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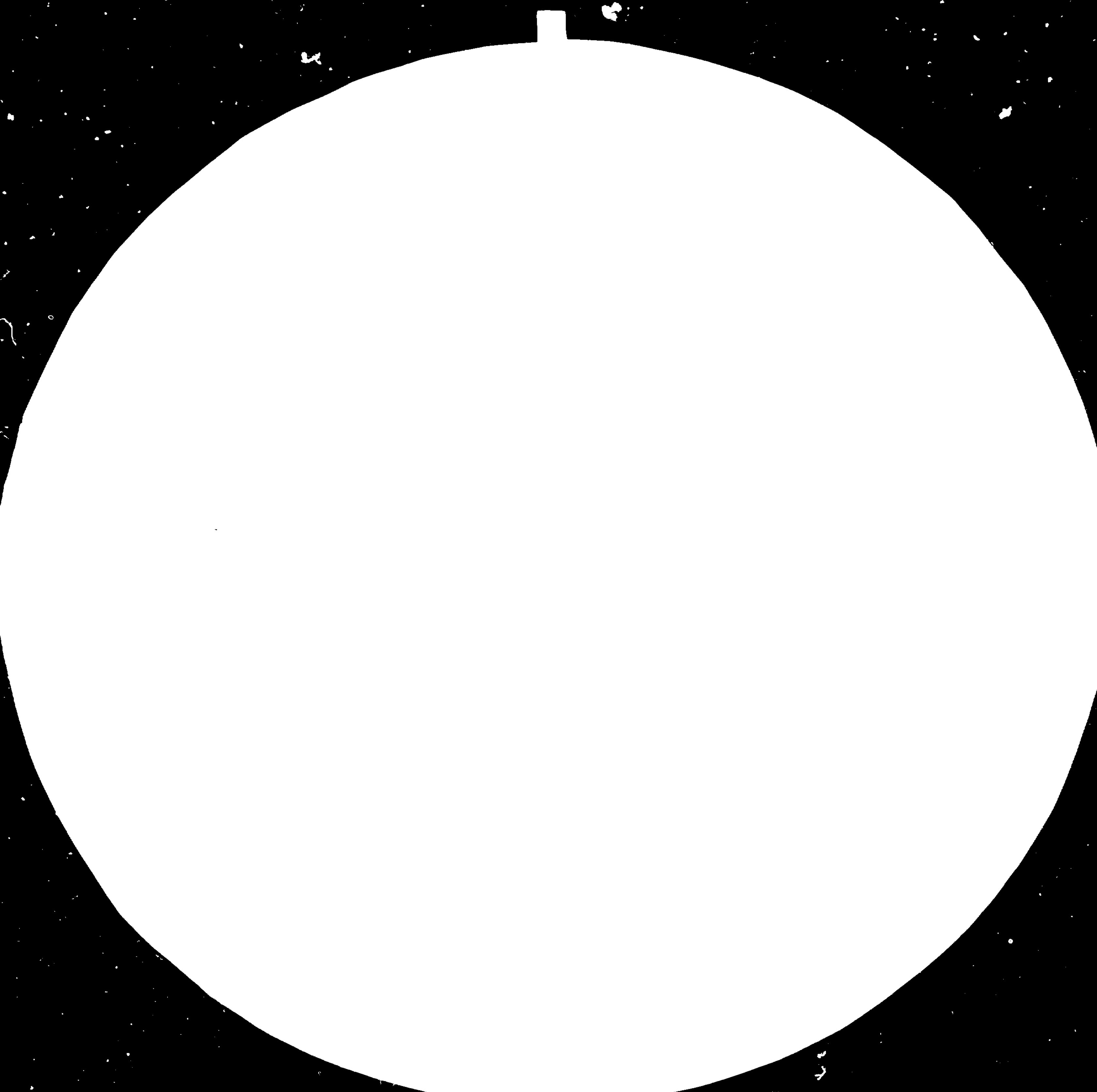

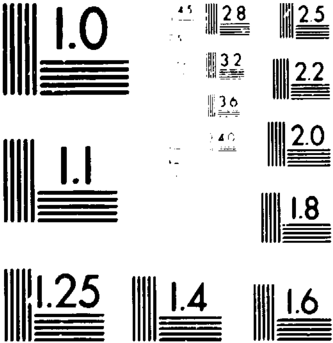
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DP/ID/SER.A/519
27 June 1984
English

ENERGY CONSERVATION IN INDUSTRY

DP/EGY/83/001

EGYPT

Technical Report: Waste Heat Recovery Techniques*

Prepared for the Government of Egypt
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of R.S. Darby,
Expert in Waste Heat Recovery Techniques

United Nations Industrial Development Organization
Vienna

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V.84-87884

EXPLANATORY NOTES

T.I.M.S.	:	Institute of Metallurgy at El-Tabbin
I.C.E.E.	:	Industrial Energy Conservation Centre attached to T.I.M.S.
Mazoot	:	Heavy Fuel Oil (Composition given in Appendix I)

1 Egyptian pound approximately 1.2 U.S. dollars

ABSTRACT

This report is concerned with the establishment of an Industrial Energy Conservation Centre in Egypt - reference DP/EGY/83/001/11-03/ 31.9.C. It deals specifically with the requirements of Egyptian industry and assistance given to the staff of the I.E.C.C. to provide advice and support in the introduction of waste heat recovery techniques. The mission covered a period of four weeks. The main recommendations are that a mobile unit equipped with measuring and metering devices be supplied to the centre and that the staff there should have experience of all energy intensive sectors throughout Egyptian industry and be aware of the practical as well as the theoretical aspects of energy conservation.

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APPENDICES

INTRODUCTION

This report covers the results of a mission to Egypt which lasted from 4th May to 29th May, 1984. During this period I was attached to the I.E.C.C. The I.E.C.C. has been established with the aims of assisting public and private industries to achieve definite measures and targets for energy conservation. The duties of the mission called for the preparation of training programmes and practical tuition in the techniques of waste heat recovery and in particular :

- training courses in the methods of waste heat recovery.
- training courses in the techniques of installing equipment to recover and re-utilise waste heat.
- assistance to I.E.C.C. staff in carrying out theorectical and practical investigations and assessments in waste heat recovery.
- assistance to I.E.C.C. staff in appraising energy conservation aspects in new projects.

Lectures on the above and related topics were given to the staff of I.E.C.C. and also to those who attended the workshops which were arranged for engineers from the chemical and metallurgical industries. Visits were made to six sites which had energy intensive processes. The workshops and the visits provided opportunities for informal discussions on a number of potential energy conservation projects.

Consequently it has been possible to make a preliminary diagnosis of the awareness of energy conservation in Egyptian industry, the present status of the I.E.C.C. and to recommend certain priority actions in order that the objectives of the I.E.C.C. may be achieved.

RECOMMENDATIONS

The following recommendations are put forward :

Items	Action
i) An "Energy Bus" is made available to the I.E.C.C. in Egypt, preferably purchased as a fully equipped unit.	U.N.I.D.O.
ii) The I.E.C.C. gains experience of the energy requirements and techniques throughout the range of industrial sectors and also finds means of increasing its knowledge of industrial procedures.	I.C.E.E.
iii) The operation and energy conservation opportunities in steam raising plant be given specific attention.	I.C.E.E.
iv) Training courses for energy manager should include energy audits and industrial housekeeping and be practical in their approach.	I.C.E.E.
v) Training courses abroad should include visits to successful applications of waste heat recovery systems.	U.N.I.D.O./ I.C.E.E.
vi) Facilities for testing and demonstrating equipment in the T.I.M.S. laboratories should include steam raising plant.	I.C.E.E.
vii) A joint study into a waste heat recovery project by an U.N.I.D.O. expert and I.C.E.E. be considered.	U.N.I.D.O./ I.C.E.E.

Items	Action
viii) The opportunity for co-generation should be exploited, particularly where natural gas is available.	I.C.E.E.

I SCOPE OF ACTIVITIES

A Training Lectures

Four lectures were delivered to the staff of I.E.C.C. and to engineers from the chemical and metallurgical industries. These lectures were entitled :

- Energy Audits and Industrial Housekeeping.
- Energy and the Chemical Industry
- The Principles of Waste Heat Recovery
- Methods of Waste Heat Recovery

The theme of the lectures was to set out a systematic approach to energy conservation, together with details of the practical methods now available for implementation. Detailed lecture notes and a full explanation of particular topics were prepared and distributed to those who attended.

The lecture notes for "Factors Affecting the Successful Implementation of Heat Recovery Equipment" were circulated, but not presented.

The content of these lectures is summarised in Appendix II.

B Site Visits

1) Helwan Iron and Steel Company

This is a large industrial complex consisting of an integrated iron and steel process. It was stated that the blast furnace gas, nominally of 28% carbon monoxide content, is variable in calorific value and not always available as a fuel. This creates operating problems for processes which depend on this gas. Investigations are therefore proceeding to supplement it with up to 10% natural gas.

One such process is a pusher furnace, used for pre-heating steel. This furnace has a ceramic and a metallic recuperator in series, which recovers heat from the furnace exhaust gas to preheat the combustion air and blast furnace gas respectively. The temperature of the exhaust gas is 850°C, the preheat temperatures 500°C and 250°C, and the flue gas prior to the stack is 400°C.

Partial substitution of natural gas will affect the quantity of combustion air needed and care must be taken not ot overheat the natural gas/blast furnace gas mixture. The staff of I.C.E.E. had studied the system and concluded that an air bleed before the metallic recuperator, will provide the best solution, with some improvement in thermal efficiency. This is a somewhat complicated situation, taking into account the thermal requirement within the furnace. It was not therefore possible to make any detailed comments, other than to enquire whether the quality and quantity of blast furnace gas could not be improved and therefore avoid these modifications. It had been hoped to meet a senior energy manager from the iron and steel company, in order to pursue the matter further, but unfortunately this did not take place.

2) <u>Delta Iron and Steel Company</u>

Met : Eng Mahrous Hanna Ibradixm (Energy Manager)

This company has three electric arc furnaces, using scrap steel as feed material together with steel rolling mills. The preheating plant is shortly to be rationalised so that only one furnace fitted with a metallic recuperator is operated.

This furnace supplied by Wellman U.K. has the following characteristics :

- oil fired, pusher type used for preheating square steel billets.

- size of billets approximately 130 x 130 x 1300 mm.

- rate production 15/18 tonnes per hour.

- temperature of billet 1230°C, residence time 195 mins.

- furnace dimension 1760 cms long, 335 cms wide.

- pusher load 56 tonnes, pusher speed 4.5 cm per sec, pusher stroke 2 metres.

- normal fuel consumption 650 kg per hour. Oil delivered at 0.5 kg/cm².

The metallic recuperator preheats air to 250°C and the flue gas is discharged at 400°C. The waste gas is diluted with air before and after the recuperator. It is not entirely clear why these air bleeds are included in the design, whether it be due to the furnace requirements or the materials of construction employed. In principle a higher air preheat and therefore more fuel saving could be achieved. My advice is to seek guidance from Wellmans.

A small boiler is installed to provide steam tracing for the Mazoot. Electrical tracing is also used. Stand-by diesel sets are installed.

3) The Elman Glass Company

Met : Eng Aly Easa (Works Manager)
Eng Mahmoud Elzud
Eng Audil Kamel

This factory produces bottles for the pharmacutical and soft drinks industry. A special grade of glass is purchased abroad for conversion into ampoules. A small oxygen plant services the needs of the ampoule process. Standby diesel sets are installed for power generation, when the public supply fails. The normal power requirement is 4/5 MW. A small boiler provides steam for preheating the Mazoot.

Mazoot is used for firing the melting furnaces. Cyclic regenerators preheat air to 1100°C. Flue gas is discharged at 500/600°C. The retaining furnace is fired with bottled gas and the annealing furnace is being converted to electrical heating.

The characteristics of recuperative burners and also measures that are being employed to recover and re-utilise the relatively low grade waste heat from glass making processes, were discussed and details provided. However, these latter applications are usually associated with space heating, which is not applicable to the Egyptian climate.

The various departments of the site are well laid out and the production operated continuously in a controlled manner. The instrumentation covers the process adequately and automatic systems, such as for the ampoules and bottling plant, are employed.

4) Society of Sugars and Distilleries in Egypt

Met : Eng Abdul Mocti El Gazzar (Chairman of the Distillation Company)

This is a large company operating many factories throughout Egypt. Sugar is processed from cane in Upper Egypt. The by-product bagasse is used as the fuel for raising steam in the factories. Excess bagasse is processed into paper.

Molasses arising from the sugar process are transported to factories near Cairo, where they are converted into industrial alcohol, acetic acid and other chemicals. In these factories mazoot is used as the fuel for raising steam and back-pressure steam turbines are installed.

The distillery was visited, where the molasses are fermented to alcohol and concentrated by distillation. Some of the alcohol is oxidised through the acitic acid. It was noted that the distillation columns were not lagged, despite an operating temperature of around 100°C. Apart from steam pressure, the other operating parameters at the boiler house, were not measured.

This factory had an effluent problem arising from the slops discharged at the base of the distillation column. The quantity and composition of the slops were supplied and this will be taken up separately in the U.K.

5) Middle East Paper Company

Met : Eng Laila Mohamed Ghamem (Chief Electrical Engineer)

This factory produces 50/60 tonnes per days of three ply paper for cartons and similar items. Three sources of waste are repulped, refined and blended for a single paper line. Water is removed mechanically from the pulp down to 60%, prior to the drying cylinders. The drying cylinders are covered with a hood, which is now the normal practice. However, the waste heat in the steam discharged is not being recovered and could be re-utilised for preheating air to assist the drying process. Details of systems which are being used for this heat recovery duty were described.

The factory has a power requirement of 2.5 MW. Equipment had been installed to maintain the power factor above 0.9. Apparently this can be a major problem in Egypt. The factory suffers from failures of the public power supply, but no standby generating sets are installed.

The steam raising plant consists of two Japanese manufactured boilers, each fitted with a steam heater and a recuperator for recovering heat from the exhaust gas, in order to preheat the combustion air to 116°C. The flue gas temperature was claimed to be 260°C. In principle the use of steam for preheating air, is not sound. Measuring devices installed were few and some of these were not working. With this type of process it should be feasible to collect and return all the condensate. It appeared that only about 50% is being recirculated. A substantial water treatment plant is installed for the make-up water. Corrosion had been occurring in the flue duct prior to the chimney, due to the pressure of sulphur in the mazoot.

Each boiler is nominally capable of raising 20 tonnes per hour of saturated steam at 28 atmos. The process requires only 7 tonnes per hour of steam at 3 atmos.

Self generation through a pass out steam turbine should be feasible and might be economic. Due regard needs to be taken of future plans for a conversion process and a paper tissue line. It was agreed that a system for self-generation will be studied.

6) Talfa Fertiliser Company

Met : Production Manager

This factory is one of many operated by the company. It is typical of a modern chemical complex, with heat and power recovery integrated into the design of the process, supplied by mainly German companies. The processes included plants for the manufacture of ammonia, nitric acid, urea and ammonium nitrate. A relatively small quantity of purge gas containing 60/70% of hydrogen is being discharged to atmosphere and studies are proceeding for the recovery of the hydrogen, through pressure swing adsorption.

Any sensible analysis of the energy flows for this site would require considerable effort and expertise. However, there might be a case for studying the utilities to determine whether improvements are feasible. It has to be accepted that any changes are likely to be capital intensive. The availability of natural gas is an important factor both as the feedstock and source of energy.

C Energy Queries

In addition to visits to the factories, queries arose during discussions after the training lectures. The more important are summarised as follows :

1. Electro Cable Egypt

Met : Eng Ahmed Rida (Chief of Erection Department)

This company produces aluminium wire from an electric annealing furnace. The process consists of heating the wire to 430°C, holding at 370°C for 3½ hours, and then cooling down to 150 - 200°C. Hot dry air at 200°C is discharged from the furnace at $8m^3$/sec.

The factory has 4 x 8000 lbs/hr of steam raising boilers at a pressure of 12 atmos. Normally two boilers are operating and the other two on stand-by duty. Approximately 50% of the boiler feed water is supplied from recovered condensate. The company has been quoted for a de-mineralisation plant for the make up water at prices around 200,000 Egyptian pounds. Because of this high cost, Eng. Ahmed has been considering the recovery of the waste heat in the exhaust air to preheat the make up water, prior to distillation in order to remove the impurities. The type of heat recovery equipment being suggested for this duty is a spray recuperator.

My advice was that neither of these proposals were sound. Furthermore the price quoted for the de-mineralisation plant, based on the data provided, was absurdly high. Eng. Ahmed was put in touch with the representative in Cairo of a well known U.K. water treatment company in order to resolve this matter.

A spray recuperator is not recommended for recovering thermal energy from dry air. Assuming that an economic de-mineralisation plant can be installed, then the waste heat in the air might be considered for preheating the feed water to the boiler, employing a conventional shell and tube heat exchanger.

2. Sulphuric Acid Plant

Met : Eng Abl El Rahman Orima

This plant is part of a fertiliser complex. High pressure steam recovered in the process is reduced through turbines to generate electrical power. The sulphur trioxide heat exchanger preheats the dry air entering the process from 50°C to 255°C, whilst the sulphur trioxide is cooled from 490°C to 300°C. Corrosion is occurring at the cold air inlet, allegedly due to acid condensation. Advice will be given on my return to the U.K.

3. Steam Pressure Reduction

Instances were quoted of the steam pressure generated at the boilers being substantially higher than required for the prescribed process duty. The steam pressure is let down through reducing valves. The availability of simple steam turbines to replace such valves, with consequent generation of electrical power, might be justified in Egypt, given also the unreliability of the public supply.

D I.E.C.C. Needs

Consultations of this matter took place mainly with Dr. Ahmed Amin and his staff from the I.E.C.C. There were discussions also with Madam Mona Hetata, the programme officer for U.N.D.P. in Cairo and Professor Selim, who is in charge of the project at I.E.C.C. The topics discussed were as follows :

1) The Energy Bus

It appears that two engineers from U.N.I.D.O. had previously visited Cairo and had recommended that the availability of an "Energy Bus" would assist the I.E.C.C. The request for a computer to control the blast furnace operation at the iron and steel company, is a separate and unrelated matter. The proposal for the "Energy Bus" is strongly supported.

It would be preferable for the "Energy Bus" to be purchased as a mobile unit, complete with all necessary measuring devices. This should include means of measuring fluid flows, temperatures and electrical power. It should also include means of measuring the composition of the production of combustion in the flue gas discharged from steam raising plant and furnaces. Normally this means carbon dioxide, oxygen and carbon monoxide.

2) Training Programmes

The I.E.C.C. already organises energy conservation workshops for Egyptian industry. It is felt that training courses directed towards energy managers be arranged, but that these should be more practically and production orientated. The outlines for such a course are shown in Appendix III. Much of the content can be derived from the lecture notes and other data supplied during this mission.

3) Energy Courses in the U.K.

The Cranfield Institute of Technology and the University of Sheffield are recommended as institutions which hold courses in waste heat recovery and energy management, suitable for sending staff from I.E.C.C.

4) Laboratory Equipment

T.I.M.S. is set up as an institute for studying and providing courses for the metallurgical industry. Consequently the laboratory equipment relates to that industry and provides few means of demonstrating energy conservation techniques.

If additional equipment is to be purchased, then a small steam raising boiler should be considered. This would allow practical demonstration of good boiler practice. It might also be provided with a small number of appropriate heat exchangers, such as an economiser, thermal wheel, heat pipe etc., which would also provide valuable experience.

5) Energy Targets

The I.C.E.E. will need to gather together the energy consumptions for sectors of Egyptian industry. These can be usefully compared with those achieved by similar industries in Western Europe. A short list of the energy usages for some sectors of the U.K. industry is set out in Appendix IV.

6) Communications

The library at T.I.M.S. has a reasonable range of books on energy conservation and related topics. One recently published book is recommended for purchase - "User Guide on Process Integration for the Efficient Use of Energy", published by the U.K. Institution of Chemical Engineers.

II FINDINGS AND CONCLUSIONS

The I.E.C.C. has been given a number of roles within the overall objective to assist Egyptian industry to save energy. This mission is concerned with the practical application of waste heat recovery methods. Therefore, these conclusions relate to the steps which need to be taken by Egyptian industry and the ability of the I.E.C.C. to provide advice and practical support.

The principles by which energy conservation should be approached and the methods available for waste heat recovery and other energy saving techniques are well established. It is useful to briefly outline these principles and then consider their status in the context of the existing operation of Egyptian industrial processes.

A programme directed towards the more effective use of energy, commences with an energy audit. This will invariably identify simple measures which save energy, can be carried out quickly and with little cost. However, such an audit presupposes that variables can be measured and then controlled. Lack of measurement and also housekeeping were evident in some of the factories visited. The proposal that the I.E.C.C. be provided with an "Energy Bus" is therefore very sound. Such a unit equipped with measuring and metering devices would be used to determine the efficiency of energy intensive processes, diagnose the faults and hence point the way to improvement. Demonstration of the effectiveness of this approach is likely to lead to requests for the appropriate instruments to be permanently installed.

The selection and installation of waste heat recovery equipment should be preceeded by a systematic appraisal of the total process and a thorough understanding of the merits and limitations of equipment commerically available. This type of information is either not available or is not readily available in Egypt. It has to be said that in some instances there is really no substitute for being able to examine a new piece of equipment and discuss its performance with operating staff. Egyptian engineers seldom have this opportunity. In this context it was noted during the visits to the metallurgical industries that, gas to gas recuperators are used, but not thermal wheels or recuperative burners which can offer advantages, nor for that matter was ceramic fibre used for insulation. When I.E.C.C. staff attend training courses abroad visits to factories utilising the latest techniques in waste heat recovery should be arranged.

The staff of I.E.C.C. suffer from two disadvantages, which are recognised. The first is that their qualifications and experience are directed towards the metallurgical industry. This industry provides many opportunities for energy conservation measures, usually related to high temperature solids and gases. Other industries have equal scope for energy conservation, but the nature of the processes and therefore the equipment required can be quite different from that of the metallurgical industry. It is important that I.E.C.C. staff gain experience of a wider range of industrial sectors. The second disadvantage is that whilst the staff are highly qualified academically, they lack practical industrial experience. In the first instance this may cause difficulties in the preparation of training courses for industrial energy managers. These courses should reflect both the practical as well as the theoretical aspects of waste heat recovery.

There are two energy matters which deserve special attention. The operation of steam raising plant in Egypt does not seem to be of a high standard. There is a lack of measuring and metering devices and from the data which is available, it could be deduced that boiler efficiences are low. Steam raising plant is common to most sectors of industry. Very significant quantities of fuel can be saved by improving their operation and studies into the potential for heat recovery will frequently lead to further economics. It is therefore suggested that the I.E.C.C. staff should specifically study the energy saving opportunities arising from steam raising plant. The "Energy Bus" will be invaluable for such work. The selection of a mini boiler plant as an initial starting point for laboratory equipment is influenced by the importance of steam generation in process industry.

The second matter is cogeneration or total energy systems. Many European countries and the U.S.A. are actively promoting cogeneration, due to the higher thermal efficiency compared with conventional power stations. It can be argued that Egypt has an additional incentive in that the public power supply is not entirely reliable, to the extent that some industries have found it necessary to instal standby diesel sets. During the visits to the factories, it was noted the cogeneration is being practised on those sites which have particularly high steam and power loads. However, the increasing availability of natural gas for industrial use should greatly increase the opportunities for applying cogeneration, as this fuel is used in gas turbines. The gas turbine is particularly well suited for providing heat and power to match industrial demands.

Summarising the I.C.E.E. is at an early stage in starting to meets its objectives. It will need to extend its skills and experience. The I.C.E.E. must also seek to gain credibility throughout the various industrial sectors by demonstrating that it can provide practical advice and support. In the event that a further mission to Egypt is arranged, it would be worthwhile for the I.C.E.E. to identify a specific industrial waste heat recovery project beforehand, which the I.C.E.E. staff and the expert could then study together.

APPENDIX I

COMPOSITION OF MAZOOT

This is a heavy fuel oil frequently used as the fuel for boilers and furnaces in Egypt. Its characteristics are:

Nett calorific value	:	9500 Kcal/kg
Specific gravity	:	950 Kg/m^3
Flash point	:	65°C (min)
Sedement	:	0.25% by weight
Water content	:	1% (by volume) max.
Sulphur content	:	2 - 3.5% (by weight)

APPENDIX II

CONTENT OF TRAINING LECTURES PRESENTED

1) Energy Audits and Housekeeping

- Definition of objectives
- Data collection
- Data analysis
- Housekeeping measures

2) Energy and the Chemical Industry

- European situation
- Cogeneration
- Use of waste combustible matter

3) The Principles of Waste Heat Recovery

- Heat recovery
- Heat transfer theory
- Fouling resistance
- Mean temperature difference
- Types of waste heat
- Cost benefits

APPENDIX II (cont)

- Selection of heat exchangers, merits, limitations and costs
- Heat exchanger design
- Systems design

4) Methods of Recovery

- Shell and tube heat exchangers
- Plate heat exchangers
- Run around coils
- Economisers
- Spray recuperators
- Gas to gas recuperators
- Regenerators
- Thermal wheels
- Heat pipes
- Recuperative burners
- Waste heat boilers
- Heat pumps
- Power recovery

APPENDIX II (cont)

- Organic rankin cycle heat engines
- Reliability problems

5) Factors Affecting the Successful Implementation of Heat Recovery Equipment

- Design
- Mal-distribution of flow
- Vibration
- Thermal fatigue
- Installation
- Insulation
- Preferred configuration

APPENDIX III

TRAINING PROGRAMME IN WASTE HEAT RECOVERY

1) The Overall Energy Scene

- The World Energy Situation
- The Egyptian Energy Situation
- Egyptian Government Policy

2) The First Stage

- Energy Audits
- Industrial Housekeeping

3) The Principles of Waste Heat Recovery

- Heat Transfer Theory
- Mean Temperature Difference
- Heat Exchanger Design
- Systems Design
- A Systematic Approach to Heat Recovery

4) Sensible Heat Exchange (Single Phase)

- Recuperators

e.g. shell and tube heat exchanger (liquid/liquid).
plate heat exchangers (liquid/liquid or gas/gas).

APPENDIX III (cont)

run around coils (gas/gas).
tubular, convection and radiation (gas/gas).
recuperative burners (gas/gas).

- Regenerators

e.g. heat wheels (gas/gas).

5) Latest Heat Exchange (Two Phase)

- Boilers and Evaporators

- Economisers

- Condensers

6. Novel Types

- Water Spray Injection (spray recuperation)

- Heat Pipes

- Heat Pumps

- Vapour Recompression

7. Power Recovery

- Cogeneration (combined heat and power)

- Turbine Expanders

- Organic Rankin Cycle Heat Engines

APPENDIX III (cont)

8. Demonstrations of Existing Heat Recovery Scheme

Select examples from Egyptian industry.

APPENDIX IV

ENERGY USAGE FOR VARIOUS U.K. INDUSTRIES

Energy Usage

(taken from "Making the Most of Materials" published by the Science Research Council in 1979)

Industry	Thermal Energy (G. Joule per tonne)	Power (k.W hr (th) per tonne)	Combined (G. Joule per tonne)
1. Iron and Steel			24
2. Aluminium			
- Smelting	212	59	
- Smelter coating	4.3	1.2	
- Remelt cast shops	9	2.5	
- Secondary smelting	14	3.9	
- Rolling	24	6.6	
- Foil	18	4.9	
- Extrusion	25	6.9	
- Casings	48	13.2	
3. Copper			
- Foundries			7 to 74
- Semi manufacture			11 to 26
- Hot stamping			64 to 68
4. Glass			24
5. Cement	3 to 6	80 to 120	
6. Coke			2.2 to 2.8
7. Textile Finishing			45 to 60
8 Paper	7 to 18	4 to 16 (as GJ/tonne)	