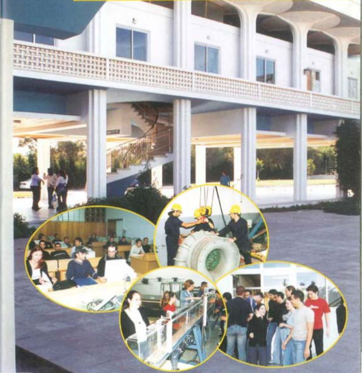
Review

2001-2002

THE HIGHER TECHNICAL INSTITUTE



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

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2002 HTI GRADUATION CEREMONY

The Higher Technical Institute held its 32nd Graduation Ceremony on Friday, 28 June 2002 at the Cyprus International Conference in Nicosia.

The Minister of Labour and Social Insurance Mr Andreas Moushouttas, attended the ceremony and awarded the Presidential Prize of £5.000 to Mr Andreas Poullaides, the graduate with the highest overall performance. Additionally the Minister on behalf of the President Mr Glafcos Clerides awarded a prize of £1000 from the President's personal budget to Mr Michalis Christoforou the graduate with the highest overall performance from the Marine Engineering Department.

The Minister of Labour and social Insurance Mr Andreas Moushouttas proceeded with the award of the diplomas to the ninety graduates while the Chairman of the HTI Board of Governors Mrs Lenia Samuel awarded the prizes for the best overall performance and the HTI Acting Director awarded the prizes sponsored by organisations and Professional bodies to the graduates who excelled in their academic studies. The Chairman of the HTI Central Academic Council Dr Ioannis Michaelides also congratulated students awarded with prizes.

The Director General of the Ministry of Labour and Social Insurance Mrs Lenia Samuel also attended the Ceremony, members of the Parliament, government officials, representatives of the political parties, trade unions and professional bodies.

The President of the Student Union, Mr Marios Laou addressed the gathering and highlighted the students_ efforts and demands for the professional recognition and restructuring of the Higher Technological Institute.

The main speaker was the HTI Acting Director Mr C. Loizou who thanked the dignitaries and all those who attended the Ceremony. His speech is as follows:

On behalf of the Ministry of Labour and social Insurance, the Higher Technical Institute and the Graduating Students, I would like to thank you for honouring us with your presence at the thirty second Graduation Ceremony of the Higher Technical Institute.

We consider your presence at our Ceremony as a proof of your interest in the work carried out at the Higher Technical Institute.

This year 90 students graduate from the three-year full-time courses namely, 30 in Electrical engineering, 15 in Mechanical Engineering, 4 in Marine Engineering, 15 in civil Engineering and 26 in Computer Studies.

Apart from the full-time courses, the HTI has also organised, 7 short courses with a total of 136 participants from industry in the framework of Continuous Professional Development.

It is well known that HTI was established in 1968 on the basis of a 5-year Program of the Cyprus with the assistance of the United Nations Development Program (UNDP), UNESCO and the International Labour Office (ILO).

We have given a total of 4336 Graduates to the Cyprus Industry and elsewhere from Technical Engineers to University Professors both in Cyprus as well as in numerous Universities abroad.

In February 2002, the Council of Ministers decided to establish a Technical University of Applied Science & Arts in which University the Higher Technical Institute together with all the Governmental Institutions of Tertiary Education will participate.

As far as the HTI infrastructure is concerned, the sport grounds and parking around the Sports Hall as well as four lecture rooms and twelve officers have been completed. We continue our efforts for the improvement of our computer and laboratory facilities. Draft regulations for the Credit Point system have been prepared and forwarded to the Board of Governors for approval.

HTI participates actively in the European Union Program Socrates/Erasmus for staff and students exchanges.

In the meantime, the HTI continues to offer excellent training to its students both locally and abroad and in addition, it is participating in research programs financed by the European Union as well as by the Government.

Furthermore, the HTI continues to offer its services to industry in consultancy work as well as in testing of materials.

Before ending my Graduation speech I would like to thank the various industries, organisations as well as individuals, for their generous donations, scholarships and prizes given to us this year. Their names appear in the Graduation Ceremony booklet.

I would also like to express our thanks to his Excellency the President of the Republic for the Presidential Prize value CY5.000, which is awarded to the best graduation student.

Apart from this price however, this Excellency the President of the Republic has offered, the same as last year, a personal prize of CY1.000 to the best Marine Engineering graduating student for which we wish to express our special thanks.

Concerning my speech I would like to wish, on behalf of the Ministry of Labour and Social Insurance and the Government, to today's graduating students progress in life and a successful career.

EDUCATIONAL ACTIVITIES

Short courses organised by HTI

SHORT COURSES/CONFERENCES/SEMINARS ORGANISED by HTI

1. The Electrical Engineering Department organised on 6 and 7 November 2001, two short courses, on ***Effects of ionising radiation on humans: Radiation protection and radio-diagnosis for nursing staff.*** The courses were organised in collaboration with the Cyprus Association of Medical Physics and Bio-Medical Engineering and sponsored by the Ministry of Health, at the Limassol General Hospital.

2. The Electrical Engineering Department organised on 25 June 2002, one short course, on ***Lightning Protection.*** The courses were organised in collaboration with the Institution of Electrical Engineers (IEE) and the Institution of Incorporated Engineers (IIE) at the HTI Amphitheatre.

3. The Electrical Engineering Department organised evening courses on **"Digital Electronics and Microprocessors"** for Technician Engineers.

4. The Engineering Practice Department in Collaboration with the Institution of Incorporated Engineers organised a course on **"Principles of Digital T.V., Cable T.V. - P.C. Networks"**. The course took place between 26 and 29 September 2002, was of 24 hours duration and was delivered by Mr Kambrotis Ferdinardos Technical Manager Theocharakis Co Greece. The course was sponsored by the Human Resource Development Authority.

5. The Engineering Practice Department in collaboration with the Service of Public Administration and Personnel organised a short course of 48 hours duration (April to September 2002) on **"Advance Word and Photoshop"**. The course was attended by 14 members of staff of the Engineering Practice Department.

6. The Engineering Practice Department organised two courses of 96 hours duration each, on **"Welding and machine shop"**. The welding course was attended by 13 soldiers and the machine shop course by 15 soldiers of the Greek Forces in Cyprus. The course took place between March 2002 to June 2002.

7. The Electrical Engineering Department in collaboration with IEE and IIE and the Cyprus Association of Medical Physics and Biomedical Engineering organised a lecture on **"Wireless Telemedicine Systems: A brief overview"** by S. Voskarides on the 6th of March 2002.

8. The Computer Studies Department in collaboration with the Cyprus Computer Society organised a series of courses on **"MS Office Applications for the soldiers of ELDYK"** during the period February - June 2002. At the end of the courses the soldiers undertook the ECDL-European Computer Driving License for the award of the ECDL certificate.

9. The Computer Studies Department in collaboration with the Cyprus Computer Society organised the following courses:

- i) **Short Course on Managing Information Security.**
- ii) **Information Security Fundaments** on 18/2/2002 at the Holiday Inn Hotel.
- iii) **LANs and Internetworking** between 22 - 24.09.02 at the Holiday Inn Hotel.
- iv) **TCP/IP** between 13 - 15.5.2002 at the Holiday Inn Hotel.
- v) **Internet Security and Fireworks** between 29 - 31.5.2002 at the Holiday Inn Hotel.
- vi) **Business Continuity Planning** between 8 - 9.4.2002 at the Holiday Inn Hotel.

CONFERENCES/SEMINARS attended by HTI academic staff

1. Mr. **S. Spyrou** attended a consultation meeting on ***Strengthening of the Policy Infrastructure of the Renewable Sources of Energy***. Organised by the Ministry of Commerce, Industry and Tourism at the Holiday Inn Hotel, Nicosia. (17 December 2002)

2. Mr. **S. Spyrou** attended a 3-day seminar/workshop for ***Learning Coordinators*** organised by the Cyprus Academy of Public Administration. (11, 12 and 13 February 2002)

3. Mr. **S. Spyrou** attended a 16-hour seminar on ***CE Marking: New Approach Directives***, organised by Technocentre Ltd at the Cleopatra Hotel. (17 and 18 June 2002).

4. Mr. **S. Spyrou** attended a consultation meeting on ***Liberalisation of the Electricity Market in Cyprus: Outline of the Legislative Framework***. Organised by the Ministry of Commerce, Industry and Tourism at the Cyprus International Conference Centre. (20 June 2002).

5. Dr **D Serghides** attended the 5- day Congress in Bologna – Italy: **EuroSun 2002 Solar Scientific-Technical Congress & Policyforum** organised by ISES-Europe between 23-27 June 2002

6. Dr **D Serghides** attended a 3-day Workshop on **Learning in Organisations** for the Members of Learning Centres organised by Cyprus Academy of Public Administration-Ministry of Finance between 10.09.2002 – 12-09.2002

7. Dr **D Serghides** attended a 2-day Seminar on **Process Management** organised by ECO-Quality, in Nicosia, between 2-3 July 2001

8. Dr **D Serghides** attended a 5-day Training Course in Engineering Management Training on **"Trends in Higher Education"** organised by Planning Bureau & University of Albany USA, in HTI between 26.03/2001 to30.03.2001

9. Mr. **S Voskarides** attended a 2-day International Workshop on **"Very Low Bitrate Video Coding (VLBV01)"** organised by the National Technical University of Athens between 11-12 October 2001.

10. Mr. S Voskarides attended a 2-day International Workshop on **Enterprise Networking and Computing in Health Care** Industry organised by Healthcom 2002, between 6-7 June 2002, where he presented paper with title **Wireless Telemedicine Systems**

11. Mr. D Lambrianides attended a 1-week course on **Modern Digital Communications** organised by Surrey University, UK, between 2-6 September 2002 (Original course date June 2002)

12. Mr. Ch Chrysafiades attended a 5-day course on **Protection of Electrical Power Systems** organised by Faraday Centre, UK between 12-16 November 2001, at Middlesbrough U.K. (UNESCO FELLOWSHIP)

13. Mr. Ch Chrysafiades attended the **Annual Conference of IAESTE,** organised by IAESTE Norway in Trondheim between 17-25 January 2002

14. Mr. A Georgiou attended a seminar on **Contract Planning and Management,** Southbank University by Mr. J. Pekris, May 2002

15. Mr. A Georgiou attended a seminar in **Daylight,** Southbank University by Mr. J. Pekris, May 2002

16. Mr. A Georgiou attended a seminar in **Building Services Management,** Southbank University by Mr. J. Pekris, May 2002

17. Mr. A Georgiou attended a seminar in **Aircraft Environments,** Institution of Building Services Engineers, London by Mr. Geoff Brundrett, May 2002

18. Mr **S. Savvides** Workshop Superintendent attended a course on **"Trends in Higher Education"** at the Rensselaer Polytechnic Institute U.S.A. between 8 – 19 October 2001.

19. Mr **S. Savvides** Workshop Superintendent participated in the **Annual General Meetings of European Higher Engineering and Technical Professionals Association (EurEta)** held in Rome between 6 – 9 June 2002.

20. Dr **G. Florides**, Senior Instructor and Dr **S. Kalogirou**, Instructor attended and presented papers in the **7th World Renewable Energy Congress** in Cologne, Germany from 29 June to 5 July 2002.

21. Mr **C. Georgiades**, Senior Instructor, attended a 3-days Seminar on" **Sound equipment and acoustics**" organised by "C.G Georgallis music house Ltd" between 2 - 4 February, 2002.

22. Mr **C. Georgiades**, Senior Instructor, attended a 3-days Workshop organised by the Academy of Public Administration, on "**Learning in Organisations**" between 10-12 September 2002.

23. Mr **P. Hadjimichael**, Electrical Instructor, attended a 3 day seminar on "**Sound Equipment and Acoustics**" organised by C.G. Georgallis Music House Ltd" between 2 and 4 Feb.2002.

24. Mr **P. Hadjimichael**, Electrical Instructor, attended a 24 hrs intensive course on "**Principles of Digital T.V. Cable T.V – PC Networks**" organised by the HTI in association with IIE Cyprus Centre between 26 - 29 September 2002.

25. Mrs **P. Katsouri** attended a 3-day seminar on "**Managing Information Security**" at Holiday Inn between 20-22 February 2002.

26. **The lecturers of the Computer Studies Department** participated in the **8th Panhellenic Conference on Informatics** that was organised by the Greek Computer Society, the Cyprus Computer Society, the University of Cyprus and the Cyprus Telecommunications Authority between 8-10 November 2001 in Nicosia.

27. Mr **P. Masouras** participated in the **14th International Olympiad in Informatics** organised by IOI held in Seoul, Korea between 18-25 August 2002.

28. Mrs **M. Theodorou** participated in the **Workshop on Natural Language Portening in Biomedical Natural Language Posessing Applications** organised by the European Federation for Medical Informatic in Nicosia between 8-10 March 2002.

29. Miss **Chr. Panayiotou** attended the **CCS Conference on Information Security** during the days 11-12 October 2002.

30. Messrs **S. Spyrou, I. Demetriou, A. Georgiou, S Voskarides, C. Ioannou** of the Electrical Engineering Department and Messrs **S. Savvides, C. Georgiades**, of the Workshops Department attended a 5 hour course on "**Lightning Protection**" organised by the H.T.I. in collaboration with IEE Cyprus Centre and IIE Cyprus Centre, on 25th June, 2002.

31. Mr **Th. Symeou** attended a course on "**Refrigeration for HVAC Equipment**" at the University of Wisconsin-Madison, USA, between 5-9 November 2001.

32. Dr **C. Chrysostomou** participated in the 3rd World Conference on structural control which took place in Como, Italy from 7 – 12 April, 2002 and presented a paper on "**Conservation of Historical Mediterranean sites by Innovative Seismic – Protection Techniques**".

32. **Dr C. Chrysostomou** participated in the Conference "**Eurocodes: Building codes for Europe**" which took place in Brussels on 25 June 2002.

VISITS/EDUCATIONAL EXCHANGE PROGRAMMES

1. 8 March 2002, a one-day visit by **S P Spyrou** to the Electronic Engineering Department of Queen Mary and Westfield College in London, UK. Discussed entry-level requirements of HTI graduates, research opportunities for HTI staff at the QMW College and possible collaboration on Medical Engineering Courses.

2. 12 April 2002. Visit to HTI by a team of **European Union experts and officials** from the Ministry of Commerce, Industry and Tourism (Peer Review) for inspection of the facilities employed in testing for the enforcement of the European Directive 92/59/EEC General Product Safety.

3. Dr **M Kassinopoulos** visited Derby University U.K. between 24 – 30 April 2002, within the Socrates staff exchange programme.

4. Mr **C. Christodoulou** visited the research centres and Plant Engineering Laboratories at Brunel University between 29 October – 2 November 2001.

5. Dr **C. Chrysostomou** went to the State University of New York at Buffalo U.S.A. on a Sabbatical leave, between September and December 2001. He performed research on energy absorption devices in collaboration with researchers of the University at Buffalo.

6. Dr **N. Angastiniotis** was an invited participant in the Hannover International Technology Co-operation Event 2002 between 18 – 19 April 2002 where four individual profiles of his Nanotechnology research activities were submitted and approved for dissemination.

7. Under a staff exchange activity within the framework of the Socrates/Erasmus Programmed, Dr. **Nicos Angastiniotis** delivered eight 45-minute lectures at South Carelia Polytechnic at Lappeenranta in Finland from 8 – 12 April 2002.

CURRENT RESEARCH PROJECTS

1. Measures of optimal RES (renewable energy resources), integration design in architecture and urban planning by Dr D Serghides
2. Proposal for possible amendments of the Cyprus seismic code by Dr C Chrysostomou
3. Stability and stress analysis of tan miller dam in Austin, Texas, USA. by Dr Ch. Papaleontiou
4. Flexural strengthening with carbon fiber-reinforced polymer composites of beams by Mr P. Polecanos
5. Use of sludge as a soil conditioner: environmental effects on soils in terms of macro and microelements concentration by Dr N. Kathijotes
6. Seismic Performance Assessment & Rehabilitation by Dr C. Chrysostomou in association with Univ. of Patras, Joint Research Centre, Laboratorio National de Engenharia, Univ. of Rome , Univ. of Paria, Imperial College, Univ. of Ljubljana and EOE International LTD. 5th Framework Program of the EU
7. Traditional Settlements by Dr C. Chrysostomou in association with members of the Association of Architects and Civil Engineers. Funded by the United Nations Office for Project Services (UNDPS)
8. Seismic Risk of Nicosia by Dr C Chrysostomou in association with the Technical Chamber of Cyprus and the Geological Survey Department. Funded by the United Nations Office for Project Services (UNDPS)
9. Dr D. Serghides is the Scientific Co-ordinator for Cyprus in the European programme of "5th Frameworks: Brundtland Solar Cities Networks"
10. Computer integrated network for manufacturing applications (CINEMA) by Dr M. Ioannides
11. E-Manufacturing/Rapid Prototyping by Dr M. Ioannides
12. Qualitative reasoning and modelling of reasoning techniques for a single and multiple agents (self-directed autonomous programs that are influenced by the environment in which they reside and revise their targets/goals appropriately) by Ms Chr. Panayiotou
13. Digital signal processing by Mr. D Lambrianides
14. Bispectral analysis: Processing of the interference pattern of electromyographic signals by Mr. S Spyrou
15. Installation and testing of an experimental computer network by Mr Soteris Hadjioannou
16. Switching function algebra: Analysis of power electronic circuits by Dr Chr. Marouchos
17. Mobile transmission for intelligent telecardiology management system by Mr S. Voskarides
18. Innovative decentralised energy and water management policies by Dr I Michaelides
19. Background work for the development of noise models for the road/highway traffic in Cyprus by Dr P Eleftheriou
20. Water purification by Dr P Eleftheriou
21. Thermochemical processing for the synthesis of nanostructured composite powders and the consolidation into net-shaped parts and thermal deposition by Dr N Angastiniotis
22. Fault diagnosis in gas cylinders using computational intelligence techniques by Dr C. Neocleous, Dr A. Stassis, and Mr C Christodoulou
23. Intelligent robotic control by Dr C. Neocleous, Mr P Demetriou
24. Predict future failure of a plant by condition monitoring by Dr V. Messarites
25. Development of mathematical models, software and hardware for improving the dynamic characteristics of structures and machine tools by Dr A. Stassis

26. Mechanical rubbish collector from the embarkments of highways by Dr L. Lazari

27. Optimisation of thermal insulation thickness in air-conditioned buildings in Cyprus by Dr I. Michaelides

28. The pedal curve and surface by Dr Chr. Demetriadis

29. Kinetic parameters estimation in non-linear adsorption systems by Dr P. Christodoulides

30. Low energy air-conditioning of buildings by Dr. G Florides

31. Hydrogen fuelled internal combustion engines by Mr. I Antoniou

32. Design and construction of a spray evaporator for sea-water desalination by Dr S Kalogirou

33. Building construction: traditional practices and memories of the past by Mrs Chr. Antoniou

34. Optmisation of the surface finish produced by various tools available in the local market under various cutting conditions for turning operation using the CNC lathe by Mr Ch. Tsioutis, Mr C. Christofi

35. Design, construction and performance evaluation of a solar air-collector for domestic applications in Cyprus by Mr Ch. Tsioutis

36. Optimisation of building design characteristics for houses in Cyprus by Mr E. Evangelou

SPORTS ACTIVITIES

- H.T.I. participated in the Championships for Tertiary Education Institutions,organised by the Cyprus University Sports Federation
- The Students Pancyprian cross-country race was organised at the H.T.I. premises
- H.T.I. achieved 3rd place in the women's volleyball Championships
- The Institute's Korfball team had an outstanding performance in the Pancyprian Students Championship.
- H.T.I. students participated in table tennis and chess Students Championship organised by the Panhellenic University Sports Federation with outstanding results
- Four H.T.I. students participated in the Middle East Mediterranean Scholar Athletes Games, which took place in Israel
- A number of intramural championship games- Futsal, volleyball, basketball, shooting and korfball- were organised at the premises of H.T.I.

CEREMONY IN MEMORY OF ANDREAS ACHILLIDES

The H.T.I. organised a ceremony in memory of late Andreas Achillides, ex Head of the General Studies Department, on Thursday 23 May 2002 at the Kastelliotissa Cultural Centre in Nicosia.

The speakers, namely his Excellency the Minister of Education and Culture Mr Ouranios Ioannides, the HTI A/g Director Mr C. Loizou, Mr D. Theodotou educationalist, Mr A. Kyprianou member of the House of Representatives and Dr Cl. Ioannides researcher, referred to the educational, political and humanitarian contribution of the distinguished deceased. All speakers exalted the aptitude, enthusiasm and zest, which characterised Andreas Achillides throughout his life.

Andreas Achillides was a beloved member of the H.T.I. academic community for 27 years. His sudden death was a profound shock to all who knew him. H.T.I. extends the most sincere and deepest sympathy to his family in their tragic loss. He will be greatly missed.

HONORARY AWARD

HTI has been awarded the honorary award ECO-Q Cyprus 2002 for the sector of the Public Organization with the greatest contribution to quality.
The Quality Award Ceremony took place in the FORUM Hotel in Nicosia on 5 September 2002.
The President of the House of Representatives Mr Demetris Christophias presented the award.

USE OF GENETIC ALGORITHMS FOR THE OPTIMISATION OF SOLAR SYSTEMS

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ABSTRACT

The objective of this work is to use genetic algorithms in order to optimise a solar energy system by maximising its economic benefits. The system is modelled with TRNSYS computer program and the climatic conditions of Cyprus. An artificial neural network is trained, using TRNSYS simulation results, to learn the correlation of collector area and storage tank size on the auxiliary energy required by the system and thus on the net solar energy price. Subsequently a genetic algorithm is employed to estimate the optimum size of these two parameters, which minimises the net solar energy price, thus the design time is reduced substantially.

1. INTRODUCTION

When a solar system is designed, the engineer seeks to find a solution which gives the maximum life cycle savings of the installation. Such savings represent the money that the user/owner will save because of the use of a solar energy system instead of buying fuel. The optimum system is often not easily found and a lot of calculations and/or simulations are required in order to decide which combinations give the best financial benefits. When a graph of life cycle savings is plotted against the collector area this is of the shape shown in Fig. 1, i.e., life cycle savings start at a negative value for a collector area equal to zero, representing the total value of money required for fuel for a non-solar system, and reaches a maximum. Further increase from this point onwards gives lower life cycle savings than the maximum value and gives even negative values for large areas in multiplication of the optimum value. In this case, the negative life cycle savings represent the money lost by the owner in erecting and operating the solar system instead of buying the fuel.

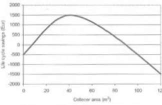

Fig. 1 Variation of collector area with life cycle savings

The optimisation process becomes even more complicated when more than one parameter is optimised like solar collector area and storage tank size. As the number of parameters investigated in order to find the optimum system characteristics increases, the number of simulations also increases exponentially, with consequent increase in time and effort required. It is therefore very important for designers to be able to select the optimum system quickly and accurately.

The objective of this work is to optimise the solar energy system in order to minimise the price of the energy produced from the system. For this purpose an artificial neural network is trained to learn the correlation of collector area and storage tank sizes on the net solar energy price and a genetic algorithm has been employed to estimate the optimum size of these two parameters by minimizing its net solar energy price. Thus, the design time could be reduced substantially and the optimum solution eventually reached is more correct than that of trial and error method, which is traditionally used for such estimations. The importance of this selection method is to make solar energy applications more viable and thus more attractive to potential users.

2. CHARACTERISTICS OF SOLAR SYSTEM

The solar system, shown schematically in Fig. 2, consists of an array of collectors, a circulating pump and a storage tank. It includes also the necessary controls and thermal relief valve, which relieves energy when storage tank temperature is above a preset value. The system is once through, i.e., there is no hot water return to storage, which is what usually happens in many industrial process heat systems and especially in food industry applications. The used hot water is replaced by mains water. Mean monthly ground temperature values are used for the mains water temperature in simulations. When the temperature of the stored water is above the required process temperature, this is mixed with mains water to obtain the required temperature. If no water of adequate temperature is available in the storage tank its temperature is topped-up with an auxiliary heater before use. For the modelling and simulation of the system, the well-known program TRNSYS is employed (TRNSYS, 1996).

Flat plate collectors are employed for this system, which are by far the most used type of solar collector. Flat plate collectors are usually permanently fixed in position and require no tracking of the sun. The characteristics of the collector considered are shown in Table 1.

Table 1. Characteristics of the collector system

Parameter	Value
Type of collector	Flat-plate
Fixing of risers on absorber plate	Embedded
Absorber coating	Black mat paint
Glassing	Low-iron glass
Efficiency mode	n v_s (Ti - Ta)/I_T
Flow rate per unit area at test conditions	0.015 kg/s-m^2
(I) Intercept efficiency	0.792
(S) Negative of first-order coefficient of the efficiency	6.67 W/m^2 °C
(b_0) Incidence angle modifier constant	0.1

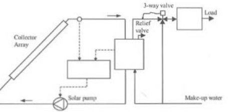

Fig. 2. Schematic diagram of the solar collector system

3. SYSTEM MODEL

The proper sizing of the components of a solar system is a complex problem, which includes both predictable (collector and other performance characteristics) and unpredictable (weather data) components. The initial step in modelling a system is the derivation of a structure to be used to represent the system. The structure that represents the system should not be confused with the real system. The structure will always be an imperfect copy of reality. However, the act of developing a system structure and the structure itself will foster an understanding of the real system. In developing a structure to represent a system, system boundaries consistent with the problem being analyzed are first established. This is accomplished by specifying what items, processes and effects are internal to the system and what items, processes and effects are external.

TRNSYS is an acronym for a "transient simulation program" and is a quasi-steady simulation model. The program consists of many subroutines that model subsystem components. The mathematical models for the subsystem components are given in terms of their ordinary differential or algebraic equations.

TRNSYS is employing the standard collector performance equation in which the intercept (I) and slope (S) factors, shown in Eq. 1, are used to model the collector.

$$n = K_{\alpha t} I - S\frac{\Delta T}{G} \tag{1}$$

where G is the global solar radiation, $k_{\alpha t}$ is the incidence angle modifier and ΔT is equal to T_i-T_a, i.e. inlet temperature to the collector minus ambient temperature. TRNSYS employs the following model for the incidence angle modifier:

$$k_{\alpha t} = 1 - b_o\left(\frac{1}{\cos(\theta)} - 1\right) \tag{2}$$

where b_o is a constant and θ is the angle of incidence. The useful energy extracted from the collectors is given by:

$$Q_u = F_R A\left[k_{\alpha t}(\tau\alpha)G - U_L(T_i - T_a)\right] \tag{3}$$

where F_R is the heat removal factor and τα is the transmittance-absorptance product.

The total useful energy for the whole year is obtained from:

$$Q_{u,a} = \sum_{d=1}^{365}\sum_{h=1}^{24} Q_u \tag{4}$$

and the auxiliary energy required, Q_{aux} is:

$$Q_{aux} = Q_{load} - \left[Q_{u,a} - Q_{loss}\right] \tag{5}$$

where Q_{load} is the energy required by the load and Q_{loss} is the energy lost from the storage tank, pipes and relief valve.

As can be seen from the above equations the energy obtained from the solar collector field depends on the inlet temperature to the collector T_i, which depends on the load pattern and the losses from the storage tank and the pipes.

3.1 Economic Analysis

The economic analysis is performed in order to obtain the annual cost of the system and the net solar energy price (NSEP). The investment cost of the solar system is obtained from:

$$C_s = C_f + C_a A + C_v V \tag{6}$$

where C_f is the area independent cost, C_a is the area (A) dependent cost, both applied to the solar collectors, and C_v is the cost of storage per m^3 of storage volume (V).

For the operation cost (C_o), maintenance and parasitic costs are considered. The former are estimated to be 2% of the initial investment. The latter account for the energy required (electricity) to drive the solar pump. The total annual cost is given by:

$$C = C_s \alpha + C_o \tag{7}$$

where α is the annuity given by:

$$\alpha = \frac{i(1+i)^N}{(1+i)^N - 1} \tag{8}$$

where i is the inflation rate and N is the number of years the system is operational, i.e., life of the system (20 years).

The net energy collected from the collector (Q_{net}) is obtained by subtracting the annual amount of auxiliary energy from the annual amount of conventional fuel required to cover the load for a fuel only system, i.e.,

$$Q_{net} = Q_{load} - Q_{aux} \tag{9}$$

Finally, the solar energy price, in £/kWh, is obtained by:

$$NSEP = \frac{C}{Q_{net}} \tag{10}$$

4. SYSTEM SIMULATION

With the aid of TRNSYS and the TMY for Nicosia, Cyprus, a number of simulations were performed. System characteristics are shown in Table 2. The optimisation parameter used in the net solar energy price (NSEP), i.e., the optimum system is the one, which gives minimum NSEP. As the load pattern is the same for all the cases considered, the parameters on which the performance of the system depends are the collector area and the storage tank volume. By increasing the collector area more solar energy is collected but the solar system costs more, whereas by increasing the storage tank volume more energy can be stored but the losses from the storage tank to the environment are increased. Small storage tank volumes exhibit lower environmental losses but increase the losses of energy though the relief valve as they can easily reach the relief valve setting temperature.

Table 2. Characteristics of the solar system

Parameter	Value/Type
Load temperature	85°C
Load flow rate	2000 l/hr
Use pattern	5 days a week, 8.00-16.00 hours each day, load used for the first ¾ of each hour
Collector to storage distance	30m
Piping UA value	20 W/°C
Piping diameter	75mm
Relief valve set temperature	100°C

All cases were simulated for a number of collector areas and a range of storage tank volumes. In this way, a database is created with the combination of the collector area and storage volume on auxiliary energy required by the system, for various cases. The idea is to create a small database of combinations of values and use these values to create a fitness function for the NSEP. The data collected from the present system from 7 runs of TRNSYS are shown in Table 3. As can be seen from Table 3 as the collector area and the storage tank are increased the auxiliary energy required is reduced because the solar system can collect and store more solar energy, but inevitably the system costs more. It is important to cover the low and upper extreme ends of the cases to be investigated plus some intermediate values. This is important for two reasons; first, the neural network learns all the range of possible values and thus it will not need to extrapolate and second the scaling functions for the input and output data need to be determined only once, based on the minimum and maximum values of the parameters in the data set. For those extreme conditions, rules of thump can be used such as storage tank must be between 40 and 300 litres per square meter of collector area.

The traditional method for finding the optimum solution is to perform many runs of TRNSYS and decide by trial and error the characteristics of the system, which gives the optimum solution. This method may lead to solutions far away from the optimum as the method strongly depends on the intuition of the engineer and the peculiarities of the system. Additionally depending on the computer system frequency and the complexity of the system, each run might need several minutes to hours to be performed. Thus, it is required for the present system not only to be able to find the optimum solution but also to reduce the time required for such task to be performed.

5. METHOD DESCRIPTION

A different approach to optimise the system based on artificial intelligence systems is suggested here. The idea is to use genetic algorithms to find the optimum values of collector area and storage tank volume, which will minimise the net solar energy price of the system. For this purpose, an accurate correlation of collector area and storage tank volume on the auxiliary energy required to cover the load is required. For this purpose a neural network is used which when trained gives a complex polynomial equation correlating these parameters.

Table 3. Training data set

Area (A) [m^2]	Storage tank volume (V) [m^3]	Q_{aux} [kJx10^6]
100	10	6.447
100	30	6.288
200	30	4.623
300	20	3.606
400	10	3.058
500	10	2.508
500	30	2.124

5.1 Group Method Data Handling Neural Network

There are various methods that can be used to model the data, i.e., correlate the collector area and storage tank volume with the auxiliary energy required. These could be based on simple regression analysis, multiple regression analysis and neural networks. One type of neural networks which is very suitable for the present application is the group method of data handling (GMDH) neural network which was used to model the data. GMDH works by building successive layers with links that are simple polynomial terms. These polynomial terms are created by using linear and non-linear regression. The initial layer is simply the input layer. The first layer created is made by computing regressions of the input variables and then choosing the best ones. The second layer is created by computing regressions of the values in the first layer along with the input variables. Again, only the best are chosen by the algorithm. These are called survivors. This process continues until the net stops getting better (according to a pre-specified selection criterion). The Group Method of Data Handling (GMDH) technique was invented by A. G. Ivakhnenko from the Institute of Cybernetics, Ukrainian Academy of Sciences (Ivakhenko, 1971), but enhanced by others (Farlow, 1984). This technique is also known as "polynomial networks". Ivakhenko developed GMDH for the purpose of building more accurate predictive models of fish populations in rivers and oceans. GMDH worked well for modelling fisheries and many other modelling applications (Hecht-Nielsen, 1991). GMDH is a feature-based mapping network.

The resulting network can be represented as a complex polynomial description of the model. The complexity of the resulting polynomial depends on the variability of the training data. In some respects GMDH, it is very much like using regression analysis, but it is far more powerful than regression analysis. GMDH can build very complex models while avoiding overfitting problems. A by-product of GMDH is that it recognizes the best variables as it trains.

The GMDH network is not like regular feedforward networks and was not originally represented as a network. The GMDH network is implemented with polynomial terms in the links and a genetic component to decide how many layers are built. The result of training at the output layer can be represented as a polynomial function of all or some of the inputs.

5.2 Genetic Algorithm

A genetic algorithm is an optimum search technique based on the concepts of natural selection and survival of the fittest. It works with a fixed-size population of possible solutions of problem, called individuals, which are evolving in time. A genetic algorithm utilizes three principal genetic operators: selection, crossover, and mutation.

Genetic algorithms (GA) are suitable for finding the optimum solution in problems were a fitness function is present. Genetic algorithms use a "fitness" measure to determine which of the individuals in the population survive and reproduce. Thus, survival of the fittest causes good solutions to progress. A genetic algorithm works by selective breeding of a population of "individuals", each of which could be a potential solution to the problem. In this case, the genetic algorithm is seeking to breed an individual that in this case minimizes the net solar energy price of the solar system.

During each step (called a generation) in the reproduction process, the individuals in the current generation are evaluated by a so-called fitness function value, which is a measure of how well the individual solves the problem. Then each individual is reproduced in proportion to its fitness: the higher the fitness, the higher its chance to participate in mating (crossover) and to produce an offspring. A small number of new-born offspring undergo the action of the mutation operator. After many generations, only those individuals who have the best genetics (from the point of view of the fitness function) survive. The best individual provides an optimum or near optimum solution to the problem.

The larger the breeding pool size, the greater the potential of it producing a better individual. However, the networks produced by every individual must be applied to the test set on every reproductive cycle, so larger breeding pools take longer time. After testing all of the individuals in the pool, a new "generation" of individuals is produced for testing. The structure of the standard genetic algorithm is shown in Fig. 3 (Zalzala and Fleming, 1997).

```
Begin (1)
        t = 0
        Initialize Population P(t)
        Evaluate fitness of Population P(t)
        While (Generations < Total Number) do begin (2)
                Select Population P(t+1) out of Population P(t)
                Apply Crossover on Population P(t+1)
                Apply Mutation on Population P(t+1)
                Evaluate fitness of Population P(t+1)
                t = t + 1
        end (2)
end (1)
```

Fig. 3. The structure of standard genetic algorithm

During the setting up of the GA the user has to specify the adjustable chromosomes, i.e. the parameters than would be modified during evolution to obtain the minimum value of the fitness function. In this work, these are the collector area and the storage tank volume. Additionally the user has to specify the ranges of these values. It is important that the ranges specified to be the same as the extreme cases used when setting up the neural network. In the present work, these are equal to 100-500m^2 for the collector area and 10-30m^3 for the storage tank volume.

The genetic algorithm parameters used in the present work are:

- Population size=50

Population size is the size of the genetic breeding pool, i.e., the number of individuals contained in the pool. If this parameter is set to a low value, there would not be enough different kinds of individuals to solve the problem satisfactorily. On the other hand, if there are too many in the population, a good solution will take longer to be found because the fitness function must be calculated for every individual in every generation.

- Crossover rate=90%

Crossover rate determines the probability that the crossover operator will be applied to a particular chromosome during a generation.

- Mutation rate=1%

Mutation rate determines the probability that the mutation operator will be applied to a particular chromosome during a generation.

- Generation gap=96%

Generation gap determines the fraction of those individuals that do not go into the next generation. It is sometimes desirable that individuals in the population be allowed to go into next generation. This is especially important if individuals selected are the most fit ones in the population.

- Chromosome type=continuous

Populations are composed of individuals, and individuals are composed of chromosomes, which are equivalent to variables. Chromosomes are composed of smaller units called genes. There are two types of chromosomes, continuous and enumerated. Continuous are implemented in the computer as binary bits. The two distinct values of a gene, 0 and 1, are called alleles. Multiple chromosomes make up the individual. Each partition is one chromosome, each binary bit is a gene, and the value of each bit (1 or 0) is an allele. Enumerated chromosomes consist of genes, which can have more allele values than just 0 and 1.

The genetic algorithm was stopped after best fitness remained unchanged for 75 generations.

6. OPTIMUM SOLAR SYSTEM

The training data set (Table 3) were learned with very good accuracy with R^2-value equal to 0.9986. A plot of the actual (modelled) and network predicted data is shown in Fig. 4. It should be noted that a multiple linear regression method could only produce correlation with R^2=0.9653 which is not acceptable for the kind of predictions required in this type of problems. A similar figure for data, which are completely unknown to the network and used for validation of the ability of the network to produce accurate results is shown in Fig. 5. It should be noted that in this case also the network provided good predictions with R^2=0.9906.

The final equation obtained from GMDH is:

$$Y = -0.29565 - 0.93105X_1 + 0.32545X_1^2 - 0.07628X_2^3 \quad (11)$$

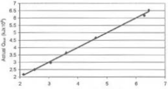

Fig. 4. Comparison of actual (modelled) and NN predicted data (training data set)

All the data required for the GMDH need to be scaled from –1 to 1. The data used subsequently with Eq. (11), for the prediction of Q_{aux}, needs also to be scaled in the same interval. For this purpose, the following equation was used:

$$y_i = \frac{2(x_i - x_{min})}{x_{max} - x_{min}} - 1 \quad (12)$$

Thus, by using the values shown in Table 3 and Eq. (12) the values of X_1 (related to A) and X_2 (related to V) can be calculated. Similarly, when the result of Eq. (11) is obtained, Eq. (12) is used to obtain the value of Q_{aux} from Y.

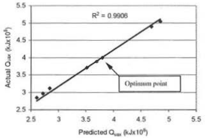

Fig. 5. Comparison of actual (modelled) and NN predicted data (validation data set)

Figure 6 shows the fitness function against the number of generations during the running of the genetic algorithm program. As can be seen the best fitness is found at the 45th generation, which is very fast. It should be noted however that the shape of the graph depends on the initial conditions. The particular case presented is for initial collector area equal to 100m^2 and initial storage tank volume equal to 30m^3. As can be seen after about 12 generations values near the optimum ones have been obtained.

Equation (11) was used together with other characteristics and economic parameters of the system in combination with a genetic algorithm program to find the optimum collector area and storage tank size (adjustable chromosomes) that minimises the NSEP. The whole model was set in a spreadsheet program in which the various parameters and equations (like Eq. 11) are entered into different cells. The adjustable chromosomes are set in different cells and the fitness function is the cell that contains an equation giving the NSEP. It should be noted that, the spreadsheet file described above need to be constructed once. The only changes required for different problems would be to modify the cells with minimum, maximum values of the input parameters and the cell containing Eq. (11).

The optimum solution reached is; collector area equal to 227.7m^2 and storage tank size equal to 13.2m^3. The net solar energy price for this solution is 0.038471 £/kWh, whereas the net solar energy price of a more practical solution with A=230m^2 and V=13m^3 are 0.038473 £/kWh. The performance of the GMDH network to predict Q_{aux} for this case is very good as it is shown by the point marked on Fig. 5, which compares the auxiliary energy predicted with the neural network with that obtained from TRNSYS. This case is checked on purpose to evaluate the prediction accuracy for the optimum case.

Fig. 6 Plot of best fitness against the number of generations

It should be noted that both the training of the neural network and the genetic algorithm program required just a few seconds to be performed whereas each run of TRNSYS requires 2.5 minutes, all on a Pentium

400 MHz machine. Thus, by reducing the number of runs of TRNSYS the time required to find the optimum solution is greatly reduced and the solution reached is more correct than by using the traditional trial and error method which most of the times relies on the intuition of the user to find a good solution.

7. CONCLUSIONS

The optimisation of a solar system is presented in this paper. Initially the system is modelled with TRNSYS and GMDH neural network, which was trained at high accuracy, as the R^2-value obtained is 0.9986. Subsequently a genetic algorithm was used to select the combination of system components, i.e. solar collector area and storage tank volume, which minimises the net solar energy price of the system. It is believed that the present method would decrease the time required by design engineers to find the optimum solution and to obtain a selection, which could not be easily spotted by traditional trial and error method, which in most of the cases depends on the intuition of the engineer.

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UB 200 Θερμομονωτικό τούβλο...

ΧΡΗΣΕΙΣ ΚΑΙ ΕΦΑΡΜΟΓΕΣ

Το UB 200 είναι Θερμομονωτικό τούβλο που προσφέρει άριστη μόνωση σε τοιχοποιίες καλύπτοντας τις αυξημένες σύγχρονες απαιτήσεις θερμομόνωσης και ηχομόνωσης. Είναι κατάλληλο τόσο για κατοικίες όσο και για δημόσια κτίρια.

ΠΕΡΙΓΡΑΦΗ ΚΑΙ ΤΕΧΝΙΚΑ ΧΑΡΑΚΤΗΡΙΣΤΙΚΑ

Το UB 200 είναι μια διεθνώς κατοχυρωμένη εφεύρεση που οφείλει τις ιδιότητες του στην ανάμιξη αργίλου. Η κυψελωτή δομή των θαλάμων αέρα παρεμβάλλεται ρυθμικά ανάμεσα στις εξωτερικές συνθήκες και στο εσωτερικό του χώρου εξασφαλίζοντας άριστη θερμομόνωση και ηχομόνωση.

ΤΟ UB 00200 ΕΜΦΑΝΙΖΕΙ ΠΟΛΛΑ ΣΗΜΑΝΤΙΚΑ ΠΛΕΟΝΕΚΤΗΜΑΤΑ ΣΤΙΣ ΚΑΤΑΣΚΕΥΕΣ

- **Υψηλή θερμομόνωση**
  Χάρη στο συνδυασμό της δομής του με τα κενά του διάτρητου τούβλου.
- **Ηχομόνωση**
  Το UB 200 απορροφά τους ενοχλητικούς διάχυτους θορύβους χάρη στη δομή του και στη σχέση της ακαμψίας του με το φαινόμενο βάρος του.
- **Σταθεροποίηση της θερμοκρασίας**
  Ο τοίχος που είναι κτισμένος με UB 200 εξασφαλίζει την επιθυμητή ισορροπία θερμοκρασιών αφού μετατρέπει τις μεγάλες ημερήσιες εξωτερικές μεταβολές της θερμοκρασίας σε μικρές διακυμάνσεις στο εσωτερικό του χώρου και συγχρόνως επιβραδύνει την αλλαγή της θερμοκρασίας στο εσωτερικό του τοίχου. Η μετατόπιση των φάσεων που επιτυγχάνεται είναι 12 ωρών (τα ιδανικά όρια κυμαίνονται μεταξύ 10-14 ωρών).
- **Μεγάλη θερμοχωρητικότητα**
  Το UB 200 έχει την ιδιότητα όταν θερμαίνεται να αποθηκεύει θερμότητα και να την αποδίδει στο περιβάλλον σε περίπτωση που η θέρμανση διακοπεί έτσι ώστε ο χώρος να μην ψύχεται γρήγορα.
- **Υγροαπορροφητικότητα**
  Απορροφά υγρασία λιγότερη από τα κοινά τούβλα και έχει υγροαπορροφητικότητα <1%.
- **Πυροπροστασία**
  Παρουσιάζει μεγάλη πυρανάσχεση δηλαδή μεγάλο χρόνο αντίστασης στη φωτιά.
- **Αντοχή στον παγετό**
  Οι κυψέλες του UB 200 δε γεμίζουν σε περίπτωση βροχής και σε περίπτωση παγωνιάς λειτουργούν ως θάλαμοι εκτόνωσης.
- **Χαμηλό συντελεστή διάχυσης υδρατμών**
  Υγιεινό περιβάλλον.
- **Εύκολη τοποθέτηση εγκαταστάσεων**
  Άνοιγμα καναλιών, τοποθέτηση δικτύου καλωδιώσεων, στήριξη σωμάτων. Μπορεί να τρυπηθεί με τρυπάνι, να κοπεί με τροχό ή να τοποθετηθούν βίδες και καρφιά στην επιφάνεια του.
- **Οικονομία στο χρόνο και στο κόστος**
  Οικονομία στο χρόνο και στο κόστος κατασκευής καθώς και στην κατανάλωση ενέργειας για θέρμανση και ψύξη.
- **Εξασφάλιση μεγάλης διάρκειας ζωής**
  Χωρίς απαιτήσεις συντήρησης.

ΟΔΗΓΙΕΣ ΕΦΑΡΜΟΓΗΣ

Η τοποθέτηση UB 200 είναι ίδια με αυτή των κοινών τούβλων, με μοναδική διαφοροποίηση στην τοποθέτηση των αρμών ώστε να μην περιορίζονται οι θερμομονωτικές ιδιότητες του. Το κτίσιμο του UB 200 ο συνδετικός πηλός τοποθετείται δεξιά και αριστερά σε δύο παράλληλες ευθείες, συνεχίζοντας και κατακόρυφα όπως φαίνεται στο πιο κάτω σχήμα. Με αυτό τον τρόπο επιτυγχάνεται εύκολα και γρήγορα κτίσιμο αλλά και υγρομόνωση, αφού το κενό που δημιουργείτε εμποδίζει τη μεταφορά της υγρασίας από το εξωτερικό στο εσωτερικό επίχρισμα.

Τυπικές Ιδιότητες

ΥΨΟΣ: 200χιλ		
ΠΛΑΤΟΣ: 250χιλ [πάχος τοιχοποιίας]		
ΜΗΚΟΣ: 300χιλ		
ΠΟΣΟΤΗΤΑ ΓΙΑ 1μ² ΤΟΙΧΟΥ: 16 τεμάχια		
ΣΥΝΤΕΛΕΣΤΗΣ ΘΕΡΜΙΚΗΣ ΑΓΩΓΙΜΟΤΗΤΑΣ λ	0,214	W/m°K
	0,184	kcal/mh°C

- *Πιστοποιητικό μέτρησης συντελεστή θερμικής αγωγιμότητας από* **ΙΝΣΤΙΤΟΥΤΟ ABAKUS ΓΕΡΜΑΝΙΑΣ**

Integrated Project

3-D NANOCONTROL

A Novel Synthesis Method for the Production of Tailor-sized Nano-structures

Prepared by Dr. Nicos Angastiniotis

This Expression of Interest was submitted in response to Call EOI.FP6.2002

AIM OF THE PROPOSED WORK

The participants constitute the indispensable components of a concrete multidisciplinary Integrated Project framework that is embodied in the context of high rate thermochemical *synthesis* and diverse *utilization* of non-agglomerated tailor-sized nano-structured particles.

GENERAL PROJECT APPROACH

The employed *generic* methodology entails the thermochemical conversion of precursor powders and their subsequent densification by means of surface deposition or consolidation into net-shaped components. The thrust of the initiative is empowered by a novel, proven and fully documented method (*Canadian Patent*, Patent Number CA2190422, November 15, 1996, *European Patent*, Patent Number EP0800883, October 15, 1997, *Japanese Patent*, Publication Number JP09-309704, December 2, 1997, *United States Patent*, Patent Number US5776264, July 7, 1998, *South African Patent*, Patent Number ZA9609689, currently being evaluated) that yields tailor-sized nano-structured powder compositions in bulk quantities from amorphous based metallic constituents.

The research approach entails four inherently scalable and proven processing steps:

- Spray drying of chemically homogeneous precursors with compositional constituents mixed at an *atomic level*.
- Fluid bed thermochemical conversion of the precursor powders followed by compositional enrichment for the realization of tailor-made nano-structured phases.
- Development of nano-structured coating application parameters based both on simulation of the interaction between particles and thermal source and deposition with different thermal spraying technologies by varying process parameters in a systematic way.
- Fabrication of dense nano-structured net-shaped components at exceptionally low temperatures.

The aforementioned steps *if integrated* will lay the foundation of a new manufacturing technology for the large-scale production and utilization of nano-structured particulate materials.

NEED AND RELEVANCE

The *primary* application fields that will be targeted are:

- ✓ Thermal-barrier coatings (TBCs) for high temperature applications (e.g. turbine engines).
- ✓ Hard coatings for prolonging the life of tools or machine components (e.g. valve stems, shafts, wire spools, etc.) subjected to severe working conditions.
- ✓ High-density net-shaped parts with high electrical and thermal conductivity.

Specific nano-structured powder compositions will be strategically targeted with a view to realizing the aforementioned applications with an immediate industrial impact, i.e.

- ZrO_2 and/or Cr_3C_2-NiCr powders with tailor-sized nano-structure. The ZrO_2 tailor-sized nano-grained powders can be used for the development of thermal-barrier coatings (TBCs). For example, current production of thermal-barrier coatings have been shown to be capable of reducing the average temperatures of metallic components by 50 to 80°C and hot-spot temperature by up to 140°C. This substantial temperature reduction has been used to extend the life of metallic components in aircraft turbines. The Cr_3C_2-NiCr tailor-sized nano-grained powders can be used for the development of coatings with superior resistance to wear and corrosion. Thermal sprayed Cr_3C_2-NiCr coatings show a wear resistance 2 to 3 times higher than that of hard chromium.
- W-Cu tailor-sized nano-grained composite powders are expected to possess a very high sintering activity and should not require sintering aids which degrade the electrical/thermal conductivity of W-Cu. Net-shaped components could be made from tailor-sized nano-grained W-Cu powders by P/M having the following metallurgical advantages: complete retention of copper in the tungsten framework at sintering (absence of copper bleed out), uniform distribution of tungsten and copper phases, excellent electrical/thermal conductivity, controlled mechanical properties and high arc erosion resistance. Net-shaped W-Cu parts can be utilized for various industrial applications, i.e. electrical contacts, heat sinks, EDM electrodes, spot-welding electrodes, etc. Furthermore, nano-grained W-Cu should exhibit excellent pressability and enhanced machinability thus enabling highly complex intricate machining.
- Coatings of Co-WC tailor-sized nano-grained cermets are expected to have wide use on ships, aircraft, and land vehicles to prevent various types of wear, corrosion and erosion, thereby reducing the need for expensive and recurring maintenance.

SCALE OF AMBITION AND CRITICAL MASS

The participants will be intrinsically and timely provided with a golden opportunity to capitalize on the scientific benefits and pertinent industrial repercussions as these are directly coupled with the *first time wide use* of these types of powders in an array of diverse and state-of-the-art application fields. It must be stated that the coating and consolidation of the as-synthesized nano-structured powders are expected to yield superior performance components with remarkable mechanical and thermal properties. *The US Military has recently fabricated a particular cermet*[1] *that relates to the nano-structured powders cited in the abstract with astonishing results*[2].

The core members of the consortium (17 academic and private European research centers and 10 industrial research centers from 13 European countries) are highly regarded, possess authoritative status in their respective fields and have been meticulously selected among the leading industrial and academic European research centers. They all incontrovertibly share an in-depth appreciation of both the strategic importance and implications of the innovation involved and exhaustively satisfy the prerequisite criteria to carry out the required tasks. All participants possess the expertise and academic background to undertake the pertinent, non-overlapping albeit complementary and strictly defined assignments in the context of at least one of the following obligatory areas of expertise: powder processing, spray dryer technology, fluidized bed technology, powder consolidation, thermal spray, microstructural and functional characterization, manufacturing systems, technology management, know-how in securing intellectual rights.

INTEGRATION

Due to the generic nature of the methodology and its wide ranging applicability to various compositions, the IP intends to pursue the parallel investigation of an extensive spectrum of compositions in addition to the aforementioned ones. The magnitude and academic caliber of the consortium is such that it can certainly accommodate the challenge with all the inherent academic and industrial benefits and repercussions.

3-D NANOCONTROL will be composed by multidisciplinary RTDs and high technology, research-performing SMEs with complementary roles and competencies which will increase their individual research capacities and scope. The core group of the organizations involved in the IP is presented in table 1.

Dr. Nicos Angastiniotis, who owns the intellectual rights of the patent, as he is the inventor, will develop the binding thermochemical data that are required for the achievement of the pre-selected compositions with the required tailor-sized nano-structured constituents. The latter will be implemented at the Nanomaterials Research Center (NRC) of the Higher Technical Institute (HTI) in Nicosia Cyprus. The NRC apart from having implementation rights on the aforementioned patented methodology possesses the capability to produce fixed-bed (limited) prototype quantities of the tailor-sized nano-structured powders with the compositions cited in the abstract and thus is in position to provide all the pertinent thermodynamic data with regards to the specifics of the large volume (fluidized bed) thermochemical conversion.

In what follows all requisite work packages are presented in sequential order in concurrence with the respective core participants:

- "Spray drying of chemically homogeneous precursors -- microstructural and functional characterization" will be executed by the organizations 1, 2, 19, 22 as quoted in table 1.

The partners involved will collaborate in the context of liquid atomisation by means of spray drying and will be expected to produce fine solid or hollow particles of specific compositions. The partners will concentrate on the characteristics of the spray drying process and will be expected to investigate the following operational variables, which offer the means to fine-tune the product characteristics: 1. Atomizer characteristics. 2. Feed solution properties, i.e. feed viscosity. 3. Feed rate. 4. Air flow rate. 5. Gas temperature.

- "Thermochemical conversion of the precursor powders and subsequent if needed compositional enrichment -- microstructural and functional characterization" will be executed by the organizations 1, 13, 17, 19, 20, 25, 26 as quoted in table 1.

The partners under reference will collaborate in the context of fluid bed particulate processing and will be expected to scale up the production of tailor-sized nano-structured powders. The partners will concentrate on the characteristics of the fluidization process and will be expected to investigate the following operational variables, which offer the means to control the product characteristics: 1. Incipient fluidization velocity. 2. Gas velocity. 3. Circulation pattern. 4. Fluidization gas. 5. Temperature. 6. Reaction time. All the parameters with respect to the specifics of the gaseous atmosphere will be provided by NRC.

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[1] Nano-structured Coating Approved for Use on Navy Ships, News Release, April 5, 2000, Office of Naval Research, Corporate Communications Office, desiol@onr.navy.mil, tel. 703-696-5032.

[2] Naval Researchers Honored for Nano-structured Coatings, News Release, February 27, 2002, Corporate Communications Office, Jennifer_Huego@onr.navy.mil, tel. 703-696-0950.

- "Thermal spraying of the as synthesized powders to form tailored-sized nano-structured dense coatings -- microstructural and functional characterization" will be executed by the organizations 2, 5, 6, 8, 10, 11, 14, 15, 18, 22, 23, 24 as quoted in table 1.

The said partners will collaborate in the deposition of the as synthesized powders and will be expected to perform at least one of the following processes or equivalent one: Plasma Spray, Vacuum Plasma Spray (VPS), Low-Pressure Plasma Spray (LPPS), Controlled Atmosphere Plasma Spray (CAPS), Flame Spray, High Velocity Oxy-Fuel Spray (HVOF), Detonation Gun. The partners will concentrate on the deposition of the as synthesized powders and will be expected to investigate the operational deposition variables (e.g. gas flow rate, spray rate, jet pressure, spray distance, etc.) in connection with the final product characteristics (e.g. microstructure, hardness, bond strength, wear resistance, thermal shock resistance, thickness).

- "Fabrication of dense nano-structured net-shaped components at exceptionally low temperatures -- microstructural and functional characterization" will be executed by the organizations 15, 16, 18 as quoted in table 1.

The aforementioned partners will collaborate in the consolidation of the as synthesized powders and will be expected to perform consolidation of prototype samples for the purpose of making dense tailor-sized nano-structured net-shaped components by means of at least one of the following methods or otherwise: cold isostatic pressing, hot pressing, hot isostatic pressing (HIP), liquid phase sintering, solid state sintering, vacuum induction furnace. The objective will be to obtain consolidated components that retain at least the nano-structured features of the as synthesized powder. The partners will concentrate on the operational variables (as applied to the implemented consolidation technique) in connection with the end-product characteristics (e.g. microstructure, hardness, density, thermal conductivity, high temperature hardness, transverse rupture strength, modulus of elasticity, abrasion resistance).

- "Comparative 2-D surface phenomena, non-equilibrium phase diagrams, catalytic properties and mathematical modelling" will be executed by the organizations 1, 4, 7, 14, 18, 23 as quoted in table 1.
- "Prototype field testing" will be executed by the organizations 3, 9, 12, 15, 21 as quoted in table 1.

The primary applications include components with superior resistance to wear, corrosion and erosion and components with enhanced electrical/thermal conductivity, controlled mechanical properties and high arc erosion resistance.

- "Automation and process integration" will be executed by the organizations 1, 13, 27 as quoted in table 1.

The proposed project describes a generic thermochemical processing technology for the production of nano-structured particulate alloys and composites and their consolidation into controlled porosity or theoretically dense structures. It is envisioned that all processing steps will eventually be linked together as an integrated manufacturing and commercially viable technology for the production of flaw-free, net-shape, nano-structured alloy and composite parts. The spray drier and fluid bed reactor can be constructed so that processing is completely isolated from the surroundings with the end product powders discharged directly into the feeder of the spray gun for surface deposition or hermetically sealed vessels for subsequent net-shape consolidation.

TABLE 1: List of the leading academic, private and industrial European research centers that will contribute to the Integrated Project.

S/N	Organization	Ctry	Contact	Area of excellence
1	Higher Technical Institute (HTI)- Nanomaterials Research Center (NRC)	CY	Dr. Nicos Angastiniotis nano@spidernet.com.cy	Expertise in producing laboratory scale nanophase powders and implementation rights of a patented methodology, which focuses on the production of nano-structured powders with amorphous based metallic constituents. The processing entails the thermochemical synthesis of strategically selected particulate materials which are characterized by microstructural constituents that can be tailored within the amorphous, or nanocrystalline range.
			Dr. Kyriacos Kalli kkalli@cytanet.com.cy	Expertise in photonics, optical characterization of materials and 2-D gas-solid reactions.
			Dr. Andreas Stassis stassis@logos.cy.net	Expertise in structural dynamics, industrial automation and manufacturing systems.
2	CERECO S.A.	EL	Constantinos Stournaras cereco@otenet.gr	Spray drying technique for the production of nanograined powders, thermal spray techniques (APS, VPS, HVOF), characterization of materials (mechanical, microstructural, physicochemical, tribological).
3	SORRENTO LTD (SME)	CY	George Stassis biostaco@cytanet.com.cy	Renovates saw and band saw blades for metal cutting, as well as imports and distributes new saw blades, grinding wheels, drills etc. Currently holds 40% of the Cyprus market in saw blades. They are very keen in participating in a future project to investigate methods of improving the tool life of their saw blades after renovation as well as improving the life of their blades specially those sold for cutting hard metals.
4	Centrul de Consultanta si Transfer Tehnologic CCTT	RO	Paul FOGARASSY ccttro@yahoo.fr	Mathematical modelling of thermal coating related phenomena, technology transfer, information and communication technology (ICT), education.
5	National R&D Institute for Welding and Material Testing ISIM	RO	Nicolae MARKOCSAN marco@isim.dnttm.ro	Plasma thermal spraying technology, coating characterization facilities, technology transfer, education.
6	University "Politehnica" Timisoara, SMTT Department	RO	Aurel RADUTA araduta@tcm.mec.utt.ro	X-ray investigation, micro and macro investigation facilities, education.
7	Université de Reims	F	Alain LODINI alain.lodini@univ-	X-ray investigation, neutron diffraction facilities, mathematical modelling, education.

	Champagne-Ardenne, LACM		reims.fr	
8	C P T. Centre de Projecció Tèrmica. Thermal Spray Centre UNIVERSITAT DE BARCELONA	E	Prof. J.M. Guilemany guileman@material.qui.ub.es	Specializes in surface engineering and particularly on coatings (either thermal sprayed or others). APS (Plasma Technik A3000-F4 gun), HVOF (CDS and DJH with propylene and hydrogen), Flame Spray, characterization (MO, SEM, TEM, XPS, XRD,...), tribological tests (rubber wheel, ball-on-disc, at room temperature and up to 400°C).
9	T.M. COMAS S.A. (SME)	E	Mr. Llorenç Comas tmcadm@tmcomas.com	Strong activity as thermal sprayers with customers in many industrial sectors. TS techniques: APS, FS and HVOF. Thermal spray of final parts to be validated by customers.
10	Institute of Physical Sciences, University of Ancona	I	Prof. Franco Rustichelli isf@alisf1.unian.it	Material testing by X-ray and neutron investigation techniques (diffraction, small angle scattering, reflectivity), scanning and transmission electron microscopy.
11	Institute of Physical Electronics of Kaunas University of Technology	LT	Sigitas Tamulevicius fei@fei.lt stamul@fmf.ktu.lt	Plasma spray deposition techniques, characterization of the mechanical properties of coatings, characterization of the materials by SEM, X-ray diffractometry, BET analysis, X-ray photoelectron spectroscopy.
12	Joint-Stock Company (SME) Technologija	LT	Romualdas Jakutis romas@technologija.lt	Production and renewal of industrial equipment parts with substantially prolonged lifetime applying novel nano-structured coatings. Characterization of mechanical properties.
13	Stork Product Engineering B.V. (SME)	NL	Eduard Winckers Eduard.Winckers@Stork.com	Stork Product Engineering B.V. is currently working on several innovative ideas and involved in technology and product development related to fluidization and nucleazation of gases, fluid and thermo dynamics, materials technology and the related use of special materials/technology for nozzles, hot structures, rotating and gas-treatment equipment for both industrial and aerospace applications. Expertise in: Applied mechanics, mechanisms, tribology, structures, materials, thermodynamics, aerodynamics, fluid dynamics, measurement and control, electronics, biotechnology, instrumentation, micro system technology, etc.
14	Advanced Materials Research Institute (AMRI), University of Northumbria	UK	Prof. Psantu Datta psantu.datta@unn.ac.uk	Characterization of micro/nano-structures. Study of materials and surfaces for effects of corrosion and wear using surface chemistry, surface analysis techniques: SEM, X-ray Diffraction, AFM/STM, XPS, SIMS. Surface modification and coating deposition. Modelling of diffusion and interface mechanisms.
15	PyroGenesis (SME)	EL	Dr. Spyros Economou seconomou@pyrogenesis.com	Advanced High Temperature Technologies, i.e. thermal spray products and services, environmental protection. Strong expertise in thermal spraying products and services. Active in synthesis of metallic powders and production of coatings or net-shape formed components. Development of sound coating and near-net shape formed industrial components from nano-structured powders.

16	ARCS	A	Georg Korb Dr. Georg.Korb@arcs.ac.at	Bulk materials via powder technology, metals, ceramics, all characterization facilities, physical properties, nanopowders (ceramics), wear properties.
17	Riga Technical University Institute of Inorganic Chemistry	LV	Dr. Janis Grabis grabis@nki.lv	Synthesis of nanosized powders by plasma-chemical and chemical methods, powders characterization, improvement of their technological parameters (passivation, granulation) and up-scaling of nanosized powders technology, preparation of granulated powders for manufacture of coatings for example by using HVOF.
18	Institute of Materials Science, National Centre for Scientific Research "Demokritos"	EL	Dr George Vekinis gvekinis@ims.demokritos.gr	Dual phase self-toughened nano-structured ceramic-ceramic composites of SiC with Al_2O_3 and SiC with Si_3N_4. Applications include aerospace, gas turbines and other high temperature structural applications.
			Dr Galina Xanthopoulou gxantho@ims.ariadne-t.gr	Nanophase meta-stable ceramic and ceramo-metal catalysts for conversion of methane and hydrocarbons to ethylene and propylene. Also for direct production of hydrogen gas from methane.
19	DGTec Ltd (SME)	F	Guy BARET guy.baret@dgtec.fr	Production of nanomaterials by different ways including aerogels, spray drying. Thermal treatment under controlled atmosphere in fluidized bed.
20	Aristotle University of Thessaloniki (A.U.Th)	EL	D.N. Tsipas tsipas@eng.auth.gr	Fluidized bed technology for the production of novel multi element coatings. Microsturctural characterization and property evaluation of materials and coatings (optical microscopy SEM, X-RAYS, RAMAN, electrochemical, atmospheric, high temperature corrosion, erosion, tribological evaluation of coatings).
21	SKLERO S.A. (SME)	EL	C. Kexagias	Heat treatment, surface engineering. Interested in the production of novel hard materials, coatings and tools with improved tribological properties.
22	Centro Sviluppo Materiali S.p.A.	I	Dr. Mario TULUI m.tului@c-s-m.it	Plasma spray under inert gas (IPS) and high pressure (HPPS), in addition to APS, VPS and HVOF.
23	Departamento de Ingeniería Mecánica y Materiales, Universidad Politécnica de Valencia	E	Prof. Alejandro Sánchez Bolinches asanchbo@mcm.upv.es	AFM, scanning and transmission electron microscopy, X-R and microstructure. Electrochemical characterization of coatings (corrosion, etc.). Physical vapor deposition.
			Prof. Manuel Pascual Guillamón mpascual@mcm.upv.es	Welding and plasma thermal spray coating. Microstructural and mechanical properties of materials.
			Dr. Francisco Segovia López fsegovia@mcm.upv.es	Fabrication and characterization of composed materials with polymeric or metallic matrices. Mechanical, thermal, thermo-mechanical, environmental behavior and microstructural characterization of polymeric and composed materials.

24	Departamento de Tecnología, Universitat Joume I	E	Dr. Kudama A. Razzak Habeeb Al-Ani razzaq@tec.uji.es	Plasma thermal spray coatings, tribological and microstructural characterization of coatings, electron microscopy and R-X methods.
25	KEAC Ltd (SME)	UK	Trevor J. Keirle keac@pipemedia.co.uk	KEAC has been involved in much of the pioneering work in the industrialization of Fluidized Bed technology. Over the past 25 years KEAC has been involved in the pioneering design and development of commercial fluidized beds supplying fluidized beds for a miscellany of processes. It specializes in combustion and fluidized bed technologies and is the owner of several patents of novel techniques in fluidized bed applications. It has an immense spread of contacts throughout industry and possesses specific and relevant fine particle experience, which is exemplified in patents, published in 19 countries. It does have in place a 300mm-dia-bed test facility (gas or electrically heated) with provision for top or bottom feed in solid or liquid form. This unit could comprise the core equipment to be used for the investigation into the properties and production scaling of nano-structured powders.
26	iplas GmbH SME/Ind.	D	Ralf Spitzl Ralf.Spitzl@cyrannus.com	Plasma enhanced chemical vapor deposition, low to atmospheric pressure plasma with high gas flow, development of microwave plasma sources and systems, plasma polymerization, abatement.
27	NS Research Ltd	CY	Nicos Raftis nsri0001@logos.cy.net	Innovation and creativity tools applied to new product development, technology management, business planning for new product introduction and know-how in securing intellectual rights working both for clients and for internally developed concepts. Expertise in machine automation, automatic gas blending systems, gas analysis, embedded systems, mathematical modelling, electronic and software development.

AN INVESTIGATION INTO THE COST EFFECTIVENESS OF THERMAL INSULATION IN HEATED BUILDINGS IN CYPRUS

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ABSTRACT

The present study is concerned with the cost effectiveness of thermal insulation and the investigation of the optimum economic thickness of insulation for heated buildings in Cyprus. It has been found that the use of thermal insulation is well justified for a thickness of insulation that varies from 50 to 80 mm depending on the type of building envelope used. It is also demonstrated that the use of thermal insulation in heated buildings brings about a reduction in the heating energy demand of up to 72% as compared to a non-insulated building. The payback period for thermal insulation varies from 3,4 to 11,4 years depending on the type of building envelope employed.

Keywords: Thermal insulation. Thermal conductivity. Central heating. Single wall. Double wall. Heat losses. Life cycle cost. Heating Value of Fuel. Fuel Consumption. Fuel savings. Payback period. Optimum economic thickness.

1. INTRODUCTION

It is generally accepted that the use of thermal insulation in heated buildings reduces the building heating requirements, it alleviates the risk for surface condensation and changes the thermal capacity and hence the thermal response of the building. Reduced heat requirements will result to considerable energy savings plus a reduction in the initial cost of the heating equipment.

For a country like Cyprus, which is by 95% dependent on imported energy, the role of thermal insulation is very important. There are, however, a number of parameters that have to be dealt with before one decides as to which solution is the best. In a previous study conducted by Birkeland (1981), several solutions were proposed concerning the use of thermal insulation in buildings in Cyprus. A remarkable progress has been made in the use of new building materials that resulted to an improvement in the quality of indoor conditions at reduced energy costs.

The purpose of this study is to review the present situation concerning the use of thermal insulation in residential heated buildings in Cyprus, identify areas for improvements and investigate the optimal thickness of insulation for the climatic and socioeconomic conditions prevailing in the island.

2. BUILDING HEAT REQUIREMENTS

The fabric heat losses through a building structure, including walls, ceilings, floors, windows, doors, etc., are calculated from the equation:

$$Q = U \times A \times \Delta T \tag{1}$$

where, Q are the heat losses in Watts, U is the overall heat loss coefficient in $W/m^{2\,o}C$, A is the surface area of the building element in m^2, and ΔT is the difference between the room and the outdoor temperatures, in ^oC.

In order to keep heat losses at minimum, it is desirable to keep the U-value as low as possible. The value of the heat loss coefficient depends on the nature and the thickness of the building material and it is calculated from the equation:

$$U = \frac{1}{R_{si} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \dots + \frac{x_n}{k_n} + R_{so}} \tag{2}$$

where, $x_1, x_2, ... x_n$ are the thicknesses of the various materials of the building component, in metres, $k_1, k_2, ... k_n$ are the thermal conductivities of the materials respectively, in W/m K and R_{si} and R_{so} the surface thermal resistances for the inside and outside surfaces of a building element respectively. It is clearly seen in the above expression that the U-value of a building component can be reduced if appropriate materials having low thermal conductivity and large thickness are used.

The cost of fuel used for meeting the heat requirements resulted from heat losses is a function of the insulation thickness. The greater the thickness of insulation is, the lower will be the heat losses and the cost of the heating fuel. The heating cost changes with the thickness in an exponential way.

According to ASHRAE (1997), the yearly energy consumption of the heating system is determined from the equation:

$$Q_{h,yr} = \frac{K_{tot}}{\eta_h} DDh(t_{bal}) \tag{3}$$

where, $Q_{h,yr}$ is the yearly energy consumption, K_{tot} is the total heat loss coefficient of the structure in W/K, η_h is the heating system efficiency, and $DD_h(t_{bal})$ is the number of Degree-days for heating at a pre-defined t_{bal}.

The heating degree bays, $DD_h(t_{bal})$, are determined from the following equation:

$$DD_h(t_{bal}) = (1day)\sum_{days}(t_{bal} - t_o)^+ \tag{4}$$

where t_o is the outdoor temperature, and the plus sign above brackets indicates that only positive values are to be counted.

The Fuel Consumption (F) is then calculated by equation 5:

$$F = \frac{Q_{h,yr}}{H} \tag{5}$$

where H is the Heating Value of Fuel.
The above method is remarkably accurate for annual heating energy of single zone buildings dominated by gains through the walls, roof and openings since machinery efficiency is not dependent on external temperatures.

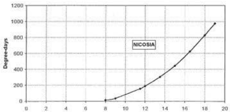

Fig.1. Degree-days, Nicosia, Cyprus

Figure 1 shows how heating degree-days vary with t_{bal} for the city of Nicosia. The plot is obtained by evaluating equation 4 for different t_{bal} temperatures. For the present investigation, t_{bal} was taken as 18°C, which is a widely used figure and represents average conditions in the building. The mean monthly hourly external temperatures as obtained from the Cyprus Meteorological Service (Hadjioannou, 1995) were used in order to obtain the degree-days for each month. By adding up the values for all the months the yearly degree-days were obtained. For the purpose of this study the degree-day value corresponding to 18 °C is taken as 829,3 degree-days.

The cost of installed insulation increases with thickness; the incremental cost is for both material and labour. An increased thickness of insulation will increase the initial costs of the building but will result in reduced heating costs. For the assessment of the cost effectiveness of the insulation investment, it is necessary to compare the initial cost of buying and installing the insulation with the sum of the annual energy savings in terms of Present Value. If this value, over a specified period of time, is greater than the initial investment, then the insulation is cost effective. Therefore, for an insulated building structure the problem is to determine the appropriate thickness of insulation that results to the minimum costs over a period of time, which is usually taken as 30 years (Duffie and Beckman, 1990).

The costs of buying and installing the thermal insulation are important factors in the cost effectiveness. On the other hand, credits should be taken for any possible reduction in the capital cost of the heating system as a result of reduced sizes of equipment. Therefore, the most appropriate approach is to use life cycle cost (LCC) methods that take into account both initial costs and future expenses.

The annual cost of fuel is found by multiplying the anticipated fuel price with the annual heat losses, taking into consideration some economic parameters like the market discount rate d, and the fuel inflation rate, i, over a period of lifetime N. According to Duffie and Beckman (1990), at the Nth year the present worth $(PW)_N$ of the Nth cost of fuel will be:

$$PW_N = \frac{C(1+i)^{N-1}}{(1+d)} \qquad (6)$$

where C is the cost of fuel for the 1st year.

The total cost over a period of N years discounted to the present with a discount rate of d and an inflation rate of i, assuming i is different than d, will be:

$$PW = \frac{C}{d+i}\left\{1-\left(\frac{1+i}{1+d}\right)^{N}\right\} \qquad (7)$$

Fig. 2. Variation of heating fuel prices in Cyprus, 1960-2001

The problem, however, in this kind of long-term analysis, is the choice of the values of inflation and discount rates, which are not safely predictable, because of a number of parameters and unforeseen facts that may affect them. In Cyprus, the rate of change of the heating fuel prices during the last 40 years was rather irregular, as shown in figure 2, plotted from data recorded from the Department of Statistics and Research (1999). As it can be seen in the graph, the prices increased by nearly 5 times during the period of 1976-86, there was a reduction that kept prices more or less constant during the period of 1986-96 with an increase at a higher rate during the period of 1996-2001.

According to Helcké (1982), a good way of thinking about inflation rates is in terms of how long it would take for prices to double. Based on this approach, and taking into consideration that in the most recent period it took 12 years for the fuel price to double, an inflation rate of 6% was chosen for the present investigation.

Table 3. Design and economic parameters

PARAMETER	VALUE
Thermal conductivity of insulation	0,029 W m K^{1}
Thermal conductivity of brick (Cyprus type), 200 mm	0,48 W m K^{1}
Thermal conductivity of brick (Cyprus type), 100 mm	0,45 W m K^{1}
Thermal conductivity of concrete	1,75 W m K^{1}
Thermal conductivity of plaster	1,10 W K^{1} m^{2}
Inside surface heat transfer coefficient, R_{si}	0,13 m^{2} K W^{1}
Outside surface heat transfer coefficient, R_{so}	0,04 m^{2} K W^{1}
Heating system efficiency, η_h	75%
Lifetime of insulation	30 years
Fuel inflation rate, i	6%
Discount rate, d	8%
Cost of heating fuel	£0,172/litre
Cost of single 200 mm brickwall, without plaster	£12,50/m^{2}
Cost of double wall with air gap, without plaster	£15,00/m^{2}
Cost of insulation (buy)	£0,07/m^{2} per mm thickness
Cost of installation of insulation	£1,00/m^{2}
Calorific Value of Fuel	38100 MJ/litre

For the purpose of the present investigation, the concepts presented aforehead have been integrated into two computer programmes that were developed. Both utilised Microsoft Excel Spreadsheets and were developed in such a way that they would allow great flexibility in the performance of calculations for fuel consumption, break-even time, heating system cost, optimum thickness, etc. These programmes offer the possibility to the user of examining the quantitative consequences of a change in one or more design parameters, technical and economic factors.

The first programme performs simulations, which enable the calculation of the following results:

- Annual thermal losses (kWh).
- Reduction in Annual Thermal Losses when insulation is introduced as compared to the non-insulated case (kWh and %).
- Annual fuel consumption according to fuel characteristics for each case.
- Reduction in fuel consumption as compared with the non-insulated case.
- Annual cost of heating for a particular price of fuel.
- Savings in annual cost for heating as compared to the non-insulated case.
- Savings in initial cost for installing the central heating system for an insulated building as compared to the non-insulated case.
- Payback period.

It is appreciated that the selection of equipment for a Central Heating System is based on the design energy load calculations. Hence, by insulating a building, a great amount of savings should be expected from the reduction of the size of the heating system due to the improved energy performance of the building associated with the reduced overall U-value of the building. In order to account for the savings in the initial cost due to the reduced size of the heating system, a statistical figure of £0,07 per design system Watt was introduced. This statistical figure was achieved from similar single zone building central heating system designs conducted by MECONE Consulting Engineers (2001) and their associated contract prices. The calculations in this part are based on design conditions for the particular location of Nicosia with an ambient air temperature of 0°C and indoor design temperature of 21°C. The increase in builders' works associated with the introduction of thermal insulation, in terms of £/m^2, was obtained statistically, and based on information collected by MECONE, from Architects, Civil Engineers, Quantity Surveyors and Construction companies in Cyprus. All parameters used, technical and economic, are listed in Table 3.

In a similar way, the second programme presents a graphical representation for the optimum thickness of insulation. The annual cost for heating and the increase in the cost for builders' works were obtained per mm of insulation thickness. The annual cost for heating was then projected for a life span of 30 years and the present worth of fuel cost was obtained. Based on the above, the payback period is also determined.

The simulation results were used to plot a number of graphs, which show the variation of the total life cycle cost (LCC) and the heating fuel cost with the insulation thickness, for four different building envelopes. These are double brick wall infilled with insulation (fig. 3), brick wall with external insulation, concrete wall with external insulation, and insulated concrete roof.

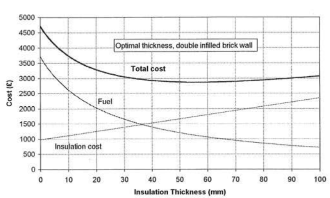

Fig. 3. Optimisation of insulation thickness, double infilled brick wall

In all four cases, the fuel cost decreases as the insulation thickness increases. The rate of decrease in fuel costs is very high at small thickness and slows down as the thickness increases, as compared to the initial investment cost (buying and fixing the insulation) which increases with the thickness).

The LCC decreases as the insulation thickness increases, it reaches a minimum, which corresponds to the optimum economic thickness of insulation, and then it increases with the thickness. The rate of decrease is high and distinct at small insulation thickness, up to around 40 mm, but slows down at larger values, beyond 40 mm. In all four cases, there is a range of values of thickness for which the difference in the LCC does not differ significantly. Thus, for the case of double brickwall infilled with insulation, this range corresponds to 50-60 mm, which implies that 50 mm can be considered as the best thickness of insulation for the case. The optimum ranges for the other three cases are shown in Table 4. In the same Table, the payback period for each case is shown. It is interesting to note the low values of payback period for the insulation employed in concrete walls, namely the roof (3,4 years) and the columns and beams (4,3 years) as well as the larger thickness of insulation. This is attributed to the higher thermal conductivities of concrete, which justifies the use of larger thickness of insulation.

Table 4. Optimal thickness of insulation

Type of building envelope	Optimal thickness of insulation (mm)	Payback time (years)
Double brick wall infilled with insulation	50-60	11.4
Single brick wall with external insulation	50-70	8.7

Concrete wall with external insulation	60-80	4.3
Roof with external insulation	60-80	3.4

Comparing between the double brick wall infilled with insulation and the single brick wall with external insulation, it is seen that the payback period for the latter is smaller and its optimum economic thickness of insulation is slightly greater than that of the double wall. An advantage claimed for external insulation is that it can be increased almost without limit to provide standards, which may apply in the future, or to accommodate special environmental requirements (Alder, 1997). Furthermore, advances in cladding and fixing technology have resulted in major improvements in terms of performance, quality and aesthetic appearance, whilst offering low maintenance finishes. On the other hand, however, it is well known that the thermal capacity of a wall will have a maximum value when the material which offers the greatest resistance to heat flow (in this case the insulation) is on the outside and a minimum when on the inside. In general, buildings having a high thermal capacity are generally more suitable for continuous use as compared to buildings which have insulation on the inside and are suitable for intermittent heating.

From the above analysis it appears that thermal insulation in heated buildings brings about a considerable reduction in the heating costs and it is a cost-effective solution if the optimal thickness of insulation is used. For comparison purposes, using the model developed in this study, the optima thicknesses of insulation shown in Table 4 were used to conduct a number of calculations aiming to determine the annual heating requirements for a typical residential house in Cyprus. The following building configurations have been used:

(a) Without insulation (Single brickwall without insulation, single glazing, non-insulated concrete wall and roof).

(b) Double brickwall infilled with insulation, double-glazing.

(c) Double brickwall infilled with insulation, insulated roof, double-glazing.

(d) Externally insulated brickwall and concrete walls, double-glazing, insulated roof, i.e. fully insulated building.

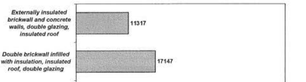

Fig. 4. Annual energy demand for various building envelope configurations

The results of these calculations were used to plot the graph of fig. 4. It is clearly seen that, when using the fourth type of building envelope, i.e. the fully insulated building, there is a considerable reduction in the heating energy demand, which accounts to 72% reduction as compared to the non-insulated building. The difference between the third and the fourth cases is a result of the insulated concrete walls (columns and beams) which in the other scenarios are not insulated.

The purpose of this study was to illustrate the benefits from using thermal insulation in heated buildings under the weather and economic conditions of Cyprus and investigate the optimum economic thickness of insulation for walls and roofs, based on certain economic parameters.

It has been proved that for a heated house in Cyprus, the use of thermal insulation not only improves thermal comfort but also results to considerable energy savings of up to 72% as compared to the non-insulated buildings.

A	Surface area, m^2
C	Cost of fuel, first year
U	Overall heat loss coefficient, $W K^{-1} m^{-2}$
d	Discount rate
$DD_h(t_{bal})$	Degree-days for heating at a pre-defined t_{bal}
i	Fuel inflation rate
k	Thermal conductivity, $W m K^{-1}$
K_{tot}	Total heat loss coefficient of a structure in $W K^{-1}$
LCC	Life cycle cost
N	Number of years
PW	Present worth
$Q_{h,yr}$	Yearly Energy Consumption
R_{si}	Inside surface thermal resistance, $m^2 K W^{-1}$
R_{so}	Outside surface thermal resistance, $m^2 K W^{-1}$
t_o	Outside air temperature, °C
x	Thickness, m
F	Fuel Consumption, litres
H	Heating Value of Fuel, kWh/litre
ΔT	Temperature difference, °C
η_h	Heating system efficiency

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What do learners of English as an additional language need to learn ?

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Language is a whole system of structures, functions and components which aims to be used as a means of communication between one human being and another. Although the word "language" could include other aspects of communication such as "body language", in this article the focus will be on verbal communication. We are going to consider language "*..as a mechanism for conveying meaning which operates independently of other means of communication and which is distinctively different from animal communication*" (David Graddol, 1995 p.4). Emphasis will be given to the acquisition of a second language and more specifically to the elements a teacher would need to adopt in order to facilitate learning for his students.

Before examining factors which are necessary for language teaching, let us consider the various *purposes* of a language. Initially, learning a foreign language is part of the *school curriculum* in many countries. Certainly in Cyprus, students in secondary schools are taught at least two European languages (English and French) besides their mother tongue. These subjects are compulsory and students do them whether they like it or not.

Another major function is for *professional advancement*. People study languages because it offers them more opportunities for a better job, promotion or even for attending various courses abroad.

A number of language students are placed in *target language communities* (TLC), where the inhabitants of that community speak the language which the student is learning.

Furthermore, another group of learners wish to learn a language for *Specific* or *Special* purposes, especially English since it has become an international language. For example, business executives, air traffic controllers, people in medical professions, as well as technology, and individuals wishing to pursue their studies overseas. Therefore, some of these needs are referred to as *EOP* (English for Occupational Purposes), *EAP* (English for Academic Purposes), or *EST* (English for Science and Technology).

Depending on the reason one wishes to involve himself in language learning, the teacher needs to foster the relevant attitude. Priority could be given either to talking, listening, reading or writing.

Some learners may be attracted to a particular *culture* and by learning the language of that culture they find themselves closer to understanding that community's inner thoughts and emotions (*cultural analysis*).

Finally there are people who engage in language learning for *miscellaneous* reasons such as having fun, or travelling. A few others could even use it as a means of *socialising*. I find this kind of learning very common among adult students who sometimes have no desire in advancing to the higher levels, even after they had successfully completed the lower stages. To them, learning a language means getting to know people, making friends, and enjoying themselves.

It is therefore evident by now that the various needs of the students are the ones which determine the teacher's method and approach to language teaching. Just as a doctor would not be able to treat his patients without having knowledge of their symptoms, similarly a teacher would be unable to teach the applicable material to his students without knowing the motives behind their decision to learn a language.

We have so far established that language is a complex and multi-functional system. Additionally, the human language is distinctively different from animal language. In fact, Yule (1985) and Aitchison (1987) have indicated properties which are unique to human language. Firstly **displacement** which means human language has the ability to refer to the past and future time. Secondly, **arbitrariness** – a term suggested by the Swiss linguist Ferdinand de Saussure (1857-1913) – which indicates that there is no essential connection between the sound and the meaning of the words. For example the word "bird" neither sounds nor looks like a bird. This applies only on onomatopoeis words : e.g. *"The duck quacked"*.

A third property is that of **productivity** (creativity) where students seem to invent their own language. (*"Humans can produce novel utterances whenever they want to"* – Jean Aitchison, 1995, p.15). Language learners in particular seem to have a very strong creative ability, because they introduce elements from their own native language.

Another unique human element is **cultural transmission**, where people are born with no knowledge of any language and through gradual social interaction, the language of a particular culture will be passed on to them.

Furthermore, human language has certain **discreteness**. This means that it has fully distinct sounds such as "ta**p**", or "ta**b**".

Duality is another property available only to humans. Duality means that language is simultaneously organised into two layers : the layer of distinct sounds, and the layer of distinct meanings. Thus, a limited number of sounds (phonemes) could be arranged in various ways to produce a number of different meanings – for example the letters t, a, c, can lead to "cat" or "act".

Patterning also is a term used to indicate the internal organisation within the language as a system. Sounds, words, and sentences are not juxtaposed in a random way. On the contrary, they follow a set pattern. Therefore, the sounds t-p-a, can only be arranged as "tap", or "pat", and not as "tpa". This patterning can be very helpful to learners of English because it can help them with the spelling of words and structure of sentences. In fact this point leads to structure dependence where words have to be placed in a certain fixed way, normally consisting of a subject and a verb. The number of words in each sentence is no indication to its basic structure. What is important is the structure of a sentence and not the elements involved.

Graddol, Cheshire, and Swann (1987) in their classification of a language, referred to English as **SUO** language (subject-verb-object) and this basic word order of English is significant to English learners because it introduces them to the fundamental layout of the language which might be different from their own mother tongue.

It appears that language is a complex and vast subject, and as such it has provoked a number of controversies for linguists. Many of these confrontations have been caused by the distinction linguists make between language. Some view it as an *abstract system*, others as *language in use*. In order for foreign language teachers to teach a language successfully it is necessary to involve elements from both of these views.

Let us first consider language as a system. This view would include *phonology* which represents speech sounds and corresponds to pronunciation, *syntax* which is the way words are arranged to form phrases and sentences and *semantics* which is the study of meaning.

Semantics is a complex issue because of the extensiveness of vocabulary and meaning. Also the meaning of a word is greatly dependent on its connection with other words. All these elements form *grammar.*

If we consider language in use we would refer to *Pragmatics* and *Discourse Analysis.* Pragmatics are the general principles followed by individuals in order to communicate and which cannot be predicted by linguists. People seem to invent their own, unique way of communication without necessarily following any rules. Discourse analysis, on the other hand, are the various devices used by speakers and writers in order to combine single sentences into a unified and consistent whole.

Bearing in mind these primary distinctions concerning language, it would be useful here to refer briefly to some of the major debates and theoretical approaches which are based on the distinction made between *language learning* and *language acquisition.* Language learning refers to the deliberate efforts to learn a language, whereas language acquisition refers to the spontaneous way of picking up a language.

The first approach is the Behaviourist Perspective based on the American psychologist *B.F.Skinner* (1904-1990) who argued that language is verbal behaviour achieved upon imitation and reward. This imitation is either accurate or inaccurate.

The American linguist *Noam Chomsky* (1928-) criticises this view and points to the uniqueness and creativity of language. Each individual produces his own sentences, without imitating anyone else. Chomsky also made the distinction between *competence and performance.* He defined competence as an idealisation and as the speakers unconscious knowledge of the language as a system. Performance on the other hand, is the language actually used with all its diversions from rules and changes during use. He also viewed language as a set of limited grammatical rules capable of producing unlimited sentences.

Dell Hymes (1962) followed, challenging Chomsky's views by declaring that language is not just a set of rules, but it is a living thing that needs to be considered in real situations. *"There are rules of use without which the rules of syntax are useless"* (cited in Harmer, 1994). People need to have *communicative competence*, meaning to know when and how to use the rules. Also to be able to use language appropriately and correctly.

I will now try to relate all these definitions, functions and linguistic controversies concerning language in the actual classroom, facing real students. Considering the complexity, enormity, and richness of human language, teaching a language especially a second language is not a straightforward task. Which is the best way to approach students and what elements after all, need to be taught ? As we have already mentioned, this depends greatly upon the reasons why students wish to learn a language, but some of the primary factors would be the following : *Pronunciation* is the first step learners need to tackle because they have to be able to make themselves understood when they speak. When teaching pronunciation, we are aiming at communicative proficiency. Also students need to distinguish between sounds. For example "ship", and "sheep". *Rhythm, stress* and *intonation* are also important in capturing the mood of the speaker.

In order though to develop this communicative efficiency in pronunciation, students will need to practise *listening* to the language used. The teacher would be the main source of listening, of course, but tapes, radio, television, and videos are also very influential. Personally I find this to be an area of great difficulty because students tend to use the teacher's voice as a model , and anything different to that imposes great problems to them. However, practice and perseverance will improve pronunciation and listening skills greatly.

As we have already seen, *grammar* is a large part of language structure, and as such cannot be ignored. Grammatical rules need to be taught, but with an open-mindedness and flexibility. Teachers must not be absolute in their definitions and severely critical to any mistakes made. Grammar needs to be used as the outline for teaching, but students must be encouraged to practise the language itself, rather than practising the rules. Also grammatical errors lead to a gradual *awareness* of the language and its potential.

Reading, listening, and discovery activities can help tremendously in exploring the great possibilities of a language. If students are allowed space to discover the rules for themselves then their learning will be more profound and lasting.

Vocabulary is another aspect of great importance. *"If language structures make up the skeleton of a language, then it is vocabulary that provides the organs and the flesh"* (Jeremy Harmer, 1994, p.153). Words can help the learner express himself clearly and accurately. They provide him with the extreme power of communicating even in the case of grammatical inaccuracies. What is important though is to realise that words are not individual, independent units. They exist together with other words, and could mean different things in different contexts. Also they could be used in idiomatic language, in metaphors, or collocations.

The main difficulty I have come across in trying to teach vocabulary is the tendency of students to translate from their own language, which sometimes leads to incomprehensible contexts.

Students have to be prompted into realising that each language is distinctively different, and should be encouraged to think in the language being taught, even at the cost of being less creative and elaborate. Reading and listening will be very useful in attaining this goal. Additionally, the English vocabulary is so diversified with so many technical terms and phrasal verbs, that becoming a proficient user of the language can be a very slow process.

Discourse is also very important in language teaching. It is essential to use language appropriately, to be able to recognise the different styles (formal / informal) and to know what to say in which situation. Such knowledge implies learning *language functions*. The variable which determines appropriacy is purpose. We decide what to say based on the purpose we want to say it : invite, apologise, congratulate, complain etc. Students will also need to be taught *language skills* and to work on *discourse organisation*. It is vital for them to differentiate the different kinds of reading : detailed reading for comprehension, or reading for the gist. Furthermore, learners have to be approached with the relevant *syllabuses*. Normally syllabuses are organised to include points of grammar, vocabulary, function situations and tasks. Depending on the particular needs of the learners, priority could be given to those elements.

Finally, we should bring to the attention of our students the fact that there are many *varieties* of English and many accents : British-English, American-English, Welsh, Scottish, to name but a few. Advanced learners need to have knowledge of these variations.

It is apparent by now that the subject of communication is inexhaustible. The task of teaching a language is elaborate. But if we attempted to draw some conclusions on this topic we would refer to certain stages of which all teachers of foreign languages should be aware. Introducing a new language falls into the non-communicative activities. The initial presentation of a language is based on controlled techniques, rules, repetitive skills. Accuracy and correcting mistakes is important, although should be kept brief. What counts most in language teaching is practice activities. These activities could be either oral or written. Oral activities would include dialogues between students, discussions, games, relaying instructions, personalisation and localisation (talking about oneself). These activities could take the form of letter-writing, article writing, application filling, sentence writing, dictation, project presentation and others. The next stage necessary would be that of communicative activities, where students have the desire to communicate, they set themselves a target, a purpose which would include a variety of language. Undoubtedly all the stages of learning have to be inter-linked and balanced. One cannot exist without the other. It is the teacher's duty to identify his students' needs, to scan and analyse their personalities, their motivations and attitudes, interests and requirements.

A teacher might have been teaching English for many years but very rarely does he encounter an identical educational group of learners. Each group is unique, setting its own rules and demands.

"*Communication between humans is an extremely complex and ever-changing phenomenon*" (Jeremy Harmer, 1994, p.46)

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CHARACTERISTICS OF A SINGLE STAGE LiBr-WATER ABSORPTION MACHINE

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ABSTRACT

The objective of this paper is to present a method to evaluate the characteristics and performance of a single stage LiBr-water absorption machine. The necessary heat and mass transfer equations are presented. The equations are employed in a computer program developed for this purpose. A sensitivity analysis is carried out and conclusions are extracted.

1. INTRODUCTION

In hot climates the heating and cooling demand of domestic dwellings can be reduced substantially with various measures such as good insulation, double-glazing, use of thermal mass and ventilation. However, due to the high summertime temperatures, the cooling demand cannot be reduced to the level of thermal comfort with passive and low energy cooling techniques and therefore an active cooling system is required. It is preferable that such a system is not powered by electricity the production of which depends entirely on fuel.

Solar energy, which is available in such climates, could be used to power an active cooling system based on the absorption cycle. The lithium bromide (LiBr)-water absorption units are the most suitable for solar applications since low-cost solar collectors may be used in order to power the generator of the machine. Such absorption units though, are not yet readily available in small residential-sizes. After a search in the world market, only one manufacturer was traced producing commercially lithium bromide-water absorption refrigerators (Yazaki of Japan). Therefore, the possibility of producing absorption air-conditioning systems in small sizes for residential buildings and the economics of using such a refrigerator, assisted by solar energy, needs to be investigated.

The objective of this paper is to present a method to evaluate the characteristics and performance of a single stage LiBr- water absorption machine. The necessary heat and mass transfer equations are specified. These equations are employed in a computer program which is used for the design of the system and a sensitivity analysis is carried out.

2. ABSORPTION COOLING

Absorption machines are thermally activated and for this reason, high input (shaft) power is not required. In this way, where power is expensive or unavailable, or where there is waste, gas, geothermal or solar heat available, absorption machines provide reliable and quiet cooling (ASHRAE, 1997). A number of refrigerant-absorbent pairs are used, for which the most common ones are lithium bromide-water and ammonia-water. These two pairs offer good thermodynamic performance and they are environmentally benign.

The ammonia-water pair is not suitable for use with solar collectors because of the high temperature needed in the generator (125°C to 170°C). This temperature can only be obtained with medium concentration ratio parabolic collectors, which have increased maintenance requirements. The generator temperatures needed for the lithium bromide-water pair are lower (75-120°C). These temperatures can be achieved with high performance flat plate collectors, compound parabolic collectors (CPCs) and evacuated tube collectors that are of lower cost and easier to install and operate.

3. LITHIUM BROMIDE (LiBr) - WATER COOLING

This type of equipment is classified by the method of heat input to the primary generator (firing method) and whether the absorption cycle is single or multiple effect. The single effect absorption technology provides a peak-cooling coefficient of performance (COP) of approximately 0.7 and operates with heat input temperatures in the range of 75°C to 120°C. The multiple effect technology gives higher COPs but can only be utilised when higher temperature heat sources are available. Double effect systems can be achieved by adding an extra stage as a topping cycle on the single-effect cycle. In this way the heat rejection from the high temperature stage is used to power the lower temperature stage. It should be noted that the refrigerant in the lithium bromide-water system is water and the LiBr acts as the absorbent, which absorbs the water vapour thus making pumping from the absorber to the generator easier and economic. A single-effect LiBr-water chiller is illustrated in Fig. 1 and the process is presented in a Duhring chart (Fig. 2). This chart is a pressure-temperature graph where diagonal lines represent constant LiBr mass fraction, with the pure water line at the left and crystallisation line at the right.

With reference to the numbering system shown in Fig. 1, at point (1) the solution is rich in refrigerant and a pump forces the liquid through a heat exchanger to the generator (3). The temperature of the solution in the heat exchanger is increased.

In the generator, thermal energy is added and refrigerant boils off the solution. The refrigerant vapour (7) flows to the condenser, where heat is rejected as the refrigerant condenses. The condensed liquid (8) flows through a flow restrictor to the evaporator (9). In the evaporator, the heat from the load evaporates the refrigerant, which flows back to the absorber (10). A small portion of the refrigerant leaves the evaporator as liquid spillover (11). At the generator exit (4), the fluid consists of absorbent-refrigerant solution, which is cooled in the heat exchanger. From points (6) to (1), the solution absorbs refrigerant vapour from the evaporator and rejects heat through a heat exchanger.

4. DESIGN OF A SINGLE-EFFECT LITHIUM BROMIDE–WATER ABSORPTION CYCLE SYSTEM

To perform estimations of equipment sizing and performance evaluation of a single-effect lithium bromide-water absorption cooler, basic assumptions and input values must be considered. With reference to Fig's 1 and 2, the basic assumptions are:

1. The steady state refrigerant is pure water.
2. There are no pressure changes except through the flow restrictors and the pump.
3. At points 1, 4, 8 and 11 there is only saturated liquid.
4. At point 10 there is only saturated vapour.
5. Flow restrictors are adiabatic.
6. The pump is isentropic.
7. There are no jacket heat losses.

The method of design is demonstrated below. The design parameters considered are listed in Table 1.

Table 1. Design parameters for the single-effect lithium bromide-water absorption cooler

Parameter	Symbol	Example-Value
Capacity	$\dot{Q}_e$	10 kW
Evaporator temperature	T_{10}	6°C
Generator solution exit temperature	T_4	90°C
Weak solution mass fraction	X_1	55 % LiBr
Strong solution mass fraction	X_4	60 % LiBr
Solution heat exchanger exit temperature	T_3	65°C
Generator (desorber) vapour exit temperature	T_7	85°C
Liquid carryover from evaporator	$\dot{m}_{11}$	$0.025 \cdot \dot{m}_{10}$

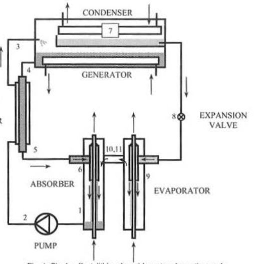

Fig. 1. Single-effect, lithium bromide-water absorption cycle.

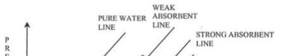

Fig.2. Duhring chart of the lithium bromide-water absorption cycle (ASHRAE, 1997).

Since in the evaporator, the refrigerant is saturated water vapour and the temperature (T_{10}) is assumed to be 6°C, the saturation pressure at point 10, as calculated from curve fits (Rogers and Mayhew, 1992), is 0.934 kPa and the enthalpy is 2511.8 kJ/kg. Since at point 11 the refrigerant is saturated liquid its enthalpy is 23.5 kJ/kg. The enthalpy at point 9 is determined from the throttling process applied to the refrigerant flow restrictor which yields that $h_9=h_8$. To determine h_8 the pressure at this point must be determined. Since at point 4 the solution mass fraction is 60% LiBr and the temperature at the saturated state was assumed to be 90°C, the LiBr give a saturation pressure of 9.66 kPa and h_4=212.2 kJ/kg. Considering that the pressure at point 4 is the same as in point 8 then $h_9 = h_8$=185.3 kJ/kg.

Once the enthalpy values at all ports connected to the evaporator are known, mass and energy balances can be applied to give the mass flow of the refrigerant and the evaporator heat transfer rate.

The mass balance on the evaporator is:

$$\dot{m}_9 = \dot{m}_{10} + \dot{m}_{11} \tag{1}$$

The energy balance on the evaporator is:

$$\dot{Q}_e = \dot{m}_{10} h_{10} + \dot{m}_{11} h_{11} - \dot{m}_9 h_9 \tag{2}$$

Since the evaporator output power $\dot{Q}_e$ is 10.0 kW and $\dot{m}_{11}$=2.5% $\dot{m}_{10}$ the mass flow rates can be calculated. The results are shown in Table 2.

4.2 Absorber Analysis

Since the values of m_{10} and m_{11} are known, mass balances around the absorber give:

$$\dot{m}_1 = \dot{m}_{10} + \dot{m}_{11} + \dot{m}_6 \tag{3}$$

and

$$x_1 \dot{m}_1 = x_6 \dot{m}_6 \tag{4}$$

The mass fractions x_1 and x_6 in Equation (4) are inputs, therefore $\dot{m}_1$ and $\dot{m}_6$ can be calculated. The results are shown in Table 2.

Table 2. Data for single-effect lithium bromide-water cooling system

Point #	h (kJ/kg)	$\dot{m}$ (kg/s)	p (kPa)	T (°C)	X (%LiBr)	Remarks
1	83	0.053	0.934	34.9	55	
2	83	0.053	9.66	34.9	55	
3	145.4	0.053	9.66	65	55	Sub-cooled liquid
4	212.2	0.0486	9.66	90	60	
5	144.2	0.0486	9.66	54.8	60	
6	144.2	0.0486	0.934	44.5	60	
7	2628	0.0044	9.66	85	0	Superheated Steam
8	185.3	0.0044	9.66	44.3	0	Saturated liquid water
9	185.3	0.0044	0.934	6	0	
10	2511.8	0.0043	0.934	6	0	Saturated vapour
11	23.5	0.00011	0.934	6	0	Saturated liquid water

The heat transfer rate in the absorber can be determined from the enthalpy values at each of the connected state points. At point (1), the enthalpy is determined from the input mass fraction (55%) and the assumption that the state is saturated liquid at the same pressure as the evaporator (0.934 kPa). This value is h_1=83 kJ/kg. The enthalpy value at point 6 is determined from the throttling model which gives $h_6 = h_5$

The enthalpy at point 5 is not known but can be determined from the energy balance on the solution heat exchanger, assuming an adiabatic shell as follows:

$$\dot{m}_2 h_2 + \dot{m}_4 h_4 = \dot{m}_3 h_3 + \dot{m}_5 h_5 \tag{5}$$

The temperature at point 3 is an input value (65°C) and since the mass fraction for points 1 to 3 is the same, the enthalpy at this point is determined as 145.4 kJ/kg. Actually, the state at point 3 may be sub-cooled liquid. However, at the conditions of interest, the pressure has an insignificant effect on the enthalpy of the sub-cooled liquid and the saturated value at the same temperature and mass fraction can be an adequate approximation.

The enthalpy at point 2 is determined from an isentropic pump model. The minimum work input (w) can therefore be obtained from:

$$w = \dot{m}_1 v_1 (p_2 - p_1) \tag{6}$$

In Equation (6) it is assumed that the specific volume (v, m^3/kg) of the liquid solution does not change appreciably from point (1) to (2). The specific volume of the liquid solution can be obtained from a curve fit (Lee *et al.*, 1990).

For the present study, since all variables are known (Table 2), the pump power is estimated as, $w = 0.29$ W

Equation (5) can now be solved for the unknown enthalpy value at point 5 giving h_5=144.2 kJ/kg. The temperature at point 5 can also be determined from the enthalpy value, and is 54.8°C.

Finally, the energy balance on the absorber is:

$$\dot{Q}_a = \dot{m}_{10} h_{10} + \dot{m}_{11} h_{11} + \dot{m}_6 h_6 - \dot{m}_1 h_1 \tag{7}$$

which gives $\dot{Q}_a$ = 13.42 kW

4.3 Generator (desorber) Analysis

The heat input to the generator is determined from the energy balance, which is:

$$\dot{Q}_g = \dot{m}_4 h_4 + \dot{m}_7 h_7 - \dot{m}_3 h_3 \tag{8}$$

and results to: $\dot{Q}_g = 14.2$ kW

The enthalpy at point 7 can be determined since the temperature at this point is an input value. In general, the state at point 7 will be superheated water vapour and the enthalpy can be determined once the pressure and temperature are known.

4.4 Condenser Analysis

The condenser heat can be determined from an energy balance, which gives:

$$\dot{Q}_c = \dot{m}_7 (h_7 - h_8) \tag{9}$$

and therefore $\dot{Q}_c$ = 10.78 kW

4.5 Coefficient of Performance

The coefficient of performance (COP) is defined as:

$$\text{COP} = \frac{\dot{Q}_e}{\dot{Q}_g} \tag{10}$$

which will give a value of 0.704.

A summary of the energy flows at the various components of the system is given in Table 3.

To find the suitable conditions for specific applications, a sensitivity analysis can be carried out utilising a computer program, which follows the sequence described above and the mathematical correlations for the fluid properties. Such a sensitivity analysis is presented below.

Table 3. Energy flows at the various components of the system

Description	Symbol	KW
Capacity (evaporator output power)	$\dot{Q}_e$	10.0
Pump minimum work input	w	0.29
Absorber heat, rejected to the environment	$\dot{Q}_a$	13.42
Heat input to the generator	$\dot{Q}_g$	14.2
Condenser heat, rejected to the environment	$\dot{Q}_c$	10.78
Coefficient of performance	COP	0.704

a. Effect of absorber inlet LiBr percentage ratio.

To check this effect the following conditions were assumed:

1. Solution heat exchanger exit temperature, T3= 55°C
2. Generator solution exit temperature, T4=75°C
3. Condenser temperature, T7=70°C
4. Evaporator capacity 10 kW
5. Evaporator temperature 6°C
6. Absorber exit LiBr percentage ratio = 60%
7. Pressure in generator and condenser = 4.82 kPa
8. Pressure in absorber and evaporator =0.934 kPa

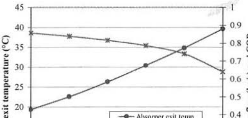

Fig. 3. Effect of absorber inlet LiBr percentage ratio.

Since the absorber exit LiBr percentage ratio is kept constant at 60%, the greater the difference between the absorber LiBr inlet and outlet percentage ratio is, the smaller the mass circulating in the absorber. Additionally, as seen in Fig. 3, the coefficient of performance increases with decreasing pump mass flow. On the other hand, to keep the cycle running at the specified stage, the temperature at the exit of the absorber has to be maintained at a lower level. However, this presents difficulties with the cooling water temperature of the absorber heat exchanger. Normally this temperature may be between 20°C and 25°C, which means that the lowest temperature at the exit of the absorber would be around 30°C.

b. Effect of generator temperature.

To check this effect the following conditions were assumed:

1. Solution heat exchanger exit temperature, T3= 55°C
2. Evaporator capacity 10 kW
3. Evaporator temperature 6°C
4. Absorber inlet LiBr percentage ratio = 52.5%
5. Absorber exit LiBr percentage ratio = 60%
6. Absorber exit temperature T1=30.4°C
7. Pressure in absorber and evaporator =0.934 kPa

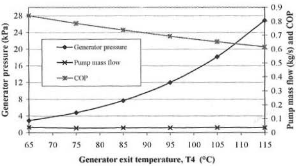

Fig. 4. Effect of generator temperature

As it is seen in Fig. 4 when the generator temperature is increased the generator pressure is also increased and this has as an effect the lowering of the coefficient of performance of the unit, considering that the pressures and temperatures at other points of the unit are kept constant. The pump mass flow changes slightly from 0.04 kg/s at a generator exit temperature of 65°C to 0.037 kg/s at 115°C.

c. Effect of heat exchanger temperatures

To check this effect the following conditions were assumed:

1. Evaporator capacity 10 kW
2. Evaporator temperature 6°C
3. Pressure in generator and condenser = 4.82 kPa
4. Absorber inlet LiBr percentage ratio = 52.5%
5. Absorber exit LiBr percentage ratio = 60%
6. Absorber exit temperature T1=30.4°C
7. Pressure in absorber and evaporator =0.934 kPa

The solution heat exchanger increases the efficiency of the unit. The greater the heat exchanger area the greater its effect is, since useful energy can be extracted from the generator solution fed to the absorber and be transferred to the solution returning to the generator where it will be heated to the evaporating point. As it is observed (Fig. 5) the coefficient of performance of the unit under the specified conditions is increased from 0.72 to a max 0.84.

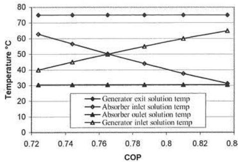

Fig. 5. Effect of heat exchanger temperatures

d. Effect of solution strength

To check the solution strength effectiveness a constant difference of 6% between the absorber inlet LiBr percentage ratio and absorber outlet ratio was considered. Also the following conditions were assumed:

1. Evaporator capacity 10 kW
2. Evaporator temperature 6°C
3. Generator solution exit temperature, T4=75°C
4. Solution heat exchanger exit temp T3=55°C
5. Pressure in absorber and evaporator =0.934 kPa

The results shown in Fig. 6 indicate that a smaller percentage in LiBr solutions will have slightly better results since the solution will absorb more readily extra water vapour. The COP for the selected conditions will very from 0.79 to 0.75. The pump mass flow will be smaller for smaller percentages in LiBr solutions and will very from 0.038 kg/s to about 0.045 kg/s. The main draw back is the absorber solution outlet temperature (T1), which will have to be kept at a low temperature for smaller percentages in LiBr solutions. As mentioned before a reasonable temperature at the exit of the absorber would be around 30°C, which would result in an absorber outlet LiBr percentage of above 58%.

Lithium Bromide is a salt and in its solid state it has a crystalline structure. When LiBr is diluted in water, there is a specific minimum solution temperature for any given salt concentration. The salt begins to leave the solution and crystallize below this minimum temperature.

In an absorption machine if the solution concentration is too high or the solution temperature is reduced too low, crystallization may occur. This is most likely to occur in the solution heat exchanger, interrupting machine operation (Trane, 54601). In such a case the concentrated solution temperature needs to be raised above its saturation point so that the salt crystals will return to the solution, freeing the machine.

The most frequent cause of crystallization is air leakage into the machine, which results in increased pressure in the evaporator. This in tern results in higher evaporator temperatures and consequently lower capacities. At high load conditions, the control system increases the heat input to the generator, resulting in increased solution concentrations to the point where crystallization may occur. Non-absorbable gases like hydrogen, produced during corrosion can also be present, which reduce the performance of both the condenser and the absorber (Herold *et al.*, 1996). A direct method for keeping the required pressure is to evacuate the vapour space periodically with a vacuum pump.

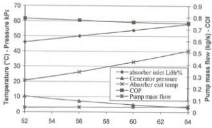

Fig. 6. Effect of solution strength

Excessively cold condenser water, coupled with a high load condition, is another cause for crystallization. In modern designs cooling tower water temperature is allowed to float with variations of load and outdoor air temperature. In this way, by using cooling water temperatures that are below design, unit performance is improved. However, in the solution heat exchanger under high load conditions, the entering temperature of the dilute solution may be low enough to reduce the temperature of the highly concentrated solution, returning from the generator, to the crystallization point.

A third reason is electric power failure. During normal shutdown the machine undergoes a dilution cycle, which lowers the concentration of the solution throughout the machine. In such a case the machine may cool to ambient temperature without crystallization occurring in the solutions. Crystallization is most likely to occur when the machine is stopped while operating at full load, when highly concentrated solutions are present in the solution heat exchanger.

6. GENERAL OBSERVATIONS

Due to corrosion problems the life expectancy of the LiBr absorption machines is approximately 20 years. The presence of oxygen can greatly accelerate the degradation and thus leaks must be avoided. If the vacuum must be broken for any reason, it is important to fill the vapour space with nitrogen or other inert gas to a pressure above atmospheric to avoid introduction of oxygen. Metals like copper and iron in the presence of aqueous LiBr, which is an electrolyte, produce ions that leave the solid surface and combine with oxygen at a distance from the surface. This leaves the solid surface of the base metal available for more attack. By controlling the solution pH level to be slightly basic instead of acidic, oxides are formed directly on the solid surface, forming a relatively stable oxide coating (passivation), protecting the surface. The pH level can be controlled by adding small amounts of hydrobromic acid (HBr). Since both elements constituting HBr are already present within the solution, the solution properties are not significantly altered. Corrosion inhibitors can also reduce corrosion rates. Such inhibitors are Lithium Chromate (Li_2CrO_4) Lithium Molybdate (Li_2MoO_4) or Lithium Nitrate ($LiNO_3$) in amounts on the order of 1% by solution weight (Herold *et al.*, 1996).

7. CONCLUSIONS

A method to evaluate the characteristics and performance of a single stage LiBr- water absorption machine was presented and the necessary heat and mass transfer equations. These equations were used in a computer program and a sensitivity analysis was carried out. This analysis shows that the greater the difference between the absorber LiBr inlet and outlet percentage ratio is, the smaller the mass circulating in the absorber. On the other hand, to keep the cycle running at a specified stage, the temperature at the exit of the absorber has to be maintained at a lower level when the absorber exit LiBr percentage ratio is lower.

Considering that the pressures and temperatures at other points of the unit are kept constant, the coefficient of performance of the unit is lowered when the generator temperature is increased, leading to increase of the generator pressure.

The solution heat exchanger increases the efficiency of the unit. The greater the heat exchanger area the greater its effect.

Finally, when checking the solution strength effectiveness for a constant difference of 6% between the absorber inlet LiBr percentage ratio and absorber outlet ratio, it was found that a smaller percentage in LiBr solutions will have slightly better results. The main draw back is the absorber solution outlet temperature (T1), which will have to be kept at a low temperature for smaller percentages in LiBr solutions. A reasonable temperature at the exit of the absorber would be around 30°C, which would result in an absorber outlet LiBr percentage of above 58%.

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ACHILLEAS DJALLIS, A MASTER CRAFTSMAN

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ABSTRACT

This document presents an outline of the speech and demonstration presented by Mr Achilleas Djallis, master craftsman to HTI 2nd year students (Engineering Practice Dept. Building and Carpentry workshops.). Mr Djallis described the conditions and the techniques in building construction at the first half of the 20th century. It is very beneficial for the students to know about the conditions and traditional techniques, which prevailed in the past. This awareness helps them to better appreciate traditional buildings, which constitute our national heritage. In addition, the students can evaluate the great changes brought to Building Industry by the rapid technological improvements, during the last 50 years in Cyprus.

1. INTRODUCTION

For some years now, it has been common practice to invite outside professionals and master craftsmen from the building industry, to give both demonstrations and lectures to HTI 2nd year students (Engineering Practice Dept. Building and Carpentry workshops.). Last year master craftsman Mr Achilleas Djallis was invited to give his personal experiences. (I would like to express my gratitude to Mr Demetris A.Djalli Head of Centre for Consultancy and Professional Development, School of Technology, University of Glamorgan, for introducing me to his father master craftsman Mr Achilleas Djallis). At the outset Mr Djallis described briefly his experience in building construction and then proceeded to the demonstration of the use of gypsum in plastering. (The photographs in the consequent pages show Mr Djallis demonstraing the application of gypsum plastre.)

2. WORK MEMORIES

Mr Achilleas Djallis begun his speech saying:

> "I am a bitter refugee from Lefkoniko, a capital village of Famagusta district. My father, as most rural Greek Cypriots was working in agriculture. (He adds with pride) I have 5 sons, who studied Engineering. Four of my sons graduated University, two of them Electrical and two Civil Engineering; all employed in high status positions.

In these four lines Mr Achilleas Djallis expressed his bitterness for being expelled from his village as well as his pride for his sons achievements. Many Cypriots, especially rural refugees, share these feelings. Cypriots are very attached to their roots, while they value and appreciate education and professional success. The highlights of his speech are summed up in the next pages.

2.1 Work Experience

Mr Achilleas Djallis was born in Lefkoniko in 1913. In 1925 he graduated the Elementary school and worked for one year as an apprentice to a builder in his village without payment. Then, for 5 years he worked with different builders locally, initially as a labourer and then to become a master craftsman. From 1927 to 1931 he worked with, "mastre" Charalambos from Lysi; one of the areas top craftsmen, who built many churches and schools. They mainly built elementary schools in the nearby villages, like Vatili, Trypimeni, Milea and Trikomo; a big beautiful school, built solely with stone cut by hand.

In 1931 he successfully tendered his first job to build the boundary wall of the elementary Lefkoniko School. Since then he has undertaken different contracts either by himself or in partnership with other builders. From 1938 to 1946 he created a small industry for the manufacture of solid bricks and tiles, with a maximum capacity of 2,500 units per day.

After 1960, job opportunities were offered with the building of new and the extension of existing schools in the newly formed Cyprus republic. He successfully tendered jobs in the elementary schools of Akanthou, Marathovouno, Ayios Seryios and Spathariko. In addition various extensions to the Gymnasium of Lefkoniko.

In 1974, while working as a contractor he was forced by the Turkish Troops to leave his house, his work and all his belongings, to become one of the 200.000 Cypriot refugees living in a refugee camp. During the difficult years in the construction industry, he continued to work as a builder but mainly small scale, maintenance works, with the exception of the construction of two houses. Although Mr Djiallis is a pensioner since 1978, he still helps his son who is an electrician with his work.

2.2. Work Conditions

The students were very interested to know about the conditions of work, the techniques and the materials used, at the early years of his employment. They were amazed of the difficulties faced by builders during the first half of the century while they kept asking questions about words they heard for the first time (kondila, paniazo, artizo). The following topics were mainly covered.

2.2.1. Transportation

Transportation was a major problem. Animals, mostly donkeys and carriages were used as a means of transport. When working at surrounding villages they needed to stay overnight during weekdays. In 1926, when he was apprentice "tsiraki" to a craftsman from Pygi, (a nearby village about 2 miles from Lefkoniko) they worked to Aloa, a Turkish village about 3 miles from Pygi. Every Saturday evening, he had to walk 5 miles (from Aloa to Pygi and then to Lefkoniko) and on Sunday evening to go back to Pygi. In 1927 when working in the village of Milea, 2.5 miles from Lefkoniko, he had to go on foot every day, while the craftsman "mastros" rode his donkey. Since 1931 he has been using a bicycle for his transport. He still rides his bicycle to the nearby coffee shop or to go shopping. In 1999 he was awarded the first prize for the oldest bicycle rider, in a festival organised by Engomi Municipality.

2.2.2. Payment

Working hours was from dawn till dusk, "yenniman iliou, dimman iliou", from Monday to Saturday. Wages were very low. At the first years of his employment (1931-40) he earned 2 shillings daily, compared to 12 piastres "yrosia" for men and 6 piastres for women labourers (1shilling=9 yrosia). During the difficult Worldwar II years, he charged only 1 pound for 1.000 tiles; sometimes the laying of the tiles was included in the above price.Quite a considerable number of house owners provided the labour themselves. The payment agreement could be with or without meals included. ("sinexoda" without meals). Many house owners could not afford to make agreed payments regularly. For that reason he preferred the more financially secured school contracts.

2.2.3. Materials

During the construction of a house the builder's task was multi-functional. At first hand he was responsible for the outline drawing of the house; usually drawn on paper with pencil in consultation with the house owner. Then he had to prepare most of the materials used, like lime, gypsum and mudblocks. In 1934, lime was brought to the area from the village of Akanthou on camel back. It was lump-lime or quicklime, sold about 1 piastra per oke. Lump lime was slaked in water in order to produce hydrated lime; this was a dangerous and laborious task. As the use of lime was costly only rich owners could afford to use lime mortar for the construction of walls, while soil mortar with straw "Kondila" was mostly used. The walls of the houses were mainly built with mudblocks.

In 1931, when Mr Djiallis built the boundary wall of Lefkoniko School with cement blocks, he rent a machine from a contractor in Kyrenia in order to prepare the cement blocks he needed. He bought the cement at a very dear price: 2 shillings per bag. (Equal to his daily earnings).

2.3. The use of Gypsum in Plastering

Gypsum was brought from the nearby village of Gypsos, in tin cans of 20 okes, sold at the price of 2 piastres to 1/2 shilling per box. Gypsum was in the form of small lumps already heated in a kiln. The gypsum needed to be crushed and sieved to be ready for use in construction. Young labourers mainly did these jobs after they finished their normal days work. Gypsum was mainly used in plastering. Other uses were to lay tiles "marmara", to support beams and lintels.

By variations in water content, time factor and stirring process the following three types of gypsum were produced: "Apsos", "Malaktos" and "Tsakistos". Mr Achilleas Djiallis explained and demonstrated to the students the three different processes. (The photographs in the next page show Mr Djiallis demonstrating the applications.)

2.3.1. "Apsos"

This is a hard mixture used for filling the corners of a room before plastering. It consists of two parts of gypsum added to one part of water. After a quick stirring a hard mixture is produced which should be immediately applied.

2.3.2. "Malaktos"

This is a soft mixture used for plastering. It is prepared in the following way:

- Add one part gypsum to one part water.
- Let it soak in water 2 minutes and then stir.
- Add a small quantity of gypsum (arlizo), leave it 2 minutes and then stir. Repeat this step several times until the mixture sets.
- The whole process lasts about 20 minutes and the result is a soft workable mixture. The gypsum plaster is applied on the wall with a plastering trowel; a metal trowel can be used as well. After the gypsum plaster sets it is floated with a damp cloth. (Paniazio)

2.3.3. "Tsakistos"

This mixture is used to cover irregularities left after the aplication of the previous gypsum plaster. A quantity of "malaktos" gypsum is mixed with water several times until the mixture is soft "tsakizo". The gypsum is applied as above and the finish is a very smooth and shining surface.

3. CONCLUSION

During the first half of the 20^{th} century working conditions in the building industry were very difficult. Poor transport means, low wages, the high cost of materials and poor technological means were the major problems faced by people employed in Building Industry. Tremendous effort and time was spent for building the traditional houses, which still exist in Cyprus today. The students need to know the difficulties involved in the construction of traditional buildings in order to appreciate and to value them. In addition, the awareness of methods and techniques used in the past helps to evaluate the drastic changes brought to Building Industry by the use of technological developments.

Traditional buildings in Cyprus are the echoes of the past, which need to be preserved for the future generation. Today, when the Turks occupy a considerable part of Cyprus heritage the preservation of traditional buildings is very crucial.

At last a man feels in complete harmony with nature when he lives in a traditional building, a unique experience I feel whenever I walk through the narrow streets of Lefkara. Having spent the last year renovating my traditional house at Lefkara I truly appreciate the workmanship of traditional craftsmen.

WASTEWATER REUSE FOR IRRIGATION: AN ALTERNATIVE WATER RESOURCE IN THE MEDITERRANEAN REGION

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Abstract: Under the drought conditions occurring around the Mediterranean region, the use of treated effluents resulting from treatment of domestic effluents may be an important resource. Using however non-conventional quality water presents a number of ecological and health risks and poses problems connected to soil and ground water contamination. This paper concentrates in evaluating the possible salinisation risks encountered on the soil profile as a result of using the above effluent and suggests possible corrective management techniques.
Keywords: treated sewage; wastewater; salinity; salinisation risk.

INTRODUCTION

Fresh water is our most precious natural resource. With many countries facing severe water shortages, reusing water for irrigation and industrial purposes is becoming more favourable. The amount of water needed to irrigate farm crops, golf courses, and other landscape usually exceeds by far the drinking water we use.

When recycled water is used for irrigation, more of our natural supply of drinking water will be available for domestic use.

In planning and implementation of water reclamation and reuse, the intended water reuse application dictate the extend of wastewater treatment required, the quality of the finished water and the method of distribution and application.

Cyprus with a total surface area of 9250 Km^2 due to its semiarid climate faces a problem of inadequacy of water for both its domestic and irrigation needs.

The mean annual rainfall over the island is 500 mm which corresponds to 4600 million cubic meters of water over its total area.

Due to the aridity of the region a proportion of about 80% of the rainfall returns to the atmosphere as loss by evaporation and evapotranspiration

If a balance is carried out of the water resources of Cyprus then in the incoming, one may include the mean annual crop of 900 million cubic meters which can be analysed into 67% surface runoff and 33% groundwater whilst in the outgoing, one may include 37% of losses in the sea, 30% pumpage and flow from springs, 21% mean annual yield of the dams and 17% as diversions for spade irrigation from the streams [3].

In Cyprus there are no permanent surface water streams or lakes but until some years ago, underground water resources were adequate to meet the local water demand.

However overexploitation of the underground water lead to a gradual decrease of groundwater resources.

The reuse of sewage effluents however should be seriously considered as an important strategy in conserving water resources.

EXPERIMENTING WITH WASTEWATER REUSE

Soil samples were taken from an area which was irrigated with treated effluent for about eleven years. Other plots in this area were also irrigated with fresh groundwater obtained from nearby wells.

Samples were taken from both irrigation plots at intervals of 10cm to a depth of 1.2m.

The location selected was in Aglandja area, the farm of the Agricultural Research Institute in Nicosia.

The soil in this area is characterised as Saltic Fluvisols, and its content was homogeneous throughout all profile.

The clay content varied from 20.2 to 22.4 % with high sand content.
We can therefore define it as sandy-clay loam. They are poor in organic matter content 1% but rich in general Carbonate (CO_3), 16-19%.

Therefore their pH is high 8.92-9.87 which shows alkalinity characteristics.

In these soils only crops with high pH tolerance can grow.

As previously mentioned two types of water were used for irrigation.

1. Fresh ground water from a nearby well
2. Treated wastewater

The sewage had domestic origin with no industrial wastes. A secondary type of treatment is carried and treated water is collected at a pond near the investigation site.

CHARACTERISTICS OF GROUND FARM-WATER USED

The following were the major characteristics of the ground water used:

- high content of soluble elements toxic to agriculture
- electric conductivity = 3.0 mmho/cm
- from the cations predominant is Na^+ = 21.7 mg/l
- from the anions predominant is Cl = 15.5 mg/l

It should be noted that Na_2CO_3 is one of most toxic to crops

CHARACTERISTICS OF TREATED EFFLLUENTS USED

Content similar to fresh ground-water but contains additional elements and salts toxic to crop.

- Electric conductivity = 3.7 mmho/cm
- High in Na+, Cl, CO3 and high pH upto 9.2

Table 1 below shows analysis of Treated Sewage (TS) in terms of cations – anions

Water Type	EC	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	CO_3	SAR
Treated Sewage	2.29	8.1	3.1	3.1	17	0.95	11.75	5.4	4.65	1.8	11.3

Table 1 Electrical Conductivity in dSm^{-1} and soluble cations-anions of water meq/l.
Average values of treated sewage used taken between 1986 and 1987

GENERAL QUALITY CHARACTERISTICS

It is anticipated that water having been used once for some purpose, can be reused in agriculture. Such effluent may possess undesirable constituents such as salts, trace elements, organic compounds, pathogens and other constituents that may affect soil, crop, public health, and generally the environment [4].

The physical, chemical and biological constituents of wastewaters are important parameters in the design, collection and reuse of treated effluent [2].

In recent guidelines [6], four categories namely salinity, infiltration, toxicity and "miscellaneous problems" are used for evaluating conventional sources of irrigation water. The physical and chemical constituents in treated effluents need careful consideration in order to evaluate or detect possible short or long-term effects on soils and crops from salts, nutrients and trace elements [2].

Constituents of concern in treated sewage are:

a. Suspended Solids, which can develop sludge deposits and consequently anaerobic conditions

b. Biodegradable organics, whose decomposition can lead to the depletion of dissolved oxygen in the receiving waters,

c. Pathogens, bacteria, viruses and parasites which can transmit diseases,

d. Nutrients, which include, nitrogen, phosphorous and potassium. Essential in plant growth, but when discharged in waters, can lead to undesirable growth.

e. Stable (refractory) organics, like phenols, pesticides and chlorinated hydrocarbons. These organics tend to resist conventional methods of wastewater treatment and are toxic to the environment

f. Hydrogen ion activity, or pH affecting solubility and alkalinity of soils.

g. Heavy metals which are of no concern to Cyprus as there are no heavy industries, and

h. Dissolve inorganics, like sodium, magnesium calcium and others, which can be damage crop and pose soil permeability problems.

This paper is concentrating in the assessment of salinisation risk, a problem of serious concern for Cyprus.

RISK ASSESSMENT

The criteria which are listed in Table 2 were applied in the investigation of the risk of the treated sewage intended for irrigation. The results show that at most times the quality of this effluent does not meet the appropriate levels and poses some kind of risks [9].

This is interpreted as great care should be taken when using such effluents in order to minimize or eliminated ground or groundwater contamination.

Further to the above and in evaluating the actual effects on the soil profile, a profile investigation was carried in order to evaluate the salinisation risk at various levels of the soil .The criteria shown in Table 2 were applied at each increment of the soil profile, the one irrigated with treated wastewater and of the other irrigated with farm water. Trend lines were drawn for each one of the criteria. The results are shown in Table 3. All derived equations have a high correlation coefficient, which verifies their accuracy.

N	Criteria	Treated Sewage value	Criteria range	Risk Estimation
1	$\frac{Ca+Mg}{Na+0{,}23Ca}$	0.35	>1	Natrium risk YES
2.	$\frac{100(Ca+Mg)}{Na}$	36	>60%	Natrium risk YES
3.	$\frac{100Mg}{Ca+Mg}$	50	<50%	Magnesium risk YES
4.	$\frac{288}{5.Cl}$.	4.9	>18	Gloridisation YES
5.	$\frac{288}{Na+4Cl}$	3.9	6-18	Chloridisation YES
6.	$\frac{288}{10Na-5Cl-9SO_4}$	4.35	1.2-6	Chloridisation YES
7.	$\frac{6620}{Na+2.6Cl}$	138	<1.2	Chloridisation YES
8.	$\frac{(Na+K)\,100}{Ca+Mg+Na+K}$	74.33	<66%	Alkalinisation possible
9.	$\frac{Na}{Ca+Mg+Na}$	0.73	<0.6	Alkalinisation possible
10.	$\frac{Na}{Ca+Mg}$	2.74	<0.7	Alkalinisation possible
11.	$\frac{Na+K}{Ca+Mg}$	2.90	<1-No 1-4 - Possible >4 - Sure	Alkalinisation possible
12.	$SAR=\frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$	9.65	<10	Dangerous level
13.	$ESP=\frac{100(0.01475SAR-0.0126)}{1+(0.01475SAR-0.0126)}$	13	<5-10%	Irrigation Dangerous

Table 2. Risk Criteria and Estimation of Salinisation Risk [5]

№	Criteria		Sewage water	
	Number	Name	Trend line	R^2
1	C1	Sodium	$y = 0.0626e^{[illegible]}$	0.9836
2	C2	Sodium	$y = 0.0626e^{[illegible]}$	0.9836
3	C3	Sodium	$y = -5.6333x^3 + 56.736x^2 - 161.53x + 146.6$	0.9241
4	C4	Chlorides	$y = -0.1492x^3 + 1.2911x^2 - 3.6298x + 8.594$	0.873
5	C5	Chlorides	$y = -7.25x^3 + 53.25x^2 - 103.5x + 49$	0.9941
6	C6	Alkalinity	$y = 1.4167x^3 - 13.607x^2 + 33.976x + 66.2$	0.9999
7	C7	Alkalinity	$y = 0.5833x^3 - 5.8214x^2 + 11.595x + 84.4$	0.9874
8	C8	Alkalinity	$y = 0.0667x^3 - 0.3786x^2 - 1.7452x + 11.8$	0.9944
9	C9	Alkalinity	$y = 0.2214x^2 - 3.3186x + 12.92$	0.9928
10	C10	Alkalinity	$y = 0.0275x^3 - 0.1439x^2 - 0.4414x + 3.238$	0.9971
11	C11	Alkalinity	$y = 0.2333x^3 - 1.8071x^2 + 1.6595x + 9.8$	0.9804
12	C12	Alkalinity	$y = 1.8286x^2 - 26.851x + 103.74$	0.9944
13	C13	SAR	$y = 0.2x^2 - 3.58x + 21.08$	0.984
14	C14	ESP	$y = 0.275x^3 - 2.3036x^2 + 2.6214x + 21.04$	0.9962
15	C15	RSC	$y = -0.6333x^3 + 5.4143x^2 - 14.552x + 12.28$	0.9672

Table 3 Summary of Trend Lines in risk evaluation of treated sewage [10]

PRESENTATION OF RESULTS

A typical example in the presentation of the results is shown in fig.1. The SAR (sodium absorption ratio) is investigated by the application of each one of the criteria at each increment of the soil profile under investigation. One may notice that the quality of the samples irrigated with groundwater obtained from nearby wells demonstrates higher values of SAR and therefore poses greater salinisation risk. This is due to the fact that most ground waters in Cyprus, due to their high content of calcium carbonate in the soils, present high level of salts.

Soils of electrical conductivity below 4 dS/m and high values of SAR, between 13 and15, are considered as sodic soils [1]. These soils also demonstrate high pH values, usually above 10, and present various agricultural problems, which are however manageable if proper care is given [7].

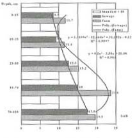

Figure 1 : SAR evaluation of the soil profile

CONCLUSIONS

The amount and kind of salts in treated effluents is probably the most important single parameter for evaluating the suitability of treated effluents for irrigation.

Potential problems are related to the total salt content, the type of salt and the concentration of one or more elements [6].

With modern irrigation systems, particularly with trickle and minisprinkler, better results can be achieved [8].

In long term planning strategy, the total salt applied in the soil and the salt removed by leaching, a management technique, should be approximately the same.

Effective management is necessary in deciding salt removal techniques and selecting proper crop.

Effective management is necessary in deciding salt removal techniques and selecting proper crop.

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PUBLICATIONS by members of HTI academic Staff

CIVIL ENGINEERING DEPARTMENT

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