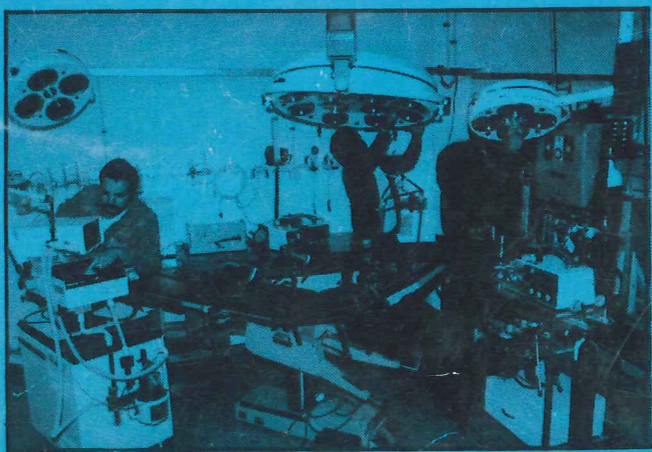
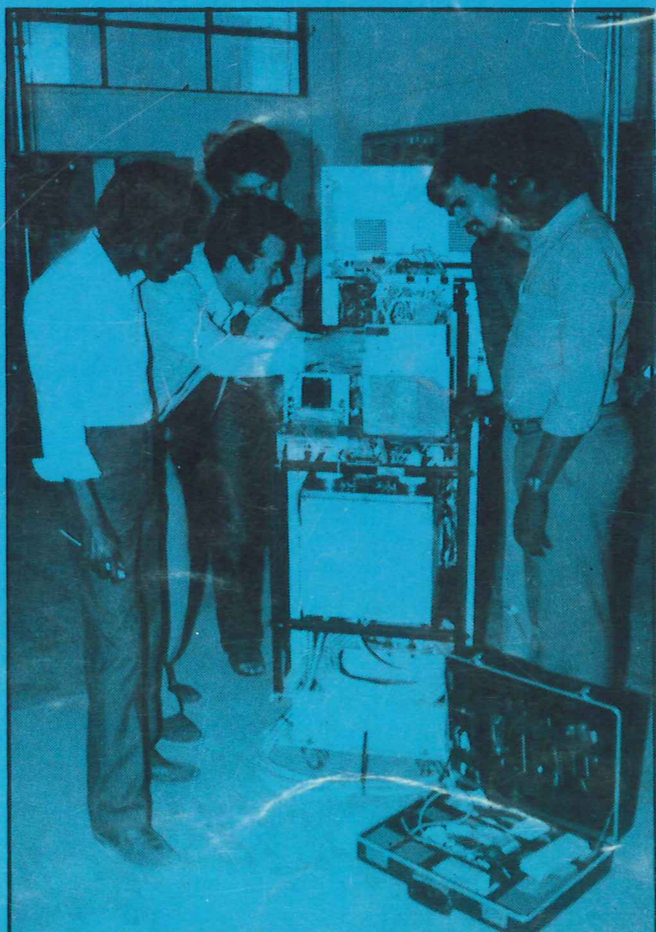
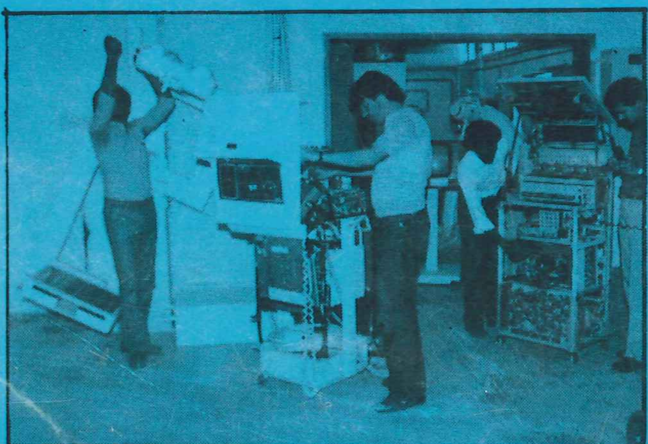
No. 15 June 1986 Nicosia Cyprus

# Review

## THE HIGHER TECHNICAL INSTITUTE



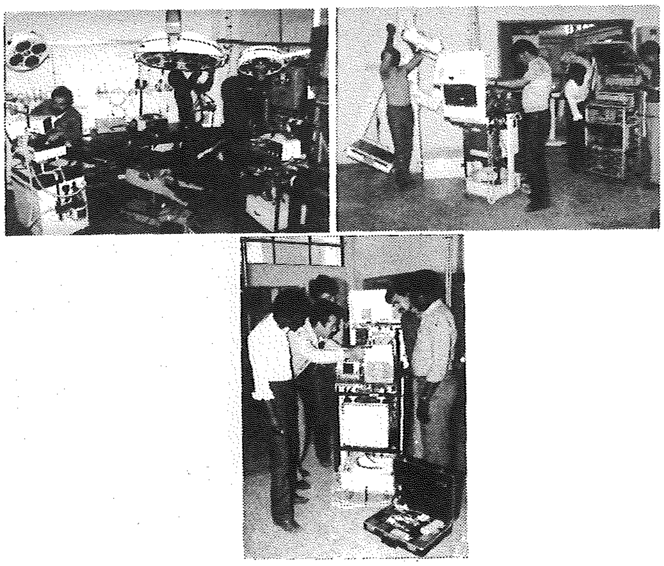




**Review**
**No. 15**
**June 1986**
**Nicosia**



**W.H.O. - sponsored students at work**
**R.T.C./HTI 1985-1986**



**Photos by I. Angeli**

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CONTENTS

The Higher Technical Institute (H T I) was established in 1968 as a Government of Cyprus project with assistance by the United Nations Special Fund (UNDP), the United Nations - Educational Scientific and Cultural Organisation (UNESCO), and the International Labour Office (ILO). Cyprus Government Executing Agency: The Ministry of Labour and Social insurance.

HTI Review

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## EDITORIAL

# We Are Looking into the Future!?

**Some Facts:**

- The Engineer must possess updated knowledge and skills in a multiplicity of disciplines.
- The country needs competent Technicians, Technician Engineers, Engineers and Managers.
- The new Technological era is engulfing us all.
- Fifth generation computers are at our doorstep.
- Bioengineering is THE THING for tomorrow.
- Fibre optics communication systems are here.

**However:**

1. The mumble - jumble of words that don't get-off the ground:
   - Lifelong Education.
   - Engineering trainers must keep up-dated.
   - Staff - retraining programmes.
   - New learning processes.
   - New instruction technologies.
2. The merry - go - round of words keep popping up daily, weekly, monthly, yearly!

**Shouldn't we All be Concerned?!**

# A STATE-MODEL REPRESENTATION OF NATIONAL ENERGY SYSTEMS: THE CASE OF CYPRUS

by Dr T. Drakos, MSc, PhD, CEng, FIEE, FIMechE

Abstract: In consideration of a review period of twenty years and of the characteristics of a small and developing economy, the national energy system is formulated in the time-domain. In the state-model description of the system $\dot{x} = Ax + Bu$ the disaggregated fuel requirements are the state variables and the disaggregated sector demand conditions are the control signals. The system and distribution matrix coefficients are expressed in terms of sectoral activities and fuel intensities and they characterize the system structure by reflecting fuel 'conservability' and sectoral fuel 'substitutability' respectively. An analysis of the Cyprus system is presented as it has evolved in recent years with reference to the structure of economic activity, energy demand and supply. In view of the identified determinants of sectoral fuel intensity variation appropriate submodels are introduced so as to estimate on a year to year basis sectoral fuel intensity variations in respect of the different mechanisms of change such as conservation, structural changes and substitution. Fuel requirements for the planning period are predicted in conjunction with scenario assumptions regarding sectoral growth, fuel price variation, conservation potential and timing. With the aid of the estimated values of the system and distribution matrix coefficients of the state-model it is possible to gain an insight into the dynamic behaviour of the structure of the national energy system.

## 1 Introduction

Energy forecasting as an aid to energy planning has attracted increasing attention in recent years following the oil crisis of 1973 and the ensuing instability of oil prices. Many models have been developed seeking to show how diverse energy scenarios depend on alternative policies that may be under the influence of governments and planners.

Such models can be classified as[1]:

(a) Energy/economic models which model the relationship between energy demand and the entire economy[2].

(b) Optimizing models concerned with the optimal allocation of fuels within a sector or within the entire economy[3].

(c) Energy industry models

(d) Sectoral demand models

(e) Energy system models that provide an integrated picture of supply and demand for all sectors[4].

Energy/economic models usually employ econometric concepts and represent energy demand as a function of GDP and the price of energy. However, the energy-GDP relationship in the energy systems of small and developing countries is not usually stable even when averaged over long periods. For example in the case of Cyprus, while energy consumption accounted for 4.5 percent of GDP in 1960 it stood at 11.5 percent of GDP in 1980.

Optimizing models usually employ linear programming techniques and they allocate the potentially available amounts of individual fuels among the various demands on the basis of priorities such as non-substitutable uses and least resource cost, with the available supplies of a particular fuel being confined to the markets in which it has the greatest economic value. In the case of Cyprus which relies almost completely on imported oil for its energy needs, the usual optimization methodology would not be realistic and more pragmatic and judgemental methods can be used in order to develop energy scenarios that optimize the system with regard to the deployment of new sources.

However, the need exists for the development of forecasts of disaggregated fuel demand under conditions where the country may attempt to minimize its dependence on oil imports by maximizing conservation and deployment of renewables and coal in some cases. In this context an energy system model giving energy balances for the purpose of developing forecasts and energy scenarios, can be employed to study alternative energy policies. The projections can be based on econometric data and would depend on exogenous assumptions about future sectoral growth and fuel prices, the uncertainty of which would necessitate the use of the scenario method.

Moreover, in the case of a small economy where also suitable data exist it is possible to develop a unified mathematical model which would compactly illustrate the structure and dynamic development of the entire energy system.

## 2 A time-domain formalism

For a system comprising an n number of fuels and an m number of sectors the physical basis of a state-model representation is the relationship

$$x_i(t) = \sum_{j=1}^{m} I_{ij}(t) Y_{ji}(t) \qquad i = 1,2,\ldots,n \qquad (1)$$

where $x_i(t)$ is the total ith fuel requirement

$I_{ij}(t)$ is the ith fuel intensity in the jth sector

$Y_{ji}(t)$ is the output or activity level in the jth sector utilizing the ith fuel

Let $\Delta t = T = 1$ year, thus expressing the model variables as averages of annual quantities for the purpose of simulating changes on a year to year basis Then by expanding equation (1) for $x_i(t+T)$

$$\Delta x_i(t) = \sum_{j=1}^{m} Y_{ji}(t)\delta I_{ij} + \sum_{j=1}^{m} I_{ij}(t)\delta Y_{ji} + \sum_{j=1}^{m} \delta I_{ij}\delta Y_{ji} \quad (2)$$

$$i=1,2,\ldots, n$$

It would be realistic to ignore the third term in equation (2) on account of the fact that by so doing time lags are catered for to some extent and further the pitfall of symmetry or 'reversibility' is avoided, noting that a negative change in activity would not interact with a change in fuel intensity. With this term neglected equation (2) may be re-written

$$\Delta x_i(t) = a_{ii}^{(c)}(t)x_i(t) + \sum_{j=1}^{m(s)} b_{ij}(t)u_j(t) \quad (3)$$

$$\text{where } a_{ii}^{(c)}(t) \equiv \frac{\sum_{j=1}^{m} \delta I_{ij}^{(c)} Y_{ji}(t)}{\sum_{j=1}^{m} I_{ij}(t)Y_{ji}(t)} \quad (4)$$

$$b_{ij}^{(s)}(t) \equiv \frac{\delta I_{ij}^{(s)} Y_{ji}(t)}{\sum_{i=1}^{m} I_{ij}(t)Y_{ji}(t)} \quad (5)$$

$$u_j(t) = \sum_{i=1}^{n} I_{ij}(t)Y_{ji}(t) \quad (6)$$

and in compact form

$$\Delta x = A^{(c)}x + B^{(s)}u \quad (7)$$

It can be seen that this state-model representation is physically meaningful in that the state variables x are those variables which characterize the state of the energy system, i.e. fuels aggregated by type, the control inputs u are the total sectoral energy demands and the variable coefficients A and B which are x and u dependent respectively characterize the system structure as it evolves dynamically in a practical system, reflecting respectively the trends in 'conservability' of particular fuels across all sectors and of the particular fuel 'substitutability' in individual sectors. The national energy system is thus placed within the broader framework of modern control theory concepts.

## 3 Trends in the Cyprus system

In older days the backbone of the economy was the export of agricultural products and minerals. Recently the tourist industry has been a significant contributory factor in the economy and a good measure of an industrial base has been reached, with exports of cement, footwear and clothing featuring prominently. Structural changes in fuel demand in the period 1960-1980 reflect salient changes in the economic structure as can be seen from table 1. The share of fuel oil has increased significantly due to the expansion of the cement industry and the rapid increase in electricity generation. Table 2 shows the historical electricity consumption which has increased everywhere with the share of the industrial sector growing at the expense of the commerical sector, reflecting industrialization. Structural changes in overall economic activity are readily attributable to relative changes in inter-sectoral activity while structural changes within individual sectors are not discernible. In fact an examination of individual sectoral activity shows that the sectoral product mix has not changed significantly in recent years. These observations suggest that the precision of forecasting may be improved by adopting a low level of sector aggregation in the modelling system. The availability of time-series data[5] enables the total economic activity to be disaggregated into a number of sectors in each of which both activity and fuel consumption are adequately homogeneous for separate representation in the model. Thirteen demand sectors have been considered many of which are in fact subsectors of the manufacturing industry. These are shown in the structured disaggregation matrix of table 3 for the year 1980. Similar data were compiled for the stable period after the 1974 war in Cyprus and based on these data related fuel intensities have been calculated. The consequent evaluation of fuel intensity variations from year to year throws some light on energy savings caused by rising fuel prices, increases of intensities due to continuing mechanization notably in the clothing industry and fuel subsituttion as for example in the Transport sector where some shift from Benzine to Gasoil engines has been observed.

## 4 Modelling fuel intensity variations

Based on the trends discussed in section 3 and with reference to equation (4) the intensity variation is plit as follows :

$$\delta I_{ij}^{(c)} = \delta I_{ij}^{(te)} + \delta I_{ij}^{(pe)} + \delta I_{ij}^{(sc)}$$

where

$\delta I_{ij}^{(te)}$ is the variation due to efficiency improvement

$\delta I_{ij}^{(pe)}$ is the variation due to price-induced savings

$\delta I_{ij}^{(sc)}$ is the variation due to structural changes

Also with reference to equation (5)

$\delta I_{ij}^{(s)}$ is the variation due to fuel substitution

The variation due to efficiency improvement is modelled by assuming maximum possible percentage rise and is related to a time trend where the time constant may be long to reflect slow action or short to reflect early action (the 'technical fix' aspect) when significant efficiency improvements are condoned by the economic system in the face of rising fuel prices. The efficiency variation thus modelled is positive always, monotonically increasing with time and exhibiting asymptotic behaviour, being bounded above by the relevant 'second law' efficiency.

The variation due to price induced savings (good housekeeping) is modelled by assuming a time trend and a price term related to an elasticity coefficient. The efficiency variation is thus positive for fuel price increases, negative for fuel price decreases (implying relaxation of housekeeping measures) and exhibiting asymptotic behaviour reflecting the limited potential of housekeeping measures.

The variation due to structural changes is modelled by assuming a time trend and a labour cost term related to an appropriate factor substitution elasticity coefficient. This reflects a rise in the intensity of some fuels (notably electricity) in some sectors where capital (energy) to labour substitution is attendant to continuing mechanization.

The variation due to fuel substitution is modelled by assuming a price term related to an appropriate fuel elasticity coefficient and it is further arranged so that a fuel's share from other fuels' substitution variations in a sector is proportional to the fuel's share in relation to total sectoral energy, thus reflecting existing market constraints.

## 5 Forecasts and observations

The modelling system described was used to make forecast for the period 1979-2000. Two internally consistent demand scenarios were adopted namely a high energy scenario assuming stable fuel prices and a low energy scenario assuming rising fuel prices and fast conservation measures. In both scenarios observed sectoral growth rates are assumed since a very low growth is not envisaged to occur either by default or by design. Fuel shares in the low energy scenario are shown in figure 1 where also shown is the total demand in the high energy scenario. It can be seen that the curves obtained make a good fit to historical data for the years 1979-1983 it being beyond the scope of the model to predict erratic variations.

In fact the historieal data seem to follow generally the pattern of the high energy scenario for the period 1978-1980, and that of the low energy scenario for the period 1981-1983, reflecting the more recent drive for energy conservation. The dynamic development of the system structure can be studied by reference to the state-model representation as can be seen from figures 2 and 3. Trends in the conservability of electricity are shown in figure 2 where it can be seen that in the high energy scenario electricity intensity change is initially positive and it reduces slowly as mechanization in industry saturates whereas in the low energy scenario the conservation effect is dominant and makes the intensity change negative, the effect gradually saturating as conservation measures diminish. Trends in the sectoral fuel substitutability are shown in figure 3 where it can be seen that in the high energy scenario benzine substitutes for gasoil without appreciable changes over time whereas in the low energy scenario gasoil substitutes for benzine, with this substitutability decreasing with time reflecting descreasing substitution potential due to market constraints. The observations made in this example can be of particular interest in the context of Refinery policy.

## 6 Conclusions

A good deal of consideration must be given to the particular characteristics of a national energy system before the appropriate forecasting methodology is adopted. However, it can be concluded from the methodology presented in this paper that for developing economies relying heavily on imported fuels for their energy requirements a unified model involving judicious fuel and sector disaggregation and internally modifying sectoral fuel intensity in respect of the different mechanisms of change, can be both feasible and effective. Moreover, a state-model representation of such systems is possible, which compactly and in physically meaningful terms can be instructive with regard to the development of the dynamic structure of the national energy system.

**Table 1 Total consumption of oil products and percentage attributed to main products 1960-1980**

| Year | Quantity | Percentage attributable to | | | |
|---|---|---|---|---|---|
| | (thousand toe) | Benzine | Gasoil | LPG | Fuel Oil |
| 1960 | 238 | 24 | 34 | 1 | 41 |
| 1965 | 321 | 20 | 36 | 3 | 43 |
| 1970 | 506 | 19 | 28 | 4 | 49 |
| 1975 | 536 | 15 | 22 | 5 | 58 |
| 1980 | 785 | 13 | 20 | 4 | 62 |

Source: Annual reports of oil companies and of the Electricity Authority of Cyprus

**Table 2 Total consumption of electricity and percentage breakdown by sector 1960-1980**

| Year | Quantity | Percentage consumption by | | | |
|---|---|---|---|---|---|
| | (million kwh) | Domestic | Commercial | Industrial | Other |
| 1960 | 178 | 24 | 40 | 30 | 6 |
| 1965 | 238 | 27 | 41 | 25 | 7 |
| 1970 | 461 | 26 | 34 | 33 | 7 |
| 1975 | 475 | 26 | 33 | 35 | 6 |
| 1980 | 719 | 26 | 30 | 35 | 9 |

Source: Annual reports of the Electricity Authority of Cyprus

**Table 3 Fuels in thousand toe of delivered (secondary) energy in 1980**

| Sector | Activity | | F1 | F2 | F3 | F4 | F5 | F6 | F7 | FT |
|---|---|---|---|---|---|---|---|---|---|---|
| Transport | Million car miles | 2000 | | | 99.6 | 100.0 | | | | 199.6 |
| Domestic | Thousand homes | 143 | 15.7 | 32.0 | | 8.8 | | 6.1 | 8.5 | 71.1 |
| Trade & Services | 1978 £m | 164 | 18.8 | 2.0 | | 2.2 | | | | 23.0 |
| Agriculture | 1978 £m | 87 | 3.4 | 1.0 | | 5.1 | | | | 9.5 |
| Mining & Quarrying | 1978 £m | 15 | 2.8 | | | | 40.0 | | | 42.8 |
| Food, bev. & Tobacco | 1978 £m | 74 | 2.8 | | | 22.2 | | | | 25.0 |
| Textiles & Footwear | 1978 £m | 66 | 1.3 | | | 6.6 | | | | 7.9 |
| Wood, paper & print | 1978 £m | 29 | 1.3 | | | 6.9 | | | | 8.2 |
| Chemicals | 1978 £m | 14 | 1.7 | | | 2.9 | | | | 4.6 |
| Cement | 1978 £m | 15 | 6.9 | | | | 120.0 | | | 126.9 |
| Clay products | 1978 £m | 10 | 1.2 | | | | 22.0 | | | 21.2 |
| Engineering | 1978 £m | 34 | 3.4 | | | 7.5 | | | | 10.9 |
| Public lighting | Consumers | 1372 | 1.7 | | | | | | | 1.7 |
| Fuel Totals | | | 61.0 | 35.0 | 96.6 | 162.2 | 180.0 | 6.1 | 8.5 | 552.4 |

Note: F1 Electricity
F2 LPG
F3 Benzine
F4 Gasoil
*F5 Fuel Oil*
*F6 Wood*
*F7 Solar (heat)*
*FT Total energy*

*Source: Department of Statistics and Research, Cyprus Ministry of Finance and estimates by the author.*

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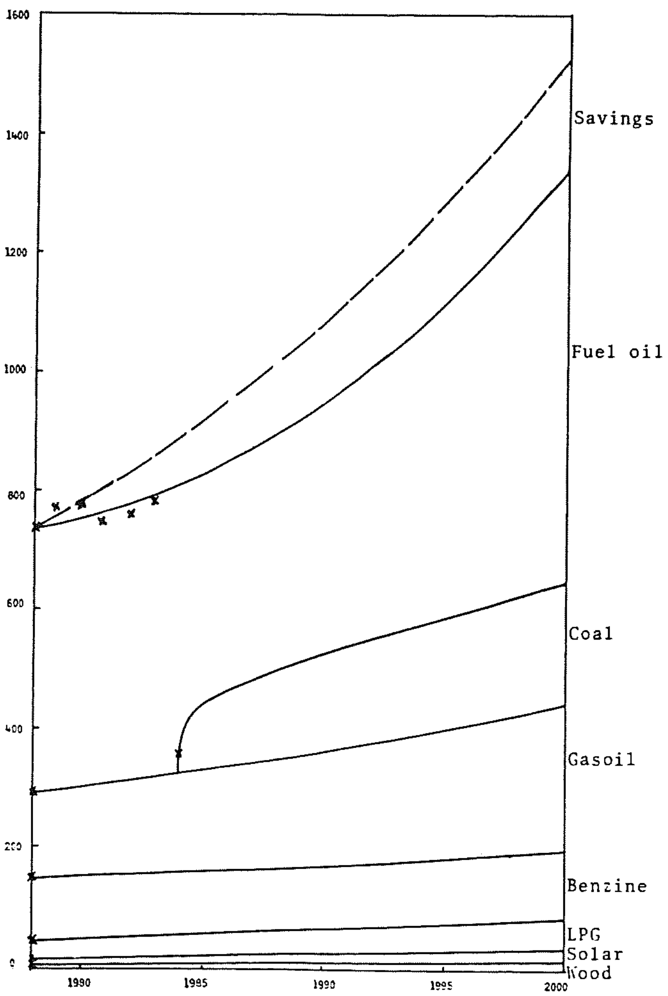


Figure 1 Fuel shares in Low Energy Scenario (Thousand toe)
Note: Quantities, as per model forecast, include savings due to efficiency improvements but exclude renewables apart from solar water heating.
x: historical data

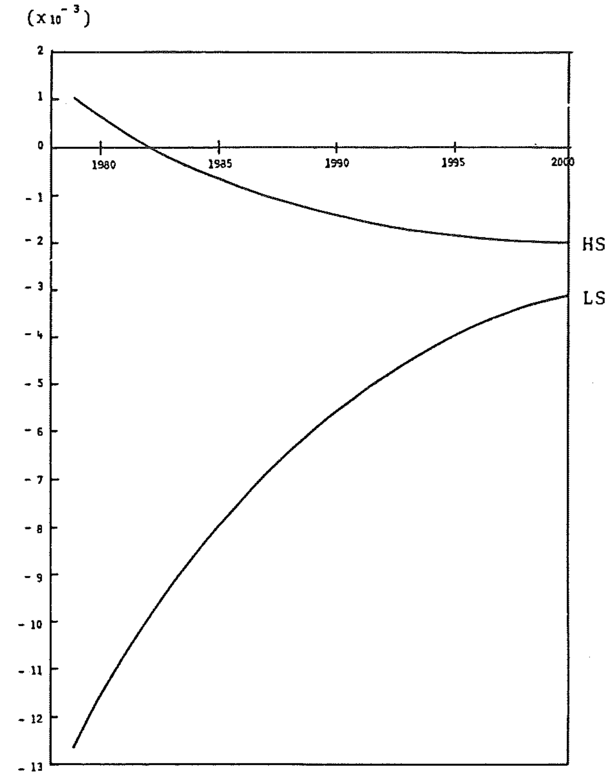


Figure 2 Variation of electricity conservability

Note: HS High Energy Scenario, LS Low Energy Scenario
High Scenario assumes zero rise in the price of electricity
Low scenario assumes 4% p.a. rise in the price of electricity.

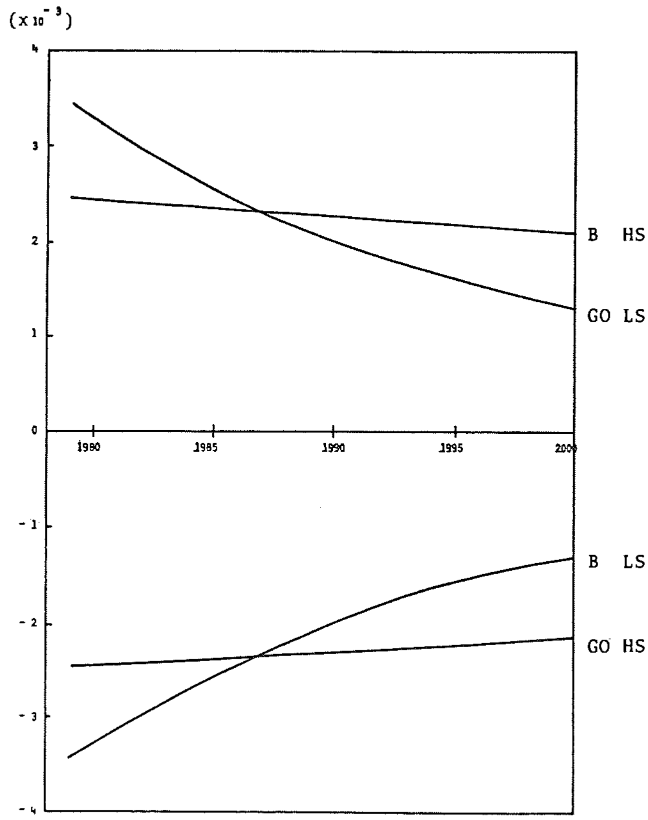


Figure 3 Variation of sectoral fuel substitutability - Transport sector

Note: B Benzine, GO Gasoil
LS Low energy scenario, assumes 6% pa rise in the price of gasoil and 4% pa rise in the price of Benzine
HS High energy scenario, assumes 2% pa rise in the price of Gasoil only.

# FIRST STEPS IN BIOMEDICAL ENGINEERING IN CYPRUS

**by Dr. A. Mallouppas**
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**Head Regional Training Centre, HTI**

**Summary**

Since 1978 two five year agreements of collaboration in Regional Training at HTI in the field of Maintenance and Repair of Hospital and Medical Equipment have been completed between the Government of Cyprus and the World Health Organisation. To undertake the training and other facets of this field of Biomedical Engineering the Regional Training Centre, RTC, was set-up as a separate unit of specialisation within the HTI. In this report a review of the RTC's work since 1978 is given and predictions as to its future role are made.

**Introduction**

Technology has invaded every field of life and discipline and medicine is no exception. This has resulted in sophisticated as well as multi disciplinary equipment being used to a great extent in major hospitals of all countries. However due to the policy for better Health Care cover for all, equipment of low or middle level technology is also being used at Rural or Primary Health Care level. The influx of different technology level equipment, and of such varied backgrounds, has resulted in the need for specialist technical personnel in order to carry out its Selection, Procurement, Commissioning, Maintenance and Repair.

The wastage of resources, through the lack of such personnel, was identified in the late 60's and early 70's by the World Health organisation, WHO, and particularly by its Eastern Mediternanean Regional Office. It was decided then that a lasting and longterm solution would be through training suitable specialists for this field of Work.

A survey by WHO was carried in the Eastern Mediteranean Region and Cyprus was chosen to host this Regional Training Activity because it offerred certain advantages such as, an existing well run technical institute (HTI) to attach such a unit to, local personnel capable of undertaking the work, good communications and political neutrality. The training activities were set-up by a joint Project Agreement between Cyprus and WHO in which Cyprus would provide the building facilities and local staff and WHO will finance the required expenses, running costs and equipment needs.

Thus in 1978 the first single course, the Polyvalent or General Technician was undertaken by RTC, which was then within the structure of the Electrical Engineering Department.

In the first WHO/Government of Cyprus Agreement a rather limited budget and facilities were foreseen for the project as a precautionary step in order to first test the idea of such an activity. It soon became evident that HTI could undertake the work both from facilities as well as staff viewpoints and specialised laboratories were increased to coincide also with the increase in training courses to be offered. By 1982 RTC was set-up as a separate discipline within the HTI structure and staff from the Electrical Engineering Department seconded to man the new unit. Separate building facilities were also added to the existing medical equipment laboratories, which were equipped by WHO.

To-day RTC offers a variety of training courses not only to WHO Sponsored fellows, but also to fellows of the Commonwealth Fund for Technical Cooperation, CFTC, and to privately sponsored students.

Its role beyond training into other related activities such as Research, Development, Calibration and Safety work related to equipment, Collaboration and Planning of training needs, are currently being discussed with WHO and if approved will open the way to establishing in Cyprus a Biomedical Engineering Centre, covering many aspects of Hospital Engineering and Medical Equipment Technology.

**Training Activities**

At present RTC runs the following courses, which cover two levels of Medical equipment technicians:

(i) General or Polyvalent: First line technicians, duration 10 months

(ii) Specialised Equipment:

| | |
|---|---|
| Technicians | |
| Diagnostic | |
| X-Ray | : Second line technicians |
| Electro-Medical | : Duration 5 months |
| Dental | |
| Operating | |
| Theatre | : |
| Clinical | |
| Laboratory | : |
| Medical | |

Electronics : Duration 10 months (from Sept. 1987)

Table 1 shows the breakdown of student numbers by country which attended the various courses. As can be seen from the list of countries RTC has a wide selection of graduates from many countries. The majority of students are fellows of the World Health Organisation and the cost to WHO of financing their stay in Cyprus to-date is of the order of US$ 800,000 excluding tuition fees to the RTC.

COURSES

| Country | Sponsoring Body | Polyvalent | Hospital Lab. | Operating Theatre | Electro-Medical | X-Ray | Total |
|---|---|---|---|---|---|---|---|
| Cyprus | WHO | 14 | 4 | 3 | 2 | 9 | 32 |
| Egypt | WHO | - | 3 | 3 | - | 2 | 8 |
| Syria | WHO | 3 | 3 | - | 3 | 1 | 10 |
| Bahrain | WHO | - | 4 | 2 | 2 | 1 | 9 |
| Afghanistan | WHO | 8 | 2 | - | - | - | 10 |
| Pakistan | WHO | 8 | 2 | - | - | 1 | 11 |
| Sudan | WHO | 14 | 4 | 3 | 5 | 11 | 37 |
| Lebanon | WHO | - | 1 | - | - | - | 1 |
| Iran | WHO | 2 | - | 3 | - | 1 | 6 |
| Somalia | WHO | 8 | - | - | - | 2 | 10 |
| Jordan | WHO | 5 | 1 | 1 | 1 | 2 | 10 |
| S. Yemen | WHO | 13 | 3 | 3 | 1 | 5 | 25 |
| Oman | WHO | - | - | - | - | 1 | 1 |
| N. Yemen | WHO | 4 | 2 | - | - | 2 | 8 |
| Iraq | WHO | - | - | - | 5 | 2 | 7 |
| Papua New Guinea | CFTC | 1 | - | - | - | - | 1 |
| Zambia | CFTC | - | 1 | - | 1 | - | 2 |
| Malta | CFTC | - | 1 | - | 1 | - | 2 |
| Greece | Private | - | 1 | - | - | - | 1 |
| Iran | Private | 1 | - | - | - | - | 1 |
| Syria | Private | - | 1 | - | - | - | 1 |
| Cyprus | Private | - | - | - | - | 1 | 1 |
| | | 83 | 33 | 18 | 21 | 41 | 196 |

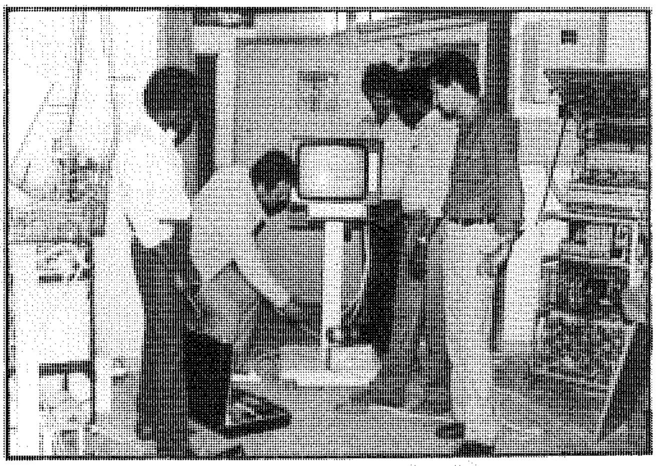
Table 1: Breakdown of RTC students by Country

## Medical Equipment Laboratories

WHO's financial contribution in Medical equipment and test instruments is of the order of US$ 1 million and has been used to set-up specialised medical equipment laboratories to enable the students to be taught Maintenance and Repair on actual Medical equipment. The RTC's inventory includes six X-Ray units, X-Ray film processor, Dialysis machines, Complete Dental Chair Unit and Dental film processor, Operating Theatre with Anaesthetic Trolley, Patient Ventilator and Medical Gases supply, Standard Clinical Laboratory Equipment, Electro-Cardiographs, Intensive Care Monitors etc.

The equipment, depending on its size and speciality, are housed in four existing specialised medical equipment Laboratories, which are the:

- X-Ray
- Dental
- Operating Theatre
- and Electro-Medical Laboratories



*Radiation Monitoring in X-Ray Lab*

Extra Laboratory space and offices are foreseen in the 1986/87 Agreement with WHO and would be used to extend the Medical Electronics, and other equipment Laboratories.

**RTC Staff**

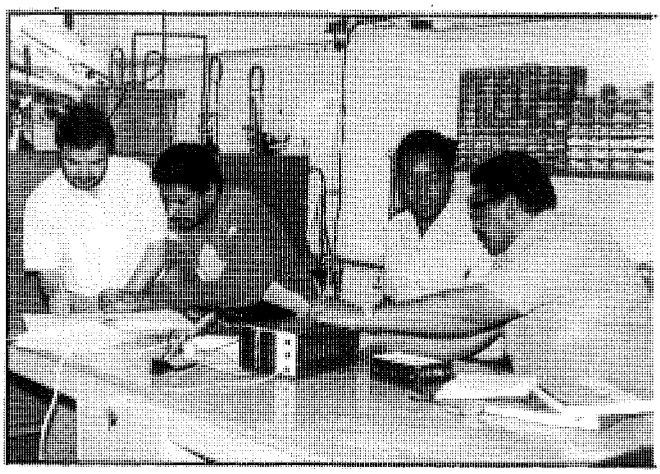
At present there are eight full-time RTC members of staff as follows:

- Head
- 4 Lecturers
- 2 Laboratory Assistants
- 1 Secretary

HTI staff from other departments depending on their Specialisation, contribute the equivalent of approximately two lecturers.

**Consultancy work**

During the period of its operation RTC has participated in official WHO consultancy missions (1),(2),(3),(4) to North and South Yemen, Somalia and



*Students working in the Medical Electronics Lab*

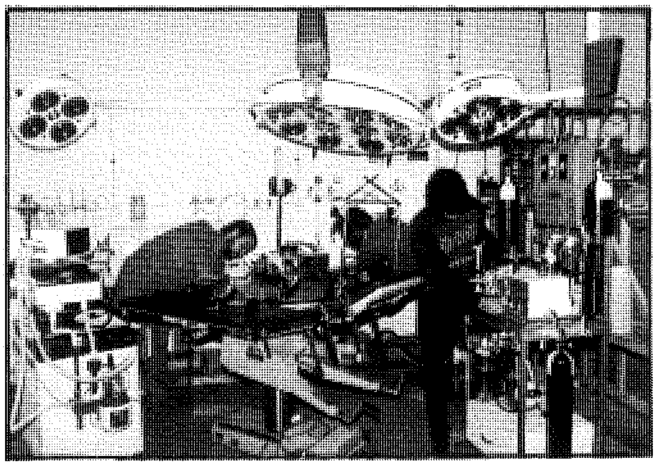
Sudan with the aim of obtaining feedback on its graduates and their work and of evaluating for WHO the situation concerning Maintenance and Repair. Recently the Head RTC was invited by WHO/Geneva to prepare on behalf of WHO its policy and strategy to be followed concerning Maintenance and Repair and its associated problems. (5), (6)..

An inter-regional conference to be organised by WHO in Cyprus in November 1986 will discuss these various aspects and hopefully reach important decisions on the future approach to the problem. RTC's role in this work it is hoped would be substantial and thus open the way to other activities as well as training.

RTC has recently also offerred its Services to local private enterprises both in medical and industrial applications (carried out a total of ten consultancies including assistance to the supply of the X-Ray Units at Makarios Hospital).

**Research and Development Work**

Within the effort to expand its activites beyond



*Calibration and Adjustments of Operating Table and Patient Ventilators in the Operating Theatre Lab.*

training RTC is currently submitting its application for a WHO Research Grant in order to develop and test a Solar Battery Charging unit for Basic Radiological X-Ray units.

An application to WHO has also been made to establish RTC as a WHO Collaborating Centre, which will result in work for study or development being given to RTC by all regions of WHO such as developing Calibration and Testing Laboratories for Medical Equipment, basic test instruments, Generic Specifications for medical equipment etc.

**Conclusions**

Although there are other national and regional Centres dealing with Maintenance and Repair, RTC has the longest and continuous record of output and achievement. It is therefore considered by people in the field the leader in the World in its type of work, a fact reflected by WHO's decision to hold its first inter-regional conference on Maintenance and Repair in Cyprus and to invite the Head of RTC to write WHO's policy in this field.

If in the coming years RTC achieves its objectives of expanding its activities beyond training and diversifying its interests then the future will be a very challenging but rewarding one and Cyprus will be placed internationally in an advantagerous position in this field of work.

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# MEDICAL EQUIPMENT SAFETY - ELECTRIC SHOCK HAZARD, CAUSE FOR CONCERN

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## 1. INTRODUCTION

The Medical Profession was quick in realising the potential of electricity by developing and using Electromedical equipment. The result was an enormous contribution to the promotion of health-care and well-being of people throughout the World. In fact it is not an understatement to say that hundreds of thousands or even millions of people have prolonged their lives because of the advancements made in medicine with the help of electromedical equipment.

Electromedical Equipment is intended to help medical personnel in the treatment of patients. It has followed the progress of electrical technology and has reached enviable standards of sophistication in both operation and safety. Its widespread application for cure and diagnosis, has also increased the dangers from electrical shock. From the early stages of development precautions were taken to protect the patients from electrocution. The numbers of accidents, however, have gradually increased. Factors contributing to this increase are many, such as the number of equipment surrounding a patient and ignorance of the basic safety rules by the operators and users.

It is the intention of this article to highlight the dangers of electrical shock caused by electricity in general, and in particular to patients "when connected up to electromedical equipment". An attempt will be made to explain the biological effects of electric current and the reasons leading to these accidents.

## 2. BASIC FACTS.

Electric power came into general use in the late nineteenth century and has revolutionalised the way of life in many ways. One of the side effects to which no real or effective antidote has been found since those early days, is the Electric Shock Hazard. The first electricians painfully discovered that electricity was more than just the simple procces of installing generators, running wires and connecting-up light fittings. There were real hazards; pain due to violent muscular contraction, body burns and death. Certain precautions were necessary. The early do's and don'ts were formulated, when the various electric companies got together, and were issued as codes of practice on safety, aiming at protecting their workers and their customers. The next step was to draw up National and International Safety Standards and Regulations. Examples of these standards are the British Standard BS5724 and the International Electrotechnical Commission IEC-601-1. Both these documents deal with the Safety of Electromedical equipment.

## 3. PHYSIOLOGICAL EFFECTS OF ELECTRIC CURRENTS.

Electricity will have effects on the human body only if the later becomes part of an electrical circuit. In other words, there is a danger of electric shock when the human body has at least two connections to a voltage source. The magnitude of the electrical current which will flow through the body depends on the voltage level and the electrical resistance of the human body. Human body tissue contains a high percentage of water, hence a good electrical conductor. Measurements, made from one hand to the other, have shown that the body resistance varies from about 1000 Ohms, when the skin is damp, to over 1,000,000 Ohms, when the skin is dry. These interesting results indicate that the human skin is a fairly good insulator -high resistance with dry hands, and the body itself a good conductor - low resistance with wet hands. Thus it can be concluded that our defence against electrical shock is... skin deep.

Electrical current affects humans in the following ways:

(a) Heating effect.

Electrical energy dissipated in the tissue resistance is converted into heat, causing a local increase in the tissue temperature. When the increase is considerable, the result is a burn.

Small current magnitudes cause local burns, while larger currents can cause severe burns over large areas of the body.

This effect is employed successfully in Electrosurgery where the concentrated current of a radio-frequency generator is used to, either cut tissue or coagulate small blood vessels.

(b) Stimulation of the Neural Tissue.

The transmission of electrical impulses through the sensory and motor nerves gives rise to Electrochemical Action Potentials. When the sensory nerves of the body are stimulated by the electric current a tingling or prickling sensation is felt, which at sufficient intensity may range from unpleasant to painful.

The stimulation of the Motor Nerves or Muscles results in the contration of the muscle fibres causing movement in the appropriate part of the body. A classic example of this effect is the passage of electric current through the hand; the stimulation of the muscles controlling the movement of the fingers will result in a crasping action. At higher current intensities we cannot let go, the results may be unpredictable.

Large current concentrations in vital organs may prove fatal. The organ most susceptible to electric current is the heart. A lower intensity current flowing in the heart muscle fibres is more dangerous than a larger current which tetanizes the entire heart. A small current excites only a portion of the heart muscle and changes the normal electrical propagation patterns of the myocardium with a subsequent desynchronised and random heart acivity. In other words, the electrical and mechanical sequences required to produce the blood pumping cycles are disturbed and the heart becomes a non-pumping, vibrating mass of muscle. This condition is known as Fibrillation or Ventricular Fibrillation. Ventricular fibrillation normally is not reversible, i.e. when the current is removed the heart will not resume normal operation. The pumping function of the heart is restored by passing a large current through it, within the next few minutes, a process known as Defibrillation. This is the commonest cause of death in fatal electric accidents.

Contrary to the above, when a high intensity current excites the heart, a complete contraction of the myocardium is caused, the heart action stops and the blood circulation is interrupted. If the current is removed soon afterwards the heart action is resumed spontaneously. Prolonged stoppage of blood circulation will cause brain damage and death eventually, because the brain tissues are destroyed when the oxygen supply is interrupted for some time.

Respiratory problems occur when the current flows through either the chest or the respiratory control centre in the brain.

(c) Electrolysis.

When a small d.c. or low frequency current is flowing, between two electrodes applied to the skin, for a long period of time, an Ulcer is caused. This is due to the electrolysis of perspiration into corrosive substances which in fact cause Chemical Burns. It is believed that the "safe" d.c. current is in the region of 10 microamperes.

Commonest examples of Electrolysis Ulcers have been encountered with ECG amplifiers.

A summary of these effects is shown in Table 1. It is stressed that the figures listed below refer to external stimulations applied through an intact skin, internally applied potentials, such as the ones via a catheter, are different. Experiments have shown that a current of about 60 micoramperes, flowing through a catheter in contact with the ventricular wall, causes ventricular fibrillation.

| CURRENT INTENSITY. (1-Second Contact) | EFFECT. |
| --- | --- |
| 0.5-1 MILLIAMPERES | THRESHOLD OF PERCEPTION |
| 5 MILLIAMPERES | ACCEPTED AS MAXIMUM HARMLESS CURRENT |
| 10-20 MILLIAMPERES | "LET-GO" CURRENT BEFORE SUSTAINED MUSCULAR CONTRACTION |
| 50 MILLIAMPERES | PAIN, POSSIBLE FAINTING, EXHAUSTION, BODY INJURIES HEART AND RESPIRATORY FUNCTION CONTINUE. |
| 100-300 MILLIAMPERES | VENTRICULAR FIBRILATION STARTS. RESPIRATORY FUNCTIONS INTACT. |
| 6-10 AMPERES | SUSTAINED MYCARDIAL CONTRACTION (NORMAL HEART RHYTHM MAY FOLLOW IF CURRENT IS REMOVED IN TIME). TEMPORARY RESPIRATORY. PARALYSIS. SEVERE BURNS AT POINTS OF HIGH CURRENT CONCENTRATION. |
| ABOVE 10 AMPERES | AS ABOVE, BUT SEVERE BURNS AND PHYSICAL INJURIES OCCUR. |

TABLE 1. Physiological effects of electrical current from 1-second external contact (intact skin) on an average human, through the body trunk (50/60 Hz. a.c. supply).

**4. EXPOSURE TO LETHAL HAZARDS... WHY ELECTROCUTED?**

Electrical hazards arising in the hospital environement can be classified into the following types.

(a) Potentials circulating a current through the patient.

It was seen earlier that when a potential is applied to the patient then a current will flow. The magnitude of this current depends on the magnitude of the applied voltage and the resistance between the two points. Consider for example Fig. 1, where a voltage of 1 Volt is applied externally, through dry, intact skin. The resistance is in the region of 500KΩ allowing a current of only 2 μA to flow. This current is well below the threshold of sensation.

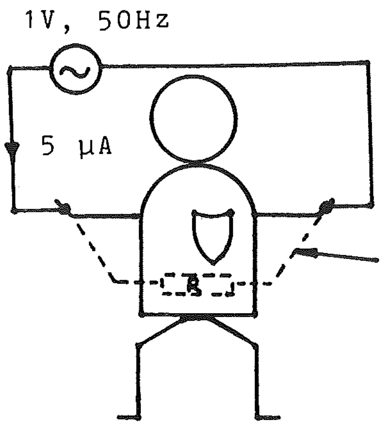


Fig.1. The patient as a resistance element.

The same voltage, however, applied as in Fig.2 the danger is real. In this case the patient is connected to an earthed ECG monitor via external skin electrodes and to an internal cardiac catheter. The resistance, in this case, may be as low as 1 kΩ, giving rise to a current of 1 mA. The magnitude of this current flowing through the heart, is fatal. In the later case even a voltage of 100 mV will be sufficient to cause fibrillation, because the current through the heart will be as high as 100 mA.

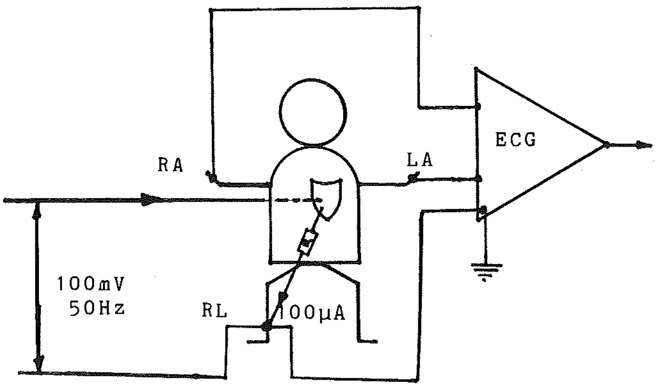


Fig.2. Connections to cause Fibrillation.

There are many ways by which the patient is exposed to either low or high voltage levels. Some cases are examined below.

(i) Mains potentials.

This is equally dangerous to both the patients and the hospital personnel. It is caused by electrical wiring which allow personal contact with live wires and/or parts of equipment, effectively amounting to exposure to lethal voltage levels.

Sources of this hazard are frayed power cords, broken plugs and wrongly wired sockets. Examples are many, consider Fig. 3. The patient touches with his hand an un-earthed, or broken earth, equipment whose coasing is at high potential, because it has developed an internal fault, some other part of his body is in contact with earth, (earthed apparatus, earthed metallic bed, electrically driven operating table etc). A current will flow from the high potential casing to earth via the patients body. The results are unpredictable.

These hazards are understood by everybody, even a non-electrically-minded person can spot them and take the appropriate precautions. In addition a good maintainance program should keep them under control.

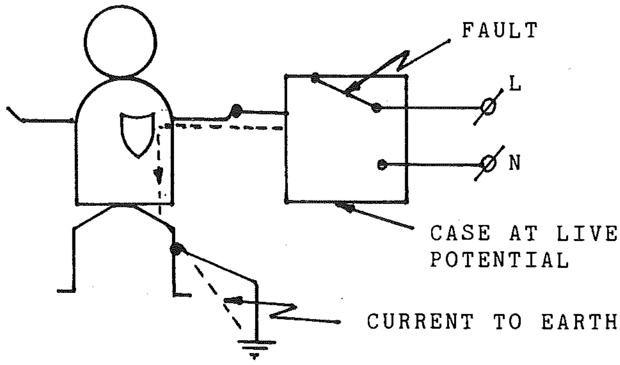


Fig.3. The patient is exposed to mains voltages.

(ii) Earth loops.

In places where there are two adjacent socket outlets, it is possible that there is a small potential difference between their earths. If a patient is connected to two pieces of equipment, which are plugged into different socket outlets, then an Earth Loop Current will flow because of the potential diference between the two earthing points. Fig. 4.

When the patient is connected to more than one mains operated pieces of equipment, care should be taken to plug in both to adjacent socket outlets whose earth points are solidly bonded together.

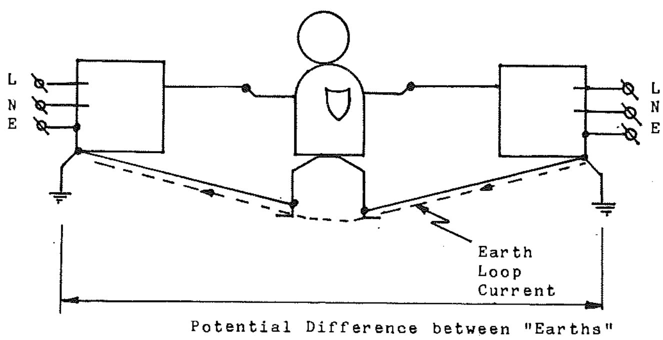


Fig.4. Flow of Earth Loop Currents.

(iii) Potentials on Un-earthed Casings or Broken Earth Connection. This is similar to (i) above, the only difference beeing that the voltage of the un-earthed casing need not be at high levels. This type of hazard can be induced quite unwittingly; consider the following situation. The patient is lying on an electrically operated bed. The bed is not earthed or the ground connection is broken. The patient is connected to a catheter and to an ECG monitor. The right leg ECG electrode is connected to earth via the monitor. The doctor attempts to adjust the catheter while touching the bed. Since the bed is not solidly connected to ground it floats at a higher potential, e.g. 100 mV. There is a difference in potential between the bed and the ground, hence a current will flow to earth through the doctor, the catheter, the patient's heart and body and the ECG electrode. The magnitude of this current is small, for the doctor, because he will not even feel it, but large enough for the patient's heart to cause fibrillation. This situation is called Micro-Shock.

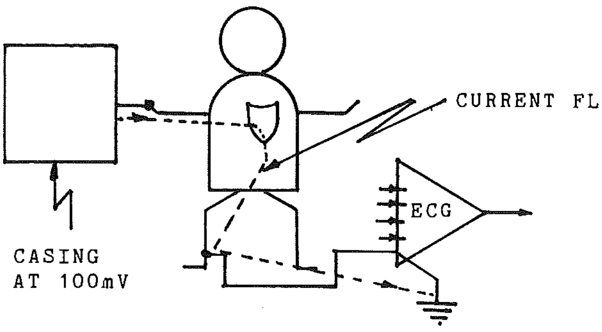


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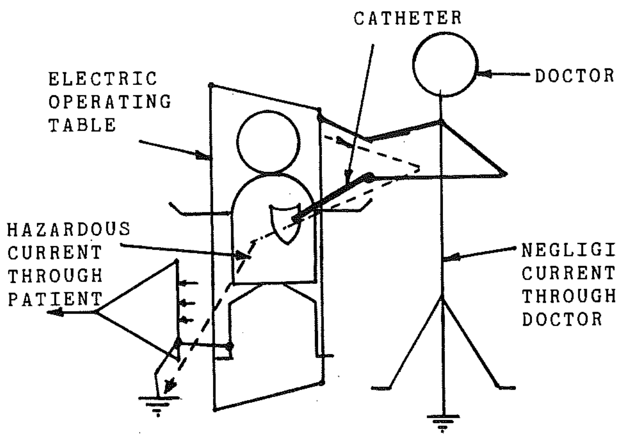
Fig.5. Micro-Shock.(a) Due to unearthed equipment and (b) due to the doctor.

(b) Leakage and patient Currents.

This type of hazard is not so obvious, in a large number of cases is not even understood. A leakage current is an inherent flow of current from the live




5b

parts of an electrical device to the exposed or accessible metal parts which are normally connected via a third wire to ground. This definition does not imply that the equipment is faulty, it states facts, leakage currents are present in all electrically operated devices. What is different in each case is the amount of this current.

Generally speaking, leakage currents are made of two components; a capacitive and a resistive.

When two conductors are separated in space, a certain amount of capacitance exists between them, the application of an alternating voltage will send a current flowing through this capacitance. It is a non-functional and unwanted current which is always present.

The resistive component of the leakage current arises from the fact that there are no perfect insulators. When a voltage exists then a small current flows through the insulation. The resistive component of the leakage current is not usually troublesome, because of the progress made in developing fairly good insulators.

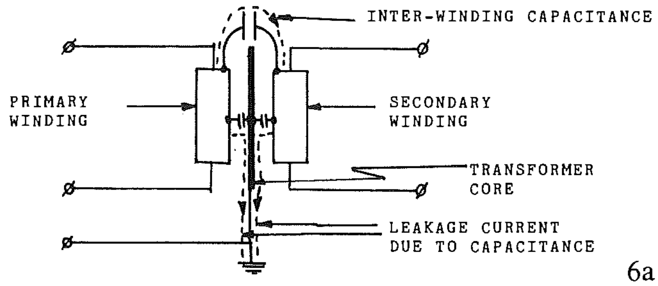



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Fig.6 illustrates two different types of earth leakage currents. In the first case a leakage current flows from the primary winding to the secondary winding across the insulation and two components of earth leakage current flow from the two windings to ground via the earthed core. In the second case the earth leakage current flows through the insulation of the various internel wires and components.

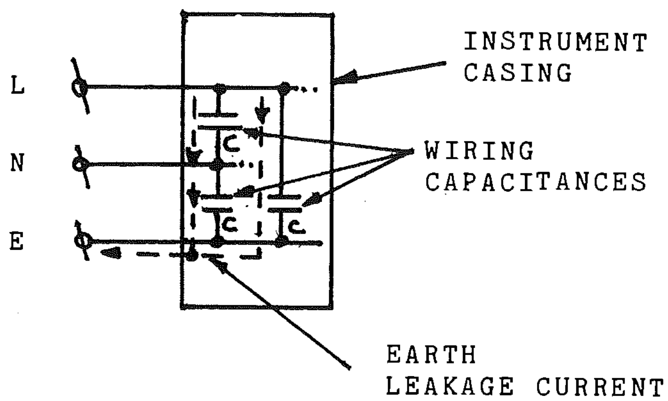


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Fig.6. Earth Leakage currents.

(b) Enclosure Leakage.

The enclosure leakage current is defined as the current which flows from the enclosure or a part of the enclosure through an external connection to earth or to another part of the enclosure. This is shown in Fig.7.

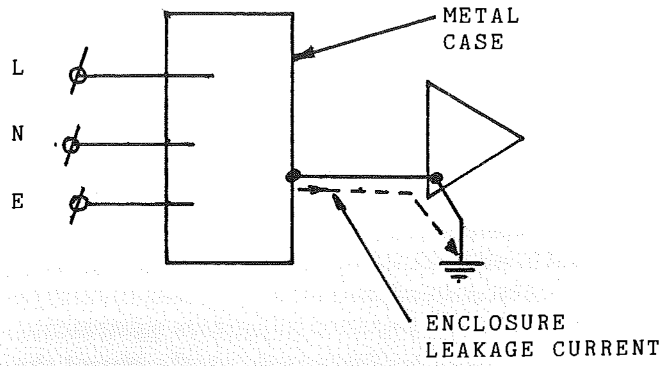

Fig.7. Enclosure Leakage.

(c) Patient Leakage Current.

A leakage current which flows from the patient connections, such as ECG electrodes, to earth via the patients body and originating from an unintentionally applied external voltage.

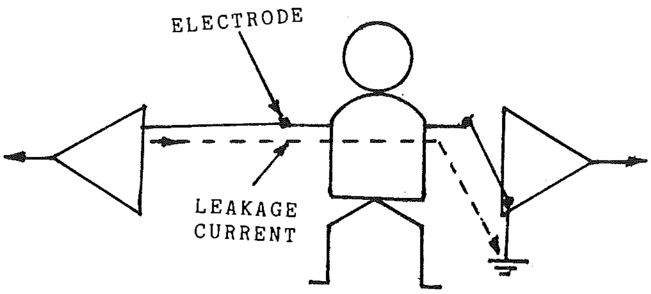

Fig.8. Patient leakage current.

(d) Patient functional Currents.

A current forced to flow in the patient in order to perform a specific function or to produce a required physiological effect. Examples are: Nurve and muscle stimulations, cardiac pacing, impedance cardiography, defibrillation, etc.

(e) Patient Auxiliary current.

A curent which flows in the patient during normal work and not intended to produce any physiological effects. A typical example is the amplifier bias currents.

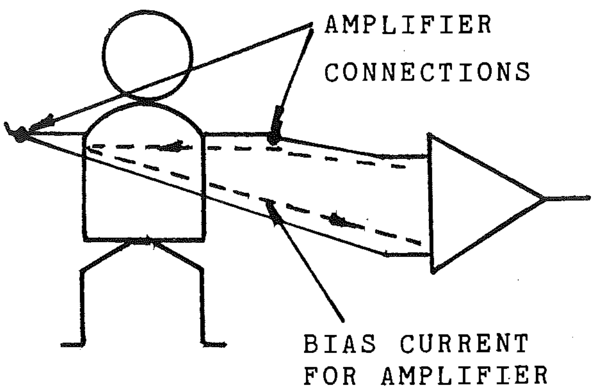

Fig.9. Patient Auxiliary Leakage current.

## 5. CLASSIFICATION OF ELECTROMEDICAL EQUIPMENT.

Electromedical Equipment is classified in BS 5724: Part 1 in accortance to the following:

(i) Type of protection against electric shock,
(ii) Degree of protection against electric shock,
(iii) Degree of protection against ingress of liquids,
(iv) Method of sterilization or disinfection,
(v) Degree of safety in the presence of flamable agents,
(vi) Mode of operation, and
(vii) Degree of electrical connection to patient.

Classification (i) is deivided into the following:

- CLASS I: Equipment in which protection against electric shock does not rely on basic insulation only, but requires additional safety precaution in the form of protective earth connection of all accessible conductive parts in such a way so that no exposed conductive parts (metalwork) can become live when the basic insulation has failed.

- CLASS II: Equipment in which protection against electric shock relies on basic insulation with additional safety protection from double or reinforced insulation. It is not provided with protective earthing conncetion and does not rely upon installation conditions.

- CLASS III: Equipment in which protection against electric shock relies on supply at safety extra-low voltage (SELV). The nominal value of this voltage is below 24 V a.c. or 50 d.c. between the conductors in an earth-free circuit which is isolated from the mains.

These classes are subdivided into the degree of protection against electric shock and are:

TYPE B: It is Class I, II or III equipment which has edequate degree of protection against electric shock with regard to allowable leakage currents and protective earth connection (if present). It is in general suitable for intentional, external and internal application to the patient, excluding direct cardiac application.

TYPE BF: Type B equipment with F-type isolated (Floating) applied part. The parts of the equipment which come intentionally in contact with the patient (Applied Parts), are isolated from all other parts of the equipment to such a degree that the allowable patient leakage current is not exceeded when 1.1 times the mains voltage is applied between earth and the applied part.

TYPE CF: Equipment which is intended for direct cardiac application. It is either Class I or II equipment or equipment with internal power source, having type-F applied part and provides high degree of protection against electric shock from leakage currents.

TYPE H: Equipment which provides protection from electric shock comparable to that of household and similar equipment.

## 6. CONCLUSIONS.

The evolution of medical engineering technology has resulted in a dramatic increase in the number of electromedical equipment available to the medics, the patients under certain circumstances are connected to numerous pieces of equipment either externally, application of skin electrodes, or internally, catheterization techniques. The usage is thus inevitable, but the electric shock hazards can be reduced.

The dangers of electric shock are everywhere; a normal person, in the surroundings of his household, has the responsibility and, hopefully, sufficient sense to deal with and avoid these dangers.

A patient lying half concious in an intensive care bed or anaesthesised on the operating table, relies totally on the safety measures taken by others;

Manufacturers of electromedical equipment must take every care to make equipment which is in accordance to relevant standards adhering strictly to specification and to disclose these specifications.

The medical personnel have the responsibility to use the Right Equipment for the Right Job from the safety point of view, i.e. by observing strictly the manufacturers recommendations concerning electrical connections to mains and to patients (external or internal, connection to specific organs to be avoidedetc.). In addition it is their duty to refer to the technical staff suspected hazardous equipment.

The hospital Technical staff have the responsibility to look after the electrical installations and the equipment and to carry out routine and preventive maintenance programs. The relevant Standards specify clearly methods which must be employed to assertain the safety levels of the installations and of the equipment.

It is clear that the exposure of the patient to electric shock hazards may result in undesirable effects. A joint effort, however, by the manufacturers, the medical staff and the hospital technical personnel will result in a much safer environment.

# POTENTIALS FOR SOLAR COOLING

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**Abstract**

This paper aims to present the prospective methods of solar cooling intended for either the preservation of food and other commodities of for the air conditioning of buildings.

Emphasis is given to systems working on the absoption cycle (heat-operated) in which solar energy is used as the heat source instead of oil or gas.

**Introduction**

The utilisation of solar energy for cooling has the singular characteristic of the supply of energy matching with the demand as there is often a direct relationship between high ambient temperatures and incidence of solar radiation availability. In addition, the production of refrigeration for the preservation of food and medicines necessary for the welfare of the human beings is greatly important in hot climates where solar energy is abundant.

However, the viability of the solar option, and thus its future prospects, for the cooling of produce will ultimately be decided by the cost-effectiveness when measured against other alternative energy sources. If the technological, economic and social cost of harnessing the solar energy is greater than the cost of other renewable options, or the delivered cost of electricity to drive conventional refrigeration machines, then solar cooling will not yield the desired solution, in spite of its inherent advantages.

The brief experience of the operation of solar cooling systems suggests that the technology is rather more complicated and technically less developed than that for solar heating - applications.

There are three basic technologies for solar cooling:-

(a) The use of photovoltaic cells to generate electricity to drive vapour compression and thermoelectric machines.

(b) The use of thermal energy to power heat engine cycles, and

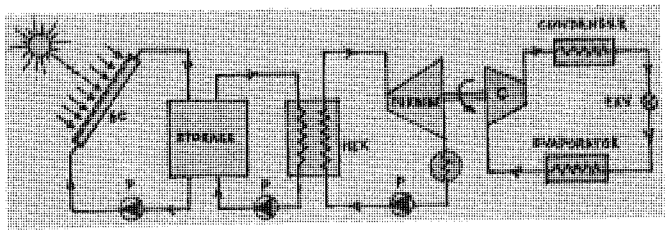
(c) The use of thermal energy to power sorption cycles (absoption systems, dessicant adsorption).

**1. Vapour compression systems**

Vapour compression systems can be driven by electric motors, as in the conventional refrigeration system; or they can use heat engines to produce mechanical shaft power to drive a compressor and/or generate electrical power. The former method can be adapted for solar application via the use of photovoltaic cells which generate direct current to drive the compressors. For this application the major innovation is the development of DC powered compressor and the necessary control gear to regulate the current flow.

**1.1. Rankine cycle systems**

The basic idea behind Solar Rankine Systems is to use high temperature solar heat to run a Rankine engine and then to use the shaft output of that engine to run a vapour-compression refrigeration system (Fig.1).



SC = Solar Collector P = pump
HEX = Heat Exchanger C = Compressor
EXV = Expansion Valve

**Fig. 1. Solar-powered (Rankine) Vapour - Compression Refrigeration System.**

In this system, a working fluid is vapourised by solar heat collected by the solar collectors, it does work on a turbine or engine and is then condensed. The combined Rankine engine and vapour compression system would have an overall efficiency of about 90% x 30% or 27%. The efficiency of the solar collector decreases as the temperature (operating) increases, whereas the efficiency of the heat engine for the same system increases as the operating temperature increases. The thermodynamic analysis of a system operating at steady state is straight forward, but not for unsteady operation. The matching of components is complex to optimise the overall performance of a system.

Conventional refrigeration units using electrical power can remove 2 to 3 units of heat energy from an environment for each unit of electrical energy supplied to run the compressor and fans; so they are said to have a cofficient of performance (C.O.P) of 2 to 3. Solar Rankine units have to provide shaft power by means of a Rankine cycle engine which converts only 10 to 30% of the supplied heat into shaft power; thus, the C.O.P. of solar Rankine units is generally considerably less than 1.0.

Rankine systems generally require higher solar collector temperatures (attainable only by focusing solar collectors) for a given C.O.P than absortion and adsorption systems. However, the presence of a "shaft-power" step provides two advantages. First, if insufficient solar energy is available to meet the refrigeration load, an electric motor can provide the additional shaft-power required, generally at lower cost than gas can be provided to run an absorption unit under these conditions. Second, where shaft power is available above that required for refrigeration, the excess can be used for electrical generation or other applications; but since this excess power is unlikely to be available at times of peak electrical utility demand, it has only limited economic value.

### 1.2. Photovoltaic powered compression systems

Photovoltaic powered drives are potentially the most efficient way of converting solar energy to shaft power. The comparatively low collection efficiencies (8-12%) are offset by the very efficient use of the delivered energy as electricity (85-90%). As the speed of a DC motor can be matched to that of the compressor, the photovoltaic system would provide a better transmission efficiency

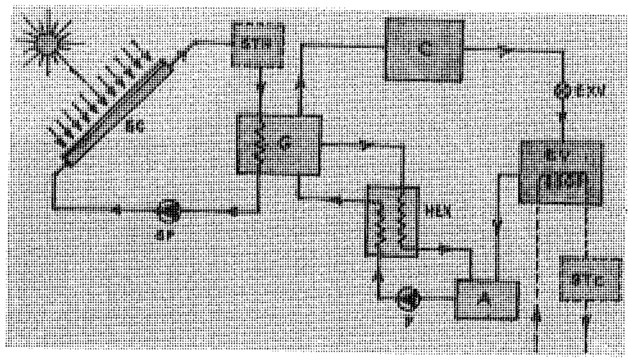
Photovoltaic powered refrigeration units are now undergoing extensive field trials for the storage of vaccine serum. Other applications such as residential refrigeration requirements, are being tested. The technical feasibility of the technology has been demonstrated, what is mainly required are practical data on performance and reliability.

### 1.3. Photovoltaic powered thermoelectric systems

Thermoelectric refrigeration uses the temperature difference produced when an electric current flows across a junction of two dissimilar thermoelectric materials, known as the Seebeck or Peltier effect. Wide use of this effect has been made in metal thermocouples for temperature measurement but the Seebeck effect in semiconductors can be considerably greater. Advantages of thermoelectric cooling include no moving parts, and no refrigerant to contain. However, the cooling capacity of a single junction is very small and inefficient. Economic considerations would tend to limit thermoelectric cooling to small systems of capacity 60-90 watts. The overall system efficiency of solar powered systems for a 40°C temperature difference has been estimated at about 2% (7).

## 2. Absorption Refrigeration Systems

Absorption refrigeration systems use the same evaporation/pressurisation/condensation method of transferring heat that Rankine systems employ, but the pressurisation step is accomplished with little or no shaft-work (Fig. 2). The vapour is first absorbed by a liquid solution for which it has a strong affinity. This process gives off considerable heat, which is rejected to the environment. The solution is then pumped to a higher pressure; and finaly it is heated in the "generator" until the absorbed vapour is driven off (this step is called "generation" or "desorption"). Thus in an absorption refrigeration system there are two heat-input steps (evaporation and generation) and two heat-rejection steps (condensation and absorption).




| | | | |
|---|---|---|---|
| SC | = Solar collector | G | = Generator |
| C | = Condenser | EXV | = Expansion Valve |
| EV | = Evaporator | A | = Absorber |
| STH | = Hot storage (high temp) | STC | = Cold storage (low temp) |
| SP | = Solar circuit pump | | |
| P | = Pump | HEX | = Heat exchanger |

**Fig. 2. Solar absorption refrigeration system**

Some systems use ammonia as the refrigerant and an ammonia/water solution as the absorbing solution. Because the ammonia vapour is always contaminated by a small amount of water vapour, these units have an added purifying step called "rectification". Ammonia units require generation temperatures well over 90°C but can provide refrigeration to quite low temperatures.

In cases where simple air conditioning rather than refrigeration is required, systems using water as the refrigerant and a lithium-bromide/water solution as the absorbing solution are suitable. The low volatility of lithium bromide makes rectification unnecessary, so these systems are simpler than ammonia systems. In addition, generator temperatures of 70-85°C are possible so flat-plate solar collectors may be employed.

The COP of lithium bromide systems is in the neighbourhood of 0.5. The moderate officiency of the collectors at 70°C and above means that the useful cooling effect will be 15 to 25% as large as the amount of solar energy incident on the collector array during the hours of operation. With either ammonia or lithium bromide systems, gas fired operation can be used when the collected or stored solar energy is not edequate.

Fig.3 illustrates the schematic of a typical solar ammonia-water refrigerator. A mixture of water and ammonia (50-60°% by weight ammonia) is boiled by solar heat, either by direct circulation in a collector or by using an intermediate fluid in a closed loop. The ammonia vapour is enriched by rectification (partial condensation), is condensed by natural air convection or cooling water. Liquid ammonia is expanded through a valve into an enclosure at low pressure (evaporator), where it evaporates and cools the brine circuit (or the refrigerator chamber). The ammonia vapour then is dissolved into water coming from the generator (boiler), and returns back to the generator by means of a pump. Since the dissolution of ammonia is exothermic, the absorber must be efficiently cooled. It is seen that the water loop acts as a compressor which transfers ammonia from the absorber to the generator.

A typical 200 lt solar refrigerator will have:

400 W solar heat supply to the generator
95 W heat rejected by the condenser
80 W refrigeration produced in the evaporator
385 W removed at the absorber

This refrigeration (80 W) could be produced by possibly 1m$^2$ of solar collector operating for ten hours of insolation, if provisions are made to limit the heat losses at night.

A frequent criticism to this system is that it still requires some electrical energy to operate the pumps. This energy is but a very small fraction of that required by the compression cycle. For the household refrigerator described, the compressor should be 200-300W whereas the pumps in the absorption cycle would be 2-3W. Even this pump can be eliminated and natural circulation used in the cycle if a third component is added (SERVEL, ELECTROLUX system).

A small amount of hydrogen in the system compensates the pressure difference between the generator and the absorber and the two pressures indicated in fig. 3 (10 and 2 bar) become partial pressures of $NH_3$, while the total pressure is everywhere 10 bar. Howerver, the hydrogen introduces a resistance to the diffusion of $NH_3$ in the absorber and lowers the system overall efficiency.

A more promising system, which requires smaller pressure difference, is the re-absorption cycle shown in fig. 4. In this cycle, the ammonia vapour from the boiler does not have to be condensed but is absorbed from the vapour phase. This requires a douple circulation of water which can again be arranged, on the basis of temperature and concentration gradients, without pumps if hydrogen is use to equilibriate pressures.

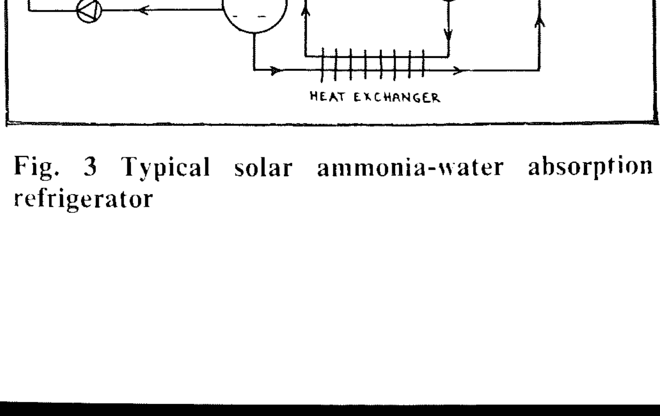



**Fig. 3 Typical solar ammonia-water absorption refrigerator**

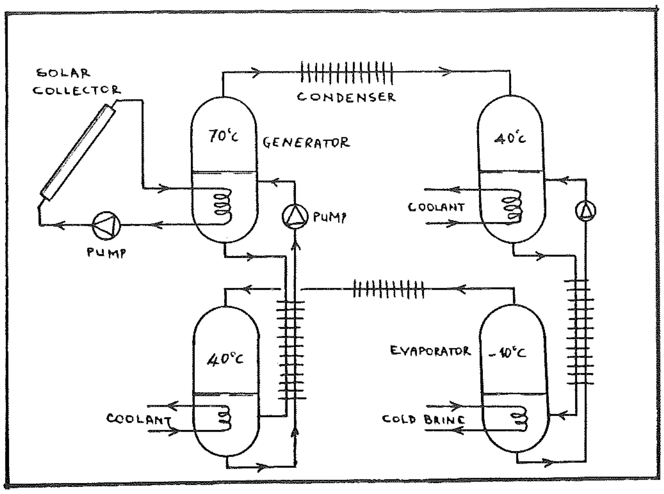



**Fig.4 Reabsorption ammonia-water system**

**3. Solar Adsorption Refrigeration (Zeolite-Water system)**

Another system which is promising is the zeolite-water adsorption refrigeration system, using water as the refrigerant and zeolite as the adsorbent.

The zeolite is a microporous composite (aluminum cilicate) which has a great affinity to water vapour. In a solar adsorption system it plays, alternatively, the role of a "chemical pump" during the eveporation process and the role of "chemical compressor" during the condensation process. It presents some advantages over other known adsorbents such as activated aluminum, activated carbon and silica gel, the most important being that it has a strong capacity of adsorption at ambient temperatures and low pressures (corresponding to the equilibrium pressure in the evaporator) and low capacity of adsorption at higher temperatures and pressures (corresponding to the equilibrium pressure in the condenser).

The basic components of a zeolite-water refrigeration system are shown in fig. 5. It consists of solar collectors filled with zeolite 13X (synthetic zeolite), a condenser and an evaporator. There is a vacuum cock connecting the collector and the condenser. The condenser could be either air cooled or water cooled. The collector is filled with predetermined amount of zeolite 13X; the eveparator is filled with predetermined amount of water. The whole system is evacuated and except for water vapour, no other gaseous medium is present in the system.

At the beginning of the day, the zeolite in the collector is almost saturated with water vapour. The valve connecting the evaporator and the collector is closed during the day whereas the one connecting the collector and the condenser is open. As the collector gets heated during the day (absorption of solar energy), the zeolite desorbs the water vapour which passes on to the condenser where it is cooled and condensed. The condensed water is collected in the liquid receiver attached to the condenser. This process continues during the day.

In the evening, the valve connecting the collector and the condenser is closed whereas the valve connecting the evaporator and the collector is opened. As the temperature of the collector decreases, it starts absorbing water vapour drawn from the evaporator (evaporation of water in the evaporator).

During the process of evaporation, the evaporator draws heat from the surrounding medium and cools it. Thus process continues till early morning when the valve connecting the collector and the evaporator is closed and the one connecting the collector and the condenser is opened. Thus the cycle repeats. Refrigeration is produced during the night; the system completes one cycle every twenty four hours.

The advantages of the system are met in its simplicity, its longlifeness and its flexibility to work at low temperatures in the hot source; it is also important that the heat produced during the adsorption process can be utilised effectively in heating water for domestic sanitary purposes.

Over and above the advantages outlined, the essential originality of the adaptation of the zeolite-water cycle in solar energy lies in the fact that the "chemical compressor" (zeolite) is integrated in the collector and the machine can operate without any moving parts.

The inconveniencies of the system are mainly the following:

(i) need to create and maintain low pressures in the system (operation under vacuum);

(ii) need for large quantities of adsorbent; 100 kg of zeolite are needed to produce one ton refrigeration. This means that the system should comprise bulky collectors.

The solar zeolite-water refrigeration system can be used in both the domestic and the industrial sectors to preserve food and other commodities. A typical refrigerator for household application could incorporate a solar collector having an absorbing surface of 1.5m$^2$ and containing about 35kg of zeolite - 13X. Under reasonable conditions of sunshine such a refrigerator could produce more than 10kg of ice which would keep the refrigerator chamber charged with 15-20kg of food and other commodities, at a temperature of 3 to 7$^0$C.

The same system could be used in a large-scale for food preservation in cold stores (hospitals, hotels, etc). It is anticipated that the refrigeration requirements of a cold store having a volume of 15m$^3$ and properly insulated to reduce heat gains, could be met by a zeolite-water system having a collector area of about 25m$^2$ containing about 550kg of zeolite.

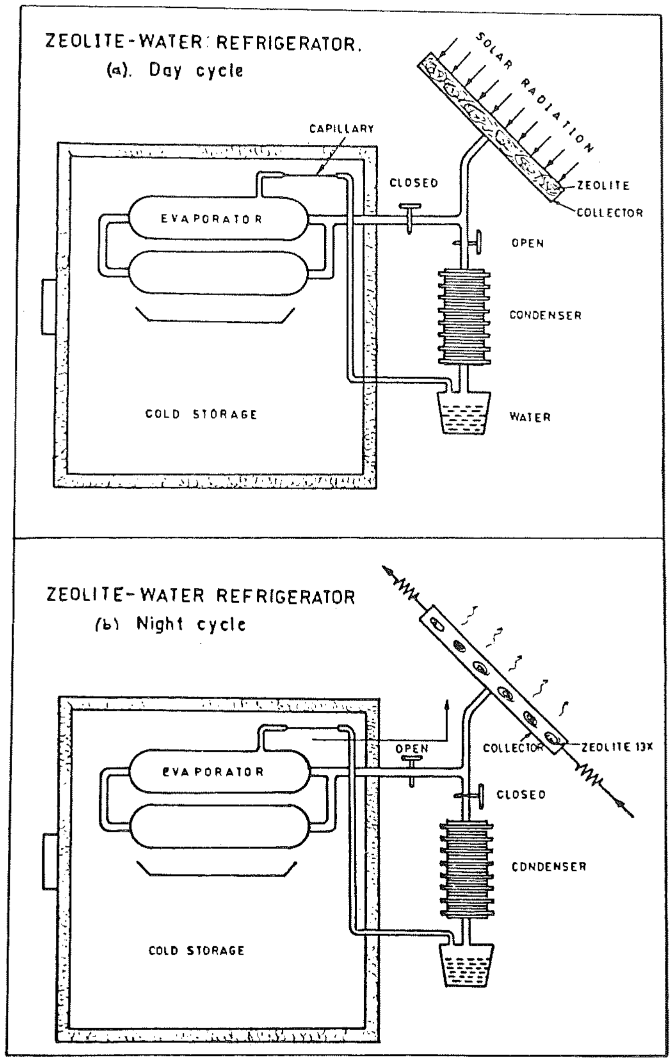



**Fig. 5. Zeolite-water Solar Rrefrigerator**

**4. Some examples of Solar Refrigeration**

Prof. Farber of the University of Florida tested a standard Servel refrigerator, using concentrating collector which heated cottonseed oil above 300$^0$C to operate the generator. The hot oil was stored in a 100 litre tank and used as needed. In the same laboratory, a flat plate solar collector was used as generator in a water-ammonia unit producing 40kg of ice per day with 1.6m$^2$ solar collector. At Delft a system was tested, producing 4kg of ice per day with 2m$^2$ of flat plate solar collector.

Another system tested at the Lawerence Berkley laboratory operates with generator temperatures between 80$^0$C and 100$^0$C, with a nominal cooling capacity of 5 tons of ice per day with total power of pumps and fans 1600W.

A further example is the lithium bromide solar system of the Ohio State University which is used to air condition a 220m$^2$ laboratory. The collectors are 66m$^2$ and use glycol-water as circulating fluid. A 10.4kW lithium-bromide water absorption system has the generator at about 90$^0$C.

For the cooling needs of the system (removal of heat) a water cooling tower is used. The energy balance to this system is split into the following:

- input to solar collector pump 557 W
- input to blower 557 W
- input to brine circulation and generator pump 476 W
- input to cooling tower pump 348 W
- input to cooling tower fan 250 W
- Solar energy input 18,200 W
- refrigeration produced 10,400 W

System overall officiency 51%
(Note that heat input by sun is free of charge!)

A compression cycle (using electricity as the prime mover) with the same performance characteristics would use:

- input to compressor 5,394 W
- input to fan (evaporator) 638 W
- input to condonser fans 615 W

It can be found from the above that the conventional, vapour comnpression cycle, in this case, would have an efficiency of about 157%, but the energy should be provided all in the form of electricity.

An example of zeolite-water solar refrigeration is the refrigerator constructed and tested by the CNRS in France (1981) which had a collector area of $1m^2$ containing 23kgs of zeolite-13X and producing 8kgs of ice daily.

A similar refrigerator using zeolite-13X as the adsorbent has been constructed at the HTI and tests are carried out using water as the refrigerant (Fig.6).

**Conclusions**

Although several systems exist that can be operated by solar energy, they cannot at present compete economically with existing systems. Many systems have actually operated and still operate both in the laboratories and in actual applications. However, much R & D effort is needed so that solar energy can replace conventional sources of energy when these become too costly.

Effort is still needed to reduce the costs of using solar energy but the eventual large-scale replacement of fossil fuels depends on their somewhat unpredictable costs.

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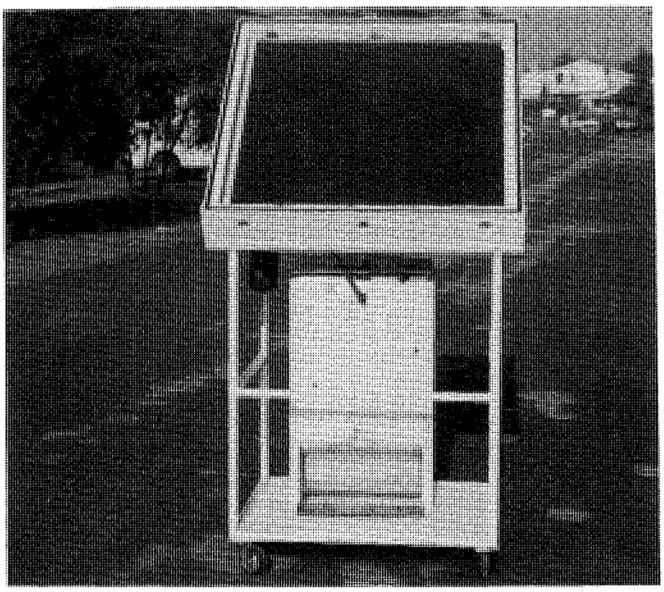


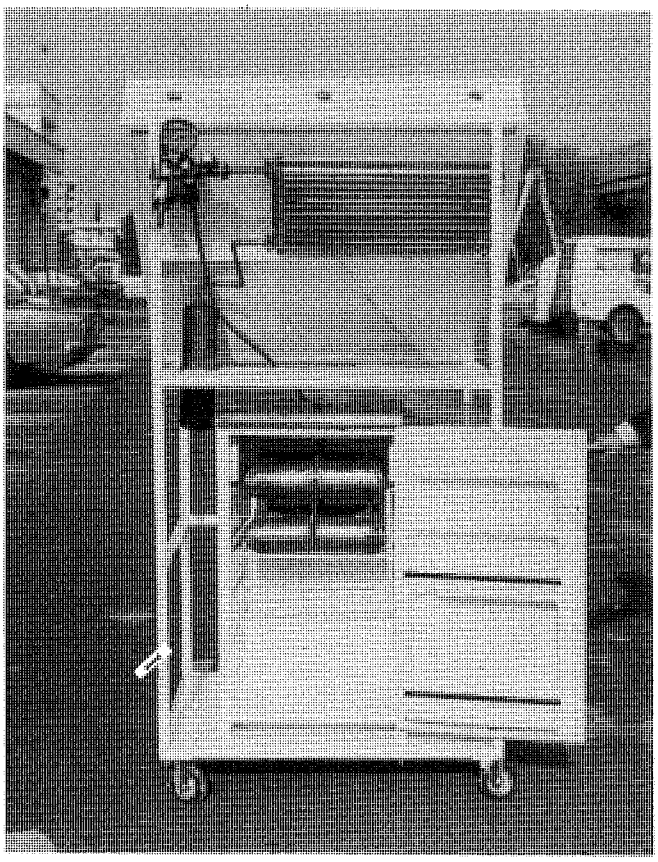


**Fig. 6 Experimental Solar Refrigerator (HTI)**

# ROSE WATER DISTILLATION PLANT AT AGROS

**P. Tramountanellis BSc (Hons)**
**Lecturer HTI**

## SUMMARY

A request was made by the cooperative of Rose Producers at Agros to the H.T.I through the Ministry of Agriculture and Natural Resources to design a modern fully Automatic Rose Water Distillation Plant to be able to handle 640 Kgs of roses every five hours. Since it is an established Policy of the H.T.I to offer consultancy services on a fee Paying basis the H.T.I consultancy committee accepted the above request and the writter undertook to carry out the design and supervission of the Rose water Distillation Plant with the assistance of Mr P. Demetriou bearing in mind the recommendations of a Technical report on Production of Rosewater in Cyprus which was based on the work of two FAO consultants. The Construction, installation and commisioning of the plant was completed in April 1986 and is now operating satisfactorily at full capacity.

The total cost is estimated to be in the region of £30,000.

The labour man hours are reduced by 80%. The Fuel cost is approximately down by 50%.

## INTRODUCTION

The rose bushes grow wild, appearing as hedgerows around small strips of land, or along the roadside, or on the edges of terraces; even when used as boundaries of the cultivated areas, which may grow vines or fruit trees, the Pattern remains irregular. The bushes do not show signs of cultivation other than by very primitive methods.

The free and profuse flowering of rose bushes in the villages of Agros, Milikouri and Alona is a clear indication of the suitable climatic and soil conditions in the area for the growing of Roses.

The two main centres of Production are Agros and Milikouri. The current annual Production of Rosa damascena flowers is about 35 tonnes (Agros 30 tonnes and Milikouri 5 tonnes), for these two centres.

The Rose under investigation is the Rosa damascena, recognized as the best rose for the production of rosewater and for the distillation of Rose Oil. The stills in operation at Agros, Milikouri and Alona are of an acceptable type for straight rose distillation. They are not of sufficient capacity, especially in Agros, to meet the peak loads at crop time. The present load limits vary between 90 and 120 Kgs of Roses. The stills available at Agros are of the direct firing type, mounted on trunnions for emptying and the largest has a capacity of 90 Kgs, of Roses to 200/270 Kgs of water. Distillation takes 8-10 hours and the programme is run on a 24-hour basis when the arrival of Roses mounts up.

There is no effective temperature control. The plant is incapable of yielding more as the capacity is insufficient for a higher arrival rate of Roses. The equipment must be brought into line with the quantity of Roses which could be available in order to achieve the desirable advance of Rosewater Production and the possibility of a follow-up on the Production of rose-oil.

In terms of yield, it takes from 3800-5200 Kgs of Roses to obtain 1 Kg of oil. The absolute essential oil yields are rather variable and may range from 58 to 65 per cent. They obviously depend on different factors, the chief of which are the climatological conditions of the season that govern the state of freshness of the Roses and the care taken during their storage before distillation and the method of manufacture.

The steam distillation which makes it possible to obtain the essential oil takes place in copper and stainless steel stills whose capacity ranges from 1500 to 3500 litres. This is done in the usual classical manner: The obtaining in the first place of the direct essential oil, then the redistillation of the highly perfumed rose water which gives the indirect essential oil.

The world Production of Perfumed roses has not increased. There has merely been geographical shift of production. There has in fact been noted in recent years a very great drop in tonnage in Bulgaria and in France. This fall is offset by a great increase in Production in Turkey and the appearance of considerable Production in Marocco as shown by the figures in the table below.

| Approximate size of Crops - 1968 | Tons |
|---|---|
| BULGARIA | 5000 |
| FRANCE | 300 |
| U.S.S.R. | 5000 |
| TURKEY | 2000 |
| MOROCCO | 2500 |

The problems facing the rose qatherers in Cyprus are enormous especially the difficulties in transport to the main still in the village. The reliance is still on the donkey, with Panniers strapped across its back and sides.

There is an evident lack of organized cultivation and it can be assumed that not only are the Rose yields per bush poor, but that the difficulty of gathering results in quantity of Roses being left on the bush.

There is a necessity to check the PH of the soils in these areas as the growing of Rosa damascena for optimum yield is favoured by slightly acidic soils (PH 6.5) with a possible tolerance to 7.0. This information is required to determine the nature and type of fertilizers and manures to be used.

Late picking of the floral heads and consequently late arrival for distillation lowers the yield and quality of the essential oil contained in the Rose as shown in the table below.

| Time of Picking | Essential oil content % | Loss % |
|---|---|---|
| 5 a.m | 0.035 | — |
| 7 a.m | 0.033 | 5 |
| 9 a.m | 0.029 | 17 |
| 12 noon | 0.025 | 29 |

The roses which arrive after the start of distillation lie on the floor of a velatively cool room. Unfortunately this leads to fermentation if the roses are heaped too high and not aerated, but in any case there is a loss of oil by evaporation.

To improve rosewater production some larger stills are required.

The adoption of improved agro-techniques such as Proper spacing, planting the rose bushes in well-located terraced fields, pruning, manuring, irrigation and spraying against diseases, insects and pests would increase yields of Roses threefold per unit area.

## ROSE WATER DISTILLATION PLANT AT AGROS

While the use of distillation dates back in recorded history to about 50 B.C the first truly industrial exploitation of this separation Process did not occur until the 12th century when it was used in the Production of alcoholic beverages. By the 16th century, distillation also was being used in the Manufacture of vinegar, Perfumes, oils and other such products. As recently as two hundred years ago, distillation stills were small, of the batch type and usually operated with little or no reflux. With experience, however, came new developments. Tray columns appeared on the scene in the 1820 along with feed preheating and the use of internal reflux. By the latter part of that century, considerable Progress had been made by Hansbrand in Germany and Sovel in France who developed mathematical relations that turned distillation from an art into a well defined technology. While one of the most important unit operations, distillation unfortunately is also one of the most energy intensive operations. It easily is the largest consumer of energy in Petroleum and Petrochemical Processing and as such, must be approached with conservation in mind. It is a specialized technology and the correct design of equipment is not an easy task. Distillation is a Process for the separation of substances according to their volatility. The portion which evaporates when heat is applied and which is subsequently condensed by cooling it in coolers is called the distillate; the portion which does not evaporate is called the distillation residue. Distillation is one of the most important methods of Purifying volatile substances.

A Preliminary investigation was carried out regarding existing processing systems as to technical efficiency and product quality and the introduction of new processing technology.

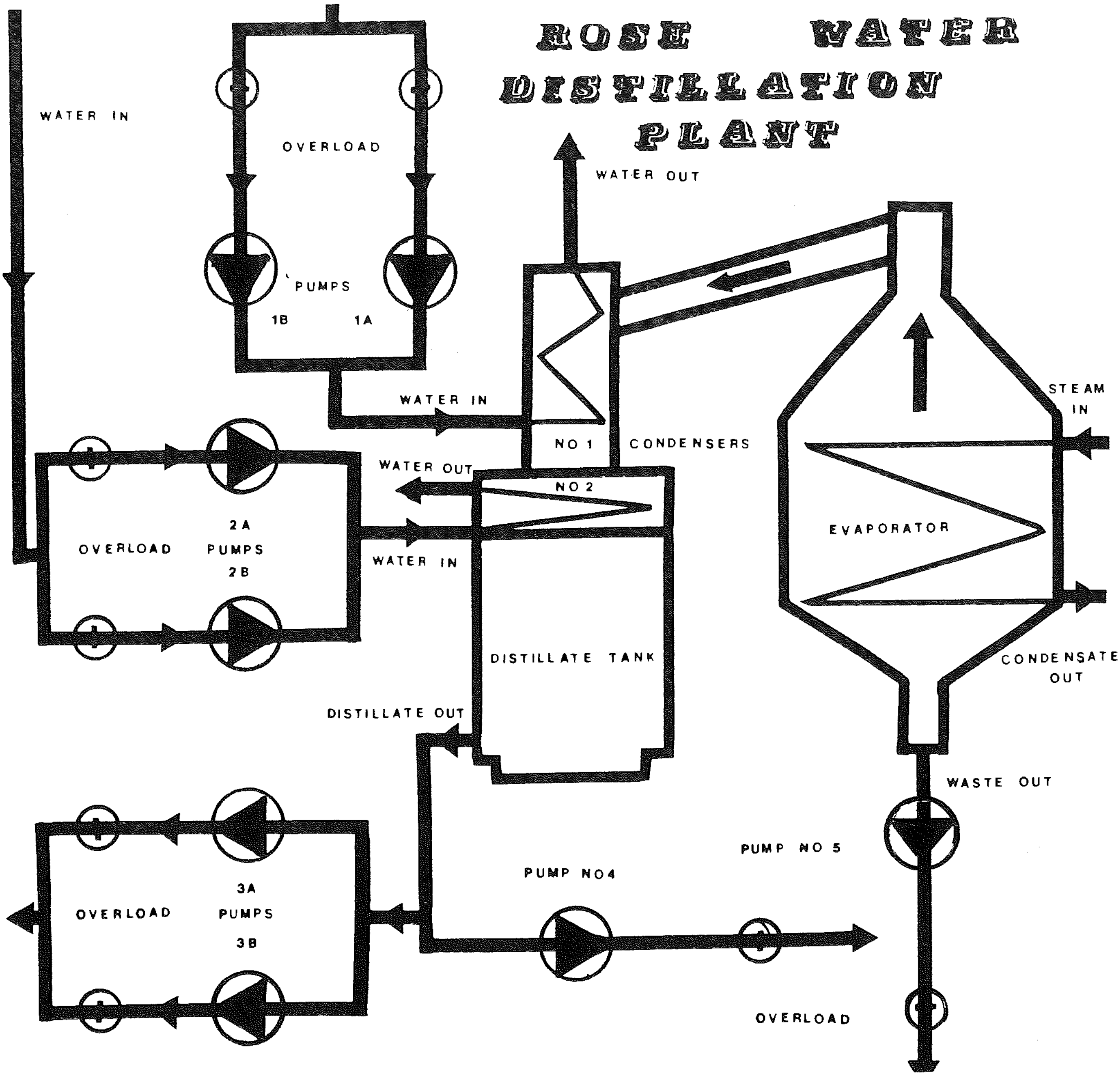
The following factors were taken into consideration in the design of the New Distillation Plant.

1. Installation of one large still, capable of taking 640 Kgs of Roses.
2. The still to be equipped with thermometer Middle height on still as well as on distillate outlet.
3. Quality control of distillate.
4. Checking Possibility of "indirect" heat for the still, heating by steam supplied from an independent boiler.
5. For energy savings.
6. For high speed distillation i.e 5 hours per batch.
7. Plant dimensions, related to available floor area and headroom.
8. Fully automatic.
9. The required composition of the residue and distillate.
10. Foaming should be avoided.
11. The rate of evaporation might influence the quality of rosewater.
12. Batch distillation.

The main advantage of batch distillation is its flexibility. A single unit can, by changing reflux ratios and boil up rates, be used for many different systems.

A batch distillation Process is very simple to control and there is no need to balance the feed and draw off as is the case with the continuous distillation approach. Batch distillation is Particularly useful when applied to feeds containing residues which have a tendency to foul surfaces since these residues remain in the still and generate problems, of heavy fouling on the heat transfer surfaces.

The schematic diagram of the New Rosewater Distillation plant at Agros is shown below. It is the batch type of distillation.




## PERFORMANCES

Loads of Rose flowers: 640 Kgs per still and per batch.
Steam Consumption: 400 Kg/HR under 5 bars
Water Consumption: 3.6 $m^3$/HR at 20°C.

## WORKING OF THE PLANT

The mixture by proportion of water and Roses is Processed in the evaporator by indirect heating through coil by steam at 5 bars. The heating being indirect, through the coil of the vessel three advantages are to be claimed:

1. No risk of local over-heating.
2. No contamination of Rosewater by off-odours.
3. All steam condensates recycled to the boiler and thus boiler water conditioning is fairly limited.

The vapour produced in the evaporator is condensed in the shell and tube type heat exchanger and then passed through another heat exchanger to cool down the distillate at an accurate temperature (25°C). The distillate is collected in the distillate storage tank and then pumped to the main Rose water storage tank.

## DESCRIPTION OF THE PLANT

a) One evaporator of 3600 Litres capacity for Roses Processing.

Material of construction 3mm stainless steel

**Evaporator equipment:**

(i) One wide loading door and a big drain valve allowing to handle Roses quickly.

(ii) One safety valve

(iii) One steam coil protected by a perforated basket.

(iv) One Pressure / Temperature gauge.

(v) Two water supply valves and two flow meters

(vi) The evaporator has a diameter of 1850 mm and has a support of four legs.

(vii) A sewage pump to empty the waste residues

b) One shell and tube type heat exchanger for condensing the vapours incorporating two thermostatic units.

Material of construction = 3 mm stainless steel.

c) One heat exchanger used to cool down the distillate at an accurate temperature. Incorporating two thermostatic units.
Material of construction: 3 mm stainless steel

d) One storage tank 1900 litres capacity for Rose water incorporating three float switches. Its volume corresponds with a normal loading of Roses.

Material of construction: 3 mm stainless steel. There is also a glass bowl system for distillate quality control, a glass tube and a calibrated ruler.

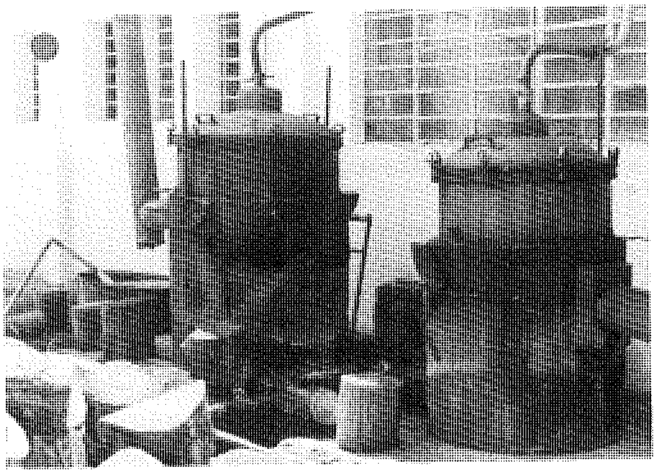


Photo 2

Photo 3

Photos 2 and 3 indicate the old type of Distillation units which burned wood. The max capacity of those units is 120 Kgs of Roses and the distillation time varies from 8-10 hours.

Photos 4, 5 indicate the New Rose water Distillation Plant featuring condensers - receivers evaporator, instrumentation, control Panel, piping and pumping systems.

The new plant can process the total amount of Roses of all six old type distillation units in half the time.

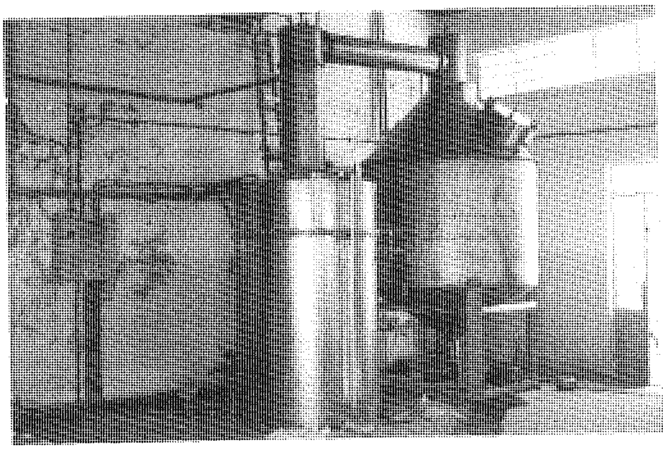


Photo 4

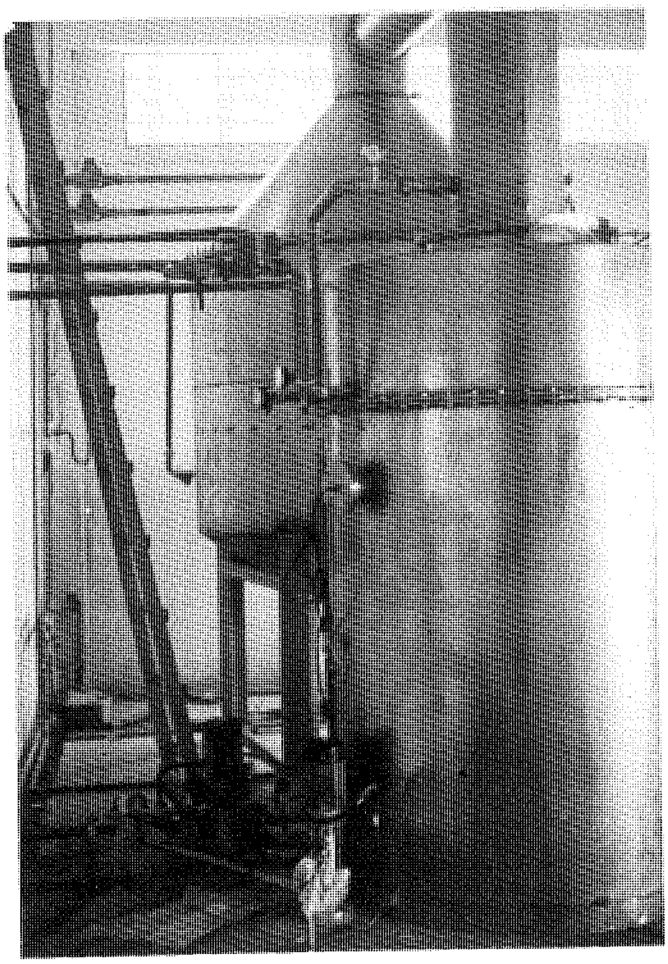


Photo 5

# ON THE GROWTH OF DISLOCATION LOOPS IN ELECTRON IRRADIATED COPPER FOILS

by Dr A.Y. Stathopoulos*,
Lecturer at H.T.I.

**Abstract**

We have irradiated foils of single crystal pure copper in the Harwell AEI EM-7 micoroscope at several temperatures from 140 to 320°C, and have measured interstitial dislocation loop densities and growth rates. We have interpreted the experimental results using the rate theory of microstructural evolution during radiation damage.

We have achieved a good agreement between loop growth measurements and rate theory calculations only when using a very recently developed dislocation sink strength. In this case we predict a temperature dependent dislocation bias for interstitials and a vacancy migration energy of about 0.75 eV, which is consistent with recent independent experimental data.

## 1 Introduction

Studies of the development of the microstructure during the irradiation of pure metals provide an insight into fundamental aspects of radiation damage. Such investigations should be of great assistance to the development of the chemical rate theory of void swelling and irradiation creep in fast reactor core components which are subjected to an intense flux of fast neutrons. The present investigation concerns the growth of interstitial dislocation loops in pure copper during electron irradiation. We have measured loop growth rates in the temperature range 140 to 320°C, and have used the rate theory to interpret the experimental results.

Several previous studies of loop and void growth in irradiated copper have been reported [1-3]. In particular, we note a recent set of electron irradiations by Fisher, White and Miller [3] in which loop growth rates were measured over a temperature range similar to that employed in the present work. Those authors also reported the presence of voids at one irradiation temperature, whereas we have not found voids in the present study. However, the major difference between the two studies is in the rate theory analysis of the loop growth rate measurements. For their analysis, Fisher et al[3] employed incorrect sink strengths, empirically modified to include the effect of bulk recombination[4], whereas our treatment, reported here has a more rigorous basis following recent theoretical advances[5,6].

## 2. Experimental

### 2.1 Procedure

Single crystalline foils of spec-pure copper containing less than 1 at. ppm of oxygen nitrogen or carbon, measured by γ-activation analysis[7], were electropolished in an electrolyte of 1:2 nitric acid in methanol at an applid voltage of ~ 4V and at temperatures of $\lesssim$ - 45°C. These conditions were used in order to reduce the amount of hydrogen gas which can be introduced into the specimens during polishing and which complicatequantitative measurements[8,9]. The specimens were kept under high vacuum and irradiated, within ~ 1/2 hr of polishing, in the Harwell AEI EM-7 microscope using a side-entry hot stage with temperature readings accurate to within ± 2°C. Bend-free specimens with large flat areas were used so that the same foil could be employed for a whole set of irradiations, that is over a range of temperatures and different thicknesses. This had the advantage of eliminating variations among specimens. During irradiation the specimen chamber was differentially pumped to $10^{-7}$ Torr by a turbomolecular pump, with liquid nitrogen cold fingers above and below the specimen. As a result of the above treatment no observable oxidation or contamination of the surface could be detected subsequently. The irradiations were carried out at fully-facussed beam conditions at 1 MeV and with no objective aperture in position, to avoid additional heating of the bottom of the foil. The temperatures covered were in the range 140 to 320°C at a displacement damage rate of $7 \times 10^{-3}$ dpa/s; this was calculated from the electron flux assuming a cross-section of 75 barns for an isotropic value of the displacement energy, $E_d$, of 19eV[10], for a direction near <023> used throughout.

During loop density measurements the thickness of the foil and the size of the small zones denuded of loops near the surface on either side of the foil were determined by stereomicroscopy to an accuracy of <10%. The position of the foil surface was determined by depositing a gold layer after the irradiations and re-examining the same areas again. At each temperature, irradiation of a minimum of five different areas on the same specimen was carried out in regions 0.6 to 0.8 μm thick to ensure representative and consistent results. In some cases

* The paper describes work carried out by the author at the University of Oxford and the Atomic Energy Research Establishment (A.E.R.E.) at Harwell, England.

at higher temperatures, 220°C and 280°C, areas of the foils too thick to see through at 1 MeV, that is > 2.5 μm were irradiated and then backthinned in order to estimate the influence of the surface on loop densities.

To study loop growth the average growth rates of many loops were used irrespective of their position in the foil. For loops which were almost parallel to the plane of the foil the average loop diameter was estimated from measurements on the loop area. The total loop area was first determined from measurements of their projected areas. This was done by tracing out the loop perimeter with a Kontron digitiser interfaced with an HP desk computer[11]. This measurement was corrected for the loop's angle of inclination in the image plane, (obtained from a Burgers vector/habit plane analysis). From this the average diameter of the inclined loops was computed. For loops which were perpendicular, or nearly so, to the plane of the foil it was sufficient to equate image-length with loop diameter.

### 2.2 Experimental Results

Fig. 1 illustrates the qualitative features of the development of the loop populations; the micorgraphs, taken from irradiations at temperatures, T, of 140°C and 227°C demonstrate how as T increases the loop density decreases and the loops grow faster. It can be seen that at a given temperature it is relatively easy to follow the change in the size of individual loops and thus to measure loop growth as described above.

Detailed loop densities, $\rho_L$, for several different temperatures are given in fig. 2 as a function of (1/T) $K^{-1}$ and they refer to average measurements throughout the foil excluding near-surface denuded zones. The dimensions of these denuded zones increased with temperature in the way shown in fig. 3. The densities determined on thick specimens after backthinning were found not to be significantly different from those determined as outlined above (also plotted in fig. 2). A possible error of ± 8% is estimated for the loop density measurements. At the higher temperatures the error bars on the graph are larger because fewer loops were measured, whereas at the lower temperatures the average number of loops counted in the measurements was about 600.

The measured rates of loop growth are plotted in fig. 4; this shows an Arrhenius dependence on (1/T) $K^{-1}$. The error bar on each point on the graph represents the standard error of the slope derived from each separate loop growth experiment.

## 3. Theoretical

### 3.1 Procedure

We have used the rate theory of radiation damage [12] to analyse the experimental results presented above. We performed the calculations using a modified version of the VS2 code [13] containing only interstitial loops and the surface of the specimen foils. The sink strengths of the foil surfaces for vacancies, $k^2_{vS}$ and for interstitials, $k^2_{iS}$ are those in the standard version of the code, namely:

$$k^2_{vS} = \frac{2k_{vL}}{\ell} \Big/ \left\{ \coth\left(\frac{k_{vL}\ell}{2}\right) + \frac{D_v}{\bar{K}_v} - \frac{2}{k_{vL}\ell} \right\} \tag{1}$$

and

$$k^2_{iS} = \frac{2k_{iL}}{\ell} \Big/ \left\{ \coth\left(\frac{k_{iL}\ell}{2}\right) + \frac{D_i}{\bar{K}_i} - \frac{2}{k_{iL}\ell} \right\}, \tag{2}$$

where $k^2_{vL}$ and $k^2_{iL}$ are the sink strengths of the interstitial loops for vacancies and interstitials, $D_v$ and $D_i$ are the diffusivities of vacancies and interstitials, and l is the thickness of the foil. $\bar{K}_v$ and $\bar{K}_i$ are the transfer velocities of vacancies and interstitials across the foil surface; these we obtained by assuming that the jump of a defect at the foil surface is the same as a jump in the bulk of the material so that $K_v = D_v/b$ and $K_i = D_i/b$, where b is the jump distance in the lattice.

We report two distinct sets of calculations in detail; these employed different analytic expressions for the loop sink strengths, $k^2_{vL}$ and $k^2_{iL}$. For the first set of calculations we used the first-order loop sink strengths:

$$k^2_{vL} = Z_v \rho_L \tag{3}$$

and

$$k^2_{iL} = Z_i \rho_L, \tag{4}$$

where $\rho_L$ is the dislocation density contained in the interstitial loops equal to $2\pi r_L N_L$, where $r_L$ are the radii and number density of the loops. $Z_i$ and $Z_v$ are the bias factors for absorption of interstitials and vacancies, respectively, by the loops. We assumed that $Z_v = 1$, and $Z_i > 1$, and defined the bias of the dislocation loops, B, by:

$$B = \frac{Z_i - Z_v}{Z_v} \times 100\%. \tag{5}$$

These calculations used empirical values for $Z_v$ and $Z_i$, which we assumed to be constants for the material

In fact, $Z_v$ and $Z_i$ are reflections of the interaction of the point defects with the strain field of the dislocation loop, which is dependent on the microstructure present and on the temperature of the specimen. Bullough and Quigley[6] recently derived sink strengths for network dislocations which include these interactions rigorously, and Woo[14] derived analogous sink strengths for dislocation loops. Woo's sink strengths, however, are appropriate only for small loops, and since we wished to study the behaviour of large loops, we used the sink strengths derived for straight dislocations[6] in our second set of calculations. This is a good approximation since the maximum diameter of the loops we considered in the study is always $\geq$ 100nm. Bullough and Quigley expressed their sink strengths in terms of equations (3) and (4) where the Z factors are*:

$$Z = \pi \frac{\{[2+k^2 e^{L/R}(Q-Pr_c^2)]kRK_1(kR)+k^2(R^2-r_c^2)K_o(kR)\}}{K_o(kR)+Pe^{L/R}kRK_1(kR)} \quad (6)$$

where

$$P = E_1(L/R)-E_1(L/r_c) + \frac{b\, e^{-L/r_c}}{n_j b\, f\, r_c}, \quad (7)$$

and

$$Q = \frac{L^2}{2}(E_1(L/R)-E_1(L/r_c)) + \frac{1}{2}\,[R(R-L)e^{-L/R} + r_c(L-r_c)e^{-L/r_c}] + \frac{b}{n_j bf}\, r_c\, e^{-L/r_c}. \quad (8)$$

They give L as:

$$L = \frac{(1+\nu)\mu b|\Delta V|}{3\pi(1-\nu)k_B T}, \quad (9)$$

where ν is Poisson's ratio, μ is the shear modulus, b is the Burgers vector, ΔV is the point defect relaxation volume, T is the absolute temperature and $k_B$ is Boltzmann's constant. $r_c$ is the dislocation core radius and is equal to $(Lb)^{1/2}$, $k^2$ is the total sink strength of the microstructure, R is equal to $(L/k^2)^{1/3}$, $n_j b$ is the jog density per atom plane, f is the fraction of adjacent sites from which a jump into the core of the dislocation is possible, and $K_0$ and $K_1$ are the modified Bessel functions of the second kind of order 9 and 1 respectively, while $E_1$ is the exponential integral

For copper, there is controversy about the magnitude of the vacancy migration energy, $E_v^m$ (15, with different experiments yielding values in the range ~0.7 eV to ~ 1.2 eV. Hence, in our first set of calculations, we varied $E_v^m$ and the empirical $Z_i$. There is also considerable uncertainty about the magnitude of the relaxation volume of an interstitial, $\Delta V_i$, and hence about the bias of the dislocations for absorbing interstitials preferentially to vacancies. Computer-simulation calculations of $\Delta V_i$ have given values in the range 0.5 Ω, τo 1.52 (Ω = atomic volume) depending on the interatomic potential the various workers used in their calculations [16]. Bearing these uncertainties in mind, we made our second set of calculations with different values of both $E_v^m$ and $\Delta V_i$. In addition, we took the vacancy relaxation volume, $\Delta V_v = -0.46\,\Omega$[17]. As suggested by Bulough and Quigley [6], we chose $f_v$=1 and $f_i$<1 and, hence, for our second set of calculations we had fourunknown parameters; $E_v^m$, $\Delta V_i$, $f_I$ and the jog density ($n_j$b).

Our calculations of interstitial loop growth used the experimental values of the temperature, foil width, loop number density and maximum loop radius, that is the radius at which the loops interacted with each other to form a network of dislocations. For each of the experimental temperatures, we calculated the growth rates of the loops at their maximum radius and compared them with the experimental results. The data set is summarized in table 1.

### 3.2 Theoretical Results

For our first set of calculations we selected a value of $E_v^m$ and varied $Z_i$ until the calculated loop growth rates were closest to the experimental results. We repeated this procedure for various $E_v^m$, and give the results in fig. 5. These show that we obtained the closest agreement between experiment and theory for $E_v^m \simeq 0.55$ eV, and $Z_i = 1.010$, that is B = 1%. This value of $E_v^m$ is considerably lower than we expected. The dislocation bias is also much lower than the 4 to 10% generally assumed[3].

Results from our second set of calculations, that is when we used the $Z_i$ and $Z_v$ given by equations 6 to 8, are shown in figs. 6 to 10. Fig. 6 gives results for $E_v^m = 0.75$ eV, a value which agrees with the more recent experimental data [15], and a jog density of 0.1. We obtained each curve by choosing a value for $\Delta V_i$, and then varying $f_i$ to provide the best fit to the experimental points. These results are clearly in excellent agreement with the experimental data for the physically realistic values of $\Delta V_i$ and $f_i$ we used here. Fig. 7 gives results for several different jog densities, and $\Delta V_i = 0.87\,\Omega$. As before, we varied $f_i$ to obtain agreement between calculations and experiment. Clearly we can replace the effects of varying the jog density almost exactly by varying $f_i$, so that our choice of jog density for these calculations did not affect the results in any significant way. In fig. 8 we show the calculated values of $Z_i$ and $Z_v$ (equations 6 to 8), and of the bias, B, as defined by equation 5, at the maximum loop radius for $E_v^m = 0.75$eV $\Delta V_i = 0.87\,\Omega$, jog density = 0.1 and $f_i = 0.165$. An important feature of these new sink strengths is the temperature dependence of these parameters, in contrast to the constant values we assumed in our first set of calculations and employed in most previous analyses.

We performed additional calculations for a range of values of $E_v^m$, with the jog density held at 0.1. Fig. 9 shows results for $E_v^m = 0.55$ eV (cf fig. 5) in which we needed unrealistically small values of $\Delta V_i$ to fit the experimental points. Fig. 10 portrays results for $E_v^m = 0.85$ eV; in this case, by contrast, we required unreasonably large values of $\Delta V_i$ to fit the experimental data. Within this range for $E_v^m$, we

* We have suppressed the subscripts i and v referring to interstitials and vacancies respectively. To differentiate between interstitials and vacancies the subscripts should apply to Z, $k^2$, ΔV, and f.

found realistic values of the parameters to provide good fits to the experimental data. However, a value of 0.75 eV for $E_v^m$ provided the best representation of the data, in good agreement with recent measurements of this quantity.

## 4. Discussion and Conclusions

In this study we have measured the densities and growth rates of interstitial dislocation loops during the electron irradiation of pure copper. In addition, we have performed a series of rate theory calculations to analyse the experimental results.

We have taken two distinct theretical approaches; first, we adopted a temperature independent (constant) empirical parameter for the dislocation bias for interstitials. With this approach we found the best agreement between experiment and theory for a vacancy migration energy ($E_v^m$) of ~ 0.55 eV and a bias (equation 5) of ~ 1%. Such a low value of $E_v^m$ lies outside the range of the independent experimental data, while the bias is also lower than generally is accepted. Our second set of calculations employed recently derived[6] analytic expressions for the bias factors $Z_i$ and $Z_v$ (equations 6 to 8). This improved rate theory gave excellent agreement with the loop growth rate measurements for the physically realistic values of $E_v^m$ (= 0.75 eV) and the interstitial relaxation volume ($\Delta V_i = 0.87\ \Omega$).

Fisher et al[3] performed a similar analysis to yield values for $E_v^m$ and $\Delta V_i$. However, as shown by Pierce et al[4], these authors used incorrect sink strengths, modified empirically to include the effect of bulk recombination. In fact, we have performed supplementary calculations during the course of this present study, using a sink strength calculated to include the effect of bulk recombination[5]. We have concluded that such a sophistication does not modify significantly the calculations reported here, and for simplicity the results presented omit this effect. Fisher et al also observed voids at one irradiation temperature, which were absent in the experiments reported here. The most likely explanation for this is differences in the level of residual gases present in the specimens.

The results of the present investigation do, we believe, demonstrate the benefits to our understanding, and model development programme, of radiation damage processes from studies on pure metals.


## Acknowledgement

I would like to thank Professor Sir Peter Hirsch and AERE Harwell for provision of laboratory facilities.


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Table 1

Parameters used in the calculations

Burgers vector magnitude, $b = 0.227$ nm

Vacancy diffusion coefficient, $D_v = D_v^o \exp(-E_v^m/kT)$

$D_v^o = 2.2 \times 10^{-5}\ m^2 s^{-1}$.

$E_v^m$ varied such that $E_v^m + E_v^f = 2.07$ eV where $E_v^f$ = vacancy formation energy.

Interstitial diffusion coefficient, $D_i = D_i^o \exp(-E_i^m/kT)$

$D_i^o = 1.7 \times 10^{-8}\ m^2 s^{-1}$.

$E_i^m = 0.12$ eV.

Recombination coefficient/interstitial diffusion coefficient,

$\alpha/D_i = 2.0 \times 10^{20}\ m^{-2}$.

Shear modulus, $\mu = 4.5 \times 10^{10}\ Jm^{-3}$

Poisson's ratio, $\nu = 0.35$

Stacking fault energy, $\gamma_{SF} = 4.005 \times 10^{-2} Jm^{-2}$

Jog density = 0.1 (unless stated otherwise)

Vacancy relaxation volume, $\Delta V_v = -0.46\ \Omega$

Dose rate = $7 \times 10^{-3}$ dpa $s^{-1}$.

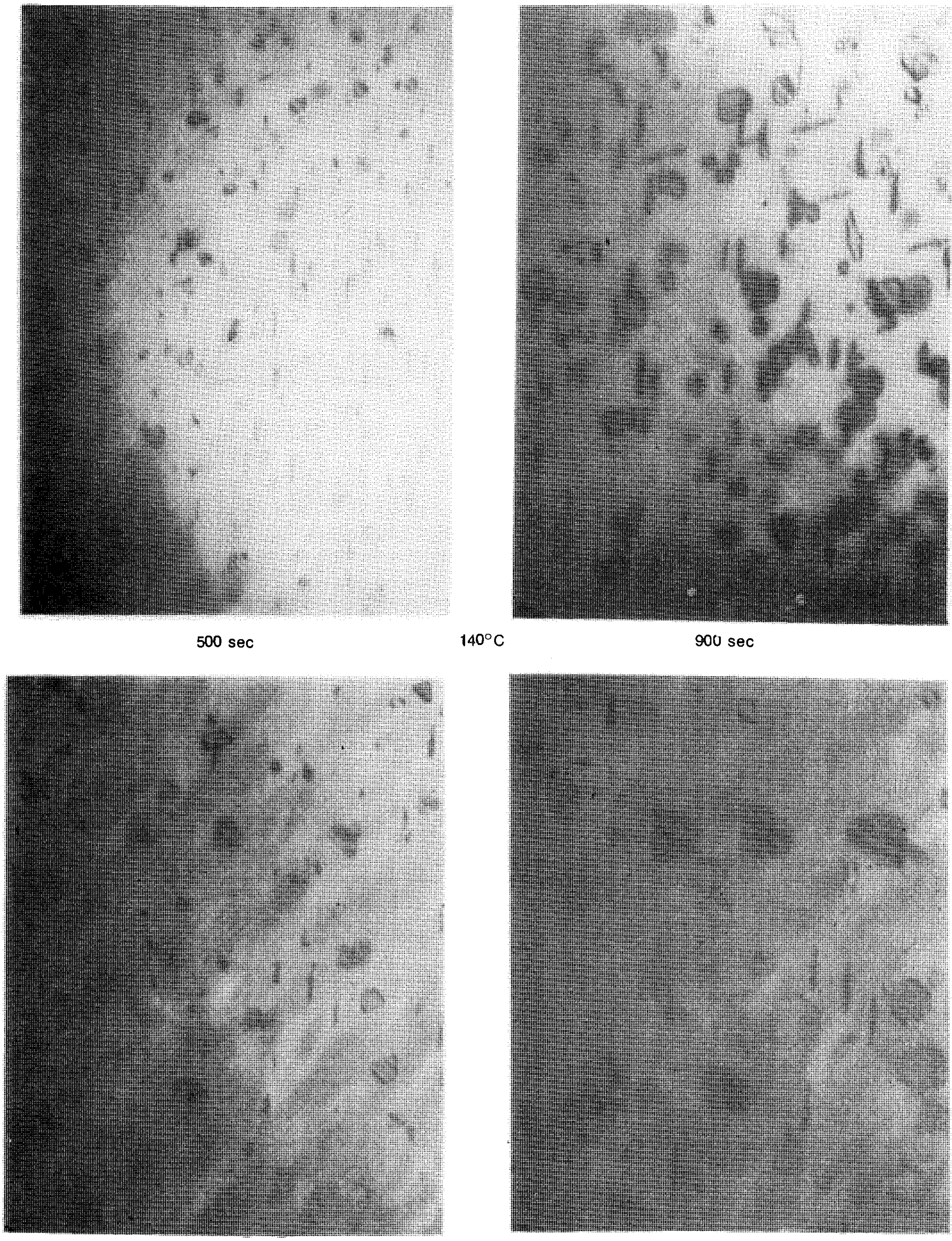


Fig. 1
Loop densities and size as a function of temperature and dose.

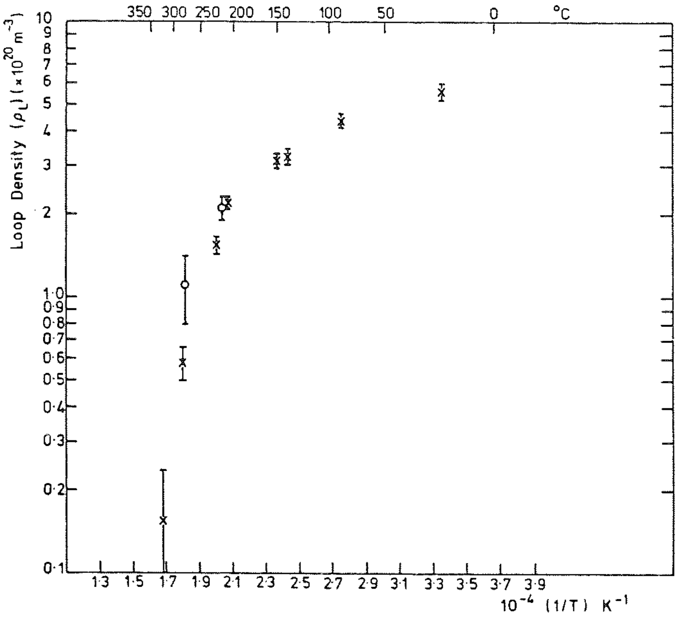


Fig. 2

Loop densities ($\rho_L$) as a function of temperature (T). The data points, O, correspond to measurements where the foils were backthinned after irradiation.

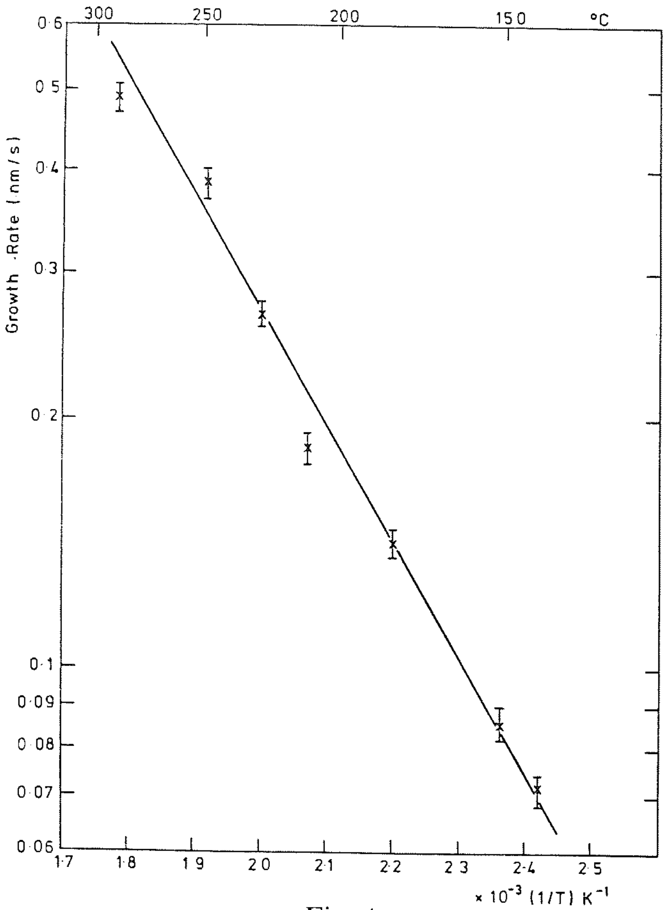


Fig. 4

Loop growth rates as a function of temperature; the line is drawn according to a 'least-squares' fit.

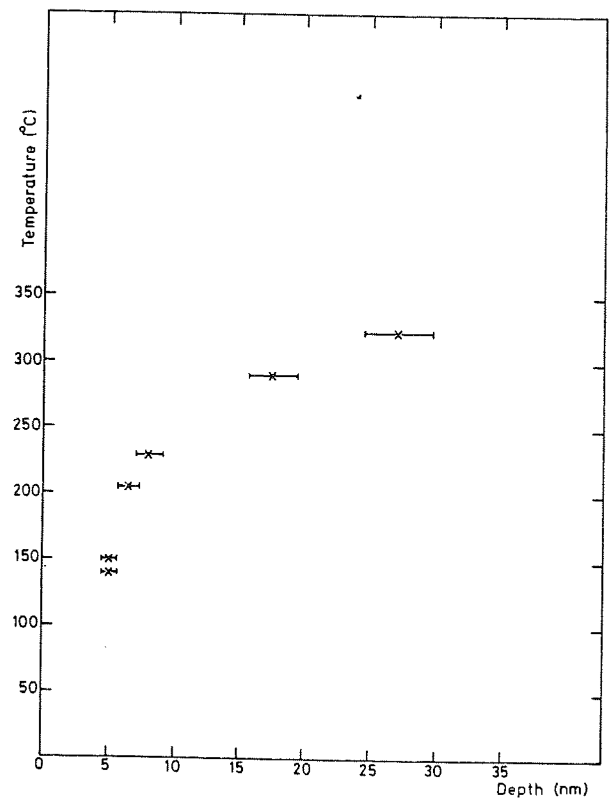


Fig. 3

Depth of loop denuded zones at the foil surfaces as a function of temperature.

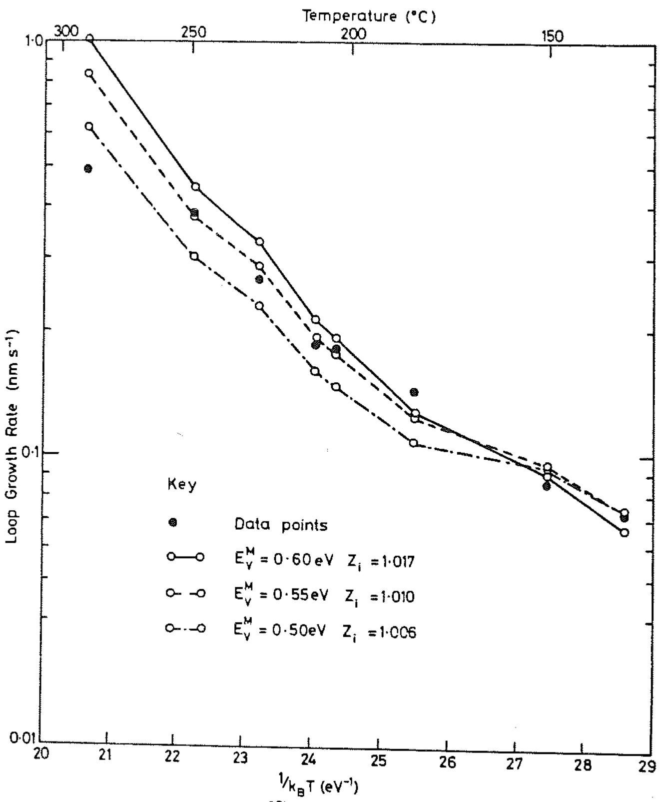


Fig. 5

Comparison of calculated and measured loop growth rates as a function of temperature. Calculations performed using the 'simple' first-order loop sink strengths (empirical $Z_i$ and $Z_v$) for a range of vacancy migration energy and dislocation bias factor $Z_i$.

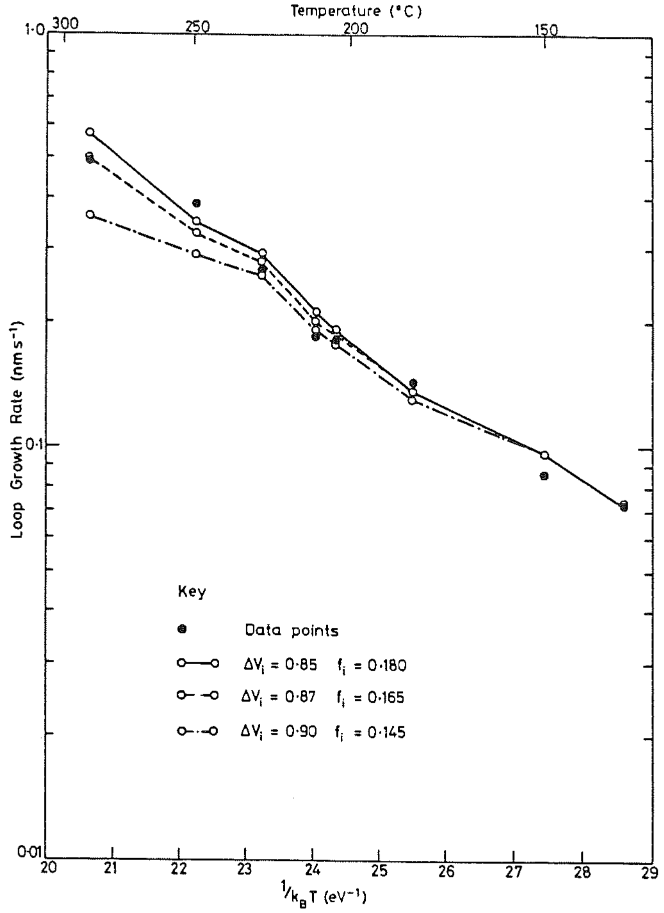


Fig. 6

Comparison of calculated and measured loop growth rates as a function of temperature. Calculations used 'new' loop sink strengths ($Z_i$ and $Z_v$ given by equations 6 to 8 of text). $E^m$ = 0.75eV. $\Delta V_v = -0.46\ \Omega$. jog density = 1/10, and a range of $\Delta V_i$ and $f_i$ values.

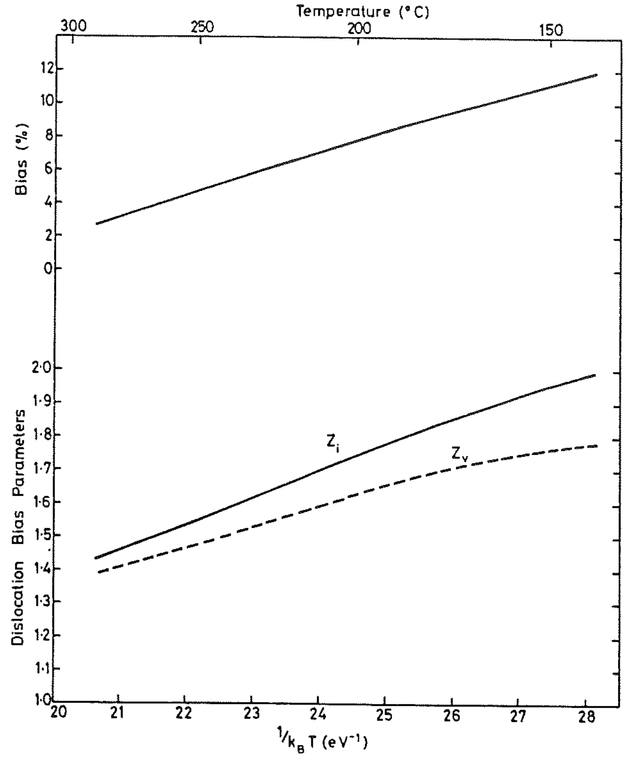


Fig. 8

Calculated dislocation bias, using equations 5 to 8 for $Z_i$ and $Z_v$, as a function of temperature for $E^m_v$ = 0.75eV. $\Delta V_v = -0.46\ \Omega$. $\Delta V_i = 0.87\ \Omega$, jog density = 1/10, and $f_i = 0.165$.

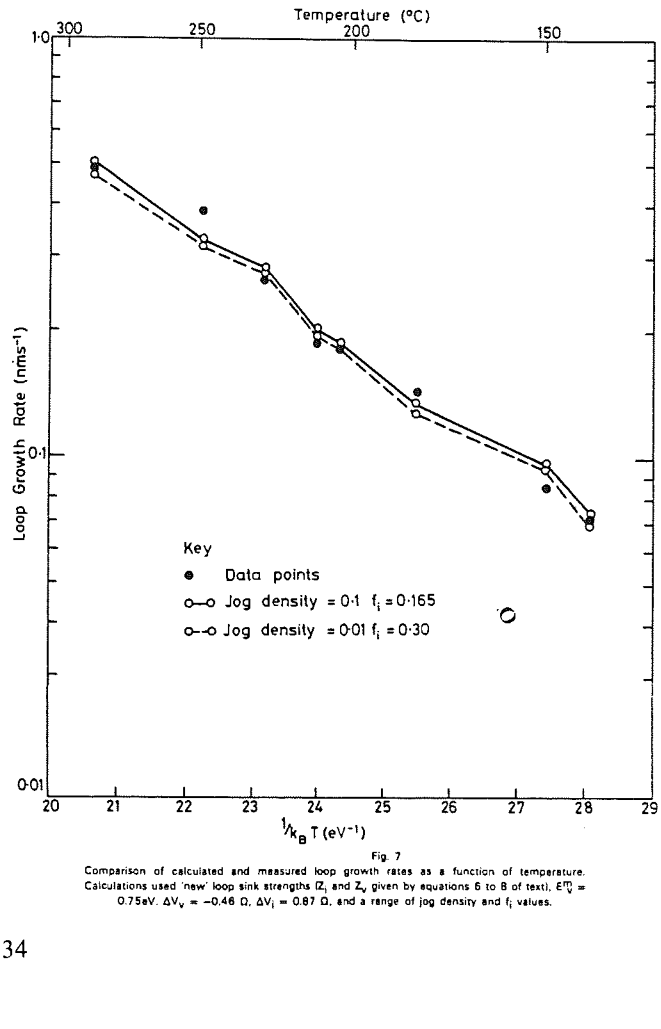


Fig. 7

Comparison of calculated and measured loop growth rates as a function of temperature. Calculations used 'new' loop sink strengths ($Z_i$ and $Z_v$ given by equations 6 to 8 of text). $E^m_v$ = 0.75eV. $\Delta V_v = -0.46\ \Omega$. $\Delta V_i = 0.87\ \Omega$, and a range of jog density and $f_i$ values.

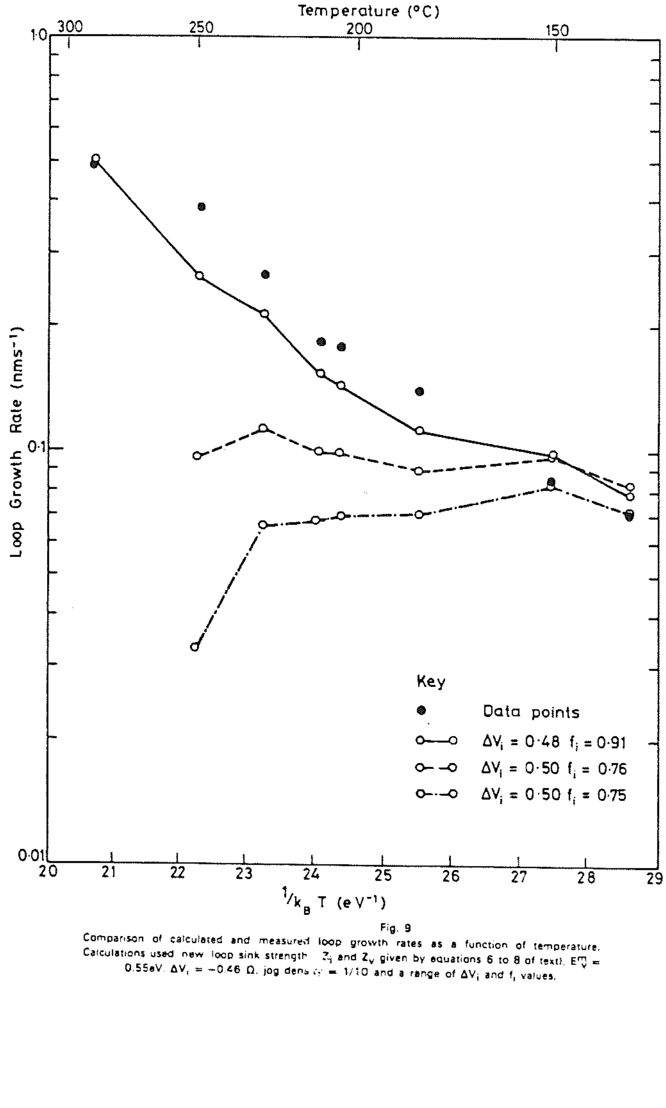


Fig. 9

Comparison of calculated and measured loop growth rates as a function of temperature. Calculations used new loop sink strength ($Z_i$ and $Z_v$ given by equations 6 to 8 of text). $E^m_v$ = 0.55eV. $\Delta V_v = -0.46\ \Omega$. jog density = 1/10 and a range of $\Delta V_i$ and $f_i$ values.

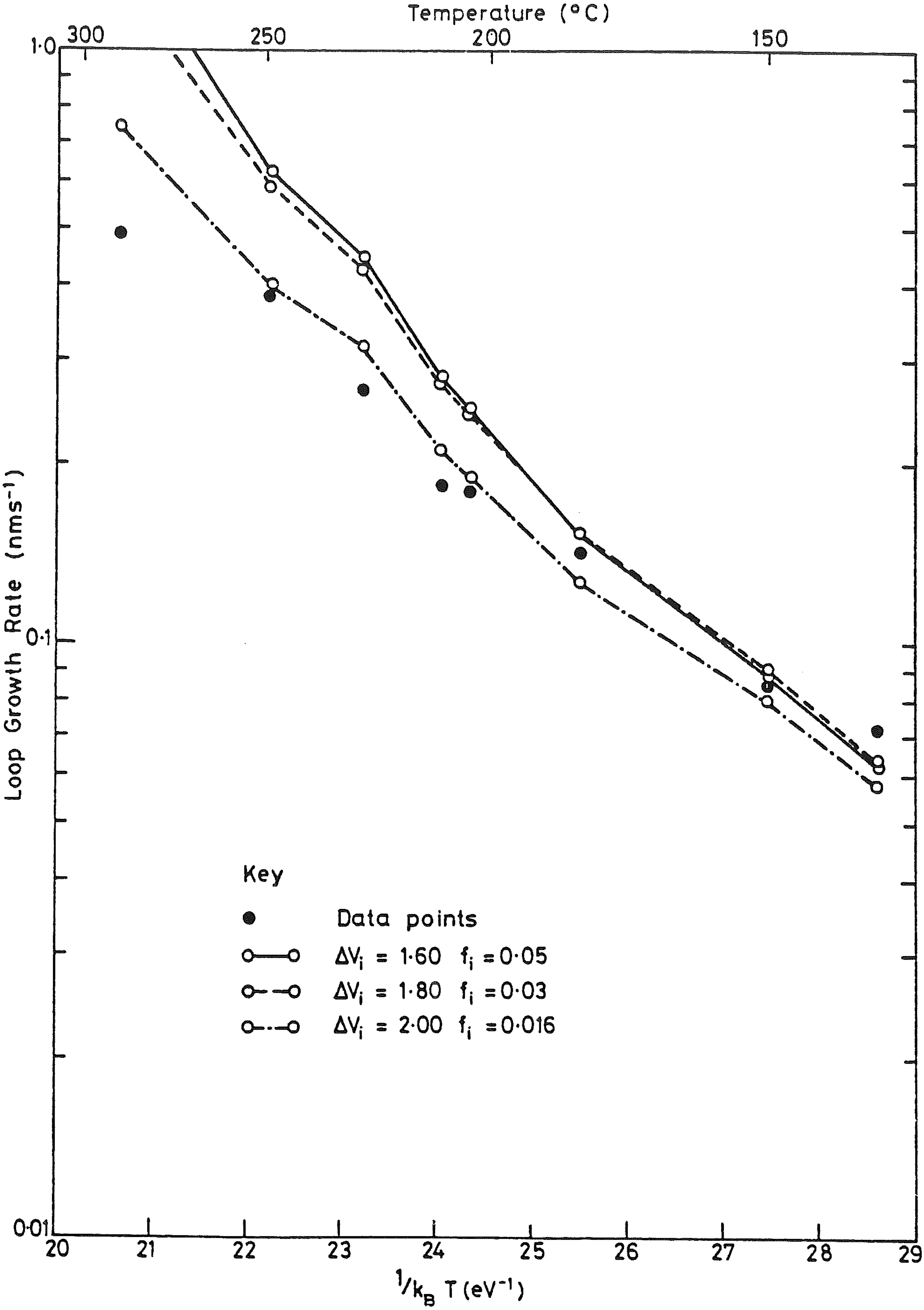


Fig. 10

Comparison of calculated and measured loop growth rates as a function of temperature. Calculations used 'new' loop sink strengths ($Z_i$ and $Z_v$ given by equations 6 to 8 of text), $E^m_v$ = 0.85eV, $\Delta V_v = -0.46\ \Omega$, jog density = 1/10 and a range of $\Delta V_i$ and $f_i$ values.

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# THE HALLEY'S COMET

by A. Achillides,MSc
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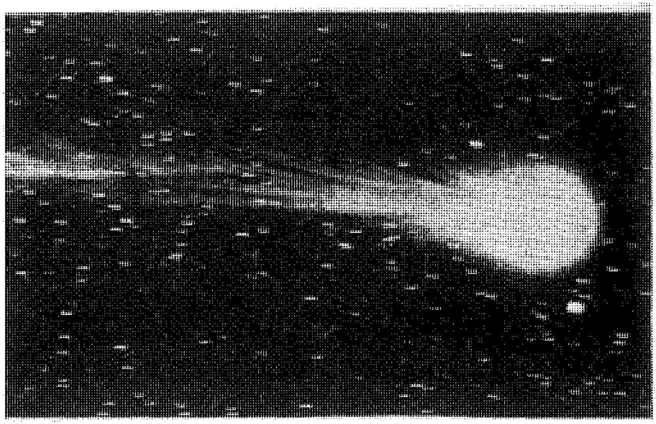
**Introduction:**

It took the world a long time to find out much about comets. To the Greeks they were atmospheric phenomena, and the first practical hint that they are truly astronomical in nature came in 1577. The great comet of that year was observed by the Tycho Brahe who found its parallax to be less than that of the moon and its distance therefore correspondingly greater. To be fair, his instruments were really the first ones that were capable of such a feat.

A comet's basic collection of matter is in the nucleus. This is an accumulation of meteoric particles, probably laced together with frozen gases, especially ammonia, not more than 800 km across, other gases, as well as meteoric dust and the like forms form a diffuse cloud or Coma around the nucleus and when a comet is still far away in the chill depths of space it can be seen only as a faint blur of light. Comets move around the sun in orbits that are often extremely eccentric; at perihelion they may be as near as mercury, but most recede at least to Jupiter's realm at aphelion. As they drift closer to the sun the increasing heat has a marked effect upon the coma. The gases vaporise forming a great cloud which is forced away from the sun by the pressure of its radiation ('the solar wind'); as perihelion approaches the tail becomes more.spectacular until, with a really great comet, it may stretch across a considerable arc of the heaven. After whirling round the sun the comet is flung back into interplanetary space; the temperature drops rapidly and the tail disappears and a few weeks later it may be invisible even with the largest telescopes. The great thing to be realized is that the tail is the least important item of the whole affair. It may extend for millions of km away from the head but nevertheless 90 per cent of the comet's mass is concentrated in the relatively tiny nucleus.

It was found recently from observations made by satellites that some comets are surrounded by a "halo" of hydrogen few million kilometers in diameter.

Comets may be conveniently divided into two groups. There are the regular or short-period objects which return to the vicinity of the sun again and again and can be predicted in advnace and there are others of much longer period (several centuries) that are normally observed only once. These are really brilliant objects but they are of less astronomical interest since our entire scrutiny may be limited to a few weeks. The regular comets have periods ranging from 3.5 years to about a century according to the length of their orbits but a great number of them are grouped around the 6.5 year mark and their aphelia all of them occur in the region of the Jupiter's orbit. The most successfuly theory of cometary evolution was proposed by Dr J.H. Oort in which he combines the genesis of comets with that of the minor planets as being due to the disruption of the original planet between the orbits of Mars and Jupiter. J. Oort points out that it requires only a small fraction of the resultant debris to account for the existence of a 200 000 000 000 comets, each with mass a 10 000 000 000 ton! This mass sounds very large indeed but on the planetary scale it is minute equivalent to the size of Mercury.



**Halley's comet photographed with the Schmidt telescope in Spain.**

The vast majority of these comets have been thrown by planetary perturbations into colossal orbits with periods of thousands of years and it seems likely that they throng in cold isolated loneliness in the dim reaches beyond Pluto's orbit.

**The Halley's comet:** One of the most famous periodic comet of all the time is the Halley's comet with a period of roughly 76 years. The comet has been recorded almost at every perihelion since 240 BC but Edmond Halley was the first to realize - that the comet of 1682 A.D. was the same as the one, appeared in 1607 and 1531 and accordingly predicted another return in 1758. The last apprearance of the comet in 1910 raised "waves of panic" between the public because the appearance of the comet was the "Divine sign"for the Dooms-day. Fortunately mankind survived and well equipped with an advance technology, was waiting for the new appearance of the comet in 1986. Scientists were expecting the new encounter impatiently in order to solve the riddle of the core's structure and the existence of organic molecules in the comet.

From all projects put forward from various countries for studing Halley's comet the most ambitious was the one planned by the European community. In that project the unmanned spaceship "Giotto" was planned to plunge into the comet's head in order to take close up photographs of the nucleus.

Sophisticated instruments on board were available for performing various experiments dealing with a) the energy and chemical composition of neutral particles given off by the comet's nucleus b) the chemical composition of dust particles c) the interplane ta ry and cometary magnetic fields and the energy and chemical compositions of positive ions given off by the cometary nucleus.

The spaceship "Giotto" was launched on July 1985 and after an eight month cruise in the interplanetary space encountered the comet's nucleus on the 13th of March just before midnight. The instruments on board began to send valuable informations to the mission control centre in Germany, confirming the broad outline of what astronomers believed to be happening in a comet. In the centre there is a small solid nucleus which emits gas and dust. The gas molecules are broken down into radicals and ionised by the action of the Sun's ultraviolet radiation and by the impact of particles in the solar wind. There is a "bow shock" where the solar wind runs into the gases expanding out from the comet. But no one had predicted the precise details. The Giotto project scientist Rudiger Reinhard remarked "there is a very large number of exciting and surprising results, more than expected". So far the most exciting result from Giotto was its observation of the nucleus of Halley's comet. Giotto was extremely lucky. When Vega 1 and Vegaz the Russian probes for studying Halley's comet, had passed by only a week earlier, the nucleus was hidden from view by its own dust; but when it came to Giottos turn, the nucleus was considerably less active, and it was exposed to view.

What Giotto saw was a large black "potato" emitting two bright jets of gas and dust.

The biggest surprise about the nucleus was its colour. As the leader of the camera team, Horst Keller put it "the nucleus is black, blacker than coal; as black as black velvet, its reflectivity is similar to the darkest material we know in the solar system". Its reflectivity is around 1 or 2 per cent, rather than the 50 percent or 50 that astronomens had been expecting for what they were calling a "dirty snow ball". Giotto's pictures show that the nucleus is 15 km long but only 8 km or less in width. In shape, Keller compared it to a potato, peanut or even a banana. The closert pictures show some structures on the surface. These ring-like depressions are probably not craters but sealed vents or nozzles where the nucleus has erupted during previous orbits of the Sun.

The unexpected darkness of the nucleus compared to the jets, explains some puzzling features of the Vega pictures. These showed two bright regions each 3 km across, that some astronomers had interpreted as a double nucleus. It is now clear that these bright spots were in fact the two jets of gas and dust. The black surface of Halley's comet is almost certainly due to some kind of organic compound and most astronomers would plump for a tar formed from simple organic molecules. But the discovery has come as strong ammunition for Sir F. Hoyle and Chandra Wickramasinghe who have long argued that comets contain substantial amounts of complex organic matter including viruses. Twelve days before encounter they predicted that the "great majority of short period comets must be astonishingly black with reflectivities at their surfaces less than one per cent". Because the nucleus is so dark it must absorb a lot of the Sun's heat falling on it. If there were ice near the surface it would evaporate away ten times faster than we observe.

This leads Keller to conclude that there must be a very thick surface crust, that insulates the ices in the centre. He said "the dirty snow hall is more dirt than show".

The close encounter of Giotto with the comets nucleus have not settled the old dispute about the origin of life. Sir F. Hoyle and C. Wickramasinghe suggested that bacteria from the comets were landed on the earth in primordial times and ignite the life on earth. Other scientists are skeptical of this claim and they argue that the results collected by Giotto are interesting but not at all surprising. They only confirm what everyone has always suspected that complex organic molecules are plentiful in space.

# MEASUREMENT OF pH

by A. Kaplanis, Graduate IERE, MIEEE, MBCS, FIHosp. E
Lecturer HTI

**Summary:**

The pH and other relevant terms are discussed and a circuit of an educational pH-measuring instrument with digital readout is given, based on lecture notes and project ideas to W.H.O.-sponsored Hospital Laboratory Technician Course participants at the Regional Training Centre/H.T.I, Nicosia.

An innovation, the pH radio pill, is briefly discussed.

**Introduction**

Measurement of pH is often desired in order to give information to the physician about the acidity or alkalinity of a solution or fluid such as blood, urine etc. Cell metabolism reacts to changes of pH and in fact human life depends on the pH of blood being kept within certain narrow limits.

**Definitions of Terms used**

(a) pH - "pondus Hydrogens" refers to the concertration of hydrogen ions which in effect is a measure of the acidity of a solution, a very important parameter in many fields.

(b) - Acids/Acidity. Acids are substances of sour taste with powerful caustic properties when concentrated e.g. sulphuric, nitric, hydrochloric acids. Some acids are poisonous - carbolic and oxalic acids. When acids are disolved in water hydrogen ions are formed.

- Acidity, such as dyspepsia, is caused by hydrogen ions ($H^+$) and depends on the concentration or the amount of Hydrogen ions in a fluid.
- Hydrogen ion concentration is measured in grams of hydrogen ions per litre or mole/litre of a solution.
- Hydrogen ion $H_3O^+$, for simplicity $H^+$, is a combination of a molecule of water and a proton found in water and all aqueous solutions.
- The acidity depends also on the total ionic strength, I, in the solvent, the influence being called salt effect, $f^x_H$, and increases the pH. The Debye - Huckel equation for the salt effect of aqueous solution relates the ionic strength I, which itself is related to the molality of ionic species and the charge of ionic species i. For ionic strength less than 0.1, this relationship is given as:-

$$\log F^x_H = -\tfrac{1}{2}\sqrt{I}$$

where $I = \frac{1}{2}\sum m_1 . Z_1^2$.

$m_i$ = molality of ionic species i
$Z_i$ = charge of ionic species i

- Another factor called the medium effect, $f_m$ also influences acidity but its effect is small enough to be neglected in most cases.

(c) Alkalinity. It is the concentration of a solution of Alkali substances such as soda, patash, ammonia etc; they have a bitter or caustic taste.

All Alkali are "bases" which in chemistry is a term for a substance that are chemical opposite to acids and have a higher concentration of hydroxile $OH^-$ than $H^+$ (Pure water is neutral because $H_2O \equiv H^+ + OH^-$).

(d) Calomel. It is also called Mercurous Chloride $Hg_2\ Cl_2$ and is a heavy white powder used in ointments for treating skin infections. In large doses it is poisonous. Calomel is used in conjuction with a glass electrode to measure pH.

**Theory:**

A Danish Scientist named S.P. Sorensen defined, in 1909, pH as "the negative logarithm of hydrogen ion concentration,"

ie pH = - $\log_{10}(H^+)$ moles/litre.

An exponential pH scale was proposed so that a hydrogen ion concentration from 1 to $10^{-14}$ is equivalent to 0 - 14 pH. In other words each pH number (0 to 14) represents a decade change in hydrogen ion activity.

Pure water has a hydrogen ion concentration of $10^{-7}$ molar so it is said that the pH of pure water is 7. Solutions having a pH greater than 7 are alkalic whilst those of pH lower than 7 are acidic.

The pH of Arterial Blood at 37°C varies normally, from 7.35 to 7.45 whilst the normal pH of venus blood at the same temperature varies from 7.32 to 7.42. Thus blood is alkalic since the normal pH is 7.4 and several mechanisms within the body maintain this value within tight limits. The mechanisms are:

(i) A Cellular level buffering system which combines with excess acids and excess alkali to neutralise their effects.

(ii) The respiratory system which keeps the carbon dioxide ($Co_2$) level within a certain range; ie the higher the $Co_2$ concentration the lower the pH.

(iii) The urinary system which regulates the bicarbonate-ion concentration when blood is cleaned.

The concentration of hydrogen ions in blood is often expressed in nanomoles per litre.

Thus a pH of 6.90 is equivalent to a hydrogen ion concentration of the antilog of (-6.90) = $1.25 \times 10^{-7}$ moles per litre or 125 nanomoles/litre.

**How pH is measured**

The measurement of the acidity or alkalinity of a solution (i.e. pH measurement), is made by determining electronically the hydrogen ion activity in that solution.

There are two methods for determining the pH values of solutions using what is called Calorimetric and Potentiometric procedures, the later being more common. In the potentiometric method there are a pH indicating electrode and a reference Calomel electrode immersed in the solution under test. See Fig. 1

There are three types of pH indicating electrodes.

These are:-

(i) The hydrogen gas electrode
(ii) The quinhydrome electrode
and (iii) The glass electrode

The glass electrode is most widely used. Both the glass electrode and the calonel reference electrode are shown herewith

All pH measurements are made by comparing the unknown pH against standard solutions called buffer solutions which have known values of pH. Suitable buffers for calibrating blood pH meters are the two phosphate buffers:-

$\frac{1}{40}$ molar potassium dihydrogen phosphate pH 6.840 at 38°C

$\frac{1}{40}$ molar disodium hydrogen phosphate

$\frac{1}{100}$ molar potassium dihydrogen phosphate pH 7.416 at 38°C

$\frac{1}{100}$ molar disodium phosphate

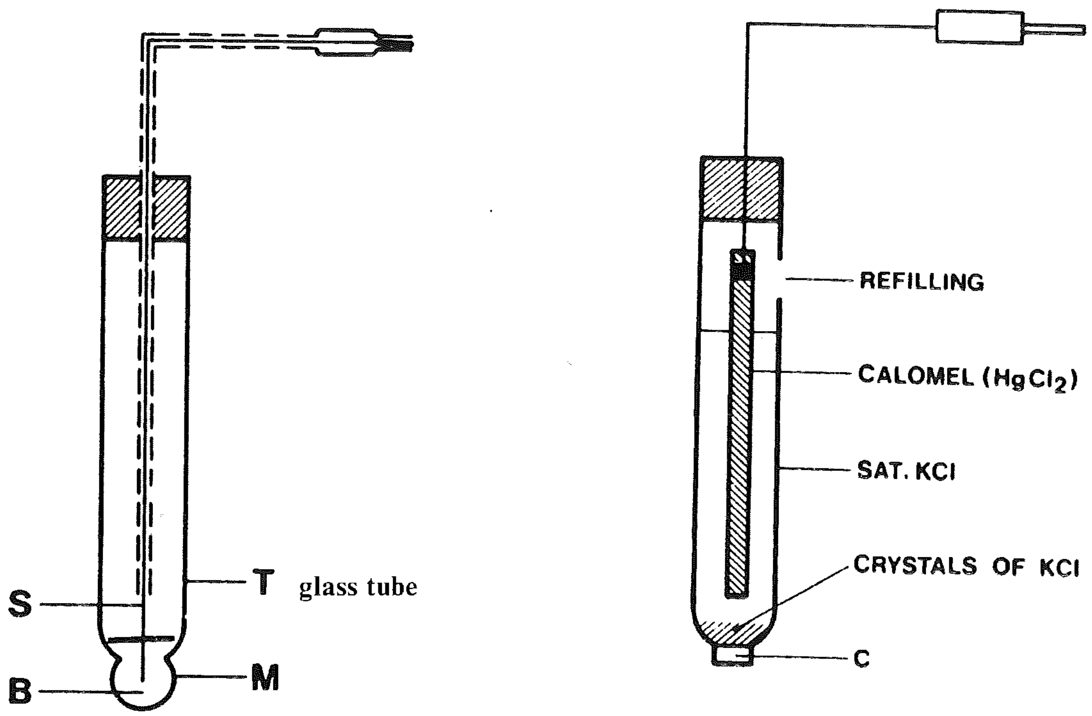



**Fig. 1**

*(a)*
*The Indicator Electrode*

*The bulb is filled with a solution (B) which has a reliable pH, a so-called buffer solution. An inner electrobe (S) is immersed in this solution.*

*(b)*
*The reference electrode*

*The Reference Electrode provides a constant potential against which the potential of the indicator electrode is measured.*

*The main tube forms a reservoir for saturated KC1 in which a calomel column is immersed.*

**The pH - meter:**

Basically a pH meter consists of a very high input impedance amplifier the output of which is used to display either pH or mV. See fig 2.

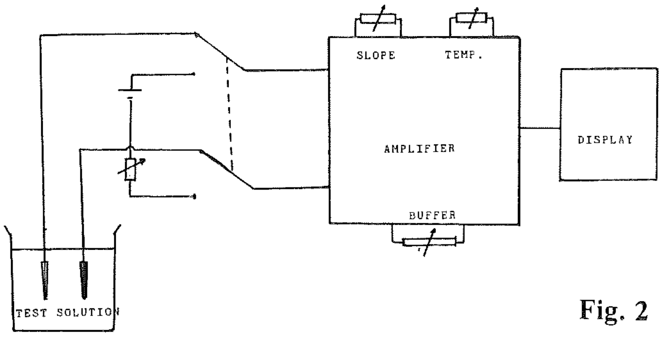



**Fig. 2**

The two electrodes in the solution will produce a potential difference in millivolts across them which is linear and proportional to the pH of the solution.

In other words the two electrodes form a "cell" having a source of voltage or emf in the order of millivolts, (proportional to the pH), and having a very high internal resistance in the order of 100 Meghoms to 1000 Meghoms.

This pH-dependent voltage, in millivolts, is then applied to an amplifier and if errors are to be within 1% or less, the input resistance of the amplifier must be much higher say 100 times higher than the internal resistance of the "cell" formed by the two electrodes.

Thus the input resistance of the amplifier should be in the region of 100,000 meghoms or more and it is for this reason that Field Effect Transistors, FET's, configured in a difference amplifier circuit, or Op-Amps are used, which have very high input impedances, ($10^{12}$ ohms,or higher).

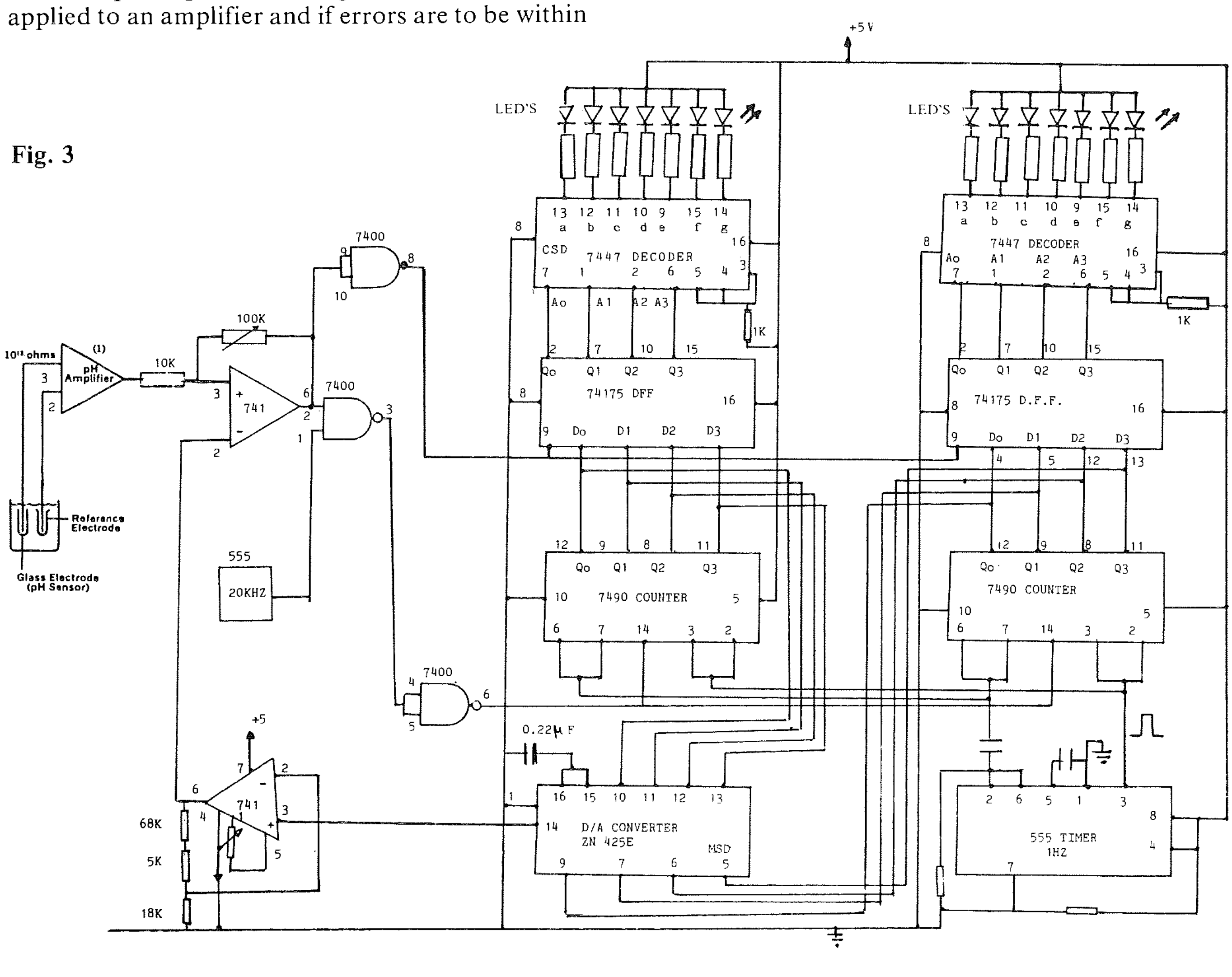
An Educational pH - meter with digital read out proposed for construction by R.T.C. students, is shown in Fig. 3.

Although this circuit, as an educational tool, serves the purpose for teaching the principles of pH measurement with digital read out, it has several limitations which, in future modifications these will be overcome.

A practical pH meter for instance should be able to detect changes of 0.01 pH units and in addition, the following controls should be incorporated.

(a) The Slope Control

**Fig. 3**



(b) The Buffer or Balance Control
(c) The Temperature control.

**The Slope Control:** The purpose of the slope control is to adjust the gain of the amplifier when the sensitivity of the electrodes has reduced due to contamination and ageing.

**The Balance Control:** This control adds a voltage in series with the pH electrode system for the purpose of adjusting the output indication to correspond to a known standard buffer solution.

What this means is that if a solution has a pH of 7 then the output voltage from the electrode should be zero and a zero voltage applied to the amplifier, the measured pH should be 7.

If the indication is not 7 the buffer control is adjusted to give a reading 7. (Actually very slight variations exist).

To do this an emf is added in series with the electrode signal, the potarity of which is such that the sum of the two emfs is zero.

**The Temperature Control:** In view of the fact that pH increases with temperature an arrangement is used in more elaborate pH meters whereby the pH is proportionately reduced to compensate for the possible increase in temperature.

The arrangement uses a thernal element which senses say the increase of temperuture of the solution under test and proportionately reduces the gain of the amplifier. Thus the pH measured will be due to hydrogen ion concentration in the solution giving no false readings due to possible increase of temperature in the solution.

Since the thermal element in effect changes the gain of the amplifier the Temperature Control is also called Gain Control of the pH meter.

## The pH Radio Pill

A special glass-electrode pH-Radio pill, the dimensions of which are 7.6 mm by 26 mm has been produced commercially which is currently used to study oesophageal reflux and other clinical investigations for both humans and large animals. This pill is in effect a tiny F.M. radio transmitter using latest Integrated Circuit technologies, producing signals in the frequency range of 350 KHZ to 550 KHZ with on output power of 10μw. The power source is a single replaceable mercury cell such as type R212.

The pill is anchored to the tooth using a fine thread, then swallowed, and the special glass electrode of the pH Radio pill produces voltages proportional to pH, linear within the range of 1 to 10 pH.

These pH dependent voltages so produced are applied to a varactor diode, that is a diode whose capacitance changes with the application of the voltages, the varactor being part of the oscillator circuit in the tiny capsule or pill. The frequency of the oscillation is therefore altered which in effect is proportional to the pH variations of the subject concerned.

It is said that the frequency alters by 2.5 KHZ per pH unit and it takes only one second to reach 95% of the final recorded value of the pH.

The field strength of the signal radiated by the pill-transmitter, which falls off as the distance cubed, is picked up by an aerial connected to a nearby radio receiver which indicates the pH on a suitable callibrated scale.

The pH radio pill apparently has been used successfully for monitoring the pericellular environment during investigations of implanted tumours in rats as well as in other clinical investigations.

The error due to temperature is said to be only 0.1 pH/$^{0}$C. A picture of the pH radio pill and its relative size, is shown in fig. 4. (Radio pills for measuring pressure and temperature of patients, for clinical investigations are also available).

"The Cordless pH Meter"

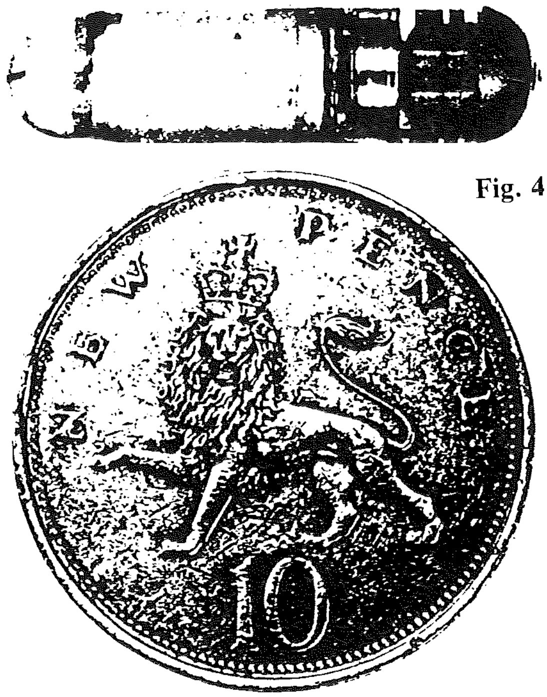


**Fig. 4**

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1. Introduction to Medical Electronics by B. Klein
2. Notes on pH measurement by B.W. Armstrong
3. Mc Craw Hill Encyclopaedia of Science and Technology.
4. Clinical uses of radio pills by B.W. Watson.
5. Manuals of pH meters of several manufacturers.

# THE ARTIFICIAL KIDNEY

by S. Hadjioannou, MSc
Lecturer HTI/RTC

## 1. The natural Kindney and Urinary system

The main functions of the urinary system is the excretion of metabolic waste products, unwanted liquids and electrolytes so as to maintain a normal body and electrolyte composition. All these products form the well known urine.

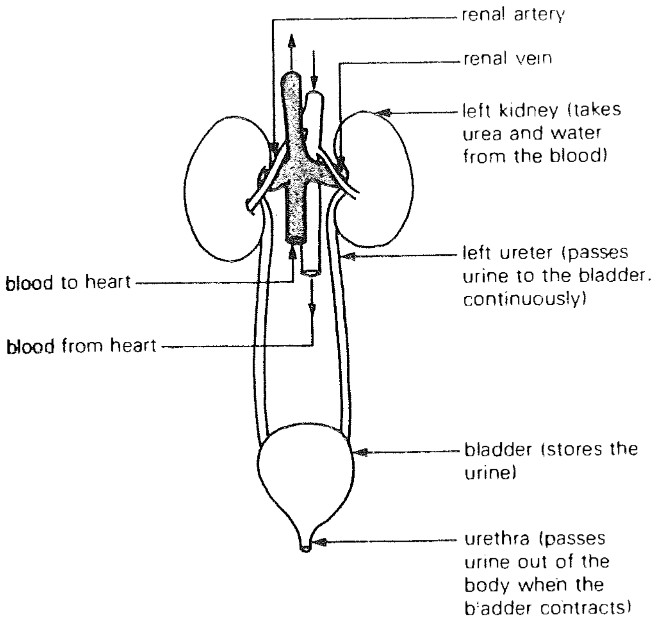


*Fig. 1. The urinary system*

The system consists of two kidneys that drain into a collecting sac called the bladder through two tubes called ureters.

The close connection of the blood circulatory system to the kidneys is obvious since the blood sustains them in life, on the one hand, and on the other hand urine is carried by the blood to the kidneys for extraction. The functional unit of the kidneys is the nephron, with each kidney containing approximately one million of these units. The nephrons are tiny tubules interlaced with the blood vessels of the kindney and due to their large number a big surface area is set up through which urine passes from the blood circulatory system to the urinary system.

A complete or partial failure of the kidneys to function properly (Renal failure) will inevidably upset the normal functions of the human body causing weakness, lethargy, anorexia, nausea, vomiting which will be fatal if proper treatment is not taken in time. Renal failure could occure as a result of hereditary reasons, infection, dehydration, improper diets, or direct blood loss which could shunt remaining blood away from the kidneys to other vital organs such as the heart and brain, depriving the kidneys of their normal blood supply. The solution to a permanent kidney failure is either a kidney transplant or a regular treatment of the patient with artificial means for removing urine from the blood. The most practical artificial method is treatment with an artificial kidney or the Hemodialysis machine, as it is called.

## 2. The Artificial Kidney

The heart of the artificial kidney is the dialyser which is a package of semipearmeable membranes. For simplicity in fig. 2 and fig. 3 only one membrane is shown. The function of the semipermeable membranes is similar to that of the nephrons in a natural kidney.

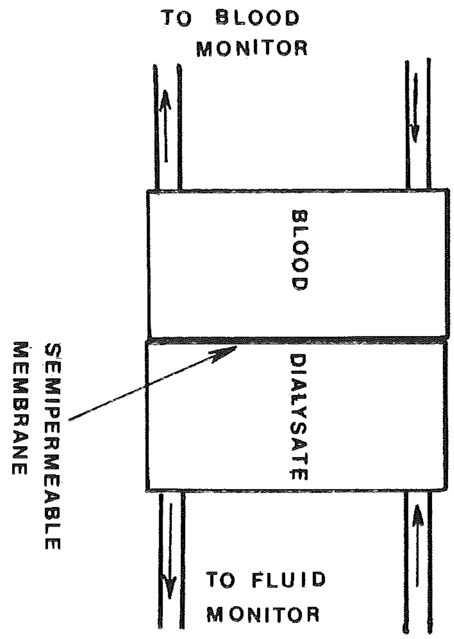


*Fig. 2. Simplified diagram of a dialyser*

This function is possible due to the fact that the membrane is semipermeable and also because a pressure is maintained between the two sides of the membrane. This is known as the transmembrane pressure (TMP) with the blood side having the more positive pressure. These two elements enable urine to pass from blood to dialysate. For red and white blood cells the passage is impossible due to their large size. It is possible for some dialysate molecules to pass to the blood but this does not cause any concern since the dialysate is a solution of salts having similar composition to that of clean blood.

Since an artificial kidney deals with two liquids, the blood and the dialysate, then it is necessarily composed of two separate parts, the FLUID MONITOR and the BLOOD MONITOR.

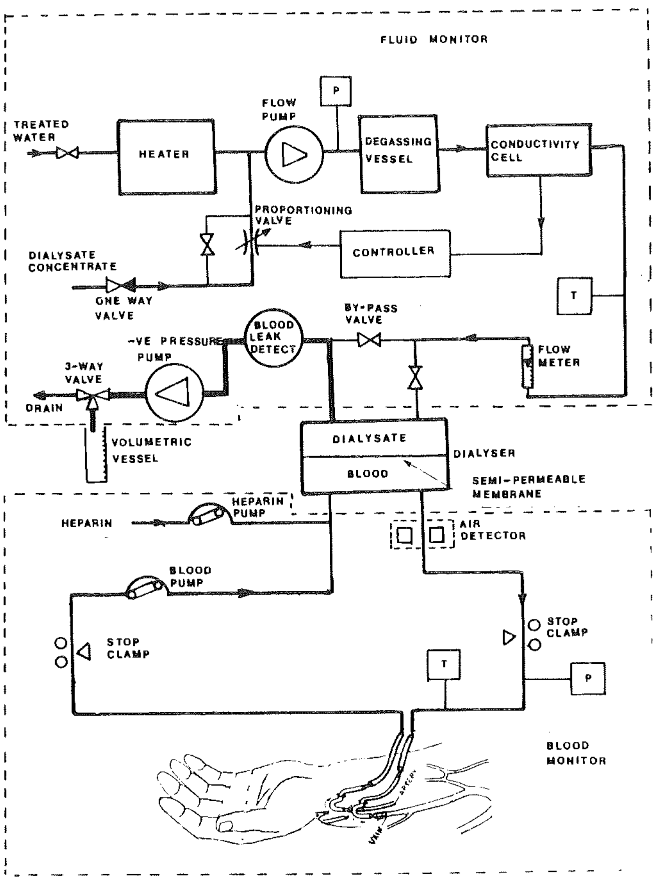


*Fig. 3. Block diagram of an artificial kidney*

## 2.a. The Blood Monitor

The function of the Blood Monitor is to pump blood from the body to the dialyser and then back to the body. The returned blood should have a temperature of about 37°C, a preset pressure, it should not have any air bubbles and should not reach any coagulation state. In case of any alarm condition the blood flow should stop immediately. To achieve those characteristics the Blood Monitor of fig. 3 includes a blood pump to circulate blood, a heparin pump, an air detector, two stop clamps, a temperature and a pressure tranducer. The heparin pumps introduces heparin which is an anticoagulation agent. It is important to detect any air bubbles in the blood stream returned to the patient with an air detector since air bubbles could cause death. The temperature of the returned blood is maintained at the required temperature in an indirect way, by heating the dialysate, through the dialyser.

## 2.b. The Fluid Monitor

The main function of the Fluid Monitor is to mix treated water and dialysate concentrate in a correct proportion and thus from the dialysate, keep it at a required temperature, so as to heat blood in an indirect way, circulate the dialysate through the dialyser and detect any possible signs of blood in the dialysate stream. This of high importance since a possible rupture of the semipermeable membrane will drain the patient of most of his blood causing death. The flow regulation is controlled by sensing the pressures in the dialysate flow circuit. The dialysate concentration is controlled by sensing the conductivity of the dialysate and controlling the opening of the proportioning value through a controller. In case an alarm condition exists in the Fluid Monitor, the dialysate flow through the dialyser is shunted off by the bypass value and also a signal is sent to the Blood Monitor and blood flow stops.

## 2.c. Ultrafiltration

Ultrafiltration is a speeded-up method for removng excess liquids from the blood through the semipermeable membrane. For this operation no dialysate is needed and a high negative pressure is applied to the membrane by a negative pressure pump. The path of the extracted liquids is shown with heavy line in fig. 3 and their volume is measured in the volumetric vessel.

## 2.d. Single Needle Treatment (SNT)

Normal dialysis patients have two cannulae implanted surgically into a hand artery and vein so that easy and painless access is achieved for each treatment in certain emergency cases (hemorrage after a series accident) the need arises to treat a patient, who does not have the cannulae, very quickly. In such a case the SNT method is adopted, that is a needle is inserted into a large blood vessel, blood is sent to the Hemodialysis machine, purified and returned to the patient through the same needle.

## 3. General aspects of Hemodialysis

An average Hemodialysis duration is about 3 x 4 hours weekly. During the treatment an exceptionally high quality of water is needed. Tap water is normally sufficiently clean to be consumed by a normal person for drinking who consumes an average of 800 litres annually. A dialysis patient might, on the other hand, be exposed to up to 30000 litres of water per year. For this reason the water used for dialysis should be of high quality.

A dialysis machine is usually used by many patients. To prevent any spread of possible deseases the machine has to be disinfected. This is done either by circulating hot water at 90°C through the Fluid Monitor or using chemical disinfection The blood lines and dialysers are disposable and so no disinfection is needed for them.

# THE CREDIT POINT SYSTEM

by Constantinos Neocleous,
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This article aims at introducing some important characteristics of the Credit Point System (CPS), mostly for the benefit of H.T.I. students and uninformed staff.

The major objective of this system is to enable the student reach a specified level of knowledge and skills, irrespective of the extent of time needed to do that.

This system has the following Important Characteristics:

1. Each course ("subject" in H.T.I. terminology) is assigned a "weighting factor" called a credit, depending on things like:

- how many hours per week is taught.
- how much time is spend by the student in studying and preparing for the course.
- how much laboratory is assigned to the course.
- how many weeks is being taught. i.e For a semester, quarter, term or a month?

**Example:**

A course such as "Electric Circuits" which has, say, 3 hrs/wk lecturing, 2 hrs/wk laboratory and requires approximately 8 hrs/wk home study and preparation, and lasts for a semester, may be assigned 4 semester credits.

The level of the course **is not** taken into consideration when assigning it with credits.

An engineering student in USA to be granted a B.Sc. degree, must complete 4 years of studies, resulting in a total number of 120-130 University level semester credits.

i.e. 4 years x $2\frac{\text{semesters}}{\text{year}}$ x $16\frac{\text{credits}}{\text{semester}}$ = 128 credits.

2. A student passes a course and **not** a year. Courses have **no** refer exams.

3. Students have the option of making their own program of studies by choosing, to some extend, what course to take, when to take it, at what time of the day and with which instructor.

Each course may have other courses as prerequisites, corequisites or it may be taken subject to the consent of the instructor who teaches it.

4. Students are given grades A,B,C,D,F. Their average is a "Weighted Average", in which A,B,C,D, are assigned some values, usually 4,3,2,1 respectively. F is fail.

**Example:**

Let a student X who has taken the following courses with the corresponding grades:

| COURSE | CREDIT | GRADE |
|---|---|---|
| $C_1$ | 4 | A |
| $C_2$ | 3 | B |
| $C_3$ | 3 | C |
| $C_4$ | 3 | B |
| $C_5$ | 2 | D |

"Weighted Average" also known as Grade Point Average (G.P.A.) is given by:

$$GPA = \frac{\sum (\text{Grade}) \times (\text{Credit})}{\sum (\text{credits})} =$$

$$= \frac{4x4+3x3+3x2+3x2+2x1}{4+3+3+3+2} = 2.6$$

5. Students following one field of studies, say "Mechanical Engineering", must take the so called core courses (the musts) which would be the fundamental courses, such as Maths, Physics, Eng'g Drawing, Computing, Statics, Dynamics, Thermodynamics, Heat Transfer etc.

They have also the option of taking electives from a restricted pool of engineering courses such as, Structures, Air Conditioning, Power Plants, Eng'g Economics, Microprocessors, Sewage Systems etc.

Finally they choose a number of electives in Liberal Arts, called cultural electives.

**Other Characteristics:**

1. Working hours extend over the whole day.
2. Absences are **not** usually taken.
3. Students have to do homework for each course. Homework is taken into consideration in establishing the student grade.
4. Student class participation may be considered by professor in establishing the final grade.
5. Specialized (and not very popular) courses may be offerd in alternate years.
6. Courses may be shared by other Universities.

**Advantages:**

1. It is a flexible and democratic system.
   * Allows for easy introduction of new courses and discard of outdated ones.
   * Students have some freedom in planning their progress, future, specialization, choice of courses, choice of instructors and timetable.
   * Students may control pace of academic development.

2. Students do not repeat a year.
   * They need to repeat only **core** courses.
   * They **transfer** only core courses. (There is a limit).
3. It provides more rational means of student assessment.

**Disadvantages**

1. It is a complex and sophisticated system.

# MICROPROCESSOR/MICROCONTROLLER - THE ALTERNATIVE SOLUTION

**by Stylianos Theodorou B.Sc (Elect)**
**Lecturer H.T.I.**

### Introduction

This article attempts to answer in general terms three very important questions which almost inevitably the designer of a logic system is prompted with, since the development of the microprocessor 'chip' nearly two decades ago.

They are:

(i) When should a microprocessor be used?
(ii) Assuming the decision favours the use of a microprocessor, which microprocessing unit (MPU) is the most appropriate?
(iii) What are the design guidelines and specific consideration areas of a microprocessor/microcontroller* based system?
(* A microcontroller is a microprocessor unit with additional parallel and/or serial I/0 as well as program memory on one 'chip' able to operate in the 'stand alone' mode).

### I. When should a microprocessor be used?

The microprocessor is considered by many as the most important development the electronics industry has seen for at least the last two decades. It was introduced to meet the need for a universal Large Scale Intergrated circuit caused by the fairly high cost and narrow application of most specialist (custom-made) LSI circuits.

Before the microprocessor, as the number of transistors on a chip increased (often in the order of thousands) the more dedicated that chip became to a particular application and the smaller the potential market for it.

Hence, since the cost of an integrated circuit is inversely related to the production volume, LSI circuits for not common applications tend to be considerably more expensive than necessary because of the restricted market.

The microprocessor on the other hand with its ability to perform a wide variety of different functions and its almost unlimited range of applications, makes volume production economical. A comparison between microprocessors and minicomputers is often made which usually results in fairly complex questions and answers. It can however be said that microprocessors in general are slower and not as powerful as the minicomputers due to the fact that the instruction set available for program construction, data manipulation e.t.c is less comprehensive. These differences however are quickly diminishing with today's gigantic steps in microprocessor technology.

The discussion so far refers to systems of medium to high level of complexity. For systems of low level of complexity a comparison has to be made between the microprocessor and discrete (random) logic (often referred to as Hard-wired logic). Discrete logic where the emphasis is on the hardware, has a high count of components, decreased reliability and small or non-existent versatility.

The microprocessor solution where the emphasis is on the software, offers low component count hence improved reliability and of course versatility is one of the characteristics of the device which formed the basis for its development.

However, due to the time required for program development and subsequent changes, the initial cost may be such that for very low system count of low complexity level and degree of versatility, the discrete logic solution is preferable. This system count decreases rapidly as logic designers (mainly hardware oriented electronics people) become familiar with programming skills and software techniques enabling them for firmware (hardware and software) design.

Figure 1 below indicates the relationship of the three possible solutions discussed so far, with the total production cost and production volume as parameters.

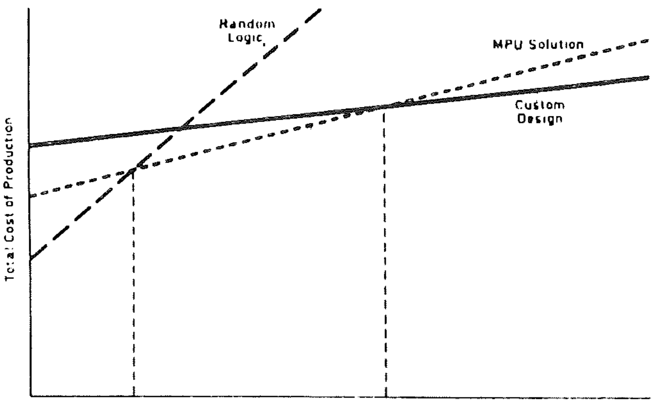


**Figure 1 – Comparison of total system development and production costs for volume production.**

The intersection of the MPU solution line with the one for Random Logic (Descrete Logic) is expected to move to the left as logic designers become familiar with MPU programming.

The intersection of the MPU solution line with that of Custom design (Custom-made LSI) is expected to move to the right as component cost decreases and MPU versatility increases. The net effect is a shift of the MPU solution line to a lower position.

Figures 2 and 3 below chart the three solutions for two system complexities.

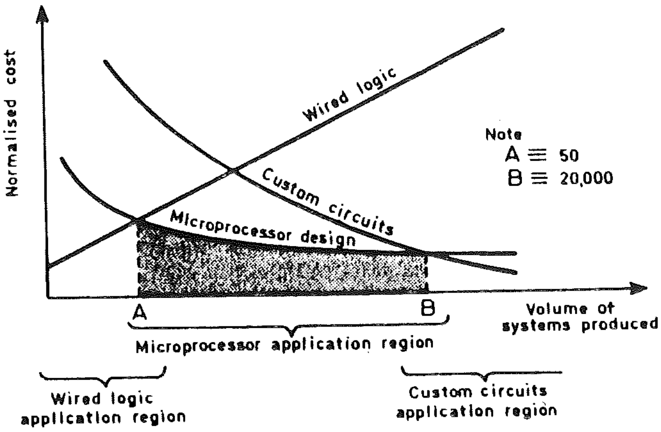


**Figure 2** For a system complexity equivalent to 200 gates (approx 50 IC's)

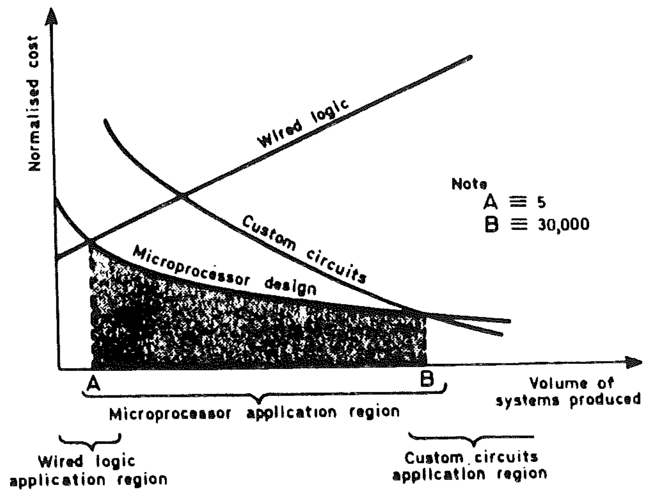


**Figure 3** For a system complexity equivalent to 500 gates (approx 150 IC's)

From these two charts it can be deduced that the more complex the system to be designed, the greater is the range of production volumes over which the MPU solution is highly competitive i.e the economic region for an MPU design extends.

Table 1 which follows summarises the comparison areas (desiding factors) other than cost, that would affect the selection of the most viable solution.

**Table 1.**

| Area for Comparison | Random Logic | MPU | Custom LSI |
|---|---|---|---|
| Design | Specific | General | Specific |
| Design Emphasis | Hardware | Software | Hardware |
| Package Count | High | Low | Low |
| Flexibility | Low | High | Moderate |
| Redesign/Modification | Difficult | Easy | Difficult |
| Circuitry | Redesign every time | Alike every time | Depends on application |
| Future expansion | Very Difficult | Easy | Depends on application |
| Operating speed | Can be very high | Fair | Can be very high |

For systems of extremely high complexity, especially when the production volume is low, the minicomputer could offer the optimum solution. However, mainly due to the computer's high unit cost, the alternative microprocessor - possibly multiprocessor - system could justify the higher development cost and cut the per system cost.

The flowchart that follows (fig. 4) represents the most common decision process between MPU and Random Logic, provided costs are not greatly different.

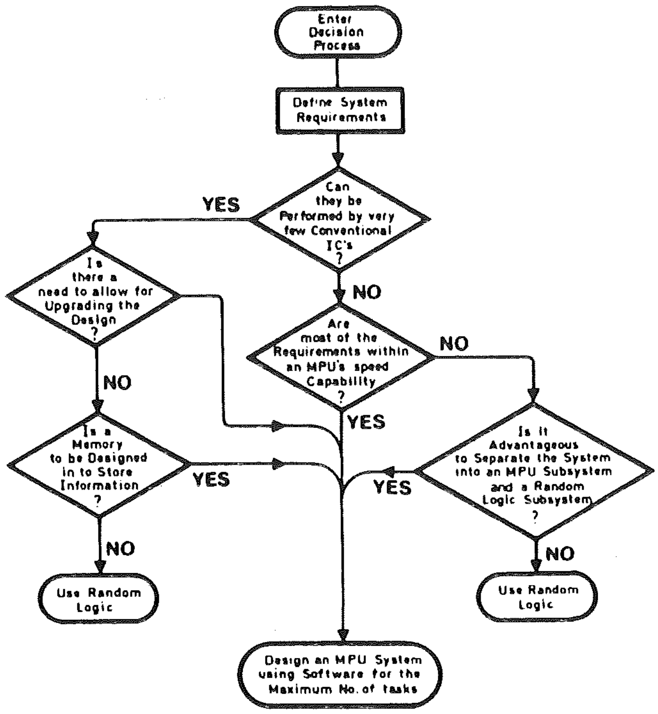


**Figure 4** Assessing the viability of an MPU solution.

Many engineers already consider the MPU solution as the first of the alternative design approaches to a problem turning only to random logic on the one hand or a minicomputer on the other, when very simple or very complex functions respectively are required. This response can be expected to increase further as microprocessor technology continues its progress and the MPUs enter deeper into everyday life.

## II. Selecting the most appropriate MPU

Once the MPU solution has been opted for, the next decision to be made conserns the selection of the most appropriate microprocessor or microcontroller unit for the project.

Certain factors not directly related with the specific project at hand can affect the decision process.

A common situation is that of a company deciding on an MPU solution for the first time and selects the most versatile and adaptable MPU with a good range of supporting components rather than the one particular model which apprears to be most economic for the current project. In doing so it is envisaged that the MPU design team can become expert with the MPU and their acquired skill save time otherwise needed for familiarisation with other MPUs in subsequent projects. Also, 'standardising' results in higher volume orders which normally lead to more advantageous quantity discounted prices from the supplier.

Another common case is that of a project requiring no special functions or features on the MPU and the designer after some preliminary analysis of the available systems selects an MPU on the basis of customer support and service rather than on technical comparisons between rival MPU specifications.

Both cases have their merits, however a generalised decision process takes place in the following two stages.

1: Evaluation of MPU performance and functional specifications

2: Scrutiny of MPU manufacturers and their customer support.

**1: Evaluation of MPU performance and functional specifications**

The microprocessor's strength is derived from the ability to manipulate **hardware** devices ('on chip' and external) under **software** control.

Therefore an evaluation of the hardware power as well as the software power is required.

**Hardware**

The following are some essential questions for hardware evaluation

- What is the MPU word (or byte) length?
  (4-, 8-, 12-, or 16 bit)
- What is the minimum MPU chip set?
  (MPU, memory and I/0)
- How flexible is the MPU and associated compatible parts such as I/0 controllers, clock drivers e.t.c?
- How good are the I/0 handling capabilities?
- Is there a common bus for easy addition of memory and I/0 interfaces?
- Is external buffering required?
- How many accumulators and what type of internal registers does it have?
- How powerful is the interrupt handling capability?
- How is the memory and I/O addressing performed?
- Is there a need for address/data bus multiplexing?
- What are the power requirements?

**Software**

The following are some essential questions for software evaluation.

- How many instruction mnemonics make up the instruction set?
- What are the addressing modes?
  (Direct, Indirect, Indexed e.t.c)
- Are special I/O instructions needed?
- How many 'branch' and 'jump' instructions are there?
- What are the mathematical capabilities?
  (Add, subtract, divide, multiply)
- What is the depth of 'stacked' subroutines?
- Based on the maximum possible clock rate and the execution time in cycles of the various instructions, are the functions fast enough for the task in hand?

With regards to the last question above, the engineer should devise 'benchmark tests' to investigate the suitability of a specific MPU for the application.

These tests can be representative tasks of actual segments of program which will be needed in the final system.

The software manual or manufacturer's data sheets can be used to write programs in the source language for the two or three MPUs to which the choise has been narrowed and the following three comparisons made.

(a) How easy is writting the program?

(b) How many program instructions are needed and how many storage bytes do these represent?

(c) How long does the program take to execute?

At the end of the hardware and software evaluation, a shortlist of MPUs capable of being used for the application is made.

**2: Scrutiny of MPU manufacturers and their customer support**

When optimum performance is not critical or following the performance and specifications evaluation, the MPU manufacturer and customer support come under scrutiny. The latter consists of three stages:

**(a) Determination of the manufacturer's credibility**

The reputation of the manufacturer and his investment in MPU technology as evidenced by the amount of descriptive literature and available customer support provide a good indication of the manufacturer's credibility. The experience of other 'volume' users with the manufacturer in question is of great importance to the assesment process.

If the manufacturer's commitment to the product is high, the users can be reasonably assured that it will remain in the product range as a standard component and that new MPUs developed to supersede it in power or flexibility, will maintain upwards compatibility of software and support.

This implies that the training cycle of the MPU team whenever a change to an upgraded MPU is required, will be kept reasonably short.

**(b) Evaluation of customer support quality**

Customer support presents itself in two forms, technical information and technical support aids.

**Technical Information**

This takes the form of documentation (manuals data and instruction sheets, faultfinding hints e.t.c) and training courses by qualified instructors and customer service engineers.

**Technical support aids**

These consist of software development packages (assemblers, compilers, resident and cross software packages, macro-assemblers etc) as well as hardware development tools (Development Systems, Emulation systems, component testers, test equipment for field troubleshooting and finished product evaluation e.t.c)

**(c) Assurance of supply security**

This is optained by verifying that the MPU manufacturer has organized second sources for his product and appointed agents to distribute the MPU components to the users and perhaps provide all necessary customer support.

A relevant point worth mentioning, is the manufacturer's record - in general - in keeping quoted schedules and delivery dates. Late deliveries have so often proved costly for both the customer and the manufacturer.

**III. Design quidelines and specific consideration areas of a microprocessor/microcortroller based system**

Although the sequence may vary for different applications the guidelines mentioned below form the basis of most project designs.

There are also certain areas in all such designs which warrant particular attention.

**Design guidelines**

- Examine System requirements
  : Number of input signals?
  : Number of output channels?
  : Type of external devices to be interfaced (Data storage, Data display, communications, controllers etc) and their signal requirements (digital, analog)?
  : Need for D/A and / or A/D converters?
  : Type of data transfer (serial and/or parallel)?
  : Polling and / or Interrupt based operation?
  : Minimum memory size?
  (Program memory-ROM/PROM-can only be an approximation until programming expertise has been gained.
  Data memory - RAM - depends on the rate at which variable data is to be stored and the time period for which it has to be kept stored).
  : Provision for future system expansion?
  : Operating speed?

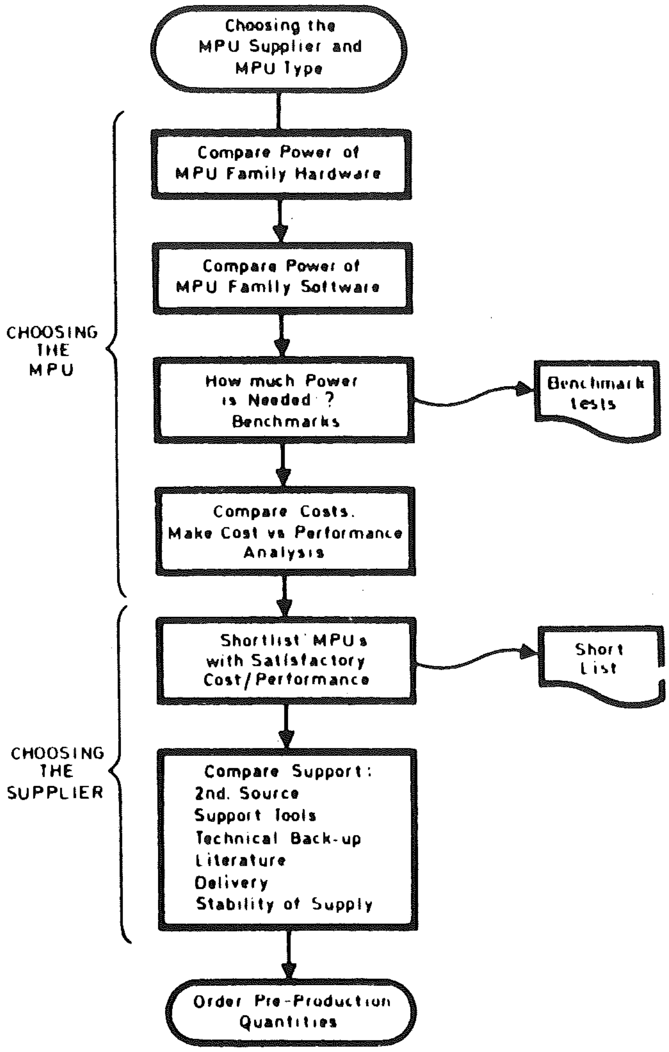


**Figure 5 —MPU Selection Process**

(System Operating Speed affects the clock rate of the micoroprocessor hence the pulse width of the control signals such as Read and Write. Therefore, care must be taken in selecting the type of memory integrated circuits. For example, if the clock rate of an 8051 microcontroller has to be 12MHZ, the pulse width of the Read signal is 400ns, which is shorter than the typical access time of core, CMOS, and most PMOS memories. See figure 6 below).

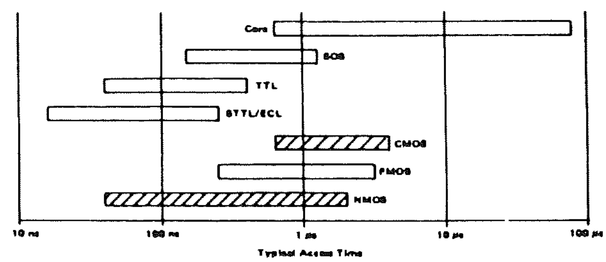


**Figure 6 —Comparison of typical access memories with different technologies.**

- Proceed with Hardware and Software design. These may run concurrently in most applications.
  : Hardware Design involves calculating the I/O logic required, conctructing peripheral interfaces and emulating the system hardware.
  : Software Design involves developing of the system flow-chart, writting and editing the source program segments and finally assembling the program.
- Debug System Software and Hardware.

  This is easier done with the help of hardware development tools such as In-Circuit-Emulators (ICE) and software development packages such as DEBUG programs.
- If system functions as required, proceed to printed-circuit board design and construction. If not, then correct the hardware and/or software problem and repeat the process.
- Perform final system test.

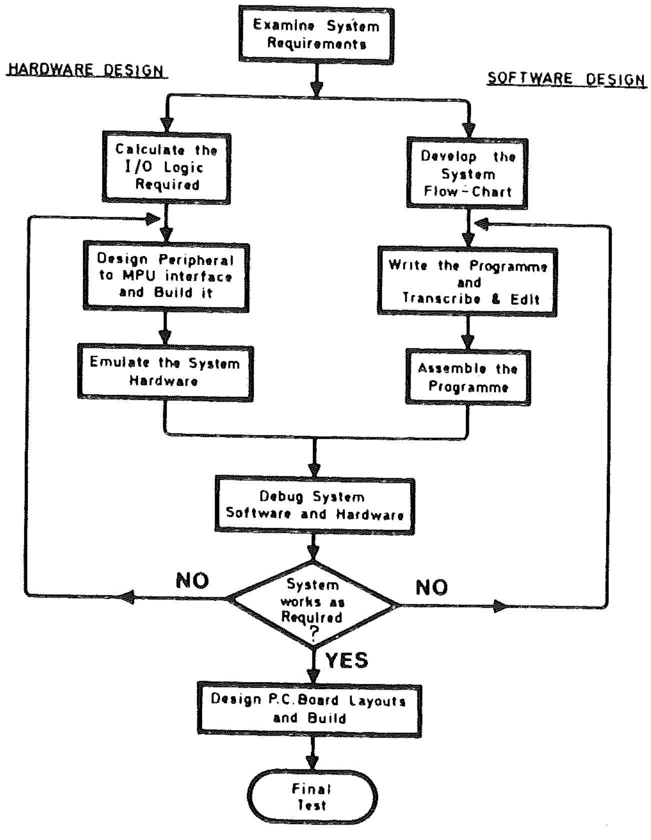


Figure 7 The design sequence.

**Specific consideration areas**

- System Power requirement
  : The calculation of the total system power requirement is essential for the selection of appropriate power sources, the definition of conductor sizes and the planning of the distribution system.
- Crosstalk and ringing
  : Microprocessor systems with their parallel address and data busses suffer from crosstalk and ringing problems particularly in modular systems (which is usually the case) where theses busses run along a motherboard onto which the microprocessor memory and I/O interface boards plug in. These busses behave like transmission lines with series inductive and parallel capacitive elements. The wider and longer the bus is, the worse the noise problem.

  A step to reduce the noise is to use fewer and larger boards thus avoiding long interconnecting busses. However, modularity, flexibility, circuit modification and maintainability are reduced.

  Whatever the board size, succesful bus design involves keeping self and mutual inductances as low as possible to keep the crosstalk low.

  The situation is considerably improved if multiple return-circuit ground tracks can be run between the bus lines. This is quite often very difficult to achieve due to p.c. layout complications.

  Another approach is to use individual wires (wire wrapping) each one twisted with a ground wire. This is even more effective but perhaps not as neat as a printed circuit motherboard. A third approach is to use a large ground plane onto which the bus wires are located 'Hard down'. The disadvantage here is that cross-capacitance may increase resulting in longer ringing periods.

  Note that the resonant frequency of the circuit is given by

  $f_0 = 1/2 \sqrt{\ } ALC$ where A is the total number of bus lines, L is the total circuit inductance (self and mutual) and C is the capacitance coupling of each line to ground.
- Clock rate
  : As mentioned previously this defines the pulse width of various control signals such as RD (Read), WR (Write), ALE (Address Latch Enable) e.t.c. Therefore special care needs to be taken regarding the selection of devices controlled by these signals such as I/O and memories where specified access time must be adhered to.
- Bus multiplexing
  : Some microprocessors like the 8085 have multiplexing address and data bus (Least Significant Byte of the address bus for 8085).

  The designer therefore using the ALE signal must provide external circuitry (latches) to maintain a valid 16-bit address for the full instruction cycle and to protect outputs from driving into each other.
- Output drive capability

: All outputs have a definite drive capability which is affected to a certain extend by the clock rate. Therefore it is very important to calculate in advance the number of devices to be driven by each output taking into account any future system expansion prospects and introduce buffers (bi-directional if necessary) at selected locations.

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# MARITIME SATELLITE COMMUNICATIONS

by A.C. Loizides, MSc
Lecturer HTI

**Abstract.** **Fast, reliable and efficient communication at sea is possible nowdays, because of the introduction, by the International Satellite Maritime Organization, of the inmarsat system. The system utilizing shore earth stations, ship earth stations and satellites made available to shipping community services the operation of which was impossible by the conventional maritime communication system.**

## 1. Introduction

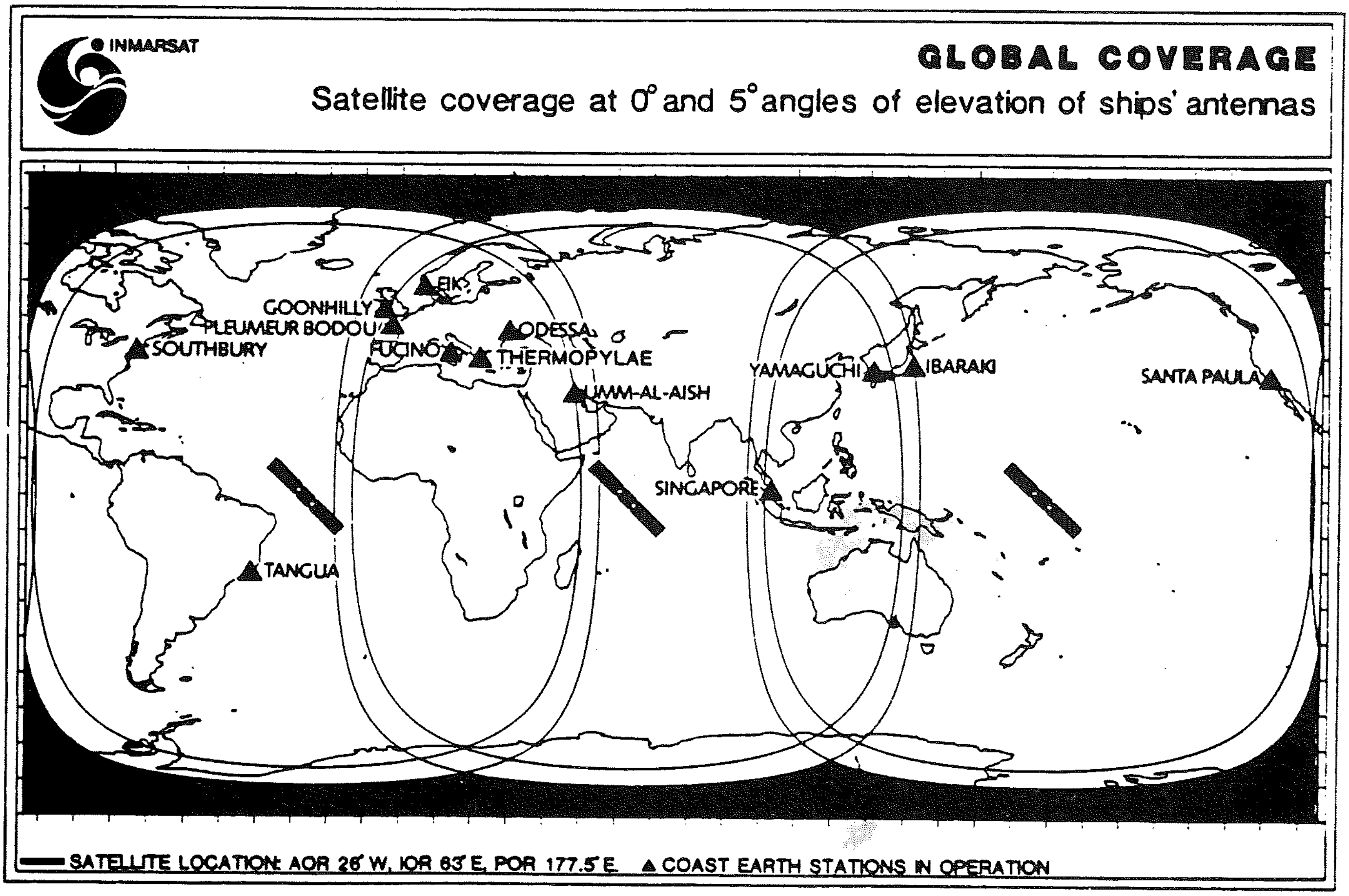
Throughout history communication at sea was possible at low range only, with media like flags, lamps or flares which were neither reliable nor adequate. The Marconi's invention of the wireless at the end of the 19th Century made maritime communication a reality, irrespective of distance or weather.

Since 1899 when the passenger liner St. Paul received the first message from a Marconi wireless station until 1965 when the first commercial communication satellite "Early Bird" was put into operation by the International Telecommunications Organisation sea communications which were based on radio transmission in the MF, HF and VHF made a very remarkable progress. It was clear however, to the maritime countries that the existing conventional system could not satisfy the rapidly advancing requirements of shipping. "Early Bird" stipulated interest in the International Maritime Organisation which in 1966 began studying of a maritime satellite communications system.

## 2. The Organisation

### a. Establishment

The Maritime Community in the International Maritime Organisation (IMO), in order to overcome the limitations and drawbacks of the conventional methods for communication at sea, decided the creation of the International Maritime Satellite Organisation (INMARSAT). The decision for the establishment was taken by IMO's General Assembly in 1976 and the constituent instruments entered into force in July 1979. The INMARSAT system became operational in February 1982. By the end of 1985 44 States became members and a number of other States are in process of joining.



The original purpose of the Organisation was the provision of space segment (satellites) and ground support facilities necessary for improving Maritime communications and for distress and safety of life at sea. In October 1985 the INMARSAT Assembly amended the Convention to give the Organisation the institutional competence to provide Aeronautical as well as Maritime Communications.

**b. The Structure of the Organisation**

INMARSAT consists of three main bodies.

The Assembly which is composed of delegates from all states - parties to the INMARSAT convention. The Assembly meets every two years to review the activities and long term policy of the Organisation.

The Council of Signatories consists of 18 signatories (usually national telecommunications agencies) with the largest investment shares and 4 others elected on the basis of geographical representation. The Council is like a corporate board of directors and meets at least three times a year. Each signatory has a voting power equivalent to its investment shares.

The Directorate which is based in London is headed by the Director General who is the legal representative and chief executive of the Organisation.

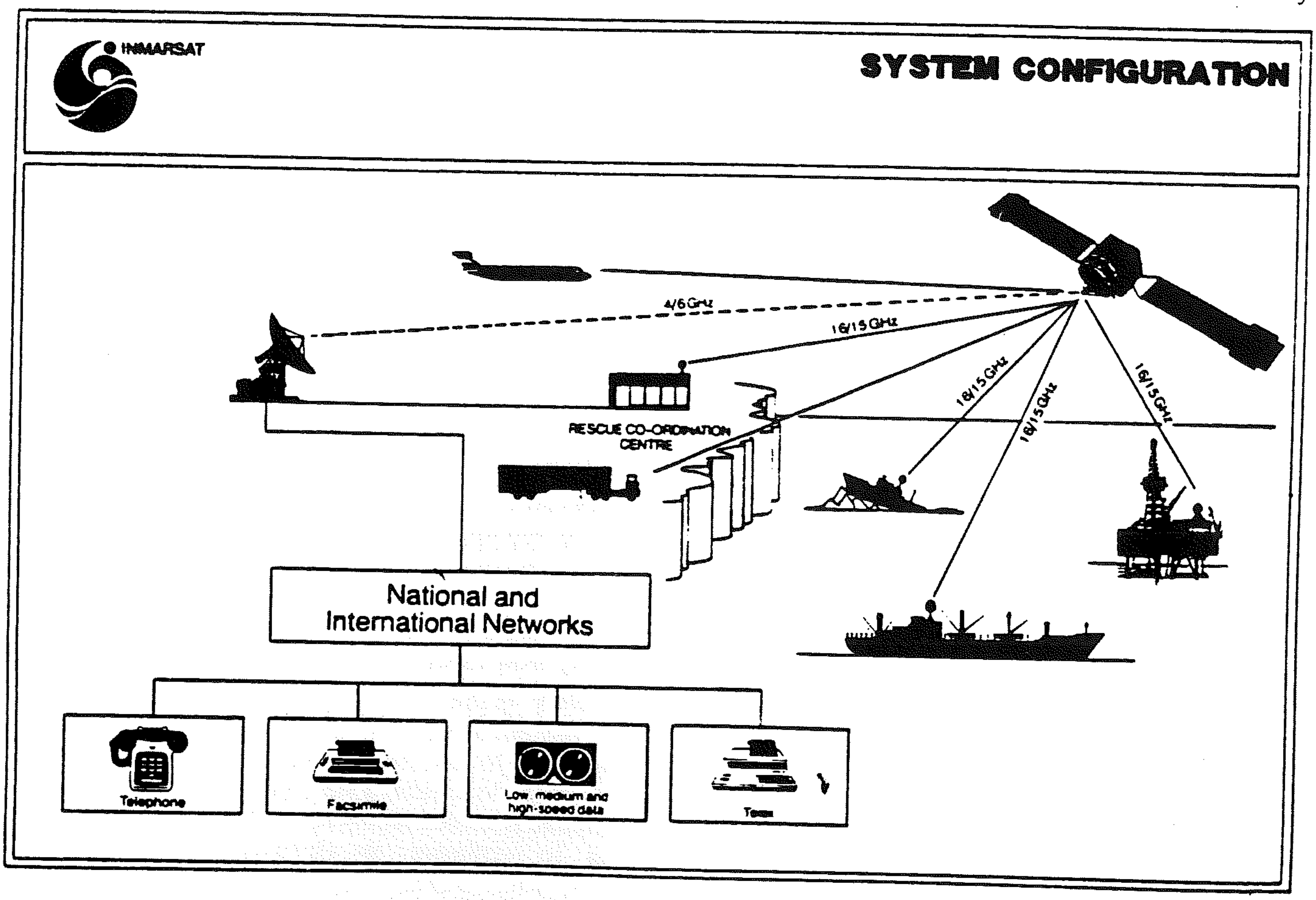
**c. Financing**

Signatories finance the system by making capital contributions in proportions to their investment shares which carrespond on a percentage basis to their usage of the system. Signatory contributions are to be repaid with interest. INMARSAT earns its revenues by billing coast earth station Signatories for their usage of the space segment. For ship-to-shore calls, coast earth stations in their turn bill the users of the system.

**3. The System**

The INMARSAT telecommunication system is made up of three main components.

Coast Earth Stations (CESs). The CESs are owned and operated by telecommunications organisations in the countries in which they are located. The stations interconnect the satellite system with the world's terrestrial communications networks. Each station has powerful transmitters and receivers working in the C-band of microware frequencies through a parabolic antena of between 10 and 13 metres diameter. Coast Earth Stations are located in many countries around the World. By



1990 is expected to be in operation 30 stations worldwide.

One CES in each ocean region is operated as a network coordination station (NCS) controlling the operation and allocating available channels to each Coast Earth Station and Ship Earth Stations within the ocean region.

The whole system is coordinated by the Operations Control Centre (OCC) which is situated in the headquarters of the Organisation in London.

**Ship Earth Stations (SESs).** The antena of the Ships Earth Stations which can be less than one metre in diameter is usually located on a mast or a ships superstructure inside a protective radome. Special mechanism keeps the antena tracking the satellite, regardless of the motion of the ship. A small cabinet housing the electronic equipment, telephone, telex and other facilities is situated below decks. Each SES has a unique number which is the dialling number of that ship. SESs transmit and receive using L-band microwaves.

**Satellites.** INMARSAT provides near global coverage (excepting the polar regions) with geostationary satellites located approximately 36.000 km above the equator over the Antlantic (AOR) Indian (IOR) and Pacific (POR) Ocean Regions, as follows.

| Region | Satellites | Orbit | Channels | Status |
|---|---|---|---|---|
| AOR | MARECS | 26.0°W | 80 | Operational |
| | MCS B | 18.5°W | 30 | Spare |
| IOR | MCS A | 63.0°E | 50 | Operational |
| | MCS C | 60.0°E | 50 | Spare |
| POR | MARECS B2 | 177.5°E | 60 | Operational |
| | MCS D | 180.0°E | 50 | Spare |

The two MARECS type satellites which were manufactured by British Aerospace and Marconi are leased from the European Space Agency. The design life of these satellites is 7 years. The first launch was in 1982.

INMARSAT uses several Maritime Communication Subsystems (MCS) installed on board satellites leased from the International Telecommunications Satellite Organisation (INTELSAT). Manufacturer of these satellites is the Ford Aerospace and Communication Corporation. They have design life 7 years and the first unit was launched in 1982.

In April 1985 INMARSAT signed a $150 million contract for three satellites with options on up to six more, with a consortium led by British Aerospace. These satellites have capacity 250 channels and are equipped to provide communication services to aircraft. They have design life 10 years. The first launch is expected to be in 1988.

**4. Communication Services**

Maritine Satellite Communication Services include:

— Telephone;

— telex - fully automatic interconnection ship-to-shore and shore-to-ship with worldwide telex network;

— low, medium, high or very high speed data;

— SOS alert with virtually instantaneous connection with the appropriate Rescue Coordination Centre of the receiving country.

— high quality facsimile transmission over the telephone channel;

— group calls, which are broadcast calls, made by authorised shore based users, to selected ships;

— slow scan television transmission to suitably equipped ships and offshore rigs are possible through INMARSAT system.

The advantages of the INMARSAT system over the conventional maritime communication system are obvious. Essential benefits for efficient operation to the international shipping and offshore oil and gas industries include inter alia: Privacy for business and social calls, reliablility, access 24 hours a day, near global coverage, communication within harbours and territorial waters, direct dial capability and improved safety.

The very high cost of the systems equipment is the main disadvantage of Maritine Satellite Communication system.

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(iv) Maritime Satellite Communications 1983
(v) INMARSAT 1985
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# PROFESSIONAL QUALIFICATIONS IN ENGINEERING

by S. Savvides T. Eng. MIElecIE
Corresponding member of the Institution of Electrical and Electronics Incorporated Engineers (IEEIE) for Cyprus.
Senior Instructor H.T.I.

## INTRODUCTION

The professional qualifications in Engineering are the following:

— the Chartered Engineer

— the Technician Engineer

— the Engineering Technician.

In order to qualify for a class of any of the professional groups above one must have:

(i) the academic qualifications required for each class

(ii) a period of approved training and

(iii) a period of acceptable experience and professional responsibility.

## DEFINITIONS

### The Chartered Engineer

Those holding the title are primarily concerned with the progress of technology through innovation, creativity and change, the development and use of new technologies, the promotion of advanced design and production methods and the pioneering of new engineering services and management techniques.

### The Technician Engineer

Those holding the title are practical engineers, playing a most vital role in industry. They often carry managerial responsibility as leaders of teams or they may occupy positions involving individual responsibility for large amounts of complex equipment. Fundamentally they are concerned with maintaining and managing existing technology at peak efficiency.

### The Engineering Technician

The Engineering Technicians apply proven techniques and procedures to the solution of practical problems and carry a measure of technical responsibility, often under the quidance of engineers or scientists. They require personal abilities enabling them to work effectively as members of an engineering team.

## THE ENGINEERING COUNCIL OF THE UNITED KINGDOM

The Engineering Council was established in 1981. The Engineering Council has a Board for Engineers Registration (BER) which works very closely with almost 50 British engineering institutions. The Engineering Council's Board for Engineers Registration has replaced the Council of Engineering Institutions (CEI) in the qualifications and registration areas. Registration with BER provides a recognised quide to the competence of an Engineer, technician engineer, and engineering technician and, as in other professional fields, such as medicine, law or accounting denotes a qualification of national-and International currency, known and understood by employers.

The BER has three sections, the professional engineer, technician engineer and engineering technician. The requirements for registration in each section are as follows.

### Professional engineer section

Stage 1. Academic standard is the Engineering Councils Part 2 examination or a recognised exempting degree in engineering or related subjects.

Stage 2. A period of approved training.

Stage 3. A period of acceptable experience and professional responsibility. The aggregate of training and experience shall normally be not less than four years. Minimum age 25.

Those entering the Register at stage 3 are authorised to use the style or title of Chartered Engineer and the designatory letters CEng, provided that they are members of a nominated chartered Engineering Institution.

### Technician Engineer Section

Stage 1. Academic stardard exemplified by BTEC Higher National Certificate in approved programme areas.

Stage 2. A minimum of two years approved training.

Stage 3. Five years engineering experience including the period of training shown above.

Minimum age 23.

Those entering the Register at stage 3 are entitled to use the style or title of Technician Engineer and the designatory letters TEng.

**Engineering Technician Section**

Stage 1. Academic standard excemplified by the BTEC National Certificate in approved programme areas

Stage 2. A minimum of two years approved training

Stage 3. Three years engineering experience including the period of training shown above. Minimum age 21.

Those entering the Register at stage 3 are entitled to use the style or title of Engineering Technician and the designatory letters EngTech.

Registration to the various sections above is usually achieved through Engineering Institutions which are nominated bodies of the Engineering Council. A number of such Institutions are listed herebelow. The section of the Register that is covered by each Institution is given as well.

From the Institutions given above the Institution of Electrical Engineers (IEE) has a Cyprus Branch. In addition the Institutions of Civil Engineers and Mechanical Engineers have a Cyprus joint group. Also the Institution of Electrical and Electronics Incorporated Engineer (IEEIE) has a corresponding member in Cyprus.

Each of the Institutions have a number of different classes of membership. Such classes vary from Institution to Institution. An indication of the classes of membership of the various professional institutions is:

— fellow members
— Corporate members
— Graduates
— Associate members
— Students
— Associates.

Those wishing to apply for membership of a specific Institution must apply for more details about the requirements and the various classess of membership.

## ENGINEERING PROFESSIONAL ASSOCIATIONS IN CYPRUS

In Cyprus there are the following professional engineers associations.

(i) The Cyprus Professional Engineers Association, which covers all disciplines in Engineering.

(ii) The Cyprus Civil Engineers and Architects Association.

With Initiative of the Graduates Association of the Higher Technical Institute a Cyprus Technician Engineers Association covering all disciplines in Engineering is in progress to be established.

| | Register Section | | |
|---|---|---|---|
| | professional engineer | technician engineer | engineering Technician |
| British Computer Society | Yes | Yes | Yes |
| Bureau of Engineer Surveyors | No | Yes | Yes |
| Chartered Institution of Building Services Engineers | Yes | Yes | Yes |
| Institution of Energy | Yes | Yes | No |
| Institute of Engineers and Technicians | No | Yes | Yes |
| Institute of Hospital Engineering | Yes | Yes | Yes |
| Institute of Marine Engineers | Yes | Yes | Yes |
| Institute of Plumbing | No | Yes | Yes |
| Institution of Civil Engineers | Yes | No | No |
| Institution of Electrical and Electronics Incorporated Engineers | No | Yes | Yes |
| Institution of Electrical Engineers | Yes | No | No |
| Institution of Electronic and Radio Engineers | Yes | Yes | No |
| Institution of Mechanical Engineers | Yes | No | No |
| Institution of Mechanical and General Technician Engineers | No | Yes | Yes |
| Institution of Plant Engineers | Yes | Yes | Yes |
| Institution of Production Engineers | Yes | Yes | Yes |
| Institution of Technician Engineers in Mechanical Engineering | No | Yes | Yes |
| Royal Institution of Naval Architects | Yes | Yes | Yes |
| Society of Civil Engineering Technicians | No | Yes | Yes |
| Society of Electronic and Radio Technicians | No | Yes | Yes |
| Welding Institute | Yes | Yes | Yes |
| Highway and Traffic Technicians Association | No | Yes | Yes |
| Institution of Structural Engineers | Yes | Yes | No |

# HTI CALENDAR OF EVENTS
# Academic Year 1985-86

by Ms Dena Charalambidou-Solomi
Lecturer, HTI.

**SEPTEMBER**

- Lectures commenced on September 16th.
- Five hundred and twenty-seven (527) students enrolled for the academic year 1985-86.
- The new Computer Course started with sixteen (16) students.
- Sixty (60) students instead of thirty (30) were enrolled for the Mechanical Engineering Course.
- The Regional Training Centre (RTC) held various courses: The Polyvalent Course with ten (10) students beginning in September and ending in July; the Hospital Laboratory Course with four (4) students beginning September and ending in February; the X-ray Course with four (4) students beginning in February and ending in July; the Electromedical Course with ten (10) students beginning in February and ending in July.
- Mr D. Lazarides, Head of the Civil Engineering Department, was posted with a civil engineering firm in Nicosia on a part-exchange scheme, to enhance his professional expertise in design practices.
- Mr Andreas Loizides, Instructor Mechanical Engineering, completed a two-year M.Sc. programme in Marine Engineering as a scholar of the International Maritine Organisation and returned to resume his duties at HTI.
- On September 25 the Director called a General Staff Meeting at 12.50 p.m. at the Lecture Theatre to review items and discuss issues which relate to academic work.

**OCTOBER**

- Classes were suspended on October 1st to celebrate Cyprus Independence Day.
- Ninenteen (19) second year Marine Engineering students having performed their sea training of about three months July to October, returned to resume lectures at HTI.
- A new part-time course, lasting for a whole year, in Quantity Surveying was introduced in October, 1985 for working Engineers and Technicians. It began with forty-nine (49) participants.
- On 16 October HTI students and staff donated blood.
- An excursion to Ayia Napa was organised by Mrs M. Frangeskou, Welfare Officer, mainly for foreign students on Saturday, October 26.
- On 28 October classes were suspended to celebrate "OXI" Day.

**NOVERMBER**

- On Monday 4 Nobember Mrs Eleonora Michaelides, Press and Information Officer, gave a lecture on "The problem of Cyprus" at 7.30 p.m. in the HTI Amphitheatre for overseas students from HTI, Hotel and Catering Institute and Productivity Centre.
- UNESCO Day was celebrated on Wednesday, November 6. Students and staff visited "Panayia tou Araga" at Lagoudera Village where they admired the famous Prescoes and architecture of the church. Some staff and students offered voluntary work i.e. putting up notices and signs and placing Litter Baskets.

Lunch was bought at Astromerits Louis Pub and Restaurant.

- On November 24 an excursion to Paphos was organised mainly for HTI overseas students by the Welfare Officer, Mrs M. Frangeskou.
- A new club the Paleontology Club made its appearance on November 25.

Its main objectives are to find and determine the various forms of life that existed in the area of Cyprus when Cyprus was under the sea.

Mr G. Florides, instructor, will be the advisor of the club.

- Wednesday, November 20 HTI celebrated Environment Day. Students and staff engaged in activities to clean and tidy HTI surroundings and grounds.
- Mr. Spyros Spyrou, Lecturer in Electronic Engineering went on a two-week study visit to Germany and Italy for the repair of dental equipment on a WHO scholarship.
- Mr Sotiris Hadjioannou, Lecturer in Electronic Engineering, went to Bulgaria 4-17 November to take part in the World Exhibition of Young Inventors which was held in Ploudiu.
- The Head of the Microprocessors Training Unit, from the Polytechnic of Central London (PCL) Mr Neil Hatchinson, conducted a short course of one week duration during the mid-semester period for HTI staff and industry on "Introduction to Microprocessors and Programming". Mr Hutchinson came on the invitation of the IEE (Cyprus Branch). The course was hosted by HTI.

**DECEMBER**

- The HTI Director was the guest of the City University, 2-5 December, to attend the graduation ceremony, on Monday, 2 December. He also visited the Polytechnic of Central London (PCL) and the Polytechnic of South Bank.
- In December Dr A. Mallouppas served as a consullant on policy issues in the repair and maintenance training for Hospital and Medical Equipment at WHO headquarters in Geneva.
- On December 16 on Monday a farewell party was held at the tavern PHAROS in honour of Chrysostomos Taurou, Lecturer in Mechanical Engineering. The party was organised by the HTI PASYDY branch and the Mechanical Engineering Department.
- On Thursday, December 19, Mr Ioannis Michaelides, Senior Lecturer, Mechanical Engineering Department, and Mr Charalambos Theopemptou Lecturer in Electronic Engineering presented a report on a research project which was carried out by members of HTI staff on the Development of a Solar Assisted Space Heating System.

The presentation ended with drinks in the HTI staff cafeteria.

- Classes were suspended on December 20, at 12.00 so the staff and students got together for Christmas drinks in the students' canteen.
- Mr H.C. Wong, a Senior Manager and principal Lecturer at the Industrial Centre of Hong Kong Polytechnic visited HTI as a UNESCO expert on Control and Instrumendation.

Mr Wong gave a lecture on Monday, 23 December, at 11.30 a.m. on the following topics: a) Introduction to programmable Controllers and Robotics/Assembly.

and (b) An Overview of Computer Integrated Manufacturing System (CIMS) and Flexible Manufacturing System (FMS).

- Mr Nicos Kathidjiotis, Lecturer in civil engineering, completed in December 1985 a fifteen month M.Sc. programme in Enviromental Engineering as a Fulbright scholar.

**JANUARY**

- Classes commence again on Tuesday, 7 January after the Christmas holidays 23 December - 6 January.
- The first semester exams are held 17-30 January.
- Mr Chrisostomos Taurou, Lecturer in Mechanical Engineering, resigned so from January 1986 to emigrate with his family to Australia.
- On January 15, 1986, Cyprus became a full voting member of IAESTE (International).
- Mr Costas Neocleous, lecturer Mechanical Engineering Department, gave a lecture on "Marine Diesel Power Plant Simulation" on Wednesday, January 22, in the HTI Amphitheatre.

**FEBRUARY**

- Monday, 3 February was semester Break.
- Classes for the second semester commenced on February, 4.
- Instructors from the Hotel and Catering Institute were invited to HTI to give a lecture to the graduating students on "Table Manners".

This lecture was given on February 19. This lecture helps to prepare students for their Formal Social Dinner to be held later in March.

The lecture on "Table Manners and the formal Dinner have been established on an annual basis.

- The Astronomy Club organised on February 20, a lecture which was given by Andreas Achillides, senior Lecturer (HTI) and Antonis Marmares, architect. The lecture was on "The Ancient Astronauts by Eric Von Doeniken". It was followed by a short film.
- Mrs Frangeskou, the welfare Officer organised an excursion to Troodos mainly for Overseas students on February 23.
- Mr Alan Campell, Lecturer from the Polytechnic of Central London (PCL) repeated the one-week course for HTI staff and industry on "Introduction to Microprocessor and Programming".
- An eleven month cource began on February 10 to help HTI graduates of the Electrical Department to pass their exams for the CEI.

The course began with forty-five participants.

**MARCH**

- The Formal Social Dinner of the third year students who are to graduate in the summer 1986 was held on Wednesday, 5 March 1986, at the Philoxenia Hotel.
- Classes were suspended on 17 of March for the traditional celebration of Green Monday.
- Classes were suspended on 25 March to celebrate the Greek national Resistance Day.
- The Second Mid-Semester Break began on March 31 and ended on April 4.

**APRIL**

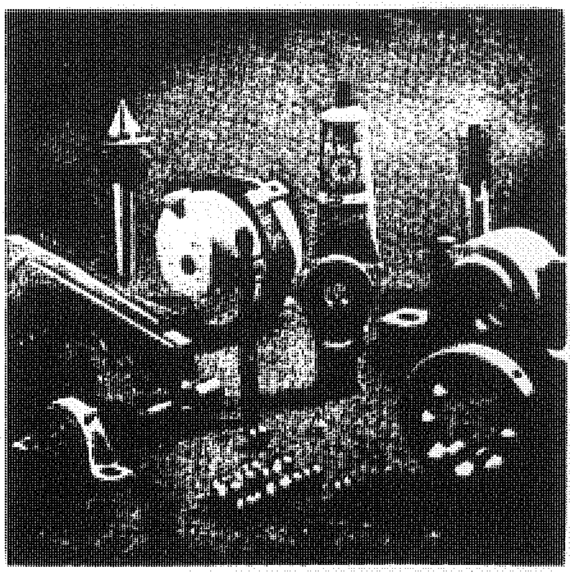
- On Tuesday, 1st April classes were suspended to celebrate Cyprus National Resistance Day.
- Mr Neil Hutchinson, Head of the Microprocessor Training Unit held a course during the Mid-Semester exam period, 31 March - 4 April on "Advanced Microprocessor & Interfacing " for HTI staff and industry. At the same time he held another short course on "Introduction to Analogue and Digital Electronics" for Mechanical Engineers working in industry.
- Mr Sotiris Hadjioannou, HTI Lecturer in Electonic Engineering, attended a short Course in Sweden from 7-17 April on GAMBRO HEMODIALYSIS MACHINE.
- The HTI Director participated in a workshop on the Design of Science and Technology Indicators which was held in London under the sponsorship of the Commonwealth Science Council.
- On 21, 22, 23, 24 of April the HTI Director, Mr G. Christoddoulides, met HTI students from all faculties and discussed with them professional problems that HTI graduates are facing.
- On April 28 HTI students and staff donated blood for the needs of the Blood Bank of the Nicosia General Hospital. HTI usualls donates blood twice a year.
- Easter Holidays began on April 30 - 9 May.

**MAY**

- On Thursday, May 1st, classes were suspended to celebrate Labour Day.
- May 14 was Sports Day for HTI. Several sports activities and final matches took place and the trophies were awarded to the winners.
- Final year students began their exams on 22 May. They are expected to finish on June 4.
- Industrial Training of Final Year students ends on 21 May.
- The HTI Graduates Association organised a symposium at the Philoxenia Hotel, 31 May - 1 June 1986, on "Technician Engineer in Cyprus".

**JUNE**

- First and second year students began their exams on June 4. They are expected to finish on June 18.
- Third year students are expected to hand in their projects on June 18: project interviews will be conducted 23-27 June.
- The Graduation Ceremony is scheduled on July 4.

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