multifuel high-performance thermo-electric convertor with a power rating ranging from a few kWe to several hundred kWe and capable of operating in a combined heat/ power mode (total energy). Such a machine, capable of producing electric power from fuel oil, coal, biomass or from waste heat should be able to compete with diesel engines used to power autonomous electrical generating sets.

The engine proposed by BERTIN is a new type of Stirling engine for generating electricity.

The present technological difficulties which are encountered in the development of these machines with a mechanical power output are the gas leakage from the dynamic seals and fouling of the regenerator exchangers due to the lubricants. The basic alternatives chosen to overcome these difficulties are a sealed machine with an electrical power output, free pistons with dry bearings and linear generators controlled by an electronic system.

The research consists of demonstrating the feasibility of such an engine using a 3 kW prototype. The design and construction of this prototype have been carried out in collaboration with Creusot-Loire. The tests of the various components have shown satisfactory mechanical behaviour, and very encouraging performances of the heat exchangers. The global efficiency of thermal/mechanical conversion was 34%. Dry bearings of the displacer rod have been tested for more than 50 hours without friction or abrasion problems.

It is now intended to carry out a major programme with the engine model to test all the technologies used therein and to measure the characteristics of the various components and of the whole prototype. Later, BERTIN will be in a position to start the design and the construction of Stirling engine prototypes for precise applications and well identified markets. Two of them apparent today are:

— domestic heat pump prime mover (2 to 10 kW);

— coal-burning industrial generator (500 to 2,000 kW).

The objective of the project under contract EE-D-1-305-F is to find a pair of materials best-suited for dry-lubricated sliding guide bearings for the Stirling engine. To achieve this, components constructed from these materials will be evaluated on a test rig reproducing operating conditions approaching those in the Stirling engine. Subsequently, the friction coefficient of the test pieces will be checked on a conventional tribometer.

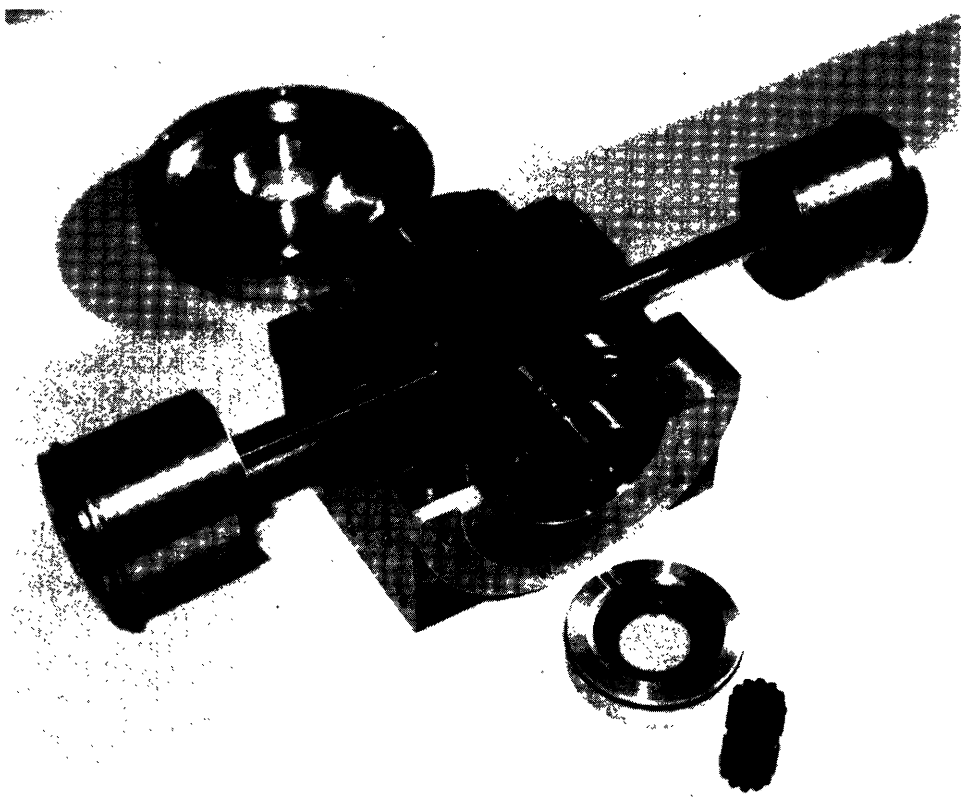


Figure 4.10.1 Complete crankassembly with pistons and bottom casing. In front: gasket and coupling element.

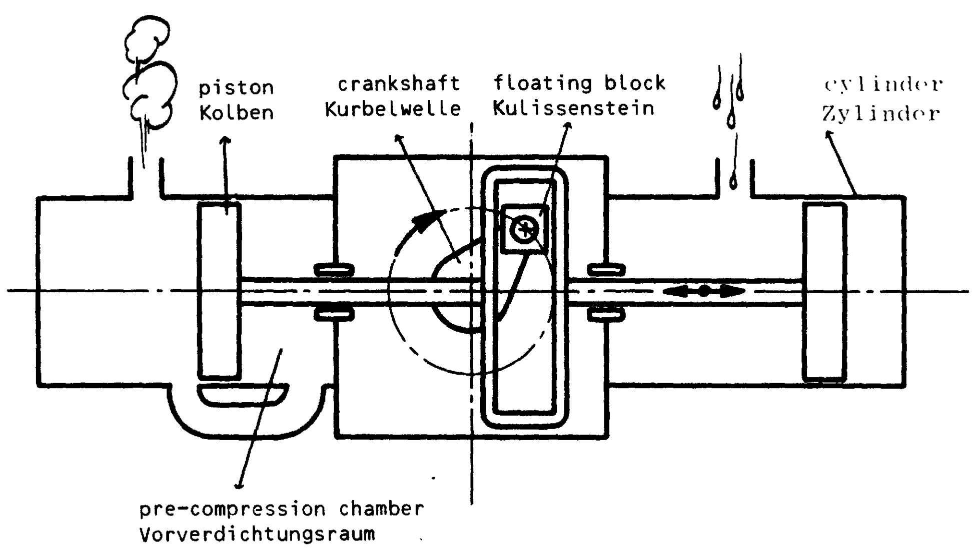


Figure 4.10.2 Principle of the two-cylinder two-stroke internal combustion engine.

Two-cylinder two-stroke internal-combustion engine of the reciprocating piston design 4.10

Ficht GmbH
Spannleitenberg 1
D — 8011 Kirchseeon

L. HAMANN

Contract number: EE-C-1-207-D

Four different multi-cylinder two-stroke engines of a new design (see figures), ranging from 100 cc. to 200 cc. in capacity and with different power outputs, have been developed and have successfully completed trials. The trials proved that this type of engine has many advantages over conventional design.

The aim of FICHT's project is now to develop, build and test a new stationary two-stroke internal combustion engine with a capacity of 1000 cc. The main features of the specification are 5 kW output at 1,500 rpm, modular construction so that it can be extended from two-cylinder units to four-cylinder units and gas operation.

The distinctive features of this engine are its rigidly connected pistons, the seals between the base of the cylinders and the crankcase, and the slotted linkage system to convert the reciprocating motion of the pistons into the rotary motion of the crankshaft. The expected advantages are a very high power-to-weight ratio, reduced mechanical losses which provide an extended working life and reduced fuel consumption with low pollution.

The design and construction of the basic two-cylinder unit have been completed. Experimental measurements confirm theoretical predictions. Measurements in the power range of 3,3 kW to 9,2 kW have been made. The minimum fuel consumption was found to be 200 gr of fuel per kWh.

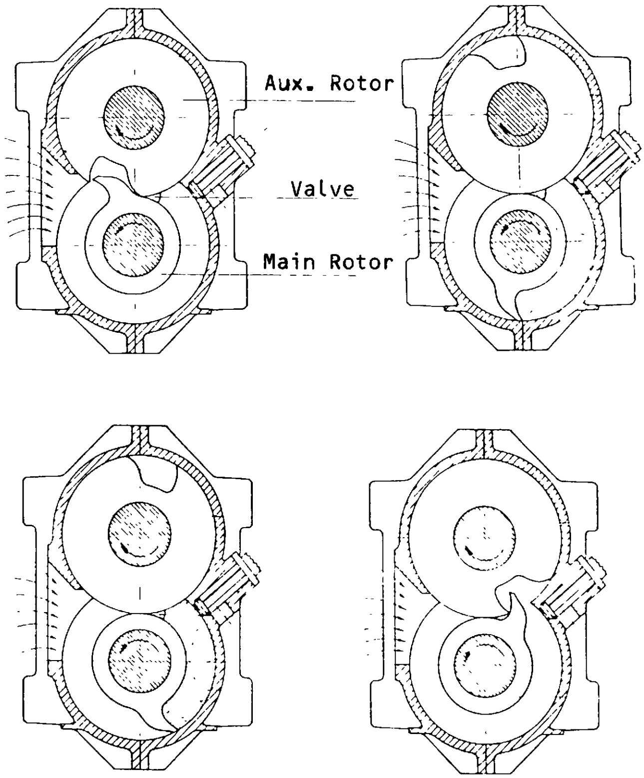


Figure 4.11.2 Stages of compression

Note: The combustion chamber is located between the compressor and the expander. It has valves of special design, which are pneumatically activated to link the compressor, combustion chamber and expander. The expander is similar to the compressor shown above.

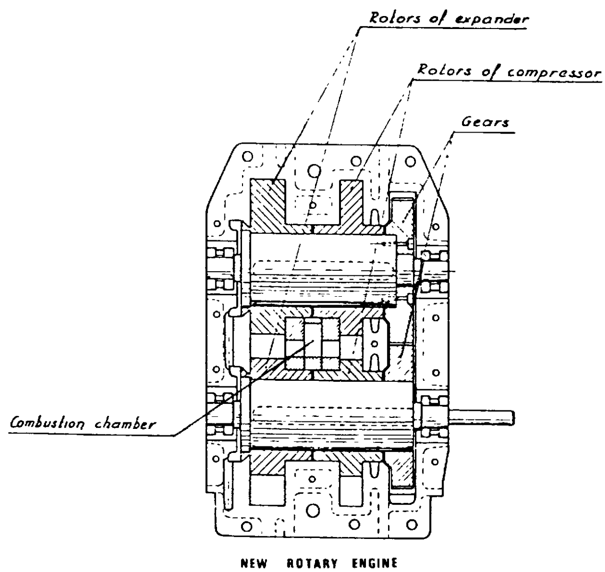


Figure 4.11.3 New rotary engine

New simple, rotary-motion internal combustion engine of high efficiency and low manufacturing cost 4.11

General Supply (Constructions) Co Ltd.
25, Stournari Street
P.O. Box 640
GR — Athens (147)

E. PELEKIS

Contract number: EE-C-1-208-GR

The project studied by GENERAL SUPPLY aims at developing a new, simple, rotary-motion internal combustion engine of 460 kW.

The main targets are: to increase the maximum temperature of the combustion gases; to increase the pressure of the combustion gases; to have effective expansion of the combustion gases; to decrease the losses due to friction, cooling, etc.; and to increase the compression ratio. In conventional internal combustion engines, the said targets cannot be substantially improved. Apart from high efficiency, further advantages claimed are: high power-to-weight and power-to-volume ratios, lower pollution of the environment and eventually lower manufacturing costs.

Initial operating tests have started and problems with mechanical stress and deformation due to high temperatures and leaking have been identified.

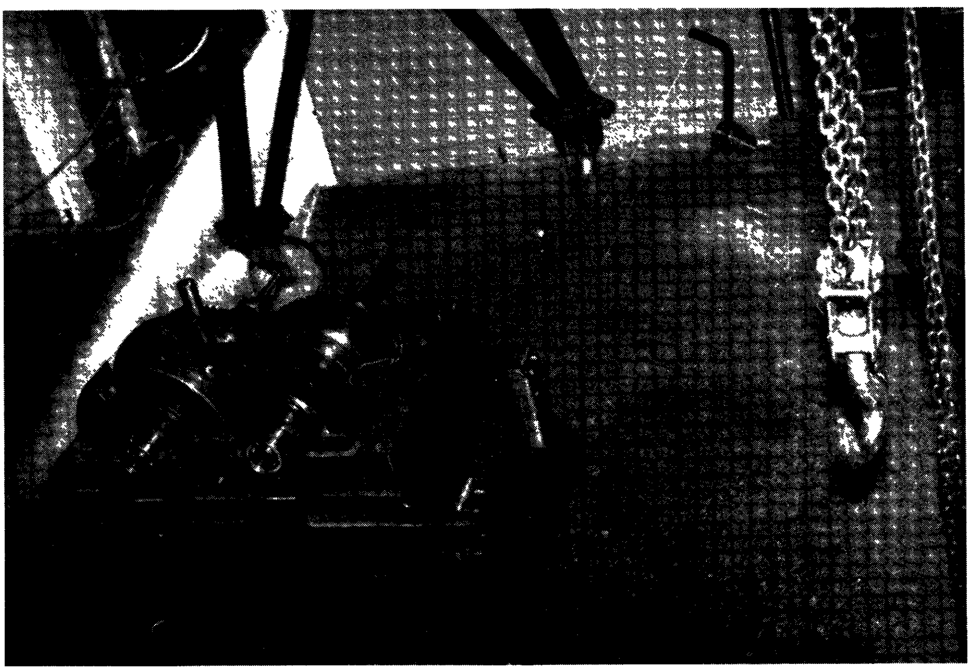


Figure 4.11.1 Inside view of the engine

Design of sailing bulk carrier 4.12

Cockerill Yards Hoboken S.A.
L. Bosschartlaan 1
B — 2710 Hoboken

I. FEHERVARI

Contract number: EE-C-4-263-B (pending)

Because of the increasing scarcity of oil, fuel costs will still rise and ship owners are reconsidering the use of modern sailing bulk carriers and tankers. A feasibility study has confirmed this point of view. Some wind tunnel tests have already been carried out and many aerodynamic investigations were made. Japan has already built an experimental sailing ship, the results of which seem to be attractive. Technologically, however, for the moment not much has been done in Europe and the design of a modern sailing ship has not yet been studied.

This investigation includes the design of a sailing bulk carrier of 30.000 TDW. The study contains the development of the general arrangement and equipment of the ship. Special attention will be paid to the problems related to this kind of ship, e.g. the auxiliary propulsion and the engine room installation, the design of the sails and the masts, the hydraulic system, the automation and the use of weather routing. At the end the necessary construction drawings will be presented.

Due to financial difficulties of the company, this research work has been discontinued.

Sector 5

ENERGY PRODUCTION

Design and development of a small-scale fluidized bed boiler with automatic control

5.1

The National Institute for Higher Education
IRL — Limerick

J.E. BANNARD

Contract number: EE-D-1-302-IRL

The aim of the project carried out by the NATIONAL INSTITUTE FOR HIGHER EDUCATION is to design and develop a small scale atmospheric fluidized bed boiler of 25 kW suitable for small industrial, commercial or even domestic applications. A significant element is the development of a reliable automatic control system for the boiler, with minimum maintenance requirements. To achieve this, microprocessor technology is to be employed.

The fluidized bed is expected to be cheap and to have high combustion efficiences with different fuel types (such as low grade coal) for part load operation. The system will have a high turndown ratio (ratio of the maximum to minimum possible heat output is 50 : 1), a short start up time (20 minutes) and will be fully automatic. Within the fluidized bed (bed area of 10 × 20 cm) internal circulation is obtained with the aid of a sloping base and a locally stronger air flow in the upper slopping part of the base. Such a circulation gives efficient mixing and combustion of the fuel with varying diameter. The heat is extracted by the fluidized bed walls which are water cooled. The high turndown ratio can be obtained by varying the height of the bed thus varying the heat transfer surface and by partially slumping the bed; which is facilitated by the sloping base. Start up is done electrically with a heater of 1 kW.

The fluidized bed combustor will be soon operational and experiments are expected to start soon.

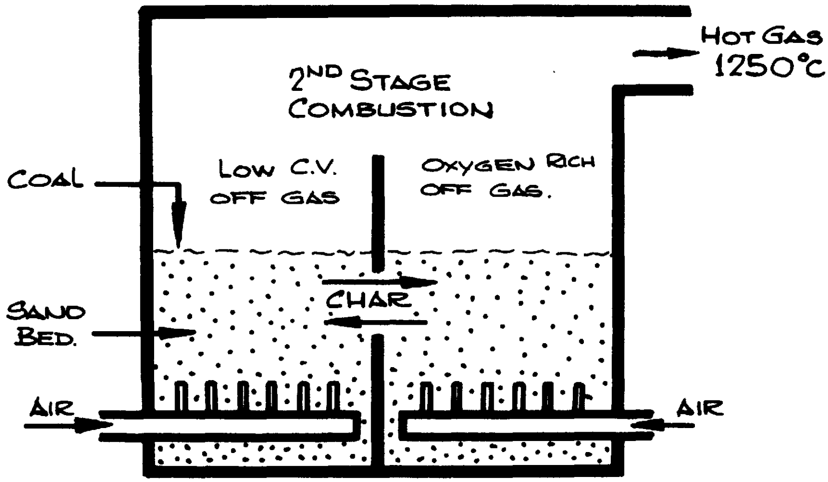


Figure 5.2.1 Production of hot gas at temperatures up to 1 250°C in a fluidized bed consisting of two compartments

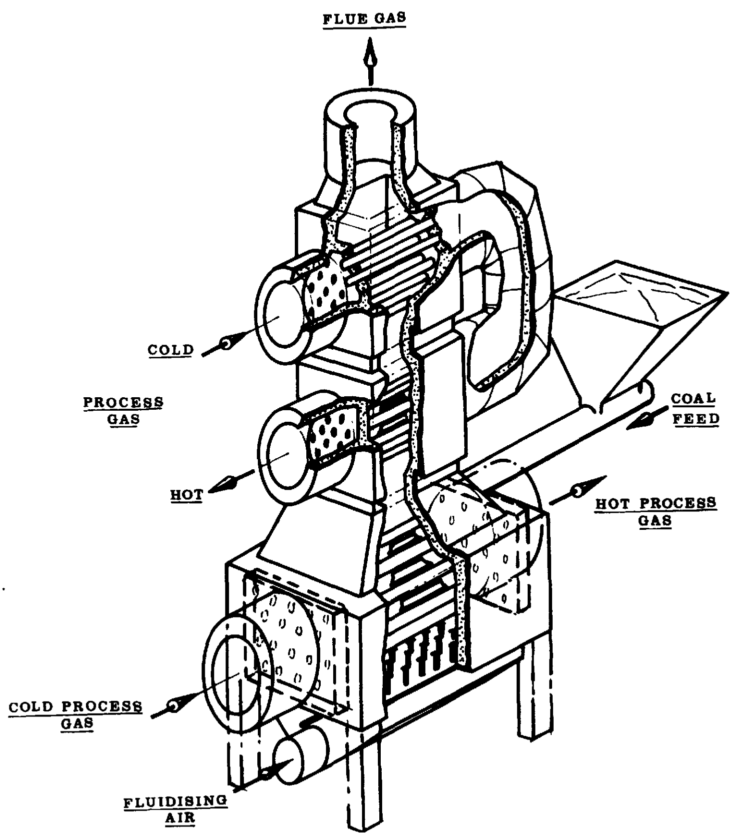


Figure 5.2.2. Fluidized bed gas heater for production of hot, dust free gas at 600°C

Production of hot gas for drying processes using fluidized bed combustion of coal — 5.2

National Coal Board,
Coal Research Establishment
Stoke Orchard,
GB — Cheltenham, Glos. GL52 4RZ

R.C. Payne

Contract number: EE-D-2-322-UK

Production of hot gas for drying processes represents a significant use of energy in E.C. countries. In many process industries, there is also a potential to substitute oil or gas by coal, if suitable technology can be developed.

At present fluidized combustion of coal is being successfully used to produce hot gas at temperatures up to 950°C in applications where some product contamination by ash is acceptable. In order to extend the range of potential applications there is a need to develop the technology to produce both hotter and cleaner gases.

The NATIONAL COAL BOARD is experimentally evaluating design concepts for fluidized beds which are able to produce a) hot air containing ash at 1 250°C and b) dust free gas at 600°C.

a) In a test installation of 400 kW, the concept design for a fluidized bed producing flue gas at 1 250°C is being experimentally tested. It consists of two adjacent fluidized beds, the first being operated as a partial gasifier producing low calorific value gas which is burnt in the oxygen containing off-gas from the second bed. The second bed is fueled by the char from the incomplete gasification of the first bed and is operated with a high excess air level as a conventional fluid bed. Preliminary tests obtained 1 200°C; further experiments should demonstrate the stable operation of this system under a range of test conditions.

b) The concept for the production of hot dust-free gas at 600°C was tested in a 200 kW unit. Air is heated by passing it through heat exchanger tubes in and above the fluidized bed. The mullite tubes used in the in-bed heat exchanger broke down several times. A study suggested the use of silicon carbide tubes which during 1 000 hrs of testing have proved to be satisfactory. The second phase of the project, the design of a full size 1,8 MW installation for a malting plant, has also been completed.

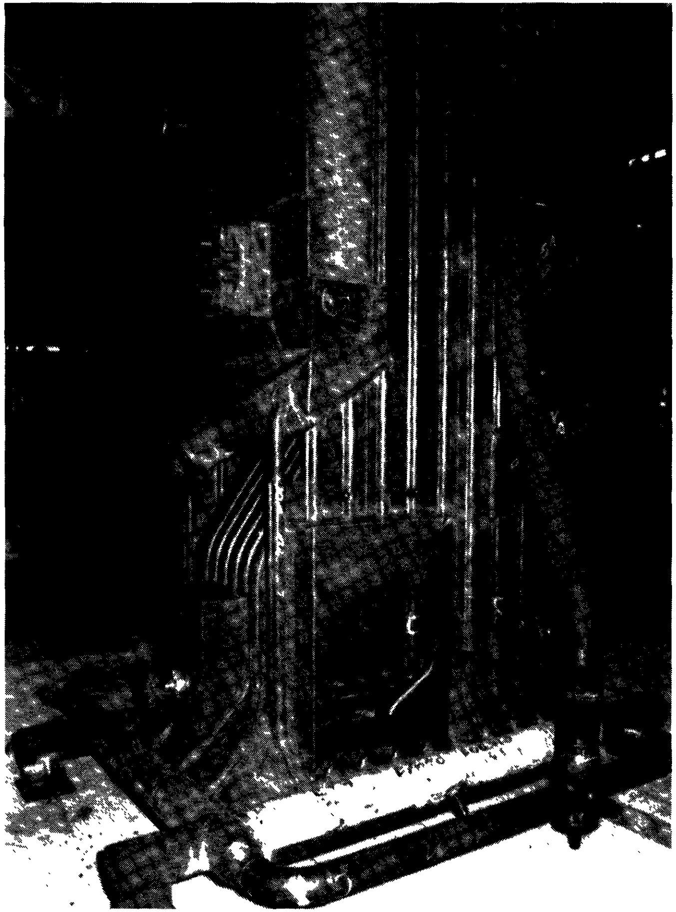


Figure 5.3.1 Return pipe, manhole, exit of ashes from superheater

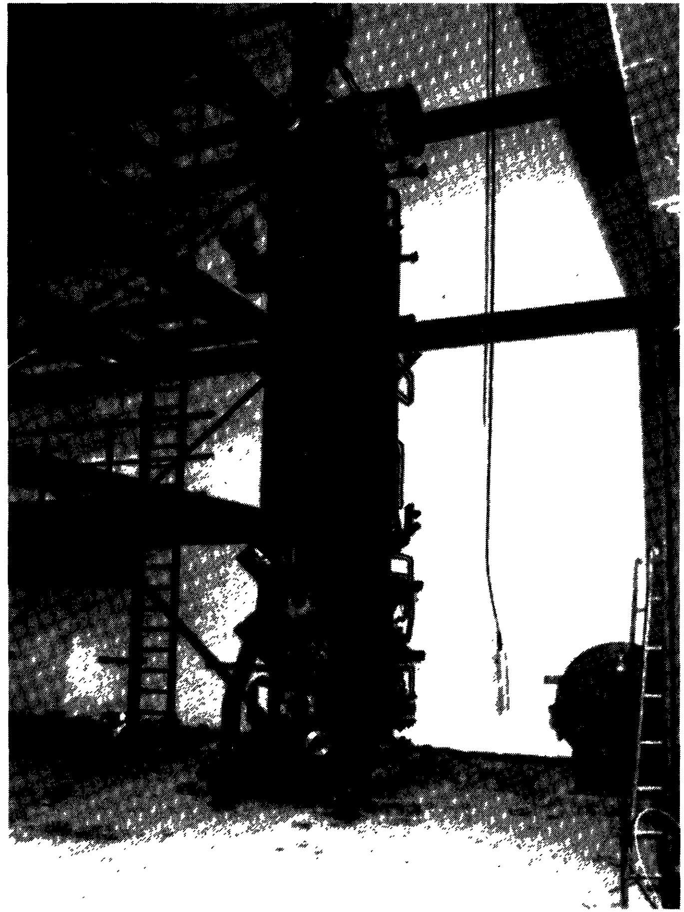


Figure 5.3.2 Boiler before mounting

Further experimental development of circulating fluidized bed combustion for application in steam boiler furnaces using low-grade fuels and coal 5.3

L. & C. Steinmüller GmbH
Postfach 100855/100865
D — 5270 Gummersbach 1

W. ALBRECHT

Contract number: EE-D-3-342-D

This research project covers the design, construction and operation of a fast external circulating fluidized bed for the combustion of various grades of coal for steam raising. Here the lighter particles are entrained by the air flow through the bed, separated from the air by a cyclone and returned to the fluidized bed. The emphasis in this project is on a low degree of fuel treatment (both small and large pieces can be burnt efficiently so that crushing of the fuel is not needed) and a good burn out which is ensured by longer and more effective mixing in the bed. The system is also characterised by low emission values of noxious pollutants and simple construction.

The pilot plant has a capacity of 1 MW, will contain desulphurization facilities, will produce steam of 450°C and 20 bars and will be fired with coal and low grade fuels.

The plant will soon be operational and the experimental programme will involve the determination of: the heat transfer across the boiler surfaces; the required auxiliary power of the plant; the efficiency; the response rate of load alteration; the behaviour with respect to erosion and to corrosion; and the emissions produced. After variation of the fuel and additive types, results will be evaluated. The research programme will be completed with a comparative analysis of the technical and economic factors thus revealed.

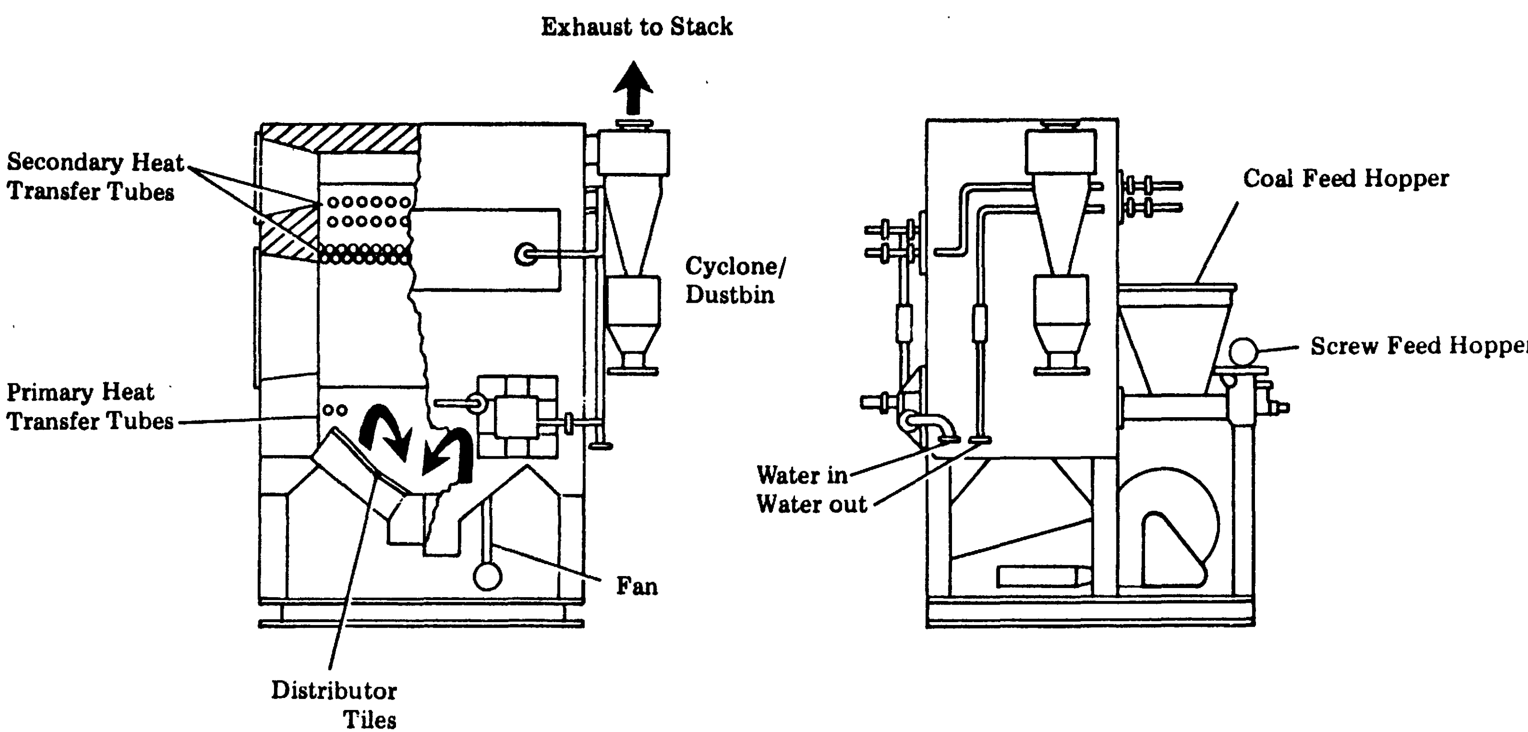


Figure 5.4.1 Fluidized bed for waste combustion

The burning of refuse derived fuel and industrial waste in fluidized bed industrial boilers 5.4

Stone International Limited
Gatwick Road
GB — Crawley West Sussex RH10 2RN

R. BURROWS

Contract number: EE-D-3-343-UK

Much research information is available on the burning of coal in fluidized bed combustion boilers, but there is very little information available on the burning of refuse derived fuel and industrial waste.

The purpose of this study is to demonstrate the feasibility of burning these fuels in fluidized beds. If this is proven, good primary fuels that are in short supply, such as gas and oil, could be replaced by these fuels.

The fluidized bed combustion of refuse derived fuel (RDF) and industrial waste is being tested in a 300 kW fluid bed installation. The wastes to be tested are refuse derived fuel, rubber, carbonacious waste, industrial sludges, chicken and pig manure, wood waste, paper and cardboards.

An internal circulation of the bed induced by the sloped profile of the bottom ensures good mixing of the fuel and good burn out. It is important to introduce the fuel in the central lower region of the bed so that it is entrained and stays in the bed as long as possible before it reaches the surface. A high proportion of the volatile hydrocarbons is however still rapidly released and is burnt above the bed giving a high CO content (0,5%). In order to avoid this, air is introduced above the bed in order to burn the CO.

Waste generally has a low calorific value and may be wet. The addition of coal or propane is therefore necessary. Testing has started and it was shown that it was possible to sustain combustion if 60% of the heat input was provided by waste residue. It was also shown that if pelletized fuel (RDF) is used an efficiency of 80% can be obtained.

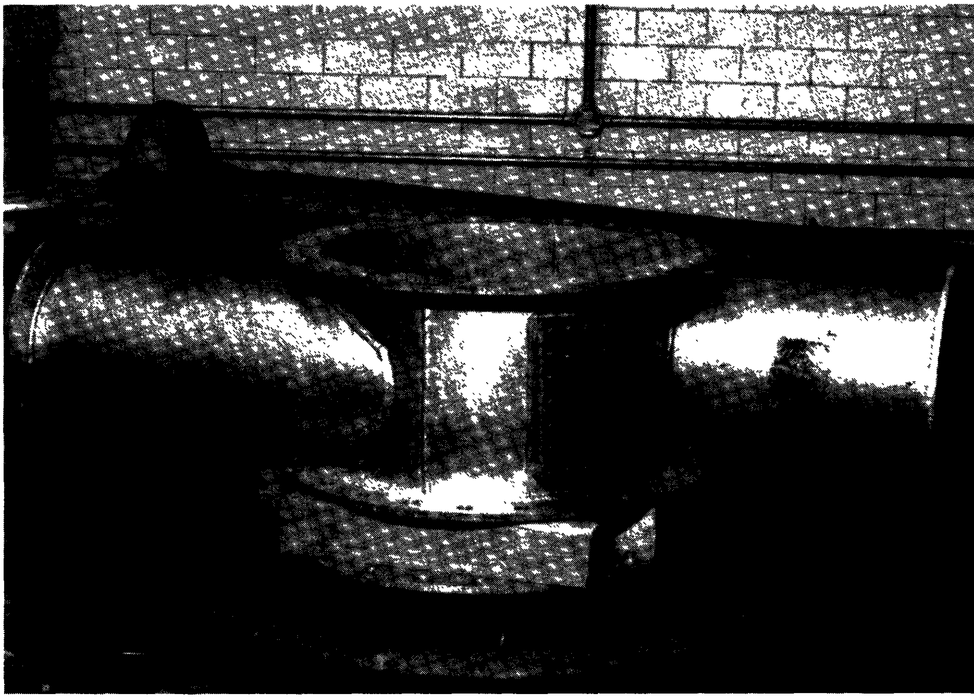


Figure 5.5.1 Swirl chamber

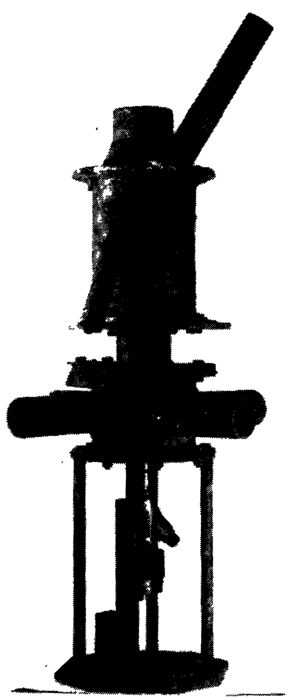


Figure 5.5.2 Mild steel furnace for preliminary tests at phurnacite works

Operation and optimisation of a furnace for the economic burning of low calorific value gases 5.5

University College
Department of Mechanical Engineering & Energy Studies
Newport Road,
GB — Cardiff, CF2 1TA

N. SYRED

Contract number: EE-D-2-325-UK

Low calorific value waste gases are often produced as a by-product of industrial processes (e.g. the off gases from the manufacture of Carbon Black and Smokeless fuels). These are regarded as a nuisance and are frequently disposed of by incineration. This requires, in many cases, the addition of premium fuel to ensure stable combustion. However, these gases can be disposed of more cost-effectively in a system which utilises their inherent potential as a low grade fuel. (In the UK, it is estimated that 0.5 million toe per annum of waste gas are produced.)

The objective of this project is to demonstrate the capability of swirl burner/furnace systems to efficiently burn and recover heat from low calorific value gases of less than 1 MJ/m^3. (A previous study indicated that a swirl burner is well suited to this application while commercial burners would not operate in this case.)

Swirl burner/furnace systems of 100 kW have been optimised both by laboratory and industrial trials:

— The laboratory trials have enabled four regions in the furnace to be defined. The main reaction region is of most significance as the majority of heat release occurs within it. The rate of heat release is dependent on the flow in the swirl region. The flow in this region is similar to that found in swirl burners and dictates the pressure loss through the system.

— The industrial trials have been on the incineration of the waste gas produced during the discharge from the ovens at the National Smokeless Fuels Ltd.'s Phurnacite Plant. These have shown the potential of such systems to incinerate low c.v. gases utilising their own inherent potential as fuel. This part of the project has also led to the development of automatic control systems to ensure efficient matching of the air and support fuel requirements (1-2% up to 3% of fuel is used) to minimise fuel consumption while retaining efficient combustion. The control system is at present undergoing reliability trials.

The resulting furnace is considerably shorter than those previously used for this purpose, thus reducing (by about 50%) the capital costs of an installation. A commercial scale unit of 1 MW is currently being constructed in the university.

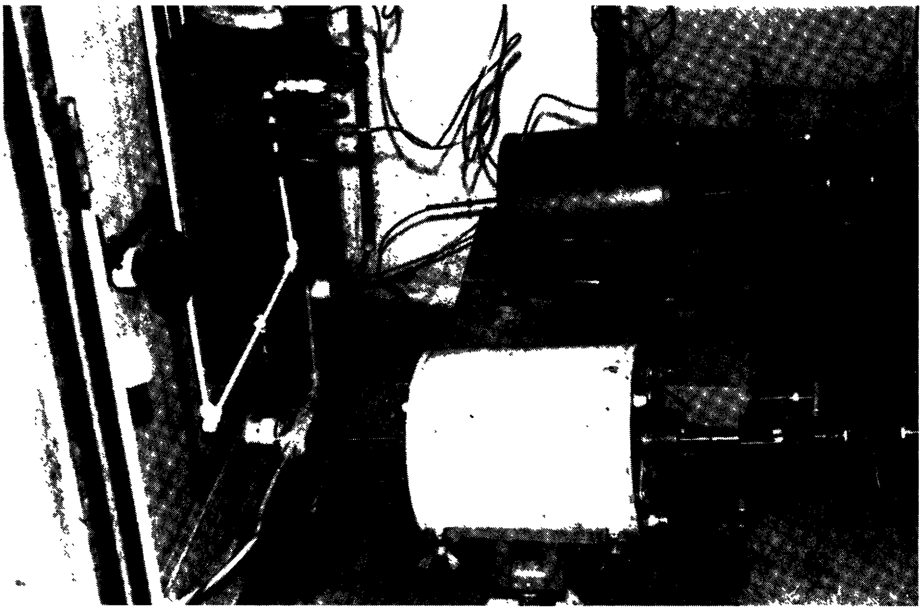


Figure 5.6.1 The 300 bars autoclaves with heating and agitation systems

New routes for producing alcohol (motor fuels and basic materials for hydrocarbon substitution) from synthesis gas

5.6

Université de Liège
Laboratoire de Chimie macromoléculaire
et de catalyse organique
Sart Tilman
B — 4000 Liège

PH. TEYSSIE

Contract number: EE-D-2-326-B

The investigation by UNIVERSITE DE LIEGE is devoted to the search for novel or improved catalysts. The efficient and selective synthesis of oxygenated chemicals (e.g. methanol, ethanol, propanol, acetic acid, esters, ethers) directly from synthesis gas (CO and H_2) was investigated. In this project, the preparation of methanol homologues (e.g. ethanol, propanols, butanols) is a particularly attractive challenge because these alcohols would be interesting fuels for cars but could also be easily converted to valuable olefins for the petrochemical industry (ethylene, propylene, butene); such an achievement would be significant in relation to the problem of the replacement of petroleum by coal.

Several patents report on the preparation of ethanol from synthesis gas with reasonable selectivities, but relatively large amounts of very expensive catalysts (Rhodium) are required in these processes. The use of less expensive metals seems therefore to be a prerequisite for industrial application unless the life and efficiency of Rhodium based systems could be substantially improved. A more important drawback of the existing processes is the lack of selectivity (the formation of other undesired hydrocarbons).

The exploratory work has led to the selection of one novel catalytic system (Co reduced species) which is likely to lead to noticeable amounts of alcohol products (12-20%) relative to hydrocarbons. This is a considerable improvement compared to previously used catalysts which generally gave only traces of these products. The pressure levels and the nature of the support can strongly influence the distribution of the product. Low pressure leads to olefins together with alcohols while high pressure in some cases gives oxygenated products. The problems of efficiency and improved selectivity in one oxygenated derivate are still unsolved.

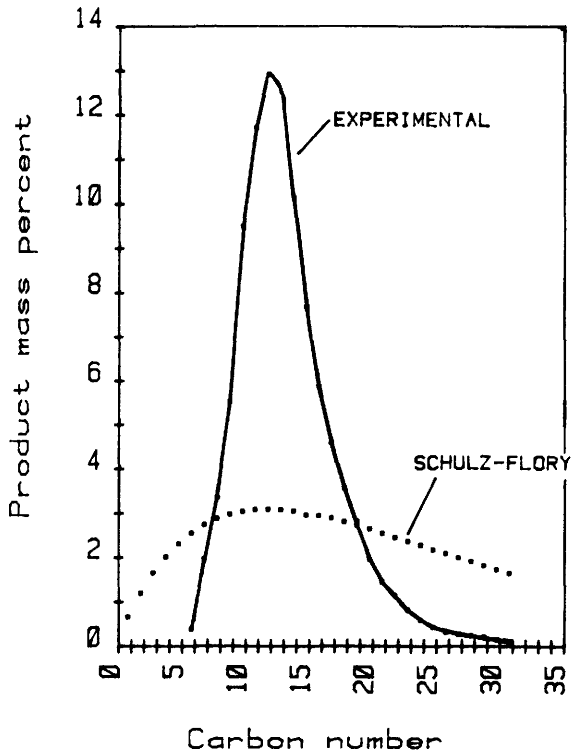


Figure 5.7.1 Experimental product distribution obtained with 8% Ru/alumina I, together with the conventional Schulz-Flory distribution

Fischer-Tropsch synthesis of hydrocarbons in the gasoil range 5.7

Katholieke Universiteit Leuven
Centrum voor Oppervlaktescheikunde
en Colloïdale Scheikunde
De Croylaan 42
B — 3030 Leuven (Heverlee)

Compagnie Française de Raffinage
rue Boileau, 22
F — 75781 Paris Cedex 16

J.B. UYTTERHOEVEN (K.U.L.)

Contract number: EE-D-2-327-B

Preparation of liquid fuels from coal is one of the major routes to make the European economy more independent of petroleum. The well-known Fischer-Tropsch synthesis (which transforms CO + H_2 into hydrocarbons, alcohols and olefins) has demonstrated its technical feasibility. The major disadvantage is the lack of selectivity to obtain higher yields of gasoline and/or diesel, which is inherent to the chemical mechanism (a polymerization scheme according to Schulz-Flory kinetics) with the type of catalysts presently used. To be applicable in European economic conditions, Schulz-Flory kinetics will have to be circumvented to improve selectivity. This requires the develomment of new catalysts and the optimisation of their use.

This work involves the development and optimisation of catalysts for the high selectivity preparation of hydrocarbons, olefins and alcohols from coal. With these catalysts it should be possible to synthesize motor fuels in a direct process which will not require major refinery operations after synthesis.

For this purpose, a batch reactor and a continuous reactor with a gas chromatograph have been installed. The active metal of the catalyst is either ruthenium or cobalt. The supports used are kieselguhr and microporous alumina. The catalysts were calcinated in air and then reduced under hydrogen in the reactor (so that they become active).

The first results obtained show that with particular types of catalyst (2% Co/alumina or 8% Ru/alumina) it is possible to achieve selective cuts, differing from the usual type of product distribution obtained with Schulz-Flory kinetics. With both Co and Ru the maximum yield was obtained for dodecane (carbon number 12) and roughly 50% of the yield had a carbon number between 10 and 15. It seems that the pore diameter of the support when Ru catalyst is used does not influence the product distribution, while the degree of loading with the active metal does. (For Co catalyst these data are not yet available). The industrial Fischer-Tropsch catalysts tested (11%-16% Co/kieselguhr) all showed Schulz-Flory behaviour. The results obtained in a batch reactor are to be confirmed in the on-line apparatus.

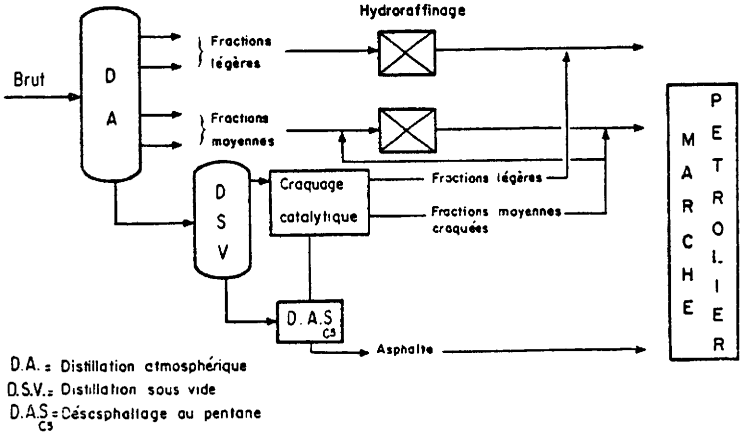
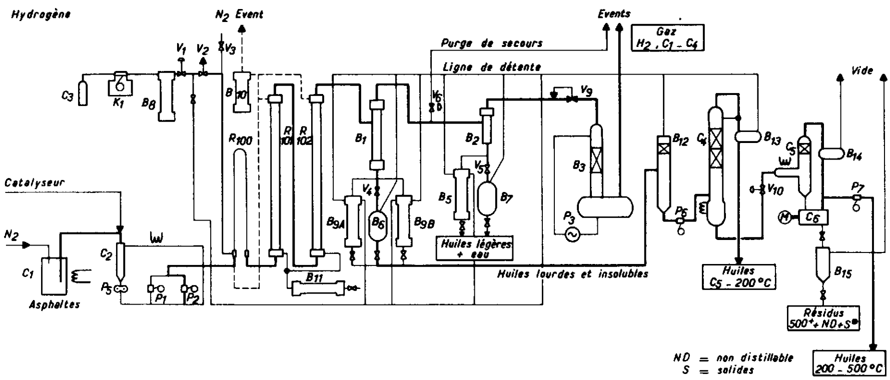


Figure 5.8.1 Crude oil distillation with different products



ALIMENTATION EN ASPHALTES	CIRCUIT D'HYDROGENE	REACTEURS	SEPARATEURS	EPURATEUR	DISTILLATION
C1 _ Fût d'asphaltes C2 _ Bac jaugeur P1 _ Pompe haute pression P2 _ Pompe haute pression P5 _ Pompe de gavage	B8 _ Réserves d'hydrogène haute pression C3 _ Cadres d'hydrogène K1 _ Compresseur V1 _ Vanne d'arrêt de secours V2 _ Vanne de réglage du débit V3 _ Vanne d'arrêt de la purge d'azote	R 100 _ Préchauffeur R 101 _ Réacteur R 102 _ Réacteur B 10 _ Ballon du circuit des disques de rupture B 11 _ Ballon du circuit de purge des réacteurs	B1 _ Séparateur chaud B2 _ Séparateur froid B5 _ Vanne de détente B6 _ Ballon de détente B7 _ Ballon de détente B9A, B9B } Sas V4 _ Vanne de détente V5 _ Vanne de détente V6 _ Vanne de purge de secours	B3 _ Laveur à soude P3 _ Pompe de circulation V9 _ Déverseur régulation de la pression	B 12 _ Ballon de recette B 13 _ Recette des légers B 14 _ Recette des huiles moyennes B 15 _ Sas de résidus C4 _ Colonne atmosphérique C5 _ Flash sous vide C6 _ Evaporateur sous vide P6 _ Pompe doseuse P7 _ Pompe de remise à la pression atmosphérique V 10 _ Vanne de détente

Figure 5.8.2 Diagram of experimental rig used for the hydrogenation of asphalts

Making the best use of asphalts by very intense hydrogenation on an entrained catalyst 5.8

Centre d'Etudes et Recherches
des Charbonnages de France (CERCHAR)
Groupe Thermique
Boîte postale 2
F — 60550 Verneuil-en-Halatte

Institut Français du Pétrole (IFP)
Boîte Postale 311
F — 92506 Rueil-Malmaison Cedex

P. CHICHE (CERCHAR)

Y. JACQUIN (IFP)

Contract number: EE-B-1-122-F

The likely trend in the level of production of crude oil, in overall consumption and in refining processes will lead to increasing supplies of heavy oil residuals which are difficult to use: they frequently have too high a sulphur content to allow them to be burnt; moreover, the conventional hydro-cracking processes cannot be applied to them.

A new way of transforming heavy oil residuals extracted from oil (asphalt) or from primary hydrogenated coal into commercial products in the petroleum or diesel-oil range is being developed. Hitherto, conventional techniques have failed because of the unadaptability of present-day commercial catalysts and resulting complexity of the equipment.

Work consists of treating the heavy oil residuals, dissolved in a solvent, by a technique similar to that of the hydrogenation of coal. This is carried out in an existing pilot plant, under stringent conditions corresponding to temperatures lying between 400°C and 425°C under a hydrogen pressure of 200 bars or above. In order to reduce the viscosity to a level compatible with normal operation of the unit, preliminary investigations have determined the nature and amount of solvent required (of the order of 50%).

The first actual hydrogenation trial—with hydrogen at 200 bars and in the presence of a soluble organic molybdenum complex catalyst—revealed that the optimum hydrogenation temperature was above 400°C at which a large proportion of the heaviest fractions were converted into light and medium products.

Further tests aim to specify the optimum hydrogenation temperature which seems to lie around 420-425°C.

Desulphurization of bituminous coal by biological leaching

5.9

E.N.E.A.
Viale Regina Margherita, 125
I — 00198 Roma

C. MANCINI

Contract number: EE-D-2-324-I (pending)

For the past 15 years or so, there has been increasingly intensive experimental research throughout the world (particularly in the USA, Canada, USSR and Japan) to determine the extent to which certain microorganisms of the genus Thiobacillus can, by means of their metabolic processes, oxidize inorganic compounds containing sulphur such as elementary sulphur, sulphides, thiosulphates, sulphites, tetrathionates, thiocyanates. (The fact that they can do so, was discovered at the beginning of the century.)

The aim of many of these studies is to determine whether micro-organisms can be used to solubilize the sulphur contained in coal. In particular, the results of current and completed studies show that it is possible to remove up to 90 or 95% of the sulphur occuring as pyritic sulphur and up to 30 or 35% of the organic sulphur.

The objective of the present study is to experimentally verify the possibility of sulphur extraction from sub-bituminous coal by means of biological leaching using a three stage counter-current reactor based on a mixer-settler principle. The programme of work comprises: the selection and the culture of suitable micro-organisms; experimental tests on the behaviour of the selected micro-organisms and technical-economic analysis of the process feasibility.

Figure 5.10.1 Machine under test showing turf cutter

Peat harvesting machinery for operation on smaller bogs

National Board for Science and technology
Shelbourne House,
Shelbourne Road,
IRL — Dublin 4

D. KEARNEY

Contract number: EE-B-5-190-EIR

The decreasing availability of labour and the high cost of machinery are largely responsible for a decrease in turf production from small bogs (turf moors). Mechanisation of turf cutting on smaller bogs is difficult. Existing machines used on small bogs have the disadvantages of poor manœuvrability and large size. These factors discourage turf production by small producers and in the past ten years output by these producers has fallen by half.

The key to an appropriate harvesting system is to develop a new method of exposing the peat to the air for wind drying. At present turning and arranging sods of peat for wind drying on small bogs is unmechanised and very labour-intensive.

This project aims to make it economically attractive to extract peat from small bogs. It involves the design and development of a machine to cut the peat and extrude it in a helical form of about 55 m in dia. The thread of the helix of the machine will have a dia. of about 10 cm. The pitch coil-coil will be 20 to 25 cm. In this configuration the peat will need no further attention until dry. Collection of the peat when dry will be very straightforward as the peat becomes brittle during drying and will be broken up at collection.

The prototype turf cutter has been tested on a bog of 88% moisture content. The maximum turf yield was 65 m^3/hr which is equivalent to 10.4 tonnes/hr of peat at 25% moisture content.

Another prototype turf cutter for an output of 90 m^3/hr (at 88% moisture) has been constructed and is to be tested.

Sector 6

ENERGY STORAGE

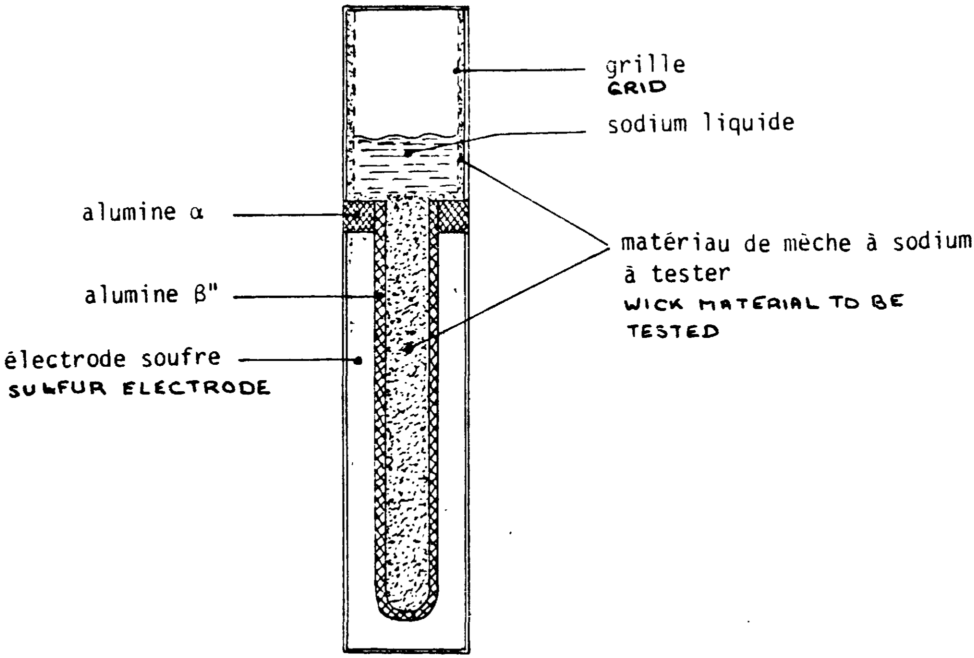


Figure 6.1.1 Principle of a Na/S cell with a wick

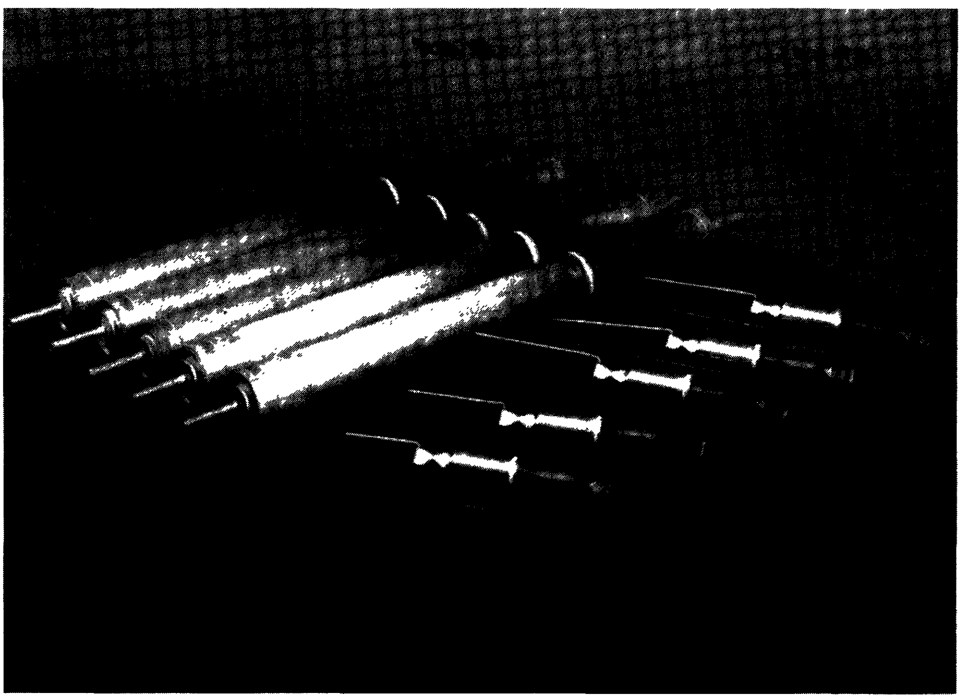


Figure 6.1.2 Na/S cells of 200 Ah and 4,5 Ah

Development and testing of a β" alumina electrolyte to be used in a Na/S battery 6.1

Laboratoires de Marcoussis
Route de Nozay
F — 91460 Marcoussis

R. VIC

Contract number: EE-E-2-422-F

The objective of the battery R + D Programme is to develop secondary batteries with a high energy (150 Wh/kg) and power density (100-150 W/kg) for application in electrical vehicles. One way to achieve this is the development of a Na/S battery which operates at 350°C. This work is focussed on the development of a β" alumina solid electrolyte. As compared to the conventional β alumina electrolyte, β" alumina gave an improvement in the power density of 35%, the battery efficiency increased from 55% tot 71%. Energy densities of 200 Wh/kg were obtained. Ten thermal cycles (350°C ⟷ 20°C) were possible without impairing the operation of the battery. Lifetime tests are now envisaged for a large number of cells.

In order to improve safety and to increase the energy density, experiments are going on to replace liquid Na in the β" alumina tube, by a wick which soaks up liquid Na and wets the electrolyte. Energy density improvements of 7% are expected and the safety of these batteries can be considerably increased. The wick will also allow the tubes with a length of 40 cm, to be in a horizontal position which can be important if these batteries will be used for car traction. Nickel and iron wicks have been developed, which gave good results. These wicks have been tested in cells which performed well when held upside down for 200 cycles.

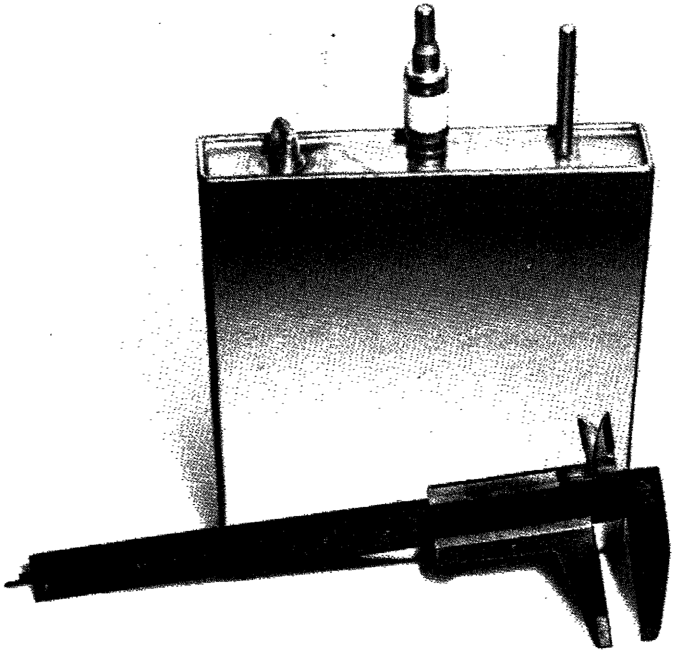


Figure 6.2.2 LiAl/FeS cell (150 Ah) type VP 100

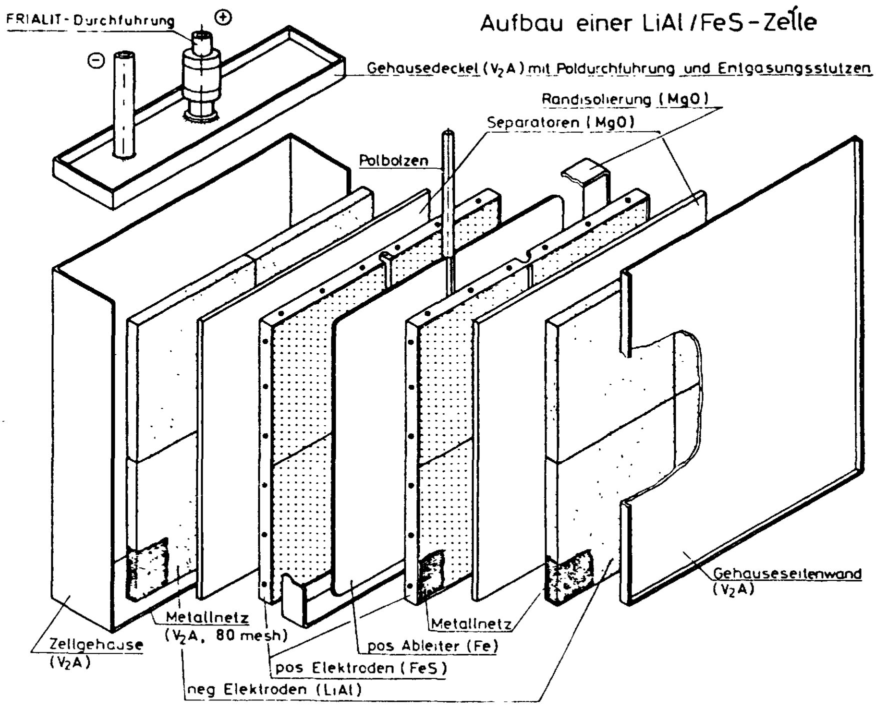


Figure 6.2.3 Exploded view of the LiAl/FeS type VP 100

Secondary batteries with a high energy and power density with a molten salt electrolyte

6.2

Varta Batterie AG
Forschungs- und Entwicklungszentrum
Postfach 1620
D — 6233 Kelkheim

W. BORGER

Contract number: EE-E-2-427-D

Work on Li/S batteries in the first phase 1977-1979 resulted in an energy density of 80 Wh/kg and a lifetime of 100 cycles. One of the drawbacks of this battery was the use of boron-nitride as a separator (a porous electrical insulator between electrodes which permits ion conduction). With boron-nitride, which is very expensive, a storage capacity of one kWh would cost around 1,000 $. A new separator material MgO has now been identified which is satisfactory and costs two orders of magnitude less. Investigations also lead to the conclusion that a ternary molten salt LiF-LiCl-LiBr is to be preferred over LiCl-KCl used up till now. LiCl-KCl has the disadvantage that at high current densities, KCl can crystallize in the pores of the separator. With laboratory cells (20 Ah, 3 h. discharge rate) lifetimes of 300 cycles have been obtained. Larger technical cells (150 Ah) had energy densities of 100 Wh/kg. After four thermal cycles between 450°C and room temperatures, the battery did not show any damage. Cycling tests of ten cells of 150 Ah are now being carried out. Safety aspects have been investigated and lead to the conclusion that LiAl/FeS batteries will not have an extra risk as compared to lead acid batteries. The cost of LiAl/FeS batteries for the case of large scale production is estimated to be between 60 and 130 DM/kWh (50% is due to the Li compounds). This compares well with the cost of Na/S, Ni/Fe and lead acid batteries which lies around 86, 300-350 and 150-200 DM/kWh. Work will now be concentrated on the construction and testing of modules which consist of several cells.

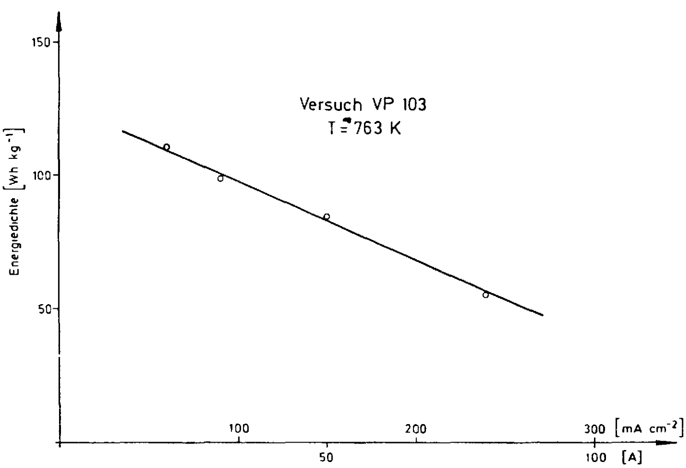


Figure 6.2.1 Energy density as a function of the discharge current

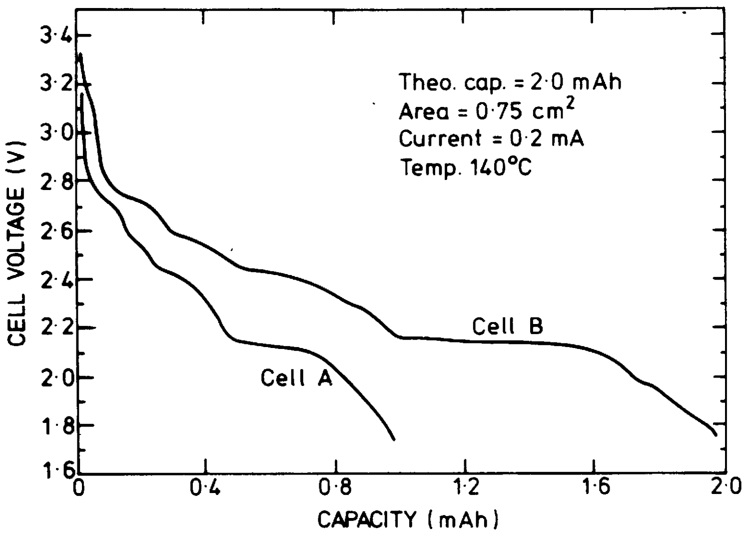


Figure 6.3.1 Discharge characteristics of two lithium-V_6O_{13} cells:
A. Standard composite cathode and B. Lithium-free composite cathode.

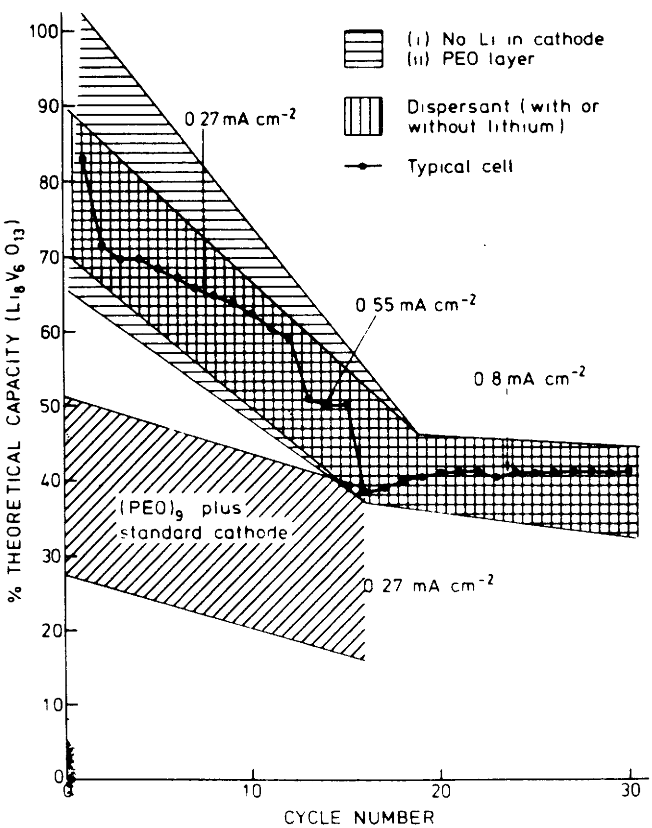


Figure 6.3.2 Discharge capacity (140°c) versus cycle number for batches of lithium-V_6O_{13} cells as a function of fabrication technique.

Advanced battery development (Anglo-Danish project) 6.3

Project manager: R.M. DELL

Contractors:

UK Atomic Energy Authority
Applied Electrochemistry
Building 220
AERE Harwell
UK — Didcot Oxon OX11 ORA

R.M. DELL (project leader UK projects)

Odense University
Energy Research Laboratory
Campusvej 55

DK — 5230 Odense

J. JENSEN (project leader DK projects)

Contract number: EE-E-2-421-UK EE-E-2-429-DK

Sub-contractors:

- Imperial College London
- University of Oxford
- Department of Inorganic Chemistry
- University of Leeds
  Department of Physics
- Danish Technical University
- Risø National Laboratory
  Department of metallurgy

Na/S and Li/S batteries developed in other projects in this programme operate at 350°C and 450°C respectively. Although a limited number of thermal cycles is possible without impairing the operation of the batteries, this remains a serious disadvantage. Therefore this part of the EC programme tries to develop high energy and power density batteries at lower temperatures. The research is carried out by the Anglo-Danish project (a close collaboration between four BRITISH and three DANISH RESEARCH INSTITUTES).

The ANGLO-DANISH group started in a first project (1977-1979) with material research for batteries. This resulted in the identification of suitable and promising materials for electrolytes and electrodes. In the second phase (1980-1983) combinations of different electrode and electrolyte materials are being tested in order to identify good cells. In the cells investigated, alkali metal atoms will give up an electron at the negative electrode, move through the solid electrolyte (which should have a high ion conductivity) and settles in a positive electrode, made of material whose crystal and electronic band structure is such that it can accommodate alkali metals (insertion electrode). The power density of a battery increases with the ion conductivity of the electrolyte, and the energy density of a battery is larger when more alkali metal ions can be accommodated in the positive electrode. During charging, the process is reversed. In this project solids are used for both the electrodes and electrolytes, this results in interface problems which form an important part of the R & D carried out.

In the first phase of the EC programme several interesting electrolyte materials have been identified which were further studied in the second phase (1980-1983). Li_3N has a high ion conductivity but may be too hard mechanically to enable an intimate contact with a solid electrode. The composite LiI/Al_2O_3 has a high ion conductivity but an explanation has not yet been given. Further study is therefore

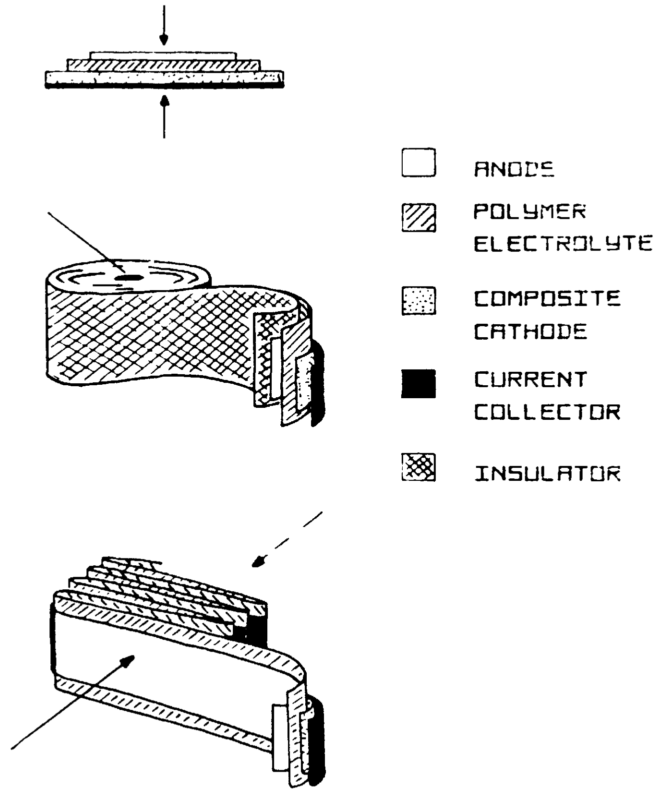


Figure 6.3.3 Solid state cell configurations, consisting of a superposition of thin electrolyte and electrode films.

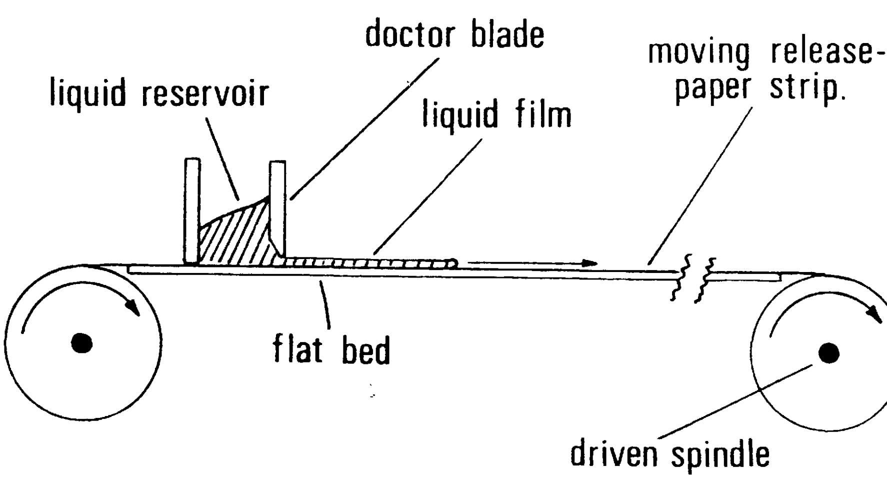


Figure 6.3.4 Production of electrolyte and electrode films with doctor-blade coating equipment.

needed in order to optimize the ion conductivity. Mixtures of polymers and lithium salts gave good ion conductivities and have unique mechanical properties: they are soft, can be formed in thin layers, are durable towards repeated deformation and have excellent binding properties. This will assure good contacts with the electrode and reduce interface problems.

Table 1: Conductivity of three electrolytes in Ohm^{-1} cm^{-1} at 140°C

Polymeric	LiI/Al_2O_3	Li_3N
3.4 10^{-4}	1.5 10^{-3}	5. 10^{-3}

For positive electrodes TiS_2 and V_6O_{13} are used. They have very favourable insertion properties for Li^+. Also composites of these materials with polymers with a good ion conductivity have been studied. A combination of an electrode and electrolyte which both contain Li^+ conducting polymers has the advantage that ions can easily move from the electrolyte into the electrode without interface problems.

The use of a composite electrode was also considered in view of the fact that ions settle close to the electrode surface (e.g. TiS_2: to a depth of 1-5 μm). By using TiS_2 powder with a particle diameter of 1-5 μm bound by a polymer with a good ion conductivity the surface can be enlarged and the energy density of the battery increased.

Promising results have been obtained with a cell consisting of a LiAl negative electrode, an electrolyte of polyethylene oxyde with Li salts and a composite positive electrode consisting of V_6O_{13} powder (intercalation material) and polyethylene oxyde. The electrodes and the electrolyte were made of thin sheets with a thickness of the order of 100 μm. Cells with a surface of 100 cm^2, operating at 120°C have been cycled 40 times without loss of performance. Also stacks of cells have been cycled satisfactorily. The cell has an extrapolated peakpower and energy density of 250 W/kg and 426 Wh/kg respectively.

Investigation of glass materials for new solid electrolytes and their associated cathodes. 6.4

Université de Bordeaux I
Laboratoire de Chimie du Solide du CNRS
F — 33405 Talence Cedex

A. LEVASSEUR

Contract number: EE-E-2-425-F

A French team of the UNIVERSITY OF BORDEAUX in a systematic material search discovered new glassy electrolytes (sulphur glass) with a very high ion conductivity ($10^{-3}\Omega^{-1}$ cm^{-1} at 25°C). With this promising material, cells will be made, similar to those of the Anglo-Danish project. The positive electrodes will also be made with TiS_2, V_6O_{13} or the composites TiS_2/sulphur glass or V_6O_{13}/ sulphur glass. Sulphur glass will serve as an electrolyte and Li or LiAl will be the negative electrode. The use of composites containing sulphur glass will allow manufacturing of the electrolyte and the positive electrode in a single glass block thus avoiding interface problems. The first cells of the type LiAl/ternary glass electrolyte/TiS_2 have been tested. Difficulties were encountered in achieving high specific energies, this is believed to be due to the positive electrode.

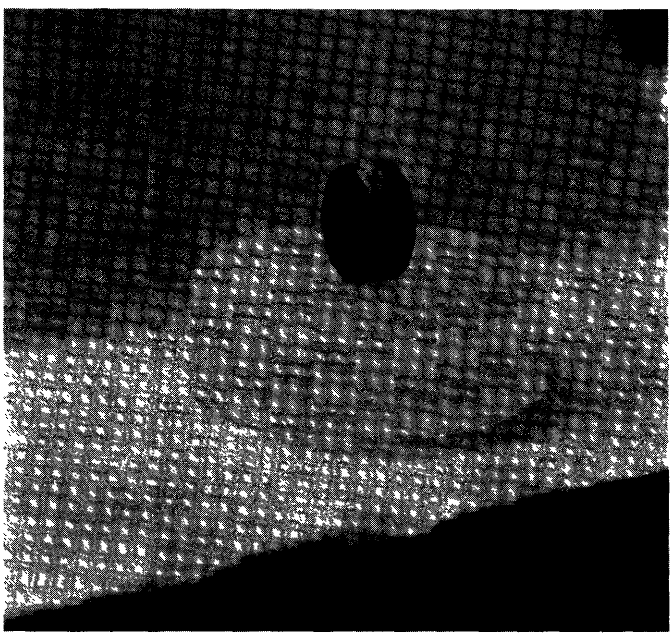


Figure 6.4.1 All solid battery cell with glass electrolyte.

Hydrogen fuel cell with an immobilized liquid electrolyte using a porous matrix

6.5

SORAPEC
192, rue Carnot
F — 94120 Fontenay-sous-Bois

D. DONIAT

Contract number: EE-E-2-428-F

In this project a porous matrix is being developed for a H_2/air alkaline fuel cell which immobilizes the electrolyte and replaces the free electrolyte. The matrix will allow a shorter inter-electrode distance which will lead to a higher (mass and volume) power density of the fuel cell. However, dissipation of heat will be more difficult. Polyamide and polypropylene were found to be equally good matrices up to 100°C and 120°C respectively. A satisfactory air electrode was developed consisting of a layer of fritted nickel covered by a very porous nickel foam containing silvered active carbon to reduce polarization due to hydrogen peroxide formation. Cells (10 cm^2) were tested for 1500 hr. at 80°C and current densities of 150 mA/cm^2 were obtained; this compares favorably with cells of the Belgian-Dutch Elenco project which is the most advanced group working on H_2/air alkaline fuel cells.

Figure 6.6.2 Vehicle battery test equipment

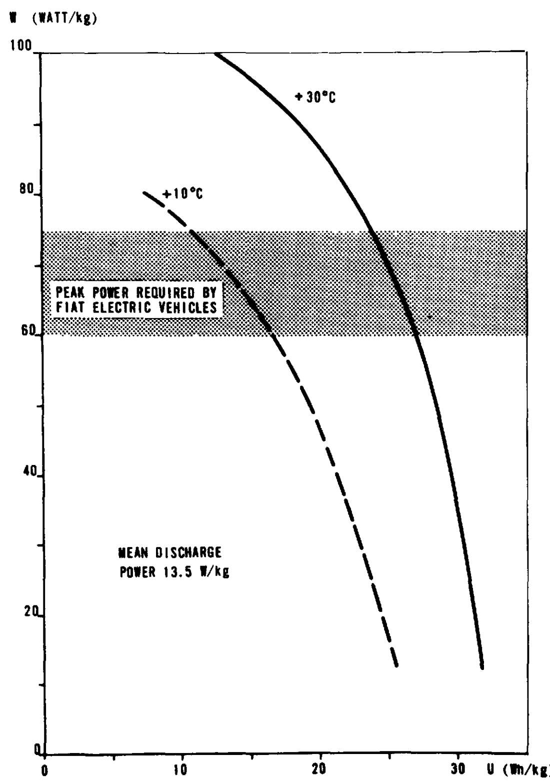


Figure 6.6.3 Discharge power curve of lead acid batteries

Development of a modular electrochemical energy storage system for road electric vehicles

6.6

Centro Ricerche Fiat
Strada Torino 50
I — 10043 Orbassano

Elektronikcentralen
Venlighedsvej 4
DK — 2970 Hørsholm

G. BRUSAGLINO

A. LAURSEN

Contract number: EE-E-2-423-I EE-E-2-426-DK

FIAT, Italy and ELEKTRONIKCENTRALEN, Denmark developed lead-acid modules for a van with battery temperature control, controlled charging and a centralized system for adding battery fluid and for collecting gas. The modules performed well during a 6 month period of vehicle testing over a distance of 2000 km with 100 charging-discharging cycles. The on board charger had an efficiency of 86%; the storage efficiency of the batteries was 83%. The overall energy consumption was 290 Wh/m for a 1.7 tonne van. This is much lower than the consumption of a first generation of electrical vehicles which ranged from 500 to 700 Wh/km. The high consumption was mainly due to heavy overcharging after short runs. A controlled charging in relation to measured Ah is thus essential.

Charging at 50 Hz would require very heavy transformers. A high frequency of 2 kW charger is therefore being developed (ELEKTRONIKCENTRALEN, Denmark) which operates at 50 000 Hz and requires small and light transformers. This will lead to a weight reduction from 30 to 7 kg. Additional advantages are: good regulation, higher efficiency, low cost. This charger will be installed in the Fiat electrical vans. Problems were encountered with the switching transistors and have not yet been resolved.

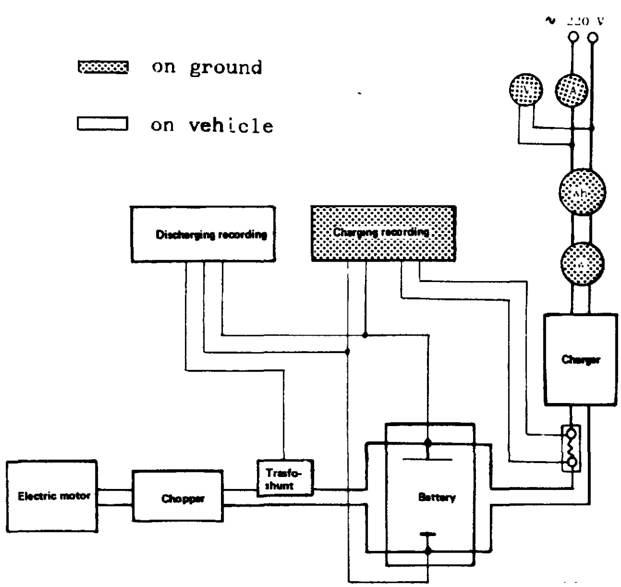


Figure 6.6.1 Schematic drawing of the equipment

High frequency power supply for both battery charging and motor field control for electrical vehicles 6.7

Chloride Legg Ltd.
Fordhouse Road
UK — Wolverhampton WV10 9EB

A.R. EDWARDS

Contract number: EE-C-2-221-UK

CHLORIDE LEGG, UK, investigated whether it was possible to develop a high frequency battery charger in such a way that it can also be used as a motor controller. This was shown to be technically possible. It would however require transistors of 0,5 MW switching at 25,000 Hz. These transistors, if available, will be too expensive for the moment.

Work was then focussed on the development of a high frequency charger of 12 kW operating at 25 kHz. With commercially available transistors the theoretical maximum power of these chargers was calculated to be 6 kW and the objective was therefore to develop two 6 kW chargers in parallel.

From the different possible options the double ended forward converter was found to be most suitable. With a prototype charger an output power of 3,3 kW was achieved; this is now being further improved.

A 1 m3 paraffin heat store on a space heating water loop with a heat pump

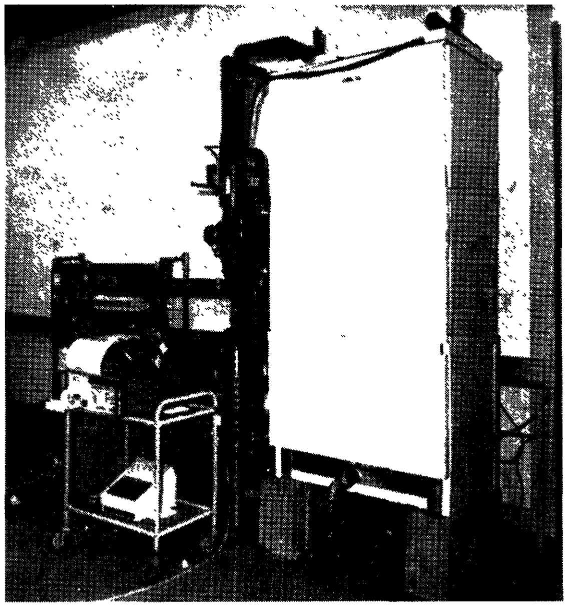


Figure 6.8.1 View of the test bench

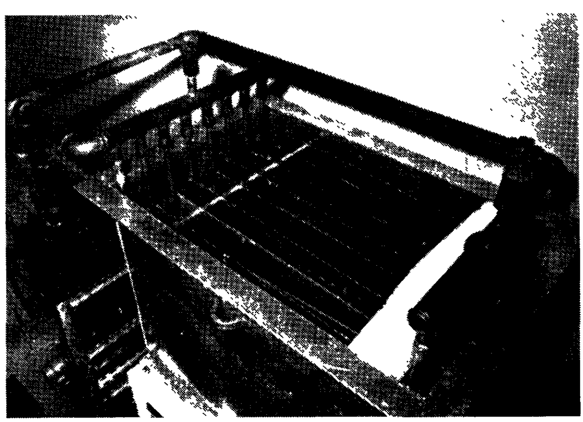


Figure 6.8.2 Paraffin store seen from above showing the water heat exchanger made of sheets of roll-bond aluminium

Short term heat storage based on the melting of paraffin and coupled to an electrical heat pump for domestic heating 6.8

Laboratoires de Marcoussis
Division Energie
Route de Nozay
F — 91460 Marcoussis

P. DUBOIS

Contract number: EE-E-1-402-F

An area where heat storage may be attractive, is daily heat storage at 80°C in combination with an electrical heat pump, in countries where the electricity cost is low during night. In addition such a storage system would allow the heat pump to run continuously, thus avoiding on/off losses which occur during normal operation with a thermostat. These on/off losses can be as high as 10-15%.

In this project a storage system with paraffin has been studied. A system consisting of a 0.9 m^3 container with paraffin in which a heat exchanger was emerged, was found to operate satisfactory. Tests in combination with an electrical heat pump for different weather conditions (climatic chamber) were carried out and the economy of such a system was calculated. The investment cost for such a storage system (assuming large scale production) is around 12,000 FF. With electricity prices of 0.38 FF/kWh (day) and 0.22 FF/kWh (night), heat storage with an electrical heat pump was economically not attractive (pay back time: 20 years). In other countries with higher electricity prices the system may become interesting in particular as it seems to be possible to decrease the investment cost. The problem of deterioration of paraffin, which has been reported elsewhere, was not noticed. This was possibly due to the limited number of cycles.

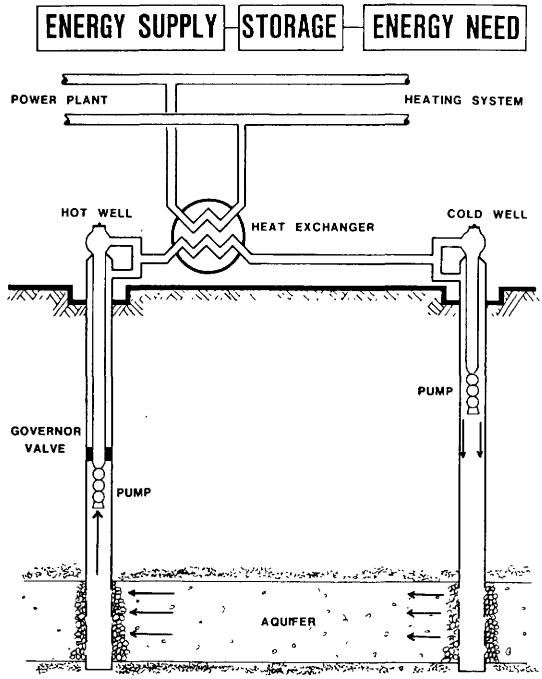


Figure 6.9.2 Aquifer heat storage system in summer operation

ENERGY BALANCE

around the year

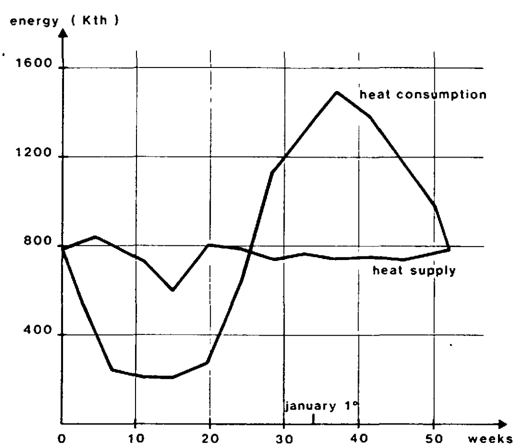


Figure 6.9.3 Heat supply and heat consumption

Seasonal heat storage at temperatures above 100°C in a 500 m deep confined aquifer: a preliminary theoretical and experimental feasibility study

6.9

C E A
Centre d'Etudes Nucléaires de Saclay
D E D R
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F — 91191 Gif-sur-Yvette Cedex

S N E A
Société Nationale Elf-Aquitaine
Centre de Recherche de Solaize
Boîte Postale 22
F — 69360 St. Symphorien d'Ozon

J. RASTOIN (C E A)

H. CLAMENS (S N E A)

Final report number: EUR 8539 available in French

Contract number: EE-E-1-403-F

Large quantities of waste heat are presently discharged (e.g. in industry, power plant, urban waste incineration) which may be used in winter for heating, if cheap long term heat storage would be available. One of the few options is storage of hot water in subsoil water conducting layers of typically 20 m high which below and above are thermally insulated by natural clay layers. The hot water is brought in and extracted from the aquifer with a doublet of drilled holes. CEA/SNEA, France made an experimental study of such an aquifer heat storage system near Paris. The aquifer is 508 m deep and the feasibility of storing heat up to 180°C was investigated. The results of this study were promising and the construction of a heat storage system for about 5000 houses is now envisaged.

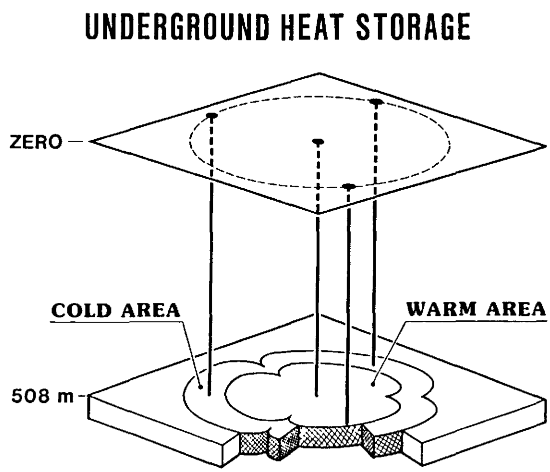
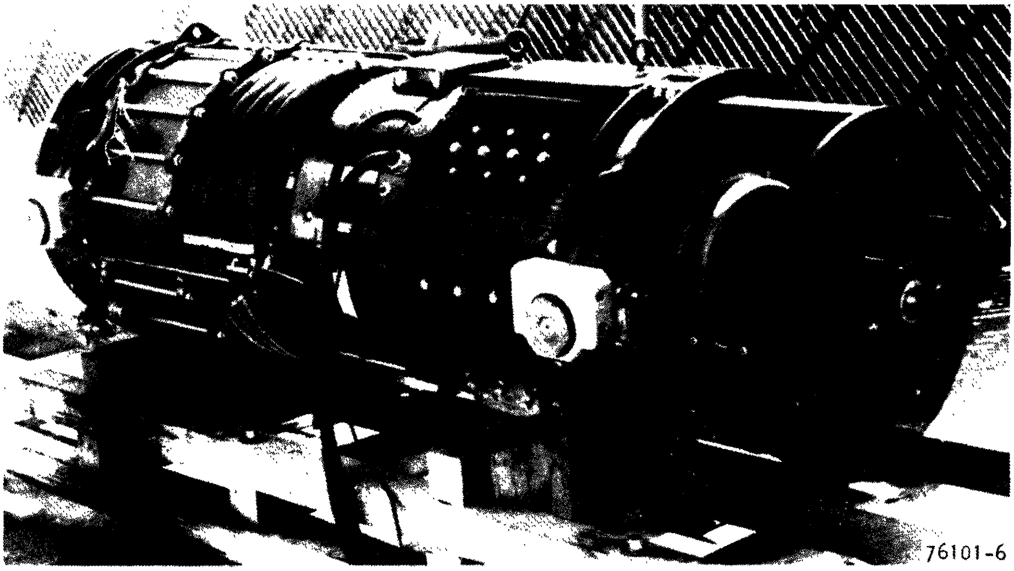


Figure 6.9.1 Schematic drawing of an aquifer heat storage system



b. ESU ON TEST

F-29896

Figure 6.10.1 Energy storage unit, ACT-1

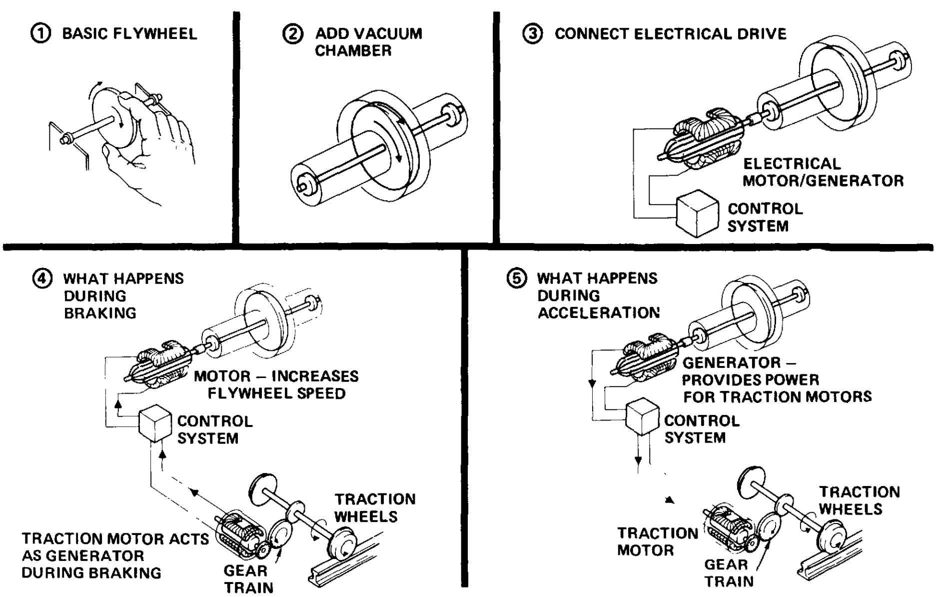


Figure 6.10.2 How the unit works

Design study for the retrofitting of flywheel units (ESU'S) under the carbody of existing commuter trains 6.10

N.V. Nederlandse Spoorwegen
Moreelsepark 1
NL — 3500 HA Utrecht

F. OUDENDAL

Contract number: EE-E-3-441-NL

The aim of the NEDERLANDSE SPOORWEGEN project is to test the application of flywheels in trains. The concept has been proven in the New York metro cars, and may be attractive to commuter service trains as well. As each railroad passenger car in a multiple unit train in commuter services wears out a large number of brake blocks, the application of flywheels would not only save traction energy—about 20%, or more—but also the energy for producing the brake block (reduction of brake block wear by 50% saves 800 kg of brake blocks per year equivalent to 4.44×10^3 kWh of manufacturing energy per year per train) and will also lead to lower maintenance costs.

A design study in progress will elaborate the mechanical modifications required to retrofit flywheel units of 1 MW and associated equipment, under the floor of two existing car trains type V (using 2 ESU'S per train it is expected to save 2.5×10^5 kWh per year per train).

Since the pay back period for such a system is long, it is not likely that this development will pay for itself in the near future. NEDERLANDSE SPOORWEGEN, however, still remains interested in this subject because of the lower maintenance outlay and costs, and advantages which cannot always be directly expressed in money terms, such as the reduction in noise generated during the braking period.

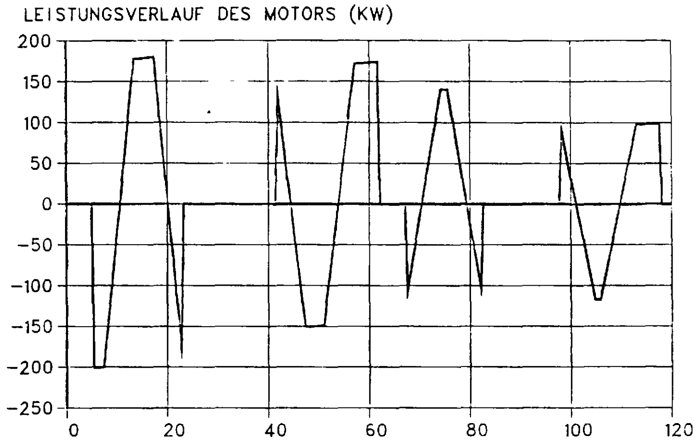


Figure 6.11.1 Development of power use (kW) of crane engine

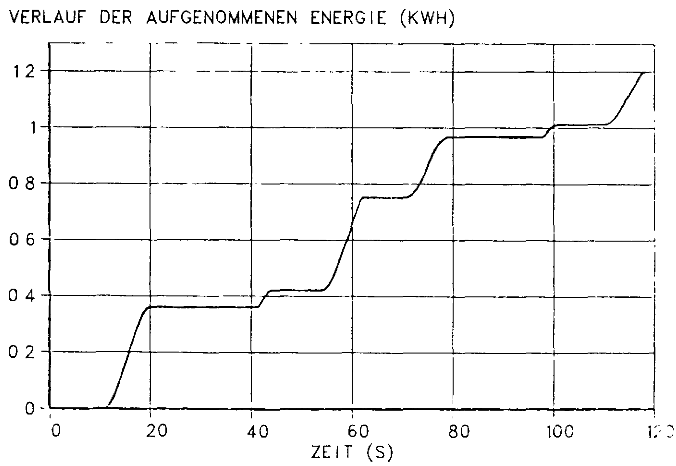


Figure 6.11.2 Energy (kWh) taken up by the crane engine as a function of time.

Development of a flywheel storage unit for energy saving in crane driving gears 6.11

Friedrich Krupp GmbH
Postfach 10 22 52
D — 4300 Essen 1

E. HÉJJ

Contract number: EE-E-3-442-D

FRIEDRICH KRUPP GmbH is investigating the possibility of saving energy by means of flywheel energy storage systems applied to cranes.

KRUPP examined several crane types for best flywheel application. They took into consideration different criteria and classified the different cranes in order of priority. Finally, they selected one type with a power of 150 kW. Calculated results indicate that while the pay back period for retrofitting a crane of this type is too long (average 21 years), the pay back period for a new crane is at the acceptable limit (average 7.8 years).

A 10 kW pilot plant flywheel with an energy storage capacity of 330 Wh is now being built.

European Communities — Commission

EUR — The second energy R & D programme — Energy conservation (1979-83) — Survey of results

Edited by: P. Zegers, P.A. Pilavachi

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