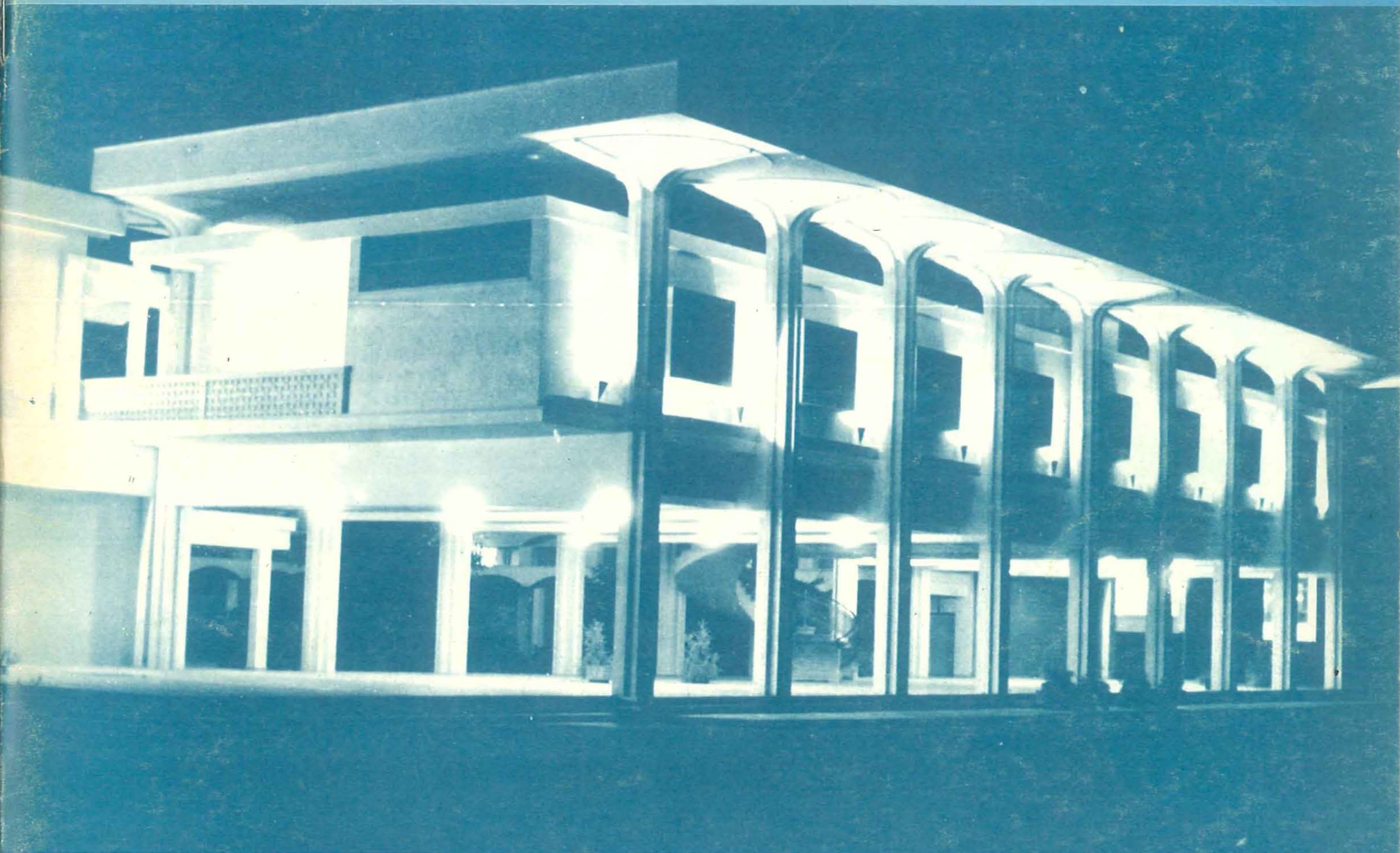
10 YEAR ANNIVERSARY EDITION



HIGHER TECHNICAL INSTITUTE NICOSIA 1968 CYPRUS

Review

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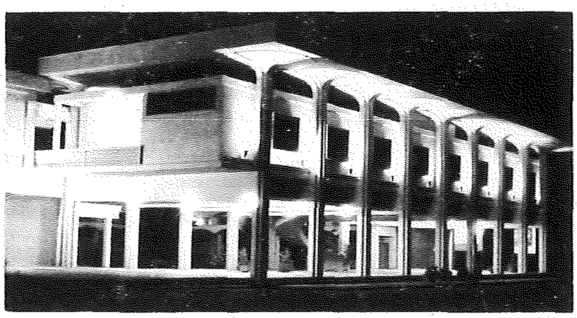

Cover photo by Ionas Aggeli.

Showing the administration wing of the H.T.I.

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

HIGHER TECHNICAL INSTITUTE NICOSIA 1968 CYPRUS

Review

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EDITORIAL

We present once again the new Edition of the Institute's Magazine, "The H.T.I. Review", which this year coincides with the 10-year Anniversary of the Higher Technical Institute.

Contributors are mainly members of the H.T.I. Staff. In two cases however, articles were accepted which were the result of co-operation of H.T.I. Lecturers with other professionals.

It will be noticed that the bias of the majority of the technical articles is towards the energy problems and the necessity for a more national approach to the utilisation of scarce resources.

It is hoped that the present publication will continue to promote the scientific and technological undestanding among the H.T.I. Faculty, students and the technical world at large.

The Editorial Committee wishes to express sincere thanks and appreciation to the many contributors to this publication for their cooperation.

GENERAL EDITOR

THE FIRST TEN YEARS

1968/69 — 1978/79

The Higher Technical Institute (HTI) which started operating in the academic year 1968—9, celebrates its 10th anniversary this year. The Institute was established as a joint project of the United Nations Development Programme and the Government of Cyprus. The Cyprus Ministry of Labour and Social Insurance and UNESCO, with assistance from the I.L.O., acted as executive agents for the project, which lasted till 1973, and entailed a total cost of $3,005,629.

The Cyprus Government contributed $1,684,669 in the form of local staff, land and buildings, and the UNDP contributed $1,320,960 by way of equipment, expert foreign staff and fellowships to local counterpart staff. The joint project came to an end in March 1973 and since then the Cyprus Government has undertaken sole responsibility for the Institute's operation.

The HTI is the highest technical educational establishment in Cyprus, its mission being to train Technician Engineers in the basic engineering specialisations of Civil, Electrical and Mechanical Engineering to meet the needs of the country's developing industry. Regular courses are of three years' duration. The Institute now also offers a three-year full-time course for Marine Officers in Engineering: it has hosted a pilot project of UNESCO for Life Long Education and offered countless short courses to Industry. In addition to its teaching role, the Institute offers consultancy to industry and has taken a leading role in certain types of applied research such as Solar Energy.

The present publication aims at giving an overview of the HTI in the many and varied aspects of its activities.

The HTI had, by July 1978 offered 562 graduates to the Labour Market, of which it is rightly proud: Those who have gone into industry have secured suitable posts with lucrative emoluments; while the smaller number of graduates (about 60) who pursued further studies abroad have been accepted as 'transfer students' by universities and colleges in Britain, the United States, Canada and Australia, so that they are able to obtain a B.Sc. degree with not more than two years of further studies. Most of the students who went abroad have distinguished themselves academically and many have continued with postgraduate studies.

Another much appreciated form of recognition has come from the Professional Engineering Institutions of Britain:

The Institutions of Plant Engineering and General Technician Engineering have accepted the holders of the HTI Diploma in any specialisation, as eligible for the qualification of T. Eng. (Technician Engineer). The Institution of Electrical Engineers (IEE) and the Institution of Mechanical Engineers (IMechE) have accepted to consider graduates of the HTI in the appropriate specialisations for exemption from Part I of the Council of Engineering Institutions examinations that lead in due course to the qualification of C.Eng. (Chartered Engineer).

Despite the politically troubled times that Cyprus has gone through in the past decade and despite the occassionally strained relations between Greek and Turk Cypriots, (the two main communities on the island), the Institute has continued to work in harmony with both communities, members of which have participated actively at all levels of the Institute's activities, i.e. as students, staff and governing body. This is perhaps the aspect of which the Institute is most proud, viz. that right up to the invasion of Cyprus by Turkey in July 1974, the HTI operated as a truly inter-communal institution. And even after the invasion, when communication between the two communities separated by the Attila line between North and South, effectively came to a stand still, members of the two communities, former colleagues and fellow students kept up their contacts, proving that human feeling is stronger than politics.

The HTI is celebrating its 10th anniversary in the absence of its Turk Cypriot members, but not without hope that another anniversary might be celebrated together.

LEACH TESTING OF COAL GASIFICATION PROCESS CHAR

Pantelis Vassiliou [1], Richard G. Luthy [2]
and Mark J. Carter [3].

A methodology is presented for assessing the potential for release of elements from solid waste resulting from gasification of coal. This methodology is applied to the case of a coal char formed from the Hygas steam-oxygen process. The char was subjected to both batch and continuous flow leach tests under a variety of simulated model water types and environmental conditions. Leachates were analyzed for twenty-five elements. It is apparent that boron was extracted in potentially environmentally significant quantities in every test and that this element should be monitored closely in future environmental assessment studies on coal conversion process solid wastes.

The solid waste evaluated in this study was Hygas pilot plant Western coal char formed at approximately 63% carbon conversion. The information presented here does provide a methodology for assessing potential problems associated with disposal of a coal conversion process char; and this body of data will serve as a reference point from which to compare results of future tests. As the data base evolves, it will be possible to begin to correlate coal conversion process operating conditions with the physical and chemical characteristics of solid waste.

Most of the effort in the investigation was devoted to quantifying the extent and rate of release of trace elements from the char when leached with eluants of varying qualities. Careful attention was given to document process operating conditions at the time the char was sampled, and to assure that the char was collected in appropriate fashion. Also considerable effort was made to characterize the physical properties of the char.

Experimental Design

As part of its efforts to coordinate DOE's high BTU coal gasification environmental assessment program, Carnegie-Mellon University has undertaken the investigation of certain process-related environmental engineering problems. One facet of this task addressed screening studies on leachability of a coal gasification process solid residue (char). In order to survey the general nature and extent of any leaching problems from gasification char an experiment was initiated to:

(1) Characterize conditions under which char may release potential contaminants.

(2) Determine individual contaminant mass emission quantities under these conditions, and

(3) Evaluate the rate at which various contaminants are released.

In order to evaluate conditions under which pollutants may be released to the environment a series of batch and continuous flow experiments were performed with waters of various qualities. Leaching solutions were resigned to model six water types:

* Distilled water (simulated rainwater, mildly acidic)
* Medium hardness (simulated surface water, buffered)
* High hardness (simulated groundwater, buffered)
* Sodium bisulfate-sulfuric acid (simulated acid mine water, strongly acidic)
* Deaerated tap water
* Acetate-tartrate/sodium hydrosulfite (simulated organic complexation under reducing conditions)

The object of these tests was to assess the potenial for release of elements from coal char with various water types to which the char may be exposed.

In addition to these tests, mixtures of soil and char were subjected to pulse leaching tests under the following conditions.

* Soil-char mixture aerobic
* Soil-char mixture anaerobic

The purpose here was to determine over a period of several months what effect common soil bacteria may have on the release of char constituents.

Experimental Results

The paper reports results of char elemental composition and physical properties, and results of seventy-two hour batch extraction studies and compares these results with 90 day continuous flow leachability tests. The data from the 90 day extraction experiments were used to determine rate of release of various elements. The soil-char studies were run for a total of 15 weeks. Each experiment was conducted in triplicate with a blank for control purposes. A logarithmic composite sampling schedule was invoked for he 90 day continuous flow tests to examine 1, 2, 4, 8, 16, 32, 64, and 90 days sample composites. Leachate from the soil char mixtures was analyzed weekly.

In order to ensure the validity of the data replicate leach tests were performed, and sample blanks were used. Leach data was reported as cumulative fraction leached over sequential leaching intervals.

Leachates in this study were analyzed for twently-five elements:

Ag	Be	Cu	Mo	Sn
Al	Ca	Fe	Na	Ti
As	Cd	Hg	Ni	V
B	Co	Mg	Pb	Y
Ba	Cr	Mn	Se	Zn

Argon plasma emission spectroscopy was used for all elemental determinations except for As, Hg, and Se.

Elemental analysis of Hygas char is presented in Table 1. The major species lie with the typical limit for elemental concentration of U.S. coals. Many of he minor elements were found at concentration towards he lower range values or less than values reported for coal ashes.

Figure 1 illustrates the continuous flow leach test apparatus; Figure 2 shows deails of a continuous flow leach test column. Continuous flow leach test results are presented in Figure 3 for distilled water. These results are relatively similar to the other eluants, except for the acetate-tartrate/sodium hydrosulfite extractant. Results for this solution are presented in Figure 4. This test represents an upper bound as to what may likely be leached from the char under strongly reducing conditions in the presence of high concentrations of organic chelating agents.

Extractions studies with soil-char mixtures under both aerobic and anaerobic test conditions are summarized in

1) Lecturer, Department of Civil Engineering, Higher Technical Institute, Nicosia, Cyprus.

1) Assistant Professor, Department of Civil Engineering, Carnegie-Mellon University, Pittsburgh, PA 15213.

3) Deputy Chief, Chemistry Branch, EPA-NEIC, Denver, Colo.

Table 2 along with the other leach test data. A schematic of an anaerobic soil-char leach test column is shown in Figure 5; the aerobic soil-char leach test columns were similar to that shown in Figure 5 except the ends of he column were left open to the atmosphere. The soil-char columns were pulse fed two times per week for fifteen weeks. The soil-char studies were performed in order to assess if soil chemistry or soil bacteria could mediate the release of elements from the char. It is recognized that this sort of test has many uncontrolled variables, yet it was believed that it was important to attempt an assessment of the effects of soil-char interactions. No documentation was found in which controlled leaching tests of this sort had been performed, so this effort was also viewed as an attempt to develop a methodology for evaluation of complex interactions between natural material (soil and bacteria) and solid wastes (char). In spite of potential interactive mechanisms, results of these tests were quite similar to the findings of the continuous flow studies using various water types. It was a rather surprising result that soil-char leaching properties did not depend on whether or not the sample was aerobic or anaerobic. One possible explanation for this was that in situ redox levels (pe) were similar in both tests in spite of the experimental configurations.

Batch extraction studies were used to obtain a rapid assessment of leaching characteristics. It was found that the batch studies were good indicators of what may be leached, but poor indicators of total quantity.

Discussion

Because no disposal sites have been selected for coal conversion wastes, the leachability study could not be tailored to site-specific conditions. The leachability test data, coupled with measurement of the waste's physical properties, provides a data base from which it is possible in a limited fashion to assess leaching effects given a variety of disposal alternatives; however various assumptions must be made. For example, if it is assumed that liquid contact time with char is dependent on bed depth and permeability, then contact times can be estimated using measured permeability data for any given compaction conditions. A knowledge of contact times can then be employed to estimate the amount of material leached from the char by use of the leach rate diagram. This permits calculation of leachate concentration assuming that no other interactions occur. That is, it must be assumed that there are no other physico-chemical effects, such as fluid hydrodynamics or chemical reactions, which may alter leaching characteristics.

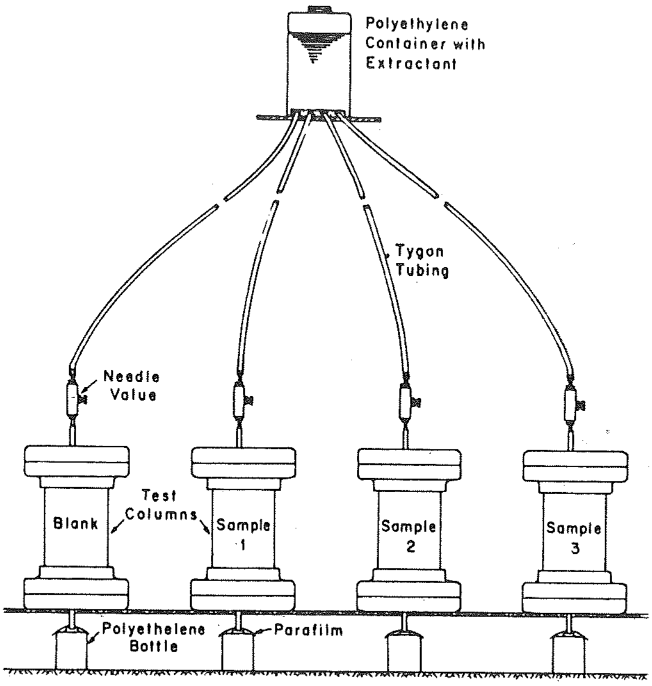

FIGURE 1: SCHEMATIC OF CONTINUOUS FLOW LEACH EXPERIMENT

TABLE 1

ULTIMATE ANALYSIS OF HYGAS COAL GASIFICATION PROCESS CHAR[1]

Element	μg/g	Element	μg/g
Ag	<25	Mg	8200
Al	28000	Mn	570
B	150	Mo	30
Ba	3600	Na	900
Be	<2	Ni	<50
Ca	47000	Pb	54
Cd	<20	Sn	<99
Co	<10	Ti	1100
Cr	18	V	<99
Cu	16	Y	<10
Fe	14000	Zn	<60

[1]Char formed from gasification of Montana Rosebud subbituminous coal during Hygas Pilot Plant Run No. 58.

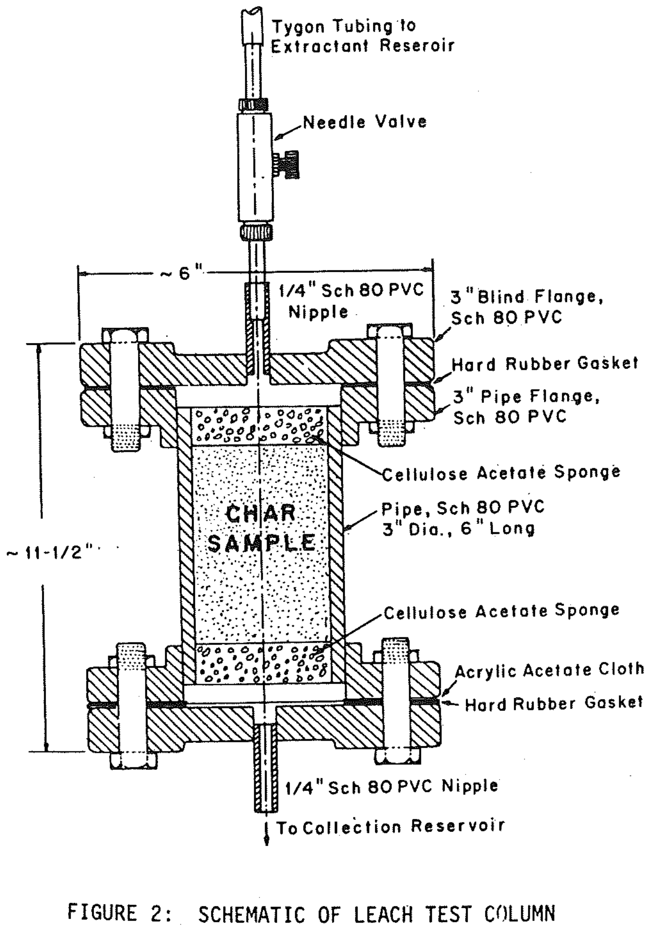

FIGURE 2: SCHEMATIC OF LEACH TEST COLUMN

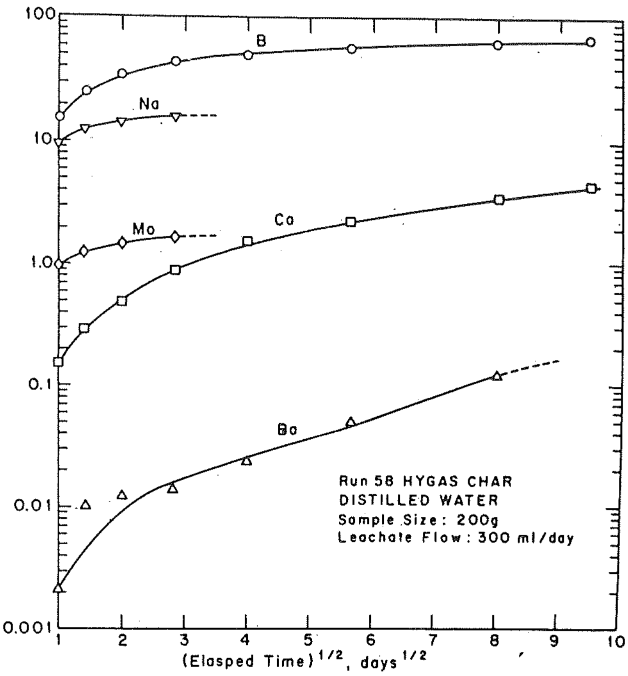

FIGURE 3: CONTINUOUS FLOW LEACHING TESTS WITH DISTILLED WATER

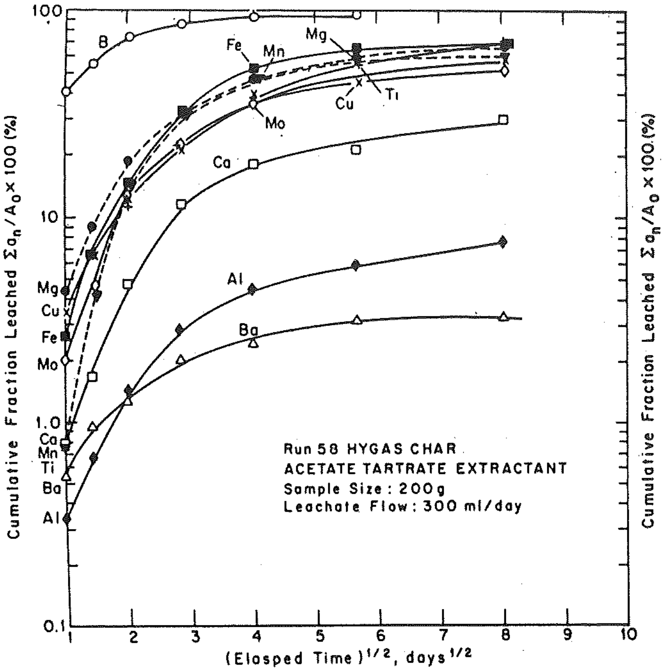

FIGURE 4: CONTINUOUS FLOW LEACHING TESTS WITH ACETATE-TARTRATE EXTRACTANT

TABLE 2

FRACTION LEACHED PER UNIT MASS OF CHAR

Type of Test	Extractant	Cummulative Fraction Leached, %										
		Al	B	Ba	Ca	Cu	Fe	Mg	Mn	Mo	Na	Ti
Ninety Day Continuous Flow	Distilled Water		67	0.05	4.4					1.7	15	
	Intermediate Hard Water		64	0.19	3.7					1.1		
	Hard Water		65	0.18	5.3					1.7		
	Acid Mine Water		71	0.03	12					1.8		
	Reaerated Tap Water		66	0.17	6.2					1.8		
	Acetate-Tartrate/ Sodium Hydrosulfite	7.7	96	3.6	30	61	70	69	63	53		73
Fifteen Week Pulse Fed Soil-Char	Distilled Water (aerobic)		42	0.007	1.0			0.50		2.5	15	
	Distilled Water (anaerobic)		47	0.007	0.76			0.38		3.4	16	

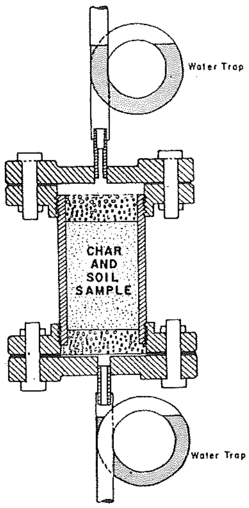

FIGURE 5: SCHEMATIC OF A SOIL-CHAR ANAEROBIC LEACH TEST COLUMN

FIGURE 5: SCHEMATIC OF A SOIL-CHAR ANAEROBIC LEACH TEST COLUMN

Because of the vagueness associated with trying to predict environmental effects associated with disposal of char, all that can be said at this point is that B is the most obvious potential problem owing to deleterious effects on irrigation waters. Boron was found in leachate samples at concentrations ranging from about 10 mg/l at the start of the experiment to about 0.2 mg/l at the conclusion of the test. Molybdenum was the only heavy metal specie routinely identified in leachate, excluding the acetate-tartrate experiment. Molybdenum concentration in leachate decreased from about 0.2 to 0.01 mg/l over the first eight days of leaching. Molybdenum could present a potential problem because groundwaters carry levels of this element which can give rise to plant concentrations toxic to cattle.

A solar Powered City

By Th. Symeou, Lecturer, Mechanical Engineering Dept., H.T.I.

The following study explores the energy sources and sinks for a hypothetical solar powered city of 10,000 inhabitants. The climatological data taken for this imaginary city are:

The area can receive sun 85% of the year with summer temperatures of 43°C and low humidities 5—30% year round while winter temperatures drop to 3°C. The above climatological data are very common in some areas of North Africa, Middle East etc. Water in the region under study is supposed to be found about 60—80 metres below ground level and its temperature is relatively constant at 20°C. The city is located away from the seaside and it consists of hotels, hospital, airport, shops and offices, central services (municipal building), residential houses etc.

It can be decided that the solar energy will be used for the following purposes:

A) Domestic hot water supply
B) Solar cooling and heating of the municipal buildings
C) Solar Energy Power Generation
D) Solar Energy Water Pumping

Each of the above systems operates independently and their operation is explained below:

A. Solar Service Water Heating

The city residents will require hot water for several purposes. Since the largest use of hot water is required in the residences of the population, individual domestic hot water solar systems could be installed on the roofs of the houses. Thermosiphon water heating package units which are comprised of a flat plate solar collector and a tank, have been found to be the most efficient, easy to operate and low in cost (fig. 1). The policy of the city government should be structured to require solar water heating for every city residence. In this manner, the city residential areas can be phased to allow dwelling unit additions as the population naturally increases. The saving in energy will approximate 500, 000 gallons of oil per year for the city if the water were heated by the sun instead of by oil fired electrical generators.

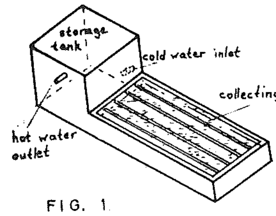

FIG. 1

B. Solar Cooling and Heating of the Municipal Buildings

By grouping the commercial and industrial buildings it is possible to provide a centralized heating and cooling plant for the structures environmental conditions (fig. 2). The plant will be powered by solar energy as well as being supplemented by fuel created by the city's wastes. A loop system will be evolved to encompass the fossil fuel power generating substations, the solar collection station and the waste treatment plant. This loop carries the water at temperature of 95—125°C to the cooling and heating plant. The plant utilizes the heat from the water to provide heat directly to the municipal buildings (2d) or send the heat through absorption refrigeration machines to provide cooling (2e). Night sky radiation (2f) can be used to provide the cooling media for the absorption machines. This utilization of the diurnal effects of solar energy can be extremely effective in arid regions with low humidity. The roofs of the municipal buildings, for example, can become shallow ponds (2f) in the evening and the hot water from the condenser of the absorption refrigeration unit is pumped to the roofs for cooling by night sky radiation.

The collectors used for the above system are of the focusing type (2a) and track the sun. These collectors are capable of generating temperatures in excess of 150°C.

While the collectors will provide most of their collected energy directly into the "loop", a portion of the sun's energy will be sent to the waste treatment plant. Solar energy can be used as an integral part of the waste water treatment process in order to promote anaerobic digestion which will produce methane gas. This gas can then be burned in boilers (2c) and the resulting heat is injected into the loop system. Solar energy will indirectly provide energy from the city's waste products by keeping

the sludge stabilizing tanks at 33°C thereby promoting anaerobic digestion.
The flue waste heat from a fossil fuel burning electrical substation can be injected into the loop system (2 b). By utilizing this heat the power plant will become about 55—60% efficient as compared to conventional plants (burning oil) which are 25—30% efficient.
The amount of heat that can be provided by the solar collectors (excluding the excess derived from the waste treatment plant) may be expected to be in the order of 12,000 gallons of oil per 100 m² of collectors, per year.

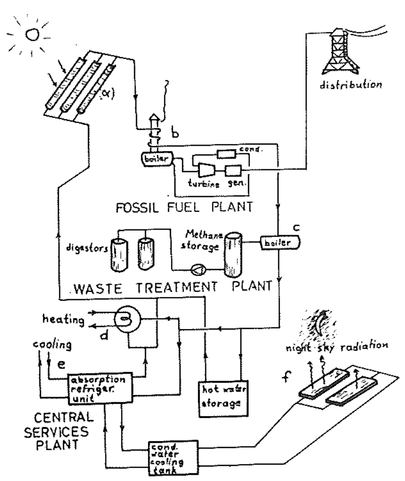

FIG. 2

C. Solar Energy Power Generation

Using a series of fossil fuel burning electrical substations and solar power generation substations, a power grid can be developed in order to provide the city with electricity.
A solar power generation plant is shown schematically in fig. 3. The type of collectors that can be used to generate electric power are heliostats. These are computer controlled mirrors which focus the sun's light into a receiver-boiler located in a 60—70 meters tall tower. The sun energy is then converted into heat (300—550°C) which drives a steam turbine which in turn drives a generator in order to produce electricity. Some type of heat storage system should be used to store the excess electricity which can be generated in certain days of the year. Storage is also required to allow electrical generation and distribution during the evening hours. It is estimated that a city of 10,000 inhabitants will require 30 MW of power. A solar generating station requires about 100 acres of land in order to produce 10 MW of power. As power from the solar generator becomes available, the oil burning power generating substations will cycle down using less fuel. As the solar generator loses its power generating capacity, the conventional power substations pick up and provide the required capacity.
A 10 MW solar generating facility operating only 8 hours per day will save approximately 2,800,000 gallons of oil per year.

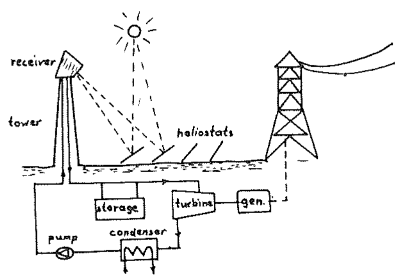

FIG. 3

D. Solar Energy Water Pumping

The system can employ concentrating solar collectors or the heliostat field used for electrical power generation, to produce heliothermal energy which is used to vaporize freon 113 in a closed loop system (fig. 4). In the evaporator the working fluid becomes saturated vapour. A single stage action turbine converts vapour into mechanical energy. The fluid flowing into the condenser returns to the liquid state. The water pumped from the well acts as the cooling media for the condenser. The turbine is coupled with centrifugal or other type pump. A solar pump installed in Arizona (U.S.) is capable of delivery 10,000 gallons of water per minute with a 35 kW solar pump using solar heated water at about 150°C.

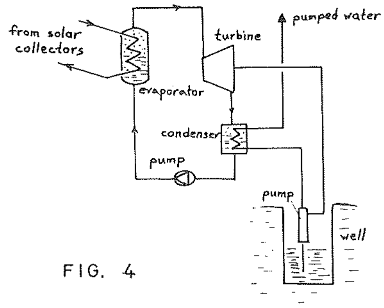

FIG. 4

Solar System Integration

Each system can operate independently without conflicting with any other solar system. With each system, significant amounts of energy may be saved in this city. The technologies required to provide the solar powered systems described above are not new and they have already been employed on projects all over the world. They have however been provided only as individual energy saving measures for cities and/or buildings but never in total as a planned part of the city's energy source. When these technologies will be combined, the first energy efficient solar city can become feasible.

Energy Conservation

Other sophisticated mechanical and architectural energy saving techniques must be employed in order to minimize the energy consumption in a solar city. Some of them are:

1. Minimize cracks and

joints in building construction.

2. Group spaces within commercial structures that have similar environmental needs.
3. Building configurations requiring minimum overall volume should be highly regarded.
4. Building entrances located on "down wind" side and provide entry wind brakes.
5. Waste heat recovery from sanitary sewer system.
6. Waste heat recovery from commercial lighting systems.
7. Unoccupied zone shut downs.
8. Air handling fan volume control.
9. Boiler and chiller water automatic reset.
10. Increased utilization of ventilation cycle with indirect evaporative cooling systems (water supplied from treated waste water).

1978 UNESCO Day and the HTI

By Mrs Olga Demetriades,
Lecturer HTI.

The Higher Technical Institute (HTI) was founded in 1968 as a joint project of the Government of Cyprus and the United Nations Development Programme — Special Fund (U.N.D.P.) whose assistance to the HTI was channeled through the United Nations Educational, Scientific and Cultural Organisation (UNESCO). Unesco has ranked the HTI as one of its most successful projects in the field of Higher Technical Education and an increasing number of foreign students are attending its courses. Since 1977 UNESCO DAY has been adopted for official celebration with a stress mainly on the cultural aspect.

This year's 31st UNESCO Anniversary was honoured by organising a visit to a Moslem Religious Monument, the Tekke in Larnaca. Both students and staff of the HTI left by bus from Nicosia in the morning and got to Larnaca at about 10 a.m. Dr. V. Englezakis from the Cyprus Research Centre was invited to be the first Guest Speaker. His subject was the Islamic Religion. He gave a most interesting talk on this vast topic and he enlightened the audience on the principles of the Islamic religon and its relation to the Christian faith.

His talk was followed by that of Mr. A. Papageorghiou of the Department of Antiquities who for the second year running had accepted to be a Guest Speaker. Mr. A. Papageorghiou talked on the Historical and Archaeological aspects of the Tekke referred to the history of the Tekke and gave us the different current versions about its foundation and existence.

At 11.30, once the talks were over, both staff and students started cleaning up the grounds just outside the garden of this Moslem shrine. All the tools, implements and equipment were unloaded from the bus and the manual work started. Everybody looked very professional and in no time the whole area was spotless and clean, the weeds uprooted, the garbage collected and even burnt. The T.V. reporters and cameramen were there and the whole activity was broadcast on T.V. Some members of staff and students were interviewed expressing oponltaneously their thoughts and feelings on the work done.

It is well known that the Tekke is a pilgrimage for the Moslems; as it is, known the HTI was set up a bicommunal institution and remained so until the Coup d' Etat in 1974 and the invasion from Turkey; among its foreign students today there are quite a number of Moslems, therefore this activity has been an appropriate one to mark the 31st anniversary of UNESCO DAY. In the Charter of the Declaration of Human Rights, Article 26, on Education and its targets, one reads the following "Education shall be directed to the full development of the human personality and to the strengthening of respect for human rights and fundamental freedom. It shall promote understanding tolerance and friendship among all nations, racial or religious groups and shall further the activities of the United Nations for the maintenance of peace".

A picnic lunch at Kiti Beach marked the end of a successful outing.

LEARNING FOR MASTERY AND THE CREDIT POINT SYSTEM

By George Philippou, Lecturer, General Studies Dept., H.T.L.

Education aims at the transmission of a set of values and beliefs, a certain body of knowledge and skills. Values can be classified as the long-range goals and they are mostly sought through the realization of the short-term objectives of each separate subject. Instructional objectives refer to specific subject matter, they are frequently stated in terms of expected student behaviour, and they should be observable and measurable. By the completion of a subject or a unit, the student is expected to be able to perform certain tasks, which he was unable to perform before instruction.

According to the traditional educational system, full realization of the instructional objectives was expected only from a small proportion of the learners. Teachers and administrators were satisfied if achievement was similar to the normal distribution. But we all know that the normal distribution is most appropriate to chance and random activity. So Bloom has recently challenged this long cherished belief by insisting that "educational efforts have been unsuccessful to the extent that the distribution of achievement approximates the normal distribution" (1971 p. 45). After all education is a purposeful activity.

By grading on the normal curve, each student is judged in terms of his relative position in the group. Consequently a considerable proportion of the students is expected to either fail or to just get by. The less ables develop cumulative deficits as they fell progressively behind and they cannot follow the pace of the average. Their self concept is gradually destroyed as they are bound to attend courses under conditions which are frustrating and humiliating year after year. Some years ago, this was accepted as an inherent and unavoidable weakness in educational practice. The argument was that since people are normally distributed with respect to ability, scolastic achievement will be distributed more or less normally. Attempts to improve the situation were concentrated in the direction of having homogeneous groups, and "ability streaming" was for a time widely practiced in some countries. But the crucial question arose "homogeneity with respect to what?" Since the variables affecting learning are many, complex, and interrelated All important student entering characteristics should be systematically considered in planning educational activities. Individual differences in ability, home environment, motivation and interest should not be ignored. So far we provided a predetermined span of time for the mastery of a given body of subject matter, we exposed the students to the same learning experiences, and measured the degrees of learning mastery attained at the end of that time. Under such conditions variability in the level of mastery should not be surprizing.

However, a new conception of mental ability makes such variability difficult to justify, while opening new avenues to educational practice. Carrol (Bloom, 1971, p. 46) defined aptitude in terms of the time required for the mastery of a certain task. If this conception is right, then aptitude is predictive of the rate of learning rather than the level of complexity of learning that is possible. Two individuals of variable abilities can achieve the same level of mastery of a certain task if they devote different amounts of time.

Based on the above principle Bloom (1971, p. 46) claims that if the quality of instruction is appropriate, and if the students are allowed the necessary time and put forth the required effort, then nearly 95 per cent should attain mastery and get A. He excludes only a 5 per cent for which the length of the required time would be prohibitive.

Bloom has also developed a specific strategy for mastery learning. He takes into consideration basic student characteristics such as aptitude, ability to understand instruction, perseverance etc, and the quality of instruction; but the most important new element in his plan is the variability of the time allowed. Since the rate of learning differs from student to student, it seems unreasonable to expect from all of them to absorb the same subject matter and attain the same degree of mastery in the same time. On the contrary it seems logical to set levels of achievement as constants and let the time act as a variable according to individual needs.

Research studies are cited by Bloom (1971, p. 55) and Shulman (1970, p. 49) which tend to confirm theoretical claims concerning the power of such strategies.

Now, what is the relationship between Bloom's ideas and the Credit Point System (C.P.S.)? The latter provides for a number of core subjects required for a course of study, and some electives taken from a set of related subjects. Due to their nature some subjects have others as prerequisites, otherwise the student is free to plan the order of the subjects and to decide the semester load according to his special needs. A minimum number of credit-hours is required per semester otherwise the student is treated as part-time student. In planning his course, each student can seek guidance and advice from a teacher acting as advisor.

Clearly the C.P.S. allows for the most important element of Bloom's strategy for mastery learning. It makes it possible to set constant levels of achievement and let the time be variable. The students can complete their studies in different periods simply by choosing different semester load appropriate to their needs and learning styles. Thus a course of four years normal duration, could be completed in three and a half by the most ables and in five years by the less ables. In the C.P.S. an average of 70 per cent (80 for graduate courses) is normally required, while no subject is passed with a grade less than 60 per cent (70 for graduate courses). Bloom provides for the complete abolition of grades, limiting evaluation to "mastery" and "non mastery". The rise of the required level of mastery in the C.P.S. is a substantial step toward Bloom's strategy.

Bloom provides for continual formative evaluation, diagnosis of student weaknesses and individual guidance and tutorship to secure the optimum quality of instruction for each student. One could argue that no direct implementation of this part is provided by the C.P.S. True, but the breaking into semester subjects, the complete mastery of the prerequisite subjects, and the variable semester load offers wide opportunities for the quality of insruction to be most appro-

priate for each students.
By planning his course of study and deciding his semester load, the student is actively participating in the process and he is more likely to work hard to manage the goals he has set. Opportunities for success are increased, and success is essential if the student is to develop positive attitudes and seek more knowledge. Students who just get by are more likely to develop negative attitudes toward learning and part of the objectives of education is lost. The selection process involved in the C.P.S. will develop a sense of responsibility and the demand for more independent study will develop the autonomous person. This is an important objective of education if we are to bring up people capable to follow the rapid changes of the modern world through the process of self-education.

In conclusion we can say that variability in achievement should not be acceptable. For example we cannot be satisfied with a 50 or 70 per cent success from a medical pracitioner or an automobile technician. Complete mastery of a minimum body of knowledge and skills is essential; it is also possible if we allow the required time and provide suitable instruction for each student. Some of the basic components of a strategy for mastery learning as conceived by Bloom are provided by the C.P.S., some others are facilitated.

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OPTIMISATION OF A RESIDENTIAL SOLAR HEATING SYSTEM

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Introduction

Solar energy is extensively used in Cyprus for the generation of hot water for domestic use. A few number of cases have been reported in which solar heating of spaces (buildings and greenhouses) were designed and implemented, their performance being still under investigation.

This paper is intended to present a method for the investigation of the **optimum size** of the solar heating system of a residential house in Cyprus aiming to achieve maximum solar energy utilisation at minimum cost over a certain period of operation. For this investigation, certain assumptions are made as follows:

(i) Light fuel oil used for conventional heating systems priced at 225 mils per Imp. gallon.

(ii) Off-peak electricity (night tariff) priced at 9 mils per kWh.

(iii) Solar collectors will be of those locally manufactured

i.e. (a) Header and tube type, having an efficiency of about 25% and priced at £12 per m²

or (b) Corrugated metal sheets fastened together (rariator type) having an efficiency of about 40% and priced at £26 per m².

(iv) Repayment period for solar heating installation: 10 years.

(v) Daily solar insolation is assumed to be at the average level for the month as shown in fig. 1 plotted from values taken from ASHRAE Handbook of Applications (1974).

(vi) The maximum heat load of the building which is a residential house 180 m² is 28.7 kW, based on design inside temperature 20°C and ambient temperature (average minimum) 3°C; the daily heat requirements (kWh/day) for each month of the heating season are (approximately):

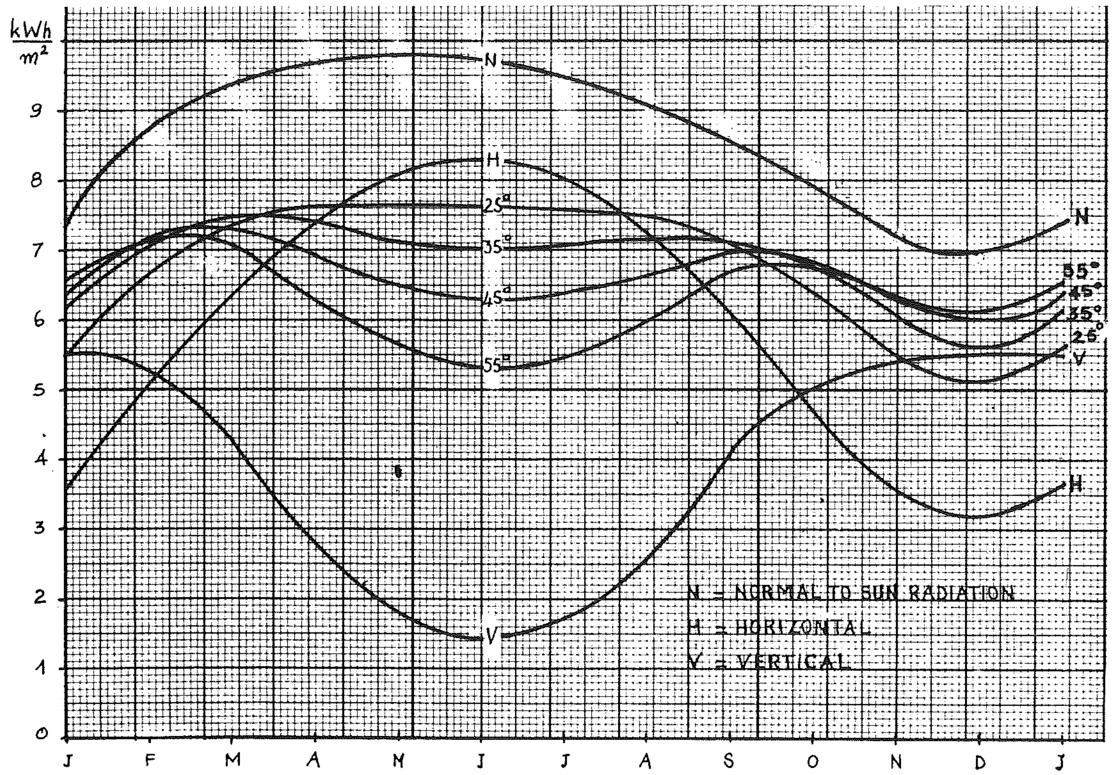

Fig. 1 Daylong solar irradiation (kWh/m²) for the 21st day of each month at latitude 35 deg North, on surfaces normal to the sun's rays; total irradiation or horizontal surfaces and South facing surfaces tilted at 25°, 35°, 45°, 55°, 90° from horizontal.

Description of proposed system

The system will consist of the following components :

(a) Flat plate solar collectors, to absorb solar energy and transfer it in form of heat to the water circulating through them.

(b) Thermal storage tank to store the hot water containing the energy collected.

(c) Circulating pumps to circulate water through the system.

(d) Auxiliary hot water boiler.

(e) Heat emitting units, preferably fan convectors operating at low temperatures (40°C).

Optimum collector tilt

The solar collector shall face towards south. For the determination of the optimum tilting angle of the collector panels fig. 1 will be used. From this graph, which gives the daylong solar irradiation of all months of the year at different collector tilts, it can be seen that the maximum collective solar irradiation of the "heating season" as a total is likely to occur at a tilt of around 55 degrees above horizontal.

Optimum collector surface area

The supply of solar heat is out of phase with the healing demand; much of the energy available in the summer will be wasted, as there is no simultaneous demand. It is obvious that a small collector of only a few square meters would "work" all year around; there will be a demand at all times for the heat it produces. In such a case, its share of the total heat demand (total contribution) would be small. With increasing collector size, the contribution will be greater, but the utilisation rate will be reduced.

The optimum collector size can be established by minimising the total cost of the installation over a number of years; for this particular case a 10-year repayment period is assumed.

Assuming that that plate collectors of the header and tube type will be used, then the useful energy collected, E, for each month would be :

$E = \eta \cdot I$ where η = efficiency of collector (25%)

E = useful energy collected (kWh/m² day)

I = solar irradiation in kWh/m² day.

Then, the collector area required to satisfy the heat demand for each month separately would be :

$$A = \frac{\text{Heat Demand}}{\text{Useful Energy Collected}}$$

where A is the collector surface area in m².

Values of E and A were calculated and tabulated in Table 1.

Table 1

Month	Useful Heat collected kWh/m^2 day	Collector Size (m^2)
October	1.719	58
November	1.620	117
December	1.564	182
January	1.648	158
February	1.793	123
March	1.752	86
April	1.566	38

Table 2

Month	Auxiliary Demand (kWh/day) at collector area (m^2)						
	182	150	125	100	75	50	0
Oct.	-	-	-	-	-	13.8	100
Nov.	-	-	-	27.5	68.0	108.5	190
Dec.	-	50.0	89.1	128.2	167.3	206.4	280
Jan.	-	13.2	54.4	95.6	136.8	178	260
Febr.	-	-	-	41.2	86.1	130.9	220
March	-	-	-	-	19.3	63.1	150
April	-	-	-	-	-	-	60
Season Total	-	63.2	143.5	292.5	477.5	700.7	1260

The estimated cost for the auxiliary energy required to assist the solar system in case of reduced collector area, based on a fuel oil cost of 7 mils per kWh (225 mils per Imp. gallon) will be as follows :

(i) Collector area 182 m^2: No auxiliary required, thus no running cost (circulating pumps running cost ignored).

(ii) Collector area 150 m^2; the estimated annual auxiliary energy required is 30 x 63.2 kWh. Thus cost of auxiliary energy over a 10-year repayment period C£ = 10 x 30 x 63.2 x 0.007 approx. C£ 133.

In the same way, the cost of auxiliary energy required over a 10-year repayment period was calculated for various sizes of solar collector and tabulated in Table 3.

The estimated initial cost for installation (collectors and other equipment and materials installed) is also tabulated in Table 3.

Values of initial cost of installation, running cost and total cost over a 10-year period are plotted against the collector size, as shown in fig. 2.

From fig. 2 the optimum collector is determined corresponding to the minimum total cost over the repayment period.

The optimum size for this system seems to be 114 square metres, and the total cost over the 10-year period in such a case will be C£3075 (C£2650 initial cost and C£425 auxiliary running cost).

Table 3

Collector size m^2	Initial Cost C£	10-year auxiliary cost C£	Total 10-year cost C£
0	1,300	2,646	3,946
50	1,900	1,470	3,370
75	2,200	1,003	3,203
100	2,500	614	3,114
125	2,800	300	3,100
150	3,100	133	3,233
182	3,484	0	3,484

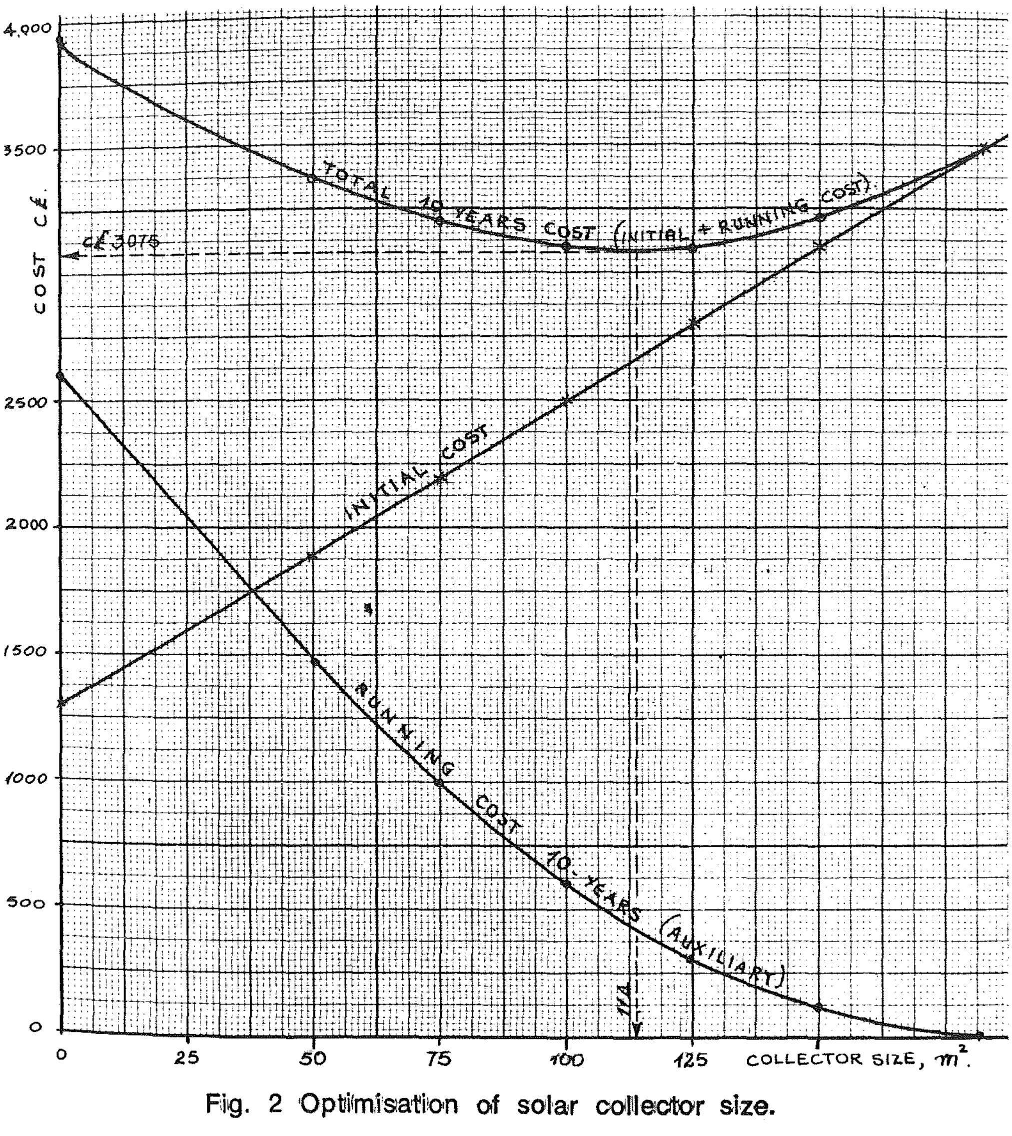

Fig. 2 Optimisation of solar collector size.

Conclusions

It has been shown that the solar heating proposed for this particular case under the conditions assumed would be more economic when combined with an auxiliary conventional source of energy rather than relying fully on the solar energy. This would mean that 85% of the heat requirements of this house will be provided by the sun.

The 114 m² of collector would mean that a number of about 76 solar panels of 1.5 m² each will be required and they shall have to be installed on the roof of the house; this may create a problem in roof area. This number can be reduced if collectors of higher efficiencies (40—50%) are used; this of course would mean higher costs. It is however believed that development and industrialisation of solar collectors will undoubtedly bring a reduction in the collector cost which in turn will reduce considerably the capital cost of the solar heating system and thus make it comparable to the conventional system.

In the present analysis comparison was made of the present expense with future savings without taking into account the interest of the capital invested which could give rather misleading results. However, with inflation future expenses (heating costs) would increase, thus the comparison would favour a larger investment, a larger collector area.

Another factor which would influence this analysis, is the future increase of fuel prices. Only two years before writing this, the light fuel oil used for heating systems was priced at 175 mils per Imp. gallon, compared to today's price of 225 mils, which means a 28.5% increase in fuel price. No one dares to predict today what the future increases will be; it is rather believed that there will be increases well beyond the normal inflation of all prices.

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Sole bonding in Footwear

By A. Valiantis, Footwear Quality Control Officer.

About 90% of all types of Footwear produced in Cyprus are constructed by bonding the sole on to the upper material by means of an adhesive. Thus the type of adhesive to be used as well the method of pre-treatment of upper and soling materials will have a tremendous effect on the bond strength of the finished footwear.

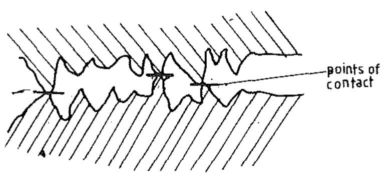
It is not unusual to hear complaints about shoes coming unstuck after a relatively short wearing time. The main reason for this is either the incorrect pre-treatment of surfaces to be bonded or the use of the wrong adhesive for the materials involved. Sometimes misunderstandings of the various properties of the particular adhesive and bad control over the in-factory bonding procedure may lead to bond failure.

Before going into details on how uppers and soling materials may be pre-treated and how the properties of the adhesive must be used correctly, I would like to explain what is an adhesive bond.

Adhesion between two surfaces depends upon the inherent attractions of atoms and molecules when brought close enough together.

But what prevents the adhesion between two surfaces when they are pressed together?

The answer is that even with the most highly polished surfaces, roughness of about 0.1 micron (4 millionths of an inch) only random point contact is achieved at adhesion distances. See figure 1.



The chance of achieving good adhesion with most solid surfaces by contact, therefore, is negligible. Even if solid surfaces were smooth enough to achieve molecular contact, they would not often be chemically clear. Layers of gas molecules tend to sit on the surfaces and form a further barrier to material contact.

Thus the practical factors to be fullfilled when making an adhesive bond are.

1. One of the materials must flow to achieve good contact at the interface.
2. The surfaces-normally the solid surface must be clean of interfering substances.

In most adhesive bonds in footwear, very high strength is required and this means that the adhesive itself in the final bond must be solid, strong enough to resist tearing, but flexible enough to resist fracture. Since adhesives generally must be liquid at the time of application, they clearly undergo a change of state. in converting to the solid.

Unfortunately, this change of state, brought about by a loss of solvent or by cooling and solidification of a melt adhesive usually involves a change in volume-normally shrinkage. Such shrinkage causes stress in the adhesive and particularly if the adhesive is different in hardness from the solid surface, it will tend to pull away from the surface to which it should adhere.

This leads to another requirement of the adhesive: in chemical terms, it must be compatible with the surface to which it should stick. This is sometimes called specific adhesion' as opposed to the adhesion which results when a liquid solidifies in contact with a very rough surface and is held by mechanical locking.

Another need for compatibility between adhesive and the material to be bonded, is that caused by the presence of foreign molecules on solid surfaces such as air or water.

For an adhesive/solid interface to be strong, the following requirements are essential:

1. The two components must be in close contact.
2. There must be no foreign material at the interface which could give a "weak layer".
3. The chemical compatibility of the two components must be good.
4. The residual stress or load at the interface due to shrinkage of the adhesive should be minimal. A rough interface will minimise these stresses if contact is good.

As would be expected, the ideal interface should be obtained when second layer of material is welded or fused to one of the same, as in injecting a PVC sole on to a clean PVC upper.

When attaching sole unit with adhesives, one is involved with these interfaces, quite apart from the importance of the nature of the sole or upper material itself.

With each of these interfaces, adhesive/upper, adhesive/sole and adhesive/adhesive, all four factors are important in securing a good final joint and their reliance upon the infactory procedures of surface preparation, adhesive application, adhesive drying, activation and pressing must be appreciated.

Preparing uppers

Upper materials usually comprise a substrate and a coating. The substrate which must have the necessary properties for making the shoe uppers, may be leather of any thickness and tannage, woven, nonwoven or knitted fabrics in natural and synthetic fibres, or unsupported polymers.

Coatings vary in thickness and chemical types (e.g. acrilic resins, P.V.C. and urethanes) and their function often combines durability with aesthetic appeal. The look of the material is controlled by finishes such as acrylic, urethane or nitrocellulose types, which are applied to the surface of the functional coating.

There is a wide variety of finishes and coatings on upper materials and each one demands a specific method of preparation to achieve a satisfactory bond as follows:

Upper Material		Methods of Pre-treatment
PVC COATED FABRICS	Solid, Semi Expanded	Wire brush rough (36—39 swg) or scour (30—40 grit) just to remove finish layer but not remove coating. Machine speeds at 1100 to 3000 r.p.m. may be used OR solvent wipe to remove finish.
	Cellular suede-like	Solvent wipe to remove finish is not usually necessary. Polyurethane adhesive is recommended for all types.

LEATHER	Resin finished aniline, "rub-off"	Wire brush rough (28—36 swg) or scour (24—36 grit) to remove finish and grain layer.
	PU patent PU wet look	Wire brush rough (28—36 swg) or scour (24—36 grit) to remove PU film and leather grain if present.
	PVC patent PVC finish for flow moulding	Wire brush rough (36—39 swg) or scour (24—36 grit) to roughen PVC film but not remove it, or solvent wipe.
	Suede	Wire brush rough (28—36 seg) or scour (24—36 grit) to just tease up fibres after lasting. Machine speeds of about 3000 rpm are recommended. Polychloroprene adhesives may be used or Polyurethane in some cases. Where PU and PVC films are present PU adhesives are used.
PU-COATED FABRICS		Wire brush rough (39 swg) or scour 30—40 grits) to remove PU coating completely except for 3 mm band along feather. Machine speeds below 2000 r.p.m. are recommended. Polyurethane adhesive. Two coats often necessary.
POROMERICS	Homogeneous	Wire brush rough (39 swg) or scour (24—36 grit) into surface microporous layer.
	Two-layer	Wire brush rough (39 swg) or scour (24—36 grit) into surface microporous layer or in certain instances into fabric base layer.
	Three-layer	Wire brush rough (39 swg) or scour (24—36 grit) to woven layer. Polyurathane adhesive. Machine speeds below 2000 s.p.m. are recommended.
TEXTILES	Hessian, Denin (natural)	None
	Hession (synthetic)	None
	Nylon	None Polyurethane or polychloroprene two-part. Two coats usually necessary.

Preparing Soles

Although the main function of the sole of the shoe is to protect the foot from the ground, it has become a very important element of footwear fashions in recent years.
The traditional leather soles have been replaced to a large extent by a wide range of attractive and fashionable units which are conveniently made from various polymers and which are readily available today.
But in spite of the dictates of fashion, soling materials require the following properties.

1. Adequate wear resistance
2. Flexibility without cracking
3. Slip resistance
4. Water resistance
5. Lightness of weight.

These properties are irrelevant, however, if there is poor adhesion between the sole and the lasted upper. In the following table, common soling materials and their methods of surface preparation prior to adhesion are shown.

Material	Description	Bond method
Leather	The traditional soling material. It has a fairly low wear resistance but is is readily accepted for its aesthetic qualities.	Can be bonded with a polychloroprene or a urethane adhesive. The soles are normally split to provide a uniform substance and are then either roughed by hand with a 28 swg roughing wheel or automatically around the margin using a wire brush or a chisel rougher. The chisel rougher is better for tight leather and wire brush for looser leather. The prepared surface should be free of weak fibres. Because of the absorbent nature of the leather surface it may be necessary to apply two coats of adhesive to the prepared surface.

PVC	Very widely used soling material which is plasticised to make a flexible, well wearing unit. PVC units can be solid or cellular. The latter are usually PVC/urethane or PVC/nitrile blends which have better flexing properties than straight PVC. Solid units can be prone to slipping. Lacquered units need special handling.	With PVC units it is important to use a urethane adhesive. A polychloroprene adhesive must never be used because the plasticiser in the PVC will weaken the adhesive, causing wear failure. The normal surface preparation is solvent wiping before adhesive application althought roughing with a 28 swg brush is also common. If the bonding area is moulded to give a rough surface rather the normally smooth surface the adhesion is improved. Bonding area of lacquered units must be cleaned carefully by roughing to ensure that the surface to be bonded is the true surface of the material.
Resin rubber	Resin rubber is a vulcanised styrene/butadiene rubber with a high styrene resin content. It is supplied mainly in sheet form for cut sole preparation.	This soling can be prepared by scouring or splitting and reducing automatically. The prepared surface can then be bonded with a polychloroprene adhesive or a two-part or prereacted urethane. If the time between preparation and adhesive application is extensive, the surface can be wiped with lascol prior to adhesive application. A more recent development is to halogenate the surface and then bond with an urethane adhesive.
Solid Units	These cover a wide range of components from women's fashion units to heavy industrial soles, and are usually very hard wearing.	These units can be hand scoured or automatically roughed using a revolving hardened cutting tool. Such prepared surfaces can be bonded with a polycloroprene adhesive or a pre-reacted or two part urethane. If the time between preparation and adhesive application is extensive, the surface can be wiped with lascol before applying the adhesive.
Mocrocellular Rubber	This rubber is usually prepared in sheet forms for cutting soles. This soling material is very light and has a reasonable wear performance.	The surface can be scoured and then bonded with a polychloroprene adhesive or special urethane adhesives. Halogenation is also widely used in conjuction with a urethane adhesive.
Crepe Rubber	This unvulcanised, natural rubber had good wearing properties and can be supplied in light colours. One dissadvantage is that exposure to oil, heat and light can soften it.	Crepe primers are applied to the surface prior to application of the polychloroprene or urethane adhesive. Halogenation is an alternative method of preparation and the treated surface can be bonded with a polychroroprene or an urethane adhesive (it is the only material which can be bonded with a polychloroprene adhesive after halogenation).
Thermoplastic Rubber	This material has been used in the footwear industry very recently for solid and cellular units which have good wearing, flexing and slip properties.	The surface is haloginated after which an urethane adhesive must be used.
Reaction moulded Polyurethane	Units prepared from this material are cellular, very light and they wear well. Lacquered units need special handling.	The mould release agent on the surface of these units usually has a disastrous effect on the adhesion. Most of the units are cleaned, therefore, by the unit manufacturer by immersing them in solvent vapour.
		The best method of surface preparation is roughing. With units which have a definite skin, it is advisable not to rough through this because the strength of the sub-cellular layer may be too weak to support the sole bond.
Polyurethane Thermoplastic	These units are usually solid and used mainly in sports footwear such as running shoes and football boots.	The bonding surface is roughed using a 28 swg roughing wheel and then bonded with a urethane adhesive.

In-factory bonding procedure

The close control over the in-factory bonding procedure is something that must be carried out continuously.

The in-factory bonding procedure involves the operations of mixing of adhesive with hardener in case of a two part adhesive, adhesive application over the two surfaces, adhesive drying, adhesive activating and adhesive spotting and pressing.

In the case of a two part adhesive the amount of hardener to be mixed with the adhesive must be according to the instructions of the manufacturer of the adhesive. The above mixture has a limited life caller the "pot life" after which the adhesive can not be used satisfactorily.

The adhesive must be applied by brush all over the area of the surfaces to be bonded, in some cases a second coat of adhesive may need to be applied on one surface because that surface may be very absorbent, i.e. textiles, resulting in the absorption of the first coatleaving the surface without any adhesive on it. That is called "starvation".

After the application of the adhesive, it must be left for some time to dry. This is called the drying time and is indicated by the manufacturer.

After the recommended drying time expires the applied adhesive has a limited life called the "open time" after which the adhesive can not give a satisfactory bond. Before pressing, some adhesives need to be reactivated for some time and at a certain temperature to become softer. The activating temperature is of a great importance and is maintained around 80°C for normal cemented soles, but generally the correct temperature depends on the type and colour of the sole. A few figures are given below:

Surface temperature	Soling Material
91°C	Black PVC
61°C	White PVC
58°C	Beige PVC
85°C	Black resin rubber
74°C	Beige resin rubber

The best type of a cement activator is the profile flash activator which operates with infrared lamps and these lamps can be raised or lowered accordingly depending on the height of the heel or sole. This gives the same temperature all over the surface of the sole. The distance of the soles from the lamps should be about 2½ inches.
The temperature of these activators must be checked periodically. A good method of checking this is by using special temperature indicating crayons. A small amount of the powdered crayon should be applied to the forepart and seat of soles before reactivation and placed in the activator. The temperature of melt is written on each type of crayon.

Immediately after re-activation the sole and the upper must be pressed together. The amount of pressure to be applied depends on the type of sole under pressure. During pressing the solvent of the adhesive evaporates and the adhesive becomes solid and holds the sole and upper together.

As soon as the pressed surfaces are removed from the press, the adhesive should have the ability of holding the two surfaces together for a few seconds until complete drying of the adhesive occurs. The adhesives have this property which is called "Green strength". After pressing, the complete shoe must be left at least 24 hours with the last in and must be checked for sole bond strength on the sole adhesion tester which gives directly the load which is needed to break the bond. That load must be compared with the standard loads to find out whether the bond is good or not.

Grübler's movability criterion for planar linkages

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It is the purpose of this brief article to explain Grübler's movability criterion and to present some of its applications in the number synthesis of the most common planar linkages.

Before any explanation of the criterion is being given it is worthwhile to consider few basic definitions.

A **mechanism** can be defined as a group of rigid bodies so connected that there is relative motion between them. Figure 1(a) shows a structure as compared to various mechanisms shown in figures 1(b), (c), (d).

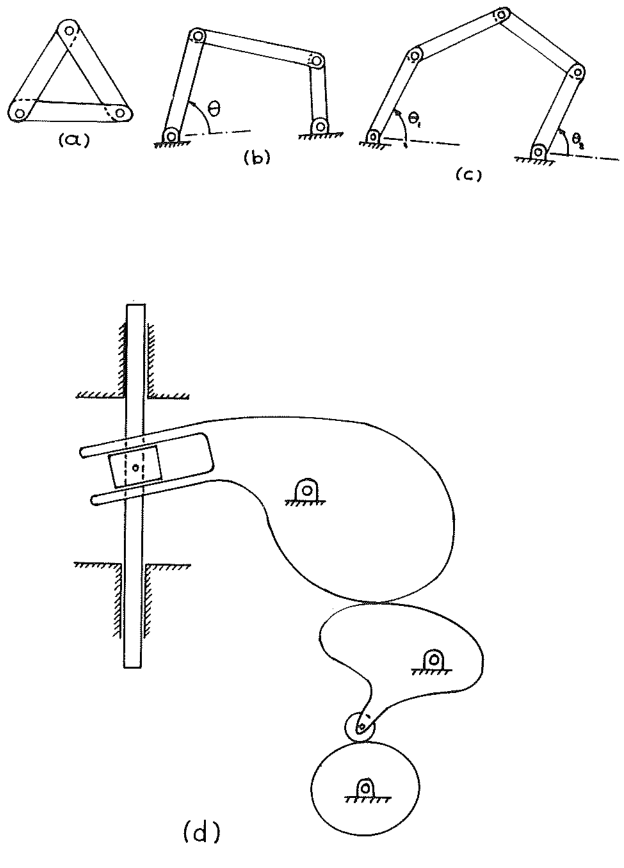


FIG 1

Rigid bodies from now on will be referred to as **links.** For example frame, connecting rods, sliders (pistons), rockers, cams, gears are links. The mechanism shown in figure 1(b) is considered to have **constrained motion** because by specifying an input angle θ then all the rest of the members of the mechanism are specified as far as the members position is concerned.

Figure 1(c) shows a mechanism that is not contrained since two input angles θ_1 and θ_2, are required to specify the position of the mechanism's links.

Figure 1(d) shows a more complex mechanism which has contrained motion.

A **linkage** is a special type of mechanism in which there are only pinned connections. Figure 2(a) shows an actual pin connection in which a pin joins two links 1 and 2 which are able to move with respect to each other.

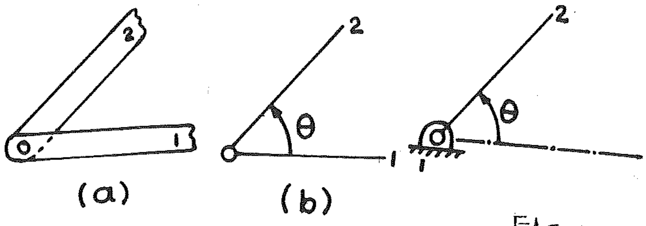
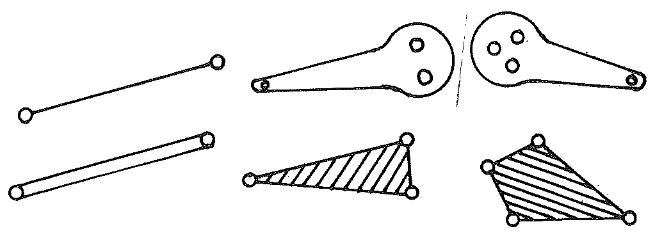


FIG 2

Figure 2(b) shows the same pin connection represented schematically by a small circle and the links by lines. For the figure 2(b) the only kind of motion allowable is turning motion of link 2 with respect to link 1 and for this reason the pair is also called **turning pair** or **revolute pair.**

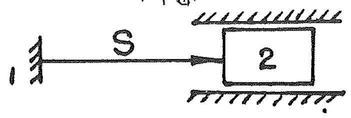
If one of the links is considered to be the frame, then the only parameter required to completely describe the position of the other link is an angle like θ in figure 2(c). Since **degree of freedom** is defined as the number of independent parameters required to completely describe the configuration of a system then it can be said that a revolute pair has one degree of freedom.

Links can be considered to be binary, ternary, quaternary etc. depending on the number of revolute pairs on the link as shown in figure 3.



Even though a linkage is a mechanism which is made of links of the kind shown in figure 3 and revolute pairs, **prismatic** pairs can also be used as far as the validity of Grübler's criterion is concerned. Figure 4 shows a prismatic pair between links 1 and 2.

FIG. 4



Such a pair is for example the cross-head in a guide and the piston in a cylinder. The only parameter required to specify the position of the slider is the displacement S and therefore the prismatic pair has also one degree of freedom.

Considering now figure 5 it can be seen that a link in a plane requires three independent parameters to specify its position. These are the coordinates X , Y and the angle θ, between a line on the link and a reference axis like x.

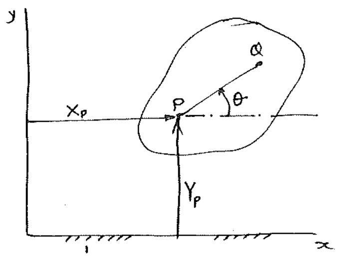


Figure 5

By fixing point P on link 1 then a revolute pair is obtained and therefore a revolute pair subtracts from a link on a plane two degrees of freedom. If instead of fixing point P the angle θ is kept fixed then a prismatic pair is obtained as is shown in figure 6 and the only parameter required to specify the position of the link is the displacement S.

Therefore a prismatic pair also subtracts two degrees of freedom from a link.

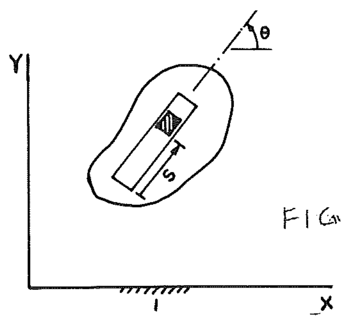


FIG. 6

Considering now a number of links like in figure 7(a) it can be said that in order to describe the position of the system shown 3L independent parameters are required, where L = number of links.

If link 1 is considered to be the frame then the number of links left are L—1 and 3(L—1) number of independent parameters are required to completely specify the system.

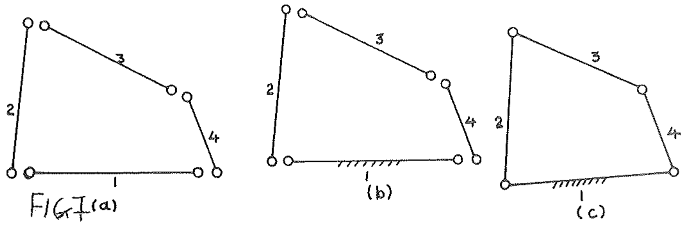


FIG. 7(a)

Since each joint (revolute or prismatic pair) subtracts two degrees of freedom from a link, then if number of joints in a linkage is J the net number of independent parameters left to describe the configuration of a linkage is 3(L—1)—2J.

This quantity is called **movability** and represented with the symbol X.

i.e. $X = 3(L-1)-2J$ (1)

Equation 1 is the Grübler's criterion of movability for planar linkages.

If X = 1 the linkage is constrained

If X = 0 the linkage is a structure

If $X < 0$ the structure is indeterminate

If $X > 1$ the linkage is unconstrained

For instance checking the movability of the two-link linkage of figure 8

L = 2, J = 2 $X = 3(2-1)-2\times2 = 3-4 = -1$

∴ Indeterminate structure

For figure 9

L = 3

J = 3

$X = 3(3-1) - 2\times3 = 6-6 = 0$

∴ structure

For figure 10

L = 4

J = 4

$X = 3(4-1) - 2\times4 = 9-8 = 1$

∴ constrained linkage

For figure 11

L = 5

J = 5

$X = 3(5-1) - 2\times5 = 12-10 = 2$

and the linkage is unconstrained and two inputs are required in order to completely describe the configuration of the linkage.

A point to be observed here is that Grüblers criterion is valid for all kinematic linkages that have only revolute pairs, while with linkages that have prismatic pairs the criterion is not totally valid. This is so particularly if on one link there are two or more parallel prismatic pairs like for instance in figure 12 in which since L = 2, J = 2 then $X = 3(2-1) - 2\times2 = 3-4 = -1$.

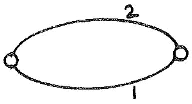
Obviously though the linkage is not a structure but a constrained mechanism.

Figures 13 to 20 show various common linkages and their movability as obtained from Grüblers criterion.

References :

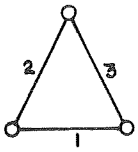
1) Hartenberg and Denait, "Kinematic synthesis of linkages" McGraw Hill Book Co.

2) Artobolevski, "Mechanisms in modern engineering design", MIR publishers.



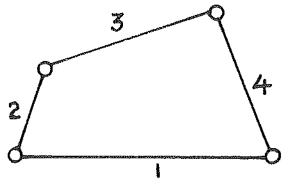
L = 2
J = 2
X = -1

fig 8



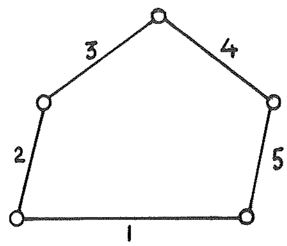
L = 3
J = 3
X = 0

Fig. 9



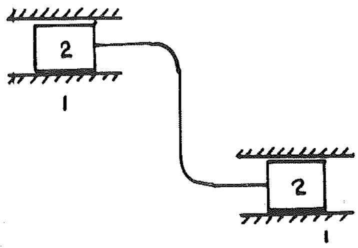
L = 4
J = 4
X = 1

fig. 10



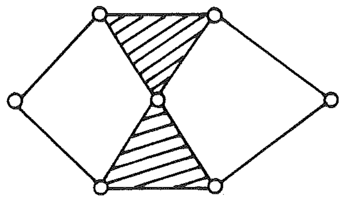
L = 5
J = 5
X = 2

fig. 11



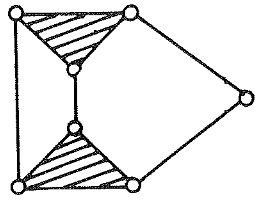
L = 2
J = 2
X = -1

fig. 12



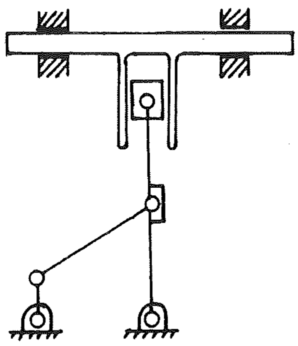
L = 6
J = 7
X = 1

fig. 13



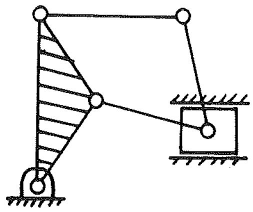
L = 6
J = 7
X = 1

fig. 14



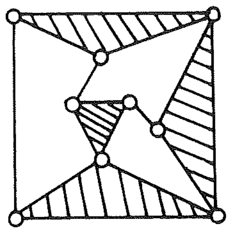
L = 6
J = 7
X = 1

fig. 15



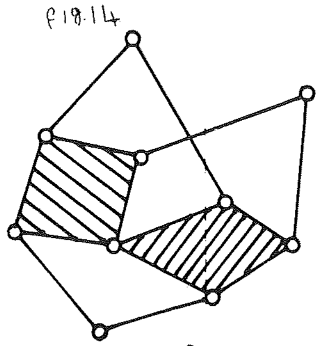
L = 6
J = 7
X = 1

fig. 16



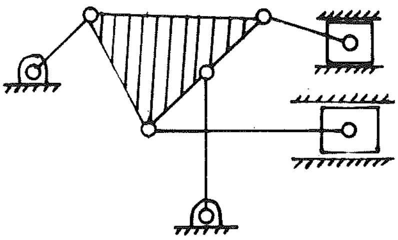
L = 7
J = 9
X = 0

fig. 17



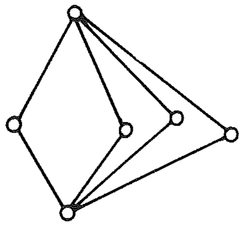
L = 8
J = 10
X = 1

fig. 18



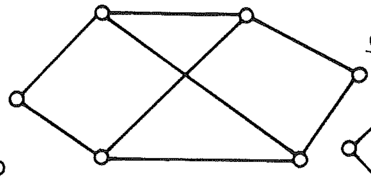
L = 8
J = 10
X = 1

fig. 19



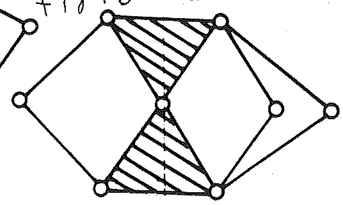
L = 8
J = 10
X = 1

fig. 20



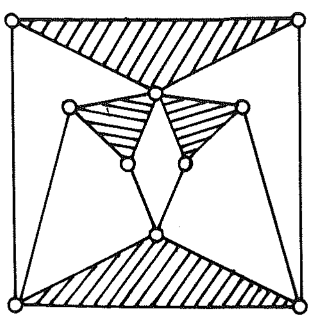
L = 8
J = 10
X = 1

fig. 21



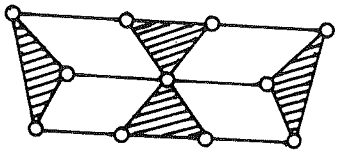
L = 8
J = 10
X = 1

fig. 22



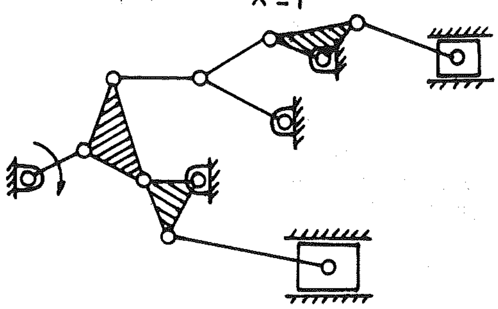
L = 10
J = 14
X = -1

fig. 23



L = 10
J = 13
X = 1

fig. 24



L = 12
J = 15
X = 1

fig. 25

The Viking mission to Mars

A. Z. Achillides, Lecturer, H.T.I.

Mars has excited man's imagination more than any other celestial body except the Sun and the Moon. Its unsual red dish color which the ancients associated with fire and blood gave rise to its being named for the Roman God of war, Mars.

The invention of the astronomical telescope by Galileo opened a new era in the observation of the planet. Instead of appearing merely as a tiny disc, Mars surface features could be resolved. Christial Huygen's made the first sketch in 1659 of the dark region Syrtis Major Giant quicksands. Able to observe a distinguishable feature, Huygen's could show that Mars rotated on a North-South axis like earth, producing a day that was about half an hour longer than Earth's.

In 1666 the Italian astronomer G. Cassini observed and sketched the Martian polar caps. Other observers, at the beginning of the eighteen century, noted changes in the surface appearance probably caused by dust storms.

In 1783 W. Herschel observed that Mars axis of rotation is inclined to its orbital plane at about the same extent as Earth's, revealing that long term changes were often associated with seasons that would result from such inclination.

In the 17th and 18th centuries, it was commonly accepted that Mars and the other planets were inhabited but the real excitement was created by Giovanni Schiaparelli and Percival Lowell between 1877 and 1920. As a result of extensive observations, Schiaparelli constructed detailed maps with many features including a number of dark, almost straight lines, some of them hundreds of km long. He referred to them as "canali" or channels. Though mistranslation they became "canals" and the idea of civilized societies was propagated.

Lowell's firm opinion that the canals were not natural features but the work of "intelligent creatures alike to us in spirit but not in form" contributed to the colorful literature. To pursue his interest in the canals and Mars he founded the Lowell observatory near Flagstaff Arizona, in 1894 and his writings about the canals and possible life on Mars created great public excitement, near the turn of the 20th cenury.

Speculation about intelligent life on Mars continued through the first part of the century but a gradual tendency developed among scientists to be very skeptical of the likelihood. The skepticism was reinforced by the results of Mariner flyby missions, one in 1965 and two in 1969. The limited coverage of only about 10% of the Martian surface by flyby photography, indicated that Mars was a lunar like planet with a uniformly createred surface.

In 1971—72 the Mariner 9 orbiter revealed a completely new and different face of Mars. The 7000 detailed pictures sent by Mariner revealed a dynamic evolving Mars with gigantic volcanoes, a valley that extends a fifth of the way around the planet's circumference, and possible evidence of flowing water sometime in the past.

At the present epoch — in has not always been so — Mars has no seas and so its land area is only a little smaller than that of the earth.

Compared with the earth Mars is a small world, only 4200 miles in diameter with a mass of about one tenth that of the Earth, travelling around the Sun, once every 687 days.

The acceleration due to gravity on its surface is 0.38 that of the earth and its mean density is 3940 kg/m^3 which is nearer that of the Moon that of the Earth. Nothing is yet known about the internal constitution of the Martian globe but, a molten core must be expected.

Since Mars has an escape velocity of 3 miles per second it has only been able to retain a relatively thin atmospehere. Current estimate,s put the atmospheric pressure at only a hundredth of the Earth's. The atmosphere can be analysed spectroscopically from the earth and various sorts of clouds can be seen.

The Martian clouds fall into three main groups: Highlevel (blue clouds), intermediate level (white) and low level (yellow). The blue clouds are so called because they are best seen with a telescope using a blue filter. They seem to lie at heights of the order of 50 miles but this is by no means certain. Their nature is uncertain; ice crystals were suggested at one time but this now seems highly unlikely: The white clouds now seem to lie at heights between 5 and 15 miles. There is more justification for suggesting that these clouds are fine ice crystals. Perhaps they are similar to some of our own clouds which on Earth are usually forerunners of bad weather. Similar too is a whitish haze sometimes seen along the line of the Martian sunrise. It is tempting to compare this to terrestrial morning mist, but it is doubtful if there is enough water vapour on Mars to cause anything like a normal mist.

More prominent, and often obscuring large areas of the planet are the yellow clouds. There are low level phenomena, almost certainly due to dust storms, material being blown up from the deserts.

The Martian polar caps are a source of great interest and show considerable variations throughout the planet's seasons. The seasons on Mars are similar in nature to those of the Earth but they differ from our own only in that hey are more extreme and about twice as long.

During the northern winter (Southern Summer) the north polar cap grows in extent and the south polar cap shrinks, sometimes vanishing altogether. In the northern summer the situation is reversed and the southern cap often expands to 3000 miles in diameter.

In spring as a cap begins to decline a dark "collar" usually forms around it and later a wave of darkening spreads over the dark areas spreading towards the equator. The marking becomes more distinct and more colour appears. Whether the dark areas are due to hyrroscopic salts or to vegetation this sort of behaviour we would expect if the polar caps were made of ice which melted and evaporated to form water vapour which would then spread over the dark areas. It seems possible that the polar caps of Mars are composed of frosty deposits which are only a few mm thick so that the amount of water locked up in the caps is pretty small. What sort of temperatures prevail on Mars? Since it lies further from the Sun than the Earth does, we would expect it to be colder, but as it possesses an atmosphere, although a thin one, it should not become as cold at night as the Moon. The planet's 24½ hour rotation period also implies that temperatures cannot drop too far or too suddenly. It now seems that the equatorial temperature of Mans can be as high as 25°C, although it drops to below —80°C at night. The climate is thus rather extreme, but not intolerable for forms of life, which do not need a dense atmosphere. Although the Martian atmosphere is rarefied by our standards — roughly equivalent to our atmosphere at an altitude of about thirty miles — it is still sufficient to stop most meteors and reduce harmful radiations.

Ever since astronomers began to study its surface in detail Mars has been considered the one planet (apart from the Earth) in the solar system in which life, possibly similar to our own, might exist. It was suggested that Mars might be the home of intelligent beings, possibly far more advanced than ourselves and such stories as the "War of the Worlds" by H. G. Wells helped to arouse public interest in the matter. For life as we know it to exist on Mars the planet would have to have an atmosphere whose density was not to greatly different from our own. Another essential is an adequate supply of free oxygen, the gas essential for human and animal life, and water. Mars has a very thin atmosphere mostly carbon dioxide, with only 0.1 per cent oxygen and very little water vapour. This, combined with the texperature range rules out any of the advanced plant or animal life we know. Still many terrestrial plants including such unlikely ones as millet and cucumber — thrive in the Martian conditions created in laboratory experiments and Martian plants, of course, would be better adapted to Mars.

The existence of a fauna is much more problematic. Rotifers and tardigrades are tiny creatures that would be capable of withstanding the climatic conditions of Martian environment. Larger animals could spend the cold dark hours in deep hibernation. The real hitch is the low atmospheric oxygen content. It has, however, been suggested that, like some of our bog plants, those of Mars may retain in their bodies the oxygen produced in the photosynthesis of carbohydrates, in which case the Martian animals could obtain the oxygen they need from the plants. Alternatively oxidation may be wholly or partly replaced by anaerobic glycolysis as a source of energy, as in the case of deep diving turtles.

Could any form of life exist on Mars? This may be one of the most important scientific questions of our time. It is also one of the most difficult to answer. Dr. H. N. Horovitz professor of Biology in the California Institute of Technology stated: "The discovery of life in another planet would be one of the momentous events of human history".

This vital question was one of the scientific goals of the Viking missions.

Vikings 1 and 2 were of identical design anl embodied two parts: an orbiter and a lander. The former is an octagonal box 2.4x 3.3 m with 4 solar batter panels extending like wings to a span of 9.7 m. It is a dual-purpose craft weighing 2.325 ton. f. On the one hand, its object was to convey the lander to Mars, launch it for landing, and then relay to Earth the data obtained by it on he surface.

The lander was hexagonal, with four-absorbing legs. It measures 2x3 m. stands about 2 m high and weigh 576 kgf. It had an operational life of 90 days. At atmospheric entry it was protected by a heat resistance shield, later discarded and it landed by a combination of a discardable parachute and retro-rocket action. The lander was an extremely ingenious piece of engineering equiped for atmospheric and surface sampling, meteorological seismic and magnetic observations as well as for three biological experiments. Each lander had 2 TV cameras of novel design for black and white and colour images. These scanned the surroundings over a full circle slowly, a narrow strip at a time by means of a small tilting mirror.

Power was produced by solar panels which open up after injection towards Mars, spanning more than 10 m tip to tip. Batteries were used when the panels are shaded from the Sun or when peak power was demanded. In turnthe batteries were charged by the solar panels. Small altitude control jets on the ends of the orbiter's four solar panels kept the spacecraft stabilized and oriented. The orbiter furnished electric power to the lander until separation.

The lander had a set of rechargable batteries which were charged during Mars surface operations by two radioisotope thermoelectric generators. The radioisotope generators convert heat produced by the nuclear source into electricity making the landers independent of solar energy. Information concerning flight performance was transmitted to Earth, throughout he flight. An onboard computer controlled all spacecraft operations and supplied commands for trajectory corrections in addition to controlling the orbiter's scientific correcions in addition to controlling the orbiter's scientific equipment while in orbit. At the same time ground controllers were monitoring all phases of the mission via the worldwide tracking facilities.

Communications with Viking were delayed longer and longer as the spacecraft got farther away from Earth. When it reached Mars a one-way message took 20 min. This meant a roundtrip minimum of 40 min for a command from earth to be received by the spacecraft in response to its initial transmission.

In 1975 Viking I and Viking II were lanuched. As they approached the red planet and began to orbit in search of suitable landing sites, the pictures they transmitted back o Earth showed in even greater details the irrefutable evidence of extensive water erosion across the planet's surface. The gigantic volcanoes photographed made those on Earth seem dwarf-like. Olympus Mons, a Martian volcano measuring almost four hundred miles across the base and looming to an incredible height of just over fifteen miles may well be, say NASA scientists, the largest volcano in the entire solar system. In 1976 the two Viking spacecraft made their historic soft landings on Mars. The first colour photographs to be sent back to Earth showed the rust-coloured Martian landscape rocky and desolate, stretched out beneath a pink sky.

One of the Viking's main objectives was the search for life. It was understood however that the failure to discover life processes migh merely be an indication of having made incorrect assumptions about the nature of the life processes. NASA scientists knew that whatever life might exist there would almost certainly be microbial.

Since it was obvious that no

living organism could survive the intensive bombardment of ultra-violet radiation on the surface, the explorers took soil samples from under small rocks. Portions of these samples were distributed to separate chambers to be subjected to three biological experiments. One test was based on the premise of life being sustained through a process known as photosynthesis.

On Earth photosynthesis occurs when green plants, using the Sun as a source of energy, consume carbon dioxide and by combining it with water and salts, form the organic compounds of which they are made. In the Viking experiment carbon dioxide that had been labelled with radioactive carbon-14 was substituted for part of the natural atmospheric gas in the test chamber and the chamber illuminated by artifitial light similar to Martian sunlight for a period of time. After a few days the remaining gas was expelled from the chamber and the soil sample heated to liberate any of the radioactively labelled carbon dioxide that it might have assimilated in a photosyntheic process. This liberated gas was then measured. A substantial quantity of labelled gas would indicate that a photosynthetic process had taken place which would be strong evidence of the presence of living plant-like organisms. The second experiment, known as the metabolic analysis, was based on the premise of life on Mars being sustained by nourishment from organic materials rather than through photosynthesis.

An analysis, therefore, very similar to the photosynthesis reaction analysis has been planned, which will "feed' organic compounds containing 'radioactively labelled carbon to the soil sample-sugar as an example.

If living organism were in the sample and they could consume the food offered to them, they will discard as waste radioactive carbon gas that can be measured. A sharp rise in the production of such metabolic gasee would be strong evidence that life is present. The third experiment was based on the premise of respiration. As metabolism takes place the composition of the gaseous environment is in a continuous change.

For this analysis which is closely related to the metabolic conversion analysis already described, a soil sample is moisted with nutrients. A sample of the Martian atmosphere was pumped ino the chamber headspace above the sample and monitored. Changes in the composition of the gases would again be evidence of the existence of life as a result of cellular respiration.

Two years after the Viking landings on Mars the question of whether or not its mini analytical laboratory found evidence of life in the Red planet's soil, remains unsettled. It is uncertain if the resuls of tests should be ascribed o genuine biological activity within the Martian soil, to unusual chemical properties of the soil or to a slight inaccuracy in the testing equipment. In the photosynthetic test the quantity of the labelled gas measured suggested that photosynthesis might have taken place, yet control tests in which the sample was heated prior to testing in order to kill off anything that might be living, also indicated a positive though much weaker reaction. In the second test the release of radioactive carbon dioxide was unexpectedly high, but scientists realized that certain peroxides believed to exist in the soil could have caused this to occur, thus making it a chemical rather than a biological reaction.

The same explanation might also be applicable to the gas exchange experiment in which oxygen was released by the sample into the atmosphere at an unexpectedly high rate.

No scientists wants the embarrasment of coming to the wrong conclusion on such an important issue as this. In summarising the results of the 26 tests that were run on all hree biology experiments, Harold P. Klein of the Ames research centre and one of the leading biologists of our time gives a "positive" result to the carbon assimilation data as well as to the labelled release experiment, but concludes that the gas exchange test merely showed some kind of oxidising material on the surface. "On the basis of all the experiments performed to date" Klein said in the comprehensive report of the Viking mission, "the labelled release experiment unlike the other biological experiments, yielded data which met the criteria originally developed for a positive. On this basis alone the conclusion would have to be drawn that metabolising organisms were indeed present in all samples tested. Can we believe such a conclusion? He answered his own question cautiously: "Clearly we must be wavy of this in the face of information indicating that all of he samples tested yielded oxygen in the gas exchange experiment upon the introduction of water. The evidence for strongly oxidising chemicals in these samples is quite convincing. Klein did not believe that the issue was resolved by the sterilisation results nor by varying lengths of incubation. He concluded. "We can't overlook the fact that all our experiments were conducted under conditions that deviated to varying exends from ambient Martian conditions. While we have accumulated data these and their underlying mechanisms may all be coincidental and not directly relevant to the issue of the life on he planet. The question of whether evidence of life or of something else was found on Mars poses a dilemma for the biology team of NASA that may not be resolved short of another go at the planet. As the Viking project scientist, Gerald A. Soffen at NASA headquarters summarised it, "there is one experiment that indicates that the Martian soil either has an agent capable of rapidly recomposing organic chemicals or that life is present. Which? That is the legacy of Viking".

Manual Programming of NC Lathes

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Introduction

In today's modern machining technology, a large number of machine tools are controlled with the aid of advanced electronic equipment, able to direct a machining process if programmed as required.
The program preparation for the machining process, on a numerically controlled machine tool, is one of the main pre-machining procedures which has a great effect on the production efficiency of the machine.

The program includes all the necessary information to direct the movements of the cutting tools, relative to the position of the workpiece, for succeeding the required shape of the machined component. The program should also include other information necessary for machining i.e. switch-on and stop the machine, turn coolant on or off etc.

Preparation of program

It will be considered that the program will be prepared for a lathe with two turrets (tool posts) which can carry six tools each. The one turret is able to move towards and away from the chuck parallel to its centre axis and for coding purposes this is called W direction and the other can move towards and away from the chuck, X direction, as well as perpendicular to the control axis of the chuck, Z direction. Fig. 1 shows the three directions of movement.

Turret 1 can carry centre drills, drills, taps and other cutting tools which can cut by moving only in the W direction.
Turret 2 can carry the common lathe cutting tools, right hand, left hand, parting off, thread chasing tools, etc., and can move either in the X or Z direction or in both directions simultaneously.
Planning sheet. The first step in programming is to prepare a planning sheet, where the machining operations are listed in operational sequence and the corresponding turret station, cutting speed, spindle speed, feed rate of each operation are listed alongside. If any operations of the two turrets are programmed to be carried out simultaneously, care must be taken to avoid collision of the two turrets. Fig. 2 shows part of a planning sheet.

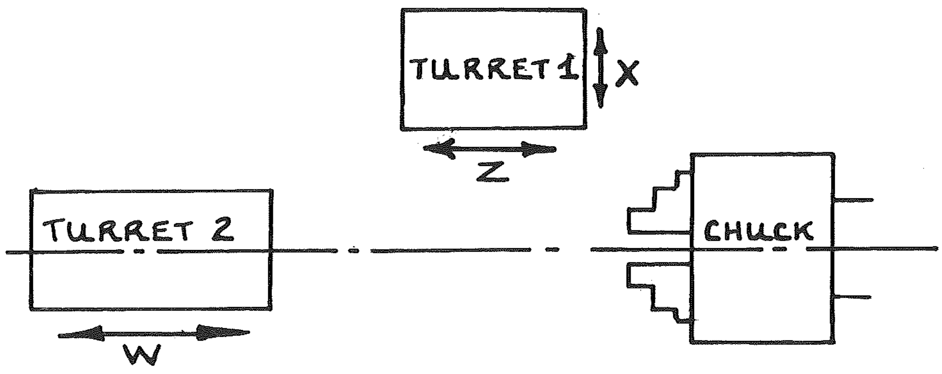

Fig. 1

OPERATION	Turret	Turret Station	Cutting Speed	Spindle speed		Feed rate	
				rev/min	code	mm/rev	code

Fig. 2

Tooling sheet. When the planning sheet has been prepared and the tools to be used are known, turrets 1 and 2 are presented in outline on the tooling sheet and adjacent to each turret face is a numbered circle in which is written the tool-holder numbers and descriptions for that particular station. These same numbers are later coded onto the program to call the appropriate tool for operation at the right moment.

Program data sheet. The information for this sheet is derived from the planning and tooling sheets and provides a complete record of all the information required to control the machine. The left hand section contains the information to be punched on the tape and the right hand section the cumulative times and time differences to enable simultaneous motions to be programmed (fig. 4). When the program data sheet has been finalized, the left hand section information is transferred to the paper tape by means of a typewriter fitted with a tape punch.

The movements of the cutting tools may be done either on an Absolute data basis or an incremental data basis. In Absolute data, the dimension is always the distance from the component datum to the point that the tool tip is to reach irrespective of the distance travelled. In incremental data, the dimension is always the actual distance travelled from one point to another.

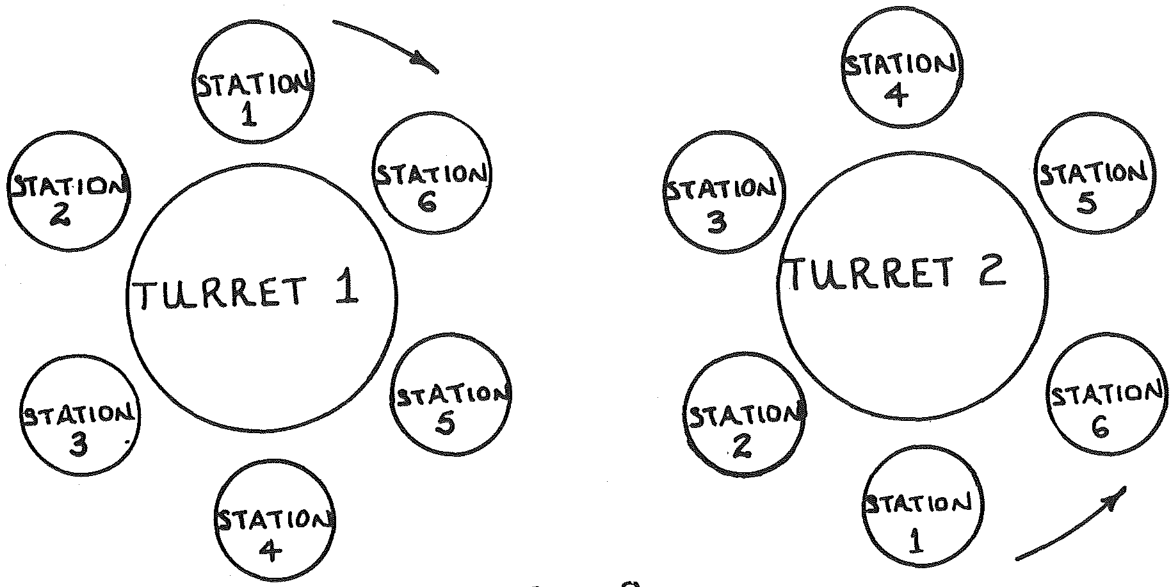

Fig. 3

SEQ. NO.	PREP. FUNC.	DIM. X	DIM. Z	DIM. W	FEED RATE F	SP. SPD S	TOOL FUNC. T	MISC. FUNC. M	OPERATION	TIME

Fig.4

N : Block number

G : Preparatory instructions to control unit

X : Movement of tool in X axis

Z : Movement of tool in Z axis

W : Movement of tool in W axis

F : Feedrate

S : Spindle speed

T : Turret face for tool selection

M : Miscellaneous functions i.e. spindle clockwise, coolant on, start program etc.

Example

For full appreciation of programming, a program will be prepared for a simple component shown in fig. 5. The movement of some of the cutting tools are also shown in the same figure.

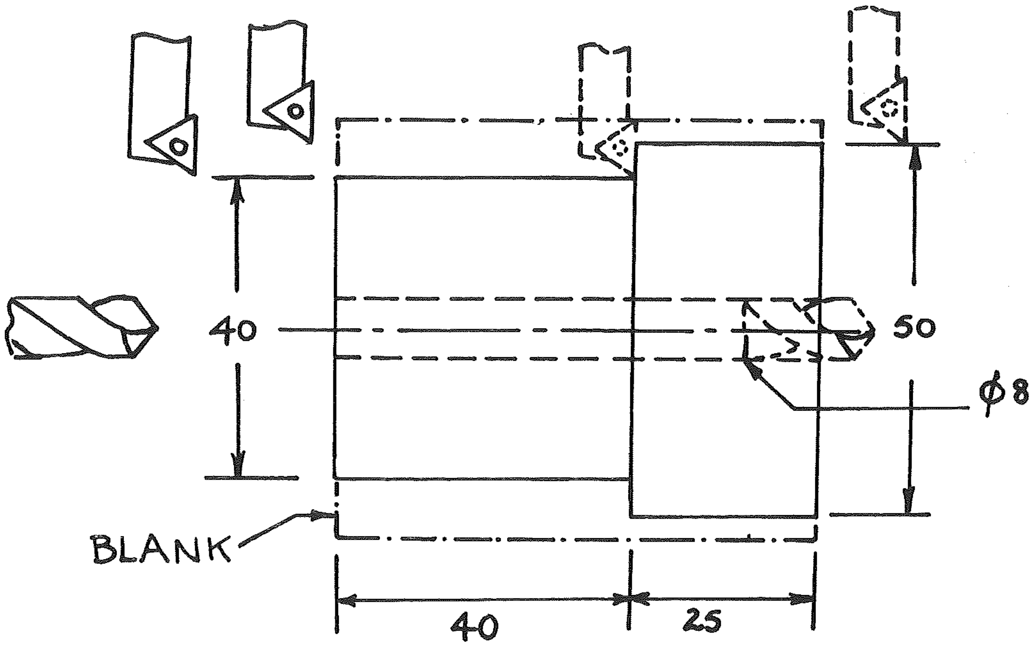

Fig. 5

Planning sheet

OPERATION	TURRET STATION	TOOL NO.	SPINDLE SPEED		FEED RATE		CUTTING TIME min
			RPM	CODE	mm/rev	CODE	
BAR STOP	1,1	1	7				
TURN 50mm dia	2,1	1	700	S11	0.15	F015	0.24
TURN 40mm dia	2,1	1	750	S12	0.15	F015	0.36
CENTRE DRILL	1,2	2	700	S11	0.1	F01	0.07
DRILL 8mm dia	1,3	3	500	S9	0.1	F01	1.34
PART OFF	2,2	2	500	S9	0.05	F005	1.00

The tools to be used are:

Turret 1

Position 1, tool to stop stock bar

Position 2, centre drill

Position 3, Φ8mm drill

Turret 2

Position 1, R.H. Cutting tool

Position 2, Parting-off tool

Program data sheet

SEQ. NO.	PREP. FUNC.	DIM. X	DIM. Z	DIM. W	FEED RATE F	SP. SPD S	TOOL FUNC. T	MISC. FUNC. M	OPERATION	TIME
N001	G92	X0	Z04	W04				M84	Set comp.datum	
N002	G90	X035	Z066		F0				starting pos.	
N003	G01			W065	F0	S11	T11	M03	Bar feed	
N004				W1	F0		T12	M80	Turret 1 back	
N005		X025	Z066		F0		T21		Turret 2 in pos	
N006			Z-008		F015				Turn 50mm dia	
N007			Z066		F0				Turret 2 return	
N008		X020			F0	S12			Turret 2 in pos	
N009			Z025		F015				Turn 40mm dia	
N010		X026			F0				Turret 2 return	
N011			Z-003		F0		T22		Cutting off tool	
N012				W066	F0	S11			Centre dr.appr.	
N013				W06	F01				Centre drilling	
N014				W1	F0	S9	T23		Drill in pos.	
N015				W066	F0				Drill approach	
N016				W-01	F01				Drilling	
N017				W1	F0				Drill return	
N018		X002			F005				Parting-off	
N019		X035			F0				Turret 2 to	
N020			Z066		F0				starting pos.	
N021									End of Program	

Times for each operation are not included as simultaneous movements of turret 1 and turret 2 are not included in this program.

Tape

The information given on the program data sheet, will be punched in a coded form onto a tape in exactly the same sequence as it is on the program sheet, not including the description of operation and the time for each operation. This tape is later placed on the tape reader of the control unit of the NC machine, which will in turn control the movements of the cutting tools to achieve the required form of component.

Modern Methods ot Structural Analysis

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INTRODUCTION

The objective of structural design is to specify an assemblage of load carrying members so that under the maximum loading condition the stresses and deformations induced in the structure shall remain within specified limits. A structurally safe design is by no means the optimum one. A number of constraints must also be satisfied, such as minimum weight — critical in aerospace vehicles where the maximum payload must be achieved, minimum cost and fabrication techniques.

In practice, the design engineer will have to satisfy these constraints, and others, before arriving at several candidate design configurations. For example, given the task of designing a bridge, a civil engineer may arrive at a suspension bridge and an arch bridge, fig. 1, as the most suitable designs for his particular job. He must then subject these configuraions to analysis to determine their structural integrity and hence decide on the best performer.

Today's typical structures, ranging from supersonic aircraft to nuclear reactor vessels, are of such complexity that a complete analysis is beyond the reach of the slide rule methods of the pre-computer days. Mathematical analysis is only possible for very special geometries and loading conditions. In general, difficulties arise not only due to the complex geometry of a structure, but also due to the complex variation of loading which the structure may carry. The most common types of load are body loads due to the weight of the structure, pressure loads due to hydrostatic or wind variations over the structure, and temperature loads caused in structural members subjected to a change in temperature and restricted in deformation. Other types of loads are centrifugal loads, which arise in rotating structure, concentrated or point loads applied at particular points, and distributed loads applied over particular lengths of a structure. The above types of load may act in any combination and in any arbitrary way over a structure, rendering mathematical solution impossible. An added complication arises sometimes when the materials used have anisotropic properties, as for example in fiber reinforced plastics which are found in an increasingly wider range of applications.

There are usually two types of analysis that a structure must be subjected to. The first is a static analysis to ensure that the applied loads are carried safely by the structural members when the structure is motionless. Secondly, it is essential in some cases to investigate the vibration characteristics of a structure, such as a tall chimney subjected to a variable wind pressure load, or an aircraft flying in turbulent air, fig. 2. A vibration analysis is essential in determining the resonance frequencies of the structure and the deformed shape at these frequencies. From the latter the stress distribution in the structure may be obtained for each of the deformed shapes.

Other types of more specialized analysis may sometimes be required, such as an analysis for investigating the effect of a crack in the stress distribution of a structure, or an elastoplastic analysis if the stress in some of the structural components is expected to be above the yield stress, or finally when the deformations in the structure are so large that the geometry changes significantly in carrying specified loads.

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THE NEED FOR COMPUTER ORIENTED ANALYSIS

In the chart of fig. 3 are given the basic methods available to the structural engineer. The analytical methods find their roots in strength of materials and theory of elasticity, and are usually restricted to the solution of relatively simple problems. The truss and the cable of fig. 4a involve only tensile or compressive stresses and are solved by simple equilibrium techniques [1, 2]. Beams, frames and arches, fig. 4b, are somewhat more involved because they involve bending and shear stresses as well as axial stresses, but in general the Engineer's Theory of Bending approach will give acceptably accurate solutions [1, 2]. Methods of solution based on Energy Principles are also used extensively in the analysis of these types of problem [3].

Moving onto two-dimensional elasticity problems, the mathematical elasticity equations may be reduced to an equation of the form

$$\nabla^4 F = 0 \qquad \ldots (1)$$

where F is a sress function the stresses are defined by $\nabla = \partial^2/\partial x^2 + \partial^2/\partial y^2$ and

$$\sigma_{xx} = \partial^2 F/\partial y^2$$
$$\sigma_{yy} = \partial^2 F/\partial x^2$$
$$\sigma_{xy} = -\partial^2 F/\partial x \partial y$$

Solution of equation (1) is possible through advanced mathematical techniques [4], but only if the stresses can be defined mahematically at the boundary. The solution for the stress distribution around an elliptical hole in a stressed panel, fig. 4c, is one classical example.

In dealing with loaded plates, fig. 4d, the classical theory of plates [5] yields an equation of the form

$$\nabla^4 w = p/D \qquad \ldots (2)$$

where ω is a lateral deflection of the plate, p is the pressure loading and D depends on the material and geometry of the plate. The moments and shear resultants at any point are given by

$$M_{xx} = D(\partial^2 w/\partial x^2 + \nu\, \partial^2 w/\partial y^2)$$
$$M_{yy} = D(\partial^2 w/\partial y^2 + \nu\, \partial^2 w/\partial x^2)$$
$$M_{xy} = D(1-\nu)\, \partial^2 w/\partial x \partial y$$
$$S_x = D\, \partial/\partial x \{\partial^2 w/\partial x^2 + \partial^2 w/\partial y^2\}$$
$$S_y = D\, \partial/\partial y \{\partial^2 w/\partial x^2 + \partial^2 w/\partial y^2\}$$

where v is Poisson's ratio, so that a solution of (2) will enable us to determine the moments and shears at a point, and hence the stresses which are assumed to vary linearly through the thickness of the plate. Here again, solution is difficult if the boundary conditions for w and moments are difficult to express mathematically.

In recent years shell structures have become increasingly popular due to structural, aesthetic and economy reasons The pressurized vessel and the cooling tower of fig. 4e are two typical examples of a shell structure. The mathematical analysis of such structures is very complicated due to the existence of direct stresses, shears and bending stresses at any point. Solutions can be obtained only for very special problems, like shallow shells and axisymmetric shell structures, fig. 4f.

In conclusion to the above background for analytical methods, the following points may be made: (1) they very rarely fit real structures in geometry, loading conditions and boundary conditions, (2) they can only be used by engineers specially trained in these mathematical solutions, and (3) they are often cumbersome to use and arrive at a working solution to a problem.

However, it must always be remembered that analytical methods are extremely useful in other ways; for example, a structural engineer may, with the above background, arrive at an overall first approximation to the solution of his problem by careful and imaginative use of such mahematical tools. Also, mathematical solutions may be compared to the experimental results for a particular classical solution and hence confirm that the fundamental assumptions made in the solution, e.g. linear variations of stresses through the thickness of thin plates, are correct. The above apply also to the problems of dynamic response of structures. Here the problem is to solve equations of the form

$$m\,d^2y/dt^2 + c\,dy/dt + ky = R(t)$$

where m is mass, c is a viscous damping coefficient, k is a stiffness coefficient, t is time and R is a forcing function. Clearly, the types of problem that may be solved must be simple in nature, and inevitably their solution is not readily applicable to real structures. Nevertheless, in the analysis of vibration response of a simple beam, fig. 5, certain mathematical assumptions must be made about the damping of the motion [6]. Experimental verification of these assumptions is of major importance in the formulation of mathematical models for the solution of vibration for more complex structures.

With the advent of the digital computer in the last two decades as a very powerful tool for performing simple arithmetic operations in very small fractions of a second, it was inevitable that techniques for the numerical solution of the classical structural problem would have been developed. Equations of the type shown by (1) and (2) may be integrated numerically by instructing the computer to perform the necessary numerical integration, which usually consists of simple arithmetic steps. However, the difficulty still remains of finding real problems whose characteristics are consistent with those of the equations, their loading and boundary conditions.

The Finite Difference method may be illustrated by its application to the problem expressed by equation (1). In this method a physical grid is superposed on the structure and the grid points are numbered, fig. 6. If the equation expressing the problem contains terms such as $\partial^4 F/\partial x^4$ say, then approximately for point 3,

$$\partial F/\partial x \approx (F_4 - F_3)/\delta$$

where δ is the distance between grid points; by a similar approximation

$$\partial^2 F/\partial x^2 \approx (F_4 - 2F_3 + F_2)/\delta^2 \qquad \ldots(3)$$

Similarly it can be shown that

$$\partial^4 F/\partial x^4 \approx (6F_3 - 4F_4 - 4F_2 + F_5 + F_1)/\delta^4$$

Clearly then, if we write one equation involving values of F at each grid point, we shall end with a set of linear equations to solve for F. These equations may be written in matrix form

$$\mathbf{HF} = \mathbf{0} \qquad \ldots(4)$$

where **H** is a matrix of coefficients and is (n x n), where n is the number of grid points, and **F** is an (n x 1) vector of the unknown F values.

Equation (4) may be solved for the unknown **F** taking the boundary conditions into consideration. With a knowledge of the F values at each grid point it is easy to calculate the stresses at each grid point by using equation (3) for σ_{yy} and similar expressions for σ_{xx} and σ_{xy}. It is not difficult to write a computer program to perform the above arithmetic operations, and a number of these are to be found mainly at academic institutions around the world.

The above numerical method failed to find a wide use due to a number of important reasons: (1) for real structures of arbitrary boundary geometry it is difficult to define the boundary conditions, (2) the method assumes δ the same between all grid points, but this assumption necessarily fails near an irregular boundary, and (3) engineers do not have a physical meaning of the values for F at each grid point or in other words the method is too mathematical for the non-specialist engineer who is faced with a particular structural problem.

It is quite evident from the aforesaid that any new method for structural analysis had to satisfy the following criteria. (1) to be numerical in nature so that use of the computer could be made, (2) to be able to deal with any type of structural problem with arbitrary geometry, loading and boundary conditions, (3) to be easy to use by the non-specialist engineer, (4) to give meaningful physical quantities as a solution to a problem, and (5) to be problem independent, i.e. not to depend on any mathematical expression specifying a special type of structural problem.

THE FINITE ELEMENT METHOD OF ANALYSIS

The Finite Element method (F.E.M.) of analysis satisfies to a large extent the criteria set out in the last paragraph of the previous section. The F.E.M. originated in the aircraft industry, but because of its generality it is now a standard analytical tool in many fields, such as ship and marine engineering, nuclear engineering and civil and structural engineering. The two principal methods are the Matrix Displacement Method as proposed by Argyris [7] and the Matrix Force Method as proposed by Argyris [7] and Denke [8]. Since these early papers, a vast amount of research work has been invested in the development of the F.E.M. and its extension to a great variety of fields, such as Fluid Mechanics and Heat Transfer [9].

The F.E.M. finds its widest application in structural analysis. A background to the Displacement Method is given below by reference to the simplest possible type of finite element, but it must be emphasized that the basic principles illustrated below apply also to the most complex type of finite element. Consider a one-dimensional structural problem, as shown in fig. 7a, where a bar is held at one end and loaded by a force P at the other. Imagine the structure to be subdivided into a number of finite (discrete) elements (three are shown in fig. 7b), the points at which they meet being known as 'nodes'. This model of finite elements is known as an 'idealized model' of the structure, and the object of the exercise is to solve for the displacements and stresses at each of the nodes. Obviously a knowledge of the stress at only a few points on the structure implies that we have to interpolate between these values to get the complete stress distribution. However, it is easy to see that the more elements we have, the closer become the nodes and so the better the interpolation.

Let us now formulate a finite element which can carry an axial stress . By reference to fig. 7c, the element will have displacements u_1 and u_2 at its nodes, and there will be axial forces P_1 and P_2 associated with these displacements. As there, are two nodes, only a linear variation of displacement within the element can be defined as follows

$$u = \tfrac{1}{2}(1-\xi)u_1 + \tfrac{1}{2}(1+\xi)u_2$$

where ξ has values of —1 and +1 at nodes 1 and 2 respectively. In matrix algebra

$$\boldsymbol{e} = \boldsymbol{N}\boldsymbol{e}_e \qquad \ldots(5)$$

where

$$\boldsymbol{e} = u$$
$$\boldsymbol{N} = [(1-\xi)/2 \;,\; (1+\xi)/2]$$
$$\boldsymbol{e}_e = \{u_1 \;,\; u_2\}^t$$

The strain within the element is

$$\varepsilon_x = \partial u/\partial x = \partial/\partial x\{\boldsymbol{e}\} \qquad \ldots(6)$$

and by equation (5) into (6) gives

$$\varepsilon_x = \partial \boldsymbol{N}/\partial x \cdot \boldsymbol{e}_e$$
$$\varepsilon_x = \boldsymbol{B}\boldsymbol{e}_e \qquad \ldots(7)$$

where **B** is the differentiated matrix $\partial N/\partial x$. Note that we can also describe the position of the element on the x axis by writing

$$x = \tfrac{1}{2}(1-\xi)x_1 + \tfrac{1}{2}(1+\xi)x_2 \qquad \ldots(8)$$

where x_1 and x_2 are the co-ordinates of nodes 1 and 2 and consequently the matrix **B** can be obtained from

$$\partial \boldsymbol{N}/\partial \xi = \partial \boldsymbol{N}/\partial x \,.\, \partial x/\partial \xi$$

where the $\partial x/\partial \xi$ term can be calculated from (8). The stress within the element can be related to the strain by

$$\sigma_x = \boldsymbol{K}\varepsilon_x$$
$$\sigma_x = \boldsymbol{K}\boldsymbol{B}\boldsymbol{e}_e \qquad \ldots(9)$$

where

$$\boldsymbol{K} = E$$

and E is the Young's modulus for the material. From energy considerations, the work done by forces P_1 and P_2 moving over their displacements u_1 and u_2 must be equal to the elastic energy stored in the element. Hence,

$$\boldsymbol{e}_e^t \boldsymbol{P}_e = \int_V \sigma_x^t \varepsilon_x \, dV \qquad \ldots(10)$$

where $\int_V$ denotes integration over volume and

$$\boldsymbol{P}_e = \{P_1 \;,\; P_2\}^t$$

is the 'nodal force vector' for the element. Substituting from above into (10) it is easily shown that

$$\boldsymbol{P}_e = \boldsymbol{K}_e \boldsymbol{e}_e \qquad \ldots(11)$$

where

$$\boldsymbol{K}_e = \int_V \boldsymbol{B}^t \boldsymbol{K} \boldsymbol{B} \, dV \qquad \ldots(12)$$

is the 'stiffness matrix' for the element. The element stiffness matrix $\boldsymbol{K}_e$ may be written down explicitly for simple elements, but in general the integration involved may be carried out numerically to a high degree of accuracy by numerical techniques. For the above element it is easy to see that

$$\boldsymbol{K}_e = \begin{bmatrix} EA/\ell & -EA/\ell \\ -EA/\ell & EA/\ell \end{bmatrix} \qquad \ldots(13)$$

where ℓ is length and A area of the element, and we could have written this immediately by engineering insight, or by performing the integration of equation (12) either by hand or numerically.

Having established the stiffness matrix for the finite element, we must now formulate its force vector $\boldsymbol{P}_e$. The simplest type of loading is a concentrated load at the nodes of the element. For example, element 3 of fig. 7b has a load P_o at its second node and no load at its first node. Its vector $\boldsymbol{P}_e$ will then be

$$\boldsymbol{P}_e = \{0 \;,\; P_o\}^t$$

However, real structures do not often have concentrated loads. More usually loads are distributed in an arbitrary way over the structure. Further, temperature loads may exist if the temperature of the structure is to change in an arbitrary way. So-called 'equivalent nodal loads' can, however, be formulated for an element, by specifying the nodal values of the load involved. For example, if the two-noded element above is to be loaded by a distributed axial force, fig. 8a, along its length, then by specifying the values at the nodes an interpolation can be made for any point inside the element of the form

$$p = \boldsymbol{N}\boldsymbol{p}_e$$

where $\boldsymbol{p}_e$ is the vector of values at the nodes. Since the work done by equivalent loads at the nodes must be the same as the total work done by the load acting between the nodes, then

$$\boldsymbol{e}_e^t \boldsymbol{P}_e = \int_0^\ell \boldsymbol{e}^t p \, dx$$

or

$$\boldsymbol{P}_e = \int_0^\ell \boldsymbol{N}^t \boldsymbol{N} \, p \, dx \qquad \ldots(14)$$

For the example of fig. 8a, assuming a constant p per unit length, then

$$\boldsymbol{P}_e = \{p\ell/2 \;,\; p\ell/2\}^t$$

and again this may have been written down explicitly, or a numerical integration of equation (14) could have been carried out to give the same result. It may also be shown that the equivalent load vector for temperature is given by

$$\boldsymbol{P}_e = \int_V \boldsymbol{B}^t \boldsymbol{K} \varepsilon_o \, dV \qquad \ldots(15)$$

where ε_o is a vector of strains that would be produced at the nodes by the temperatures. For the example of fig. 8b, if the temperature change within the element has a constant value of T, then the equivalent load vector would have been

$$\boldsymbol{P}_e = \{-EA\alpha T \;,\; EA\alpha T\}^t$$

where α is the coefficient of thermal expansion for the material. The equivalent load vector for a finite element then, is essentially the lumping of internal loads onto the nodes. If several load types act at the same time, the separate equivalent load vectors may be summed into a total load vector for the element. Returning now to the complete structure of fig. 7b, the individual elements will interact at the common nodes through their common displacement terms. The stiffness and load terms may therefore be combined into a set of linear equations for the complete structure,

$$\boldsymbol{K}\boldsymbol{e} = \boldsymbol{P} \qquad \ldots(16)$$

where **r** is the vector of the unknown displacements u_7 and u_{14}, and **K**, **P** are the stiffness matrix and the load vector for the structure respectively. The matrix **K** is symmetric and is (n x n), where n is the number of displacements, in the structure. The solution of equation (16), for the unknown displacements is often performed by the Choleski decomposition method taking into account the physically known displacements, as for example displacement at node 1 of fig. 7b being known to be zero.

After solving for the vector **r** the displacements corresponding to a particular element may be picked out of the vector. For example, displacements u_2 and u_3 correspond to the matrix $\mathbf{\varrho}_e$ for element 2 of the structure. From equation (9) then, the stress σ_x may be evaluated simply by carrying out the matrix multiplications involved, i.e. :

$$\sigma_x = \mathbf{K}\mathbf{B}\mathbf{\varrho}_e$$

Note that for the present example the stress σ_x is constant in the element and consequently the stress at the two nodes is the same. For constant stress problems then the element of fig. 7c may be used to give accurate results. However, suppose that we have a linear stress problem on our hands, as shown in fig. 9a. The above finite element does not have linear terms in its formulation, but nevertheless we could still use it to solve this problem. Simply increase the number of elements, fig. 9b, so as to give us a solution of the form shown in fig. 9c. It would be more efficient on the other hand, to use a finite element which includes linear stress variation terms in its formulation. One such element is shown in fig. 9d, where now the element has three nodes so that the displacement variation may be quadratic, and hence the stress and strain variation will have constant and linear terms. The formulation of such an element will follow the principles outlined above, and in the solution of the problem of fig. 9a only a few of these elements will be required to yield the correct solution.

The Force Method of analysis is the reverse of the Displacement Method in that it works with stresses as nodal parameters and interpolates within the element. For a force based finite element

$$\boldsymbol{\sigma} = \mathbf{N}\boldsymbol{\sigma}_e$$

where **P** are the nodal forces or stresses, σ are the stresses within the element, and **N** is a matrix of polynomial functions. The analysis is essentially the same as for a displacement finite element, but the equivalent equation to (16) is

$$\mathbf{F}\mathbf{P} = \mathbf{\varrho}$$

where **F** is a flexibility matrix and **P** are the unknown nodal forces or stresses. This method is not used often, however, because of the difficulty in determining the known values of **P** i.e. in finding the force redundancies in the structure to make it statically determinate so that **F** will become positive definite. Nevertheless, force based finite elements are used in some displacement finite element systems, but the element flexibility matrix is inverted to produce a stiffness matrix so that equation (16) may be used.

In the same way that an element stiffness matrix was formulated above, in a dynamic response analysis a 'mass' matrix must also be formulated for an element. This may be achieved by lumping the mass onto the nodes in such a way that the kinetic energy of the lumped masses is the same as the kinetic energy for the finite element. It may be shown that

$$\mathbf{m}_e = \int_V \mathbf{N}^t \mathbf{a} \mathbf{N}\, dV$$

where $\mathbf{m}_e$ is an element mass matrix and a is a matrix of density for the element. In combining all the elements results in the following equation for the solution of the vibration for the complete structure

$$\mathbf{M}\ddot{\mathbf{\varrho}} + \mathbf{C}\dot{\mathbf{\varrho}} + \mathbf{K}\mathbf{\varrho} = \mathbf{R}(t)$$

where **M**, **C** and **R** are mass, damping and forcing function matrices and denotes differentiation with restion with respect to time.

The F.E.M. is a very numerical method of analysis as it involves a vast amount of matrix operations to set up stiffness, load and mass matrices, numerical integration steps, matrix combinations, in setting up matrices **K** and **M** for example, numerical solution of linear equations and so on. Its attractiveness lies in the fact that all the numerical operations involved can be broken down into simple arithmetical operations which the computer can handle at very fast times.

FINITE ELEMENT SYSTEMS AND THEIR USE

In the above section, the principles of the finite element method were outlined with reference to the simplest possible type of element. that of constant axial stress. An immediate extension of this is to formulate the element in three dimensions, fig. 10a; all that is required is to introduce some transformaion matrices for the nodal displacements, so as to convert the displacements U, V, W at a node to an axial component, so that the stiffness and load marices for the element will now refer to these displacements. Such a three dimensional, constant axial stress finite element, finds an immediate application in the solution of three dimensional frame structures, as shown in fig. 10b.

It should be evident at this point that the F.E.M. is a very computer oriented method of analysis. The computer may be programmed to carry out the vast number of matrix multiplications involved in the formation of the element stiffness and load vector matrices, also to solve the usually large number of simulaneous equations of equation (16). Finite element systems are very large computer programs which have at their heart a 'family' of different types of finite elements to deal with all types of engineering structures. A good family of elements must include 'beam' elements, 'membrane' elements, 'solid' elements, 'plate' elements, 'shell' elements and so on. The displacements at each node will depend on the type of stresses described internally by the element, for example the plate element must have rotational displacements at each node to describe the variation of moments internally. In fig. 11 are shown the different types of elements with their internal stresses. Note that the variation of stresses internally will depend on the number of nodes on an element and that although not shown here there are triangular elements as well as the quadrilateral elements shown. Each of these types of element will be designed to carry loads of the type required in engineering analysis. For example the beams will carry distributed loads the shells pressure loads, body loads, temperature loads and so on. The variation of these loads within an element will again depend on the number of nodes on the element, so for example the eight noded shell element of fig. 11f can describe a quadratic variation of pressure within it if the values at the nodes are given.

There are a number of internationally acknowledged finite element systems such as the British ASAS (Atkins Stress Analysis System), the German ASKA (Automatic System for Kinematic Analysis), and the American NASTRAN (NASA Structural Analysis). The specific details behind the design of each of these computer programs differ to some extent (especially so in the extent of using the computer efficiently), but a general outline of the sequence of computer instructions is shown in fig. 12. The user of the program prepares the input data on computer cards (or on some input medium such as a disc file) in a prescribed format. The computer then reads this input data and checks it for geometric and structural consistency. It then generates the stiffness and load matrices for each element in the structure, and combines these to form stiffness and load matrices for the complete structure. A solution for the unknown displacements is then performed and the stresses for each element are calculated using this solution. Finally the stresses of each element are either printed out or presented graphically for the engineer to use in his design.

The use of such a program will be illustrated by reference to a simple shell structure, fig. 13. This is reinforced by beam members along the curved edges and carries, as an example, a variable pressure load. The user must prepare his input data to supply the following information:

(i) X, Y, Z, coordinates of each node,
(ii) node numbers connected to each element,
(iii) nodal thicknesses of shell elements, and moments of inertia and areas of beam elements,
(iv) material properties e.g. Young's moduli, Poisson's ratios, shear moduli etc.,
(v) the values of known displacements, for example displacements, are zero at nodes 1 to 5 in fig. 13,
(vi) the load values at the nodes e.g. pressure values at nodes.

Often the preparation of this data is straightforward and is not carried out by the engineer, but by non-engineer assistants whose job is not the analysis of the engineering results, but purely the preparation of such data.

The engineer does not have to know how the program will function, but he must be able to interpret the output results which are usually self-evident. For the present problem the results will be shell stresses for each of the shells and beam stresses for each of the beams. Also available will be the displacements at every node so that deflection curves may be contructed to show how the structure will deflect.

The user must also be aware that he must use the correct elements for his particular problem. In the above example shell elements and not membrane elements must be used, because the problem is of shell tvpe, i.e. all the shell stresses are expected to be important. Also the stiffeners of the structure must be curved beams and not flange elements, again because the stresses expected in these stiffeners will not be just axial stresses, but moments and shears as well. The example of fig. 13 has also highlighted the important fact that elements of different type, e.g. shells and beams, may be used in the idealisation of a structure to model the physical problem. Also, the fact that if the boundary shape is curved, then an element with curved sides must be used (two nodes on a side will only represent a straight side) and finally the fact that if the load inside the element is variable, then a better approximation will be represented by an element which has a higher order interpolation.

It should be evident at this point that the F.E.M. can cope with virtually all engineering structures. The question arises as to how many elements the engineer has to use in a particular job. The answer is that the number depends on the job, but in the author's experience most large engineering structures may be modelled using anything between 500—2000 elements to obtain an accurate structural analysis. The engineer is often aware of which parts of his structure are expected to have rapidly varying stresses so that he must use more elements in these regions so as to model more accurately the stress variation; similarly, he may use less elements in regions where the stresses are expected to change slowly. Also, depending on the boundary shape, the engineer may have to use more elements near a boundary whose shape is changing rapidly, so that this shape is modelled more accurately. Finally, in regions of rapid variation in loading, more elements have to be used to model better the load variation. In the limit, of course, when a very large number of elements is used the solution is very close to the exact solution. However, engineers will accept anything up to 5% error in their solution (the use of safety factors is one reason for doing so) so that a great number of elements is never required.

The finite element systems cited above have reached a point where they can deal with most problems in structural analysis, ranging from static analyses to crack failure analyses. The emphasis nowadays is to help the user to cut down on costs related to preparing his data and interpreting his results. So-called pre-processors are specially written programs that will prepare the idealisation of particular types of structure (or parts of structure) automatically (indeed the user himself may write such programs for his own use). Also so-called post-processors are specially written programs that use the solution results (stresses or displacements) to present them in a way that the user can grasp the significance and variation of the results in an efficient manner.

Until a few years ago the F.E.M. was used almost exclusively in the aerospace industry to ensure the structural integrity of complete aircraft, helicopters, satellites, as well as for parts of these structures. Having proven its usefulness, in the more recent years it has found a vast range of applications in the rest of the engineering disciplines. In civil engineering it has been used successfully in the analysis of bridges of all types, soil mechanics and building construction. In mechanical engineering for car-chassis analysis, engine block characteristics and rotary machinery, such as turbine blades. In nuclear engineering in the analysis of nuclear reactor vessels. In marine engineering for ships, supertankers, deep-sea-going vessels and more recently in the new technology of off-shore-drilling platforms.

Certainly one of the reasons for the success of the F.E.M. is that in recent years computer technology has progressed to such an extent as to make access to computing facilities easy for most engineering firms. Even though its ease of use and reliability has been demonstrated there is still a large proportion of engineers who are either still in doubt about the F.E.M. or have never heard of this new tool for analysis. The author is convinced that the situation will change drastically within the next decade due to the fact that in recent years most of the younger engineers come into contact with the F.E.M. during their training, and also due to the decreasing availability of materials which will make the use or F.E.M. essential so as to achieve an optimum design.

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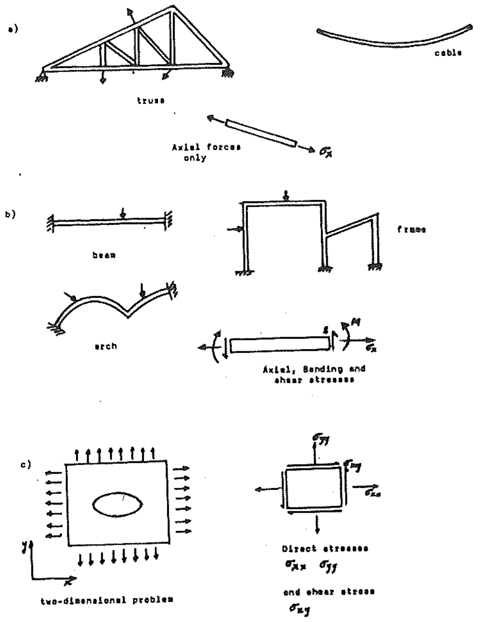

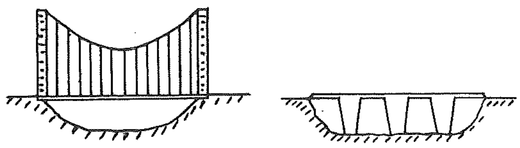

Fig. 1. A suspension and an arch bridge

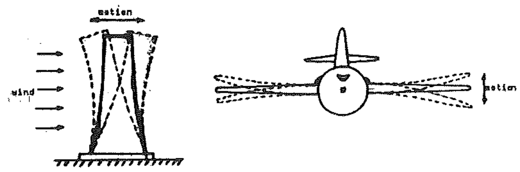

Fig. 2. One mode of vibration for a chimney and the wings on an aircraft

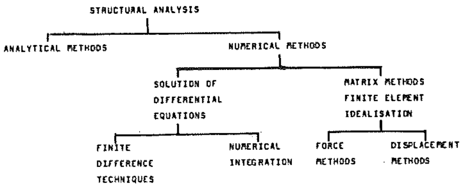

Fig. 3. Methods of structural analysis

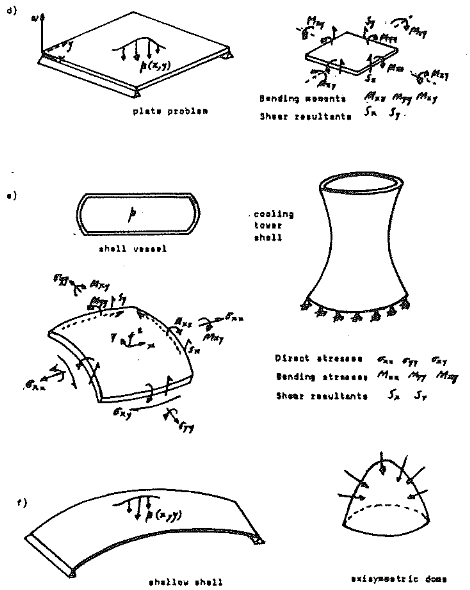

Fig. 4. Types of problems and the relevant stresses in structural analysis

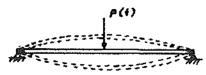

Fig. 5. First mode of vibration of a simple beam

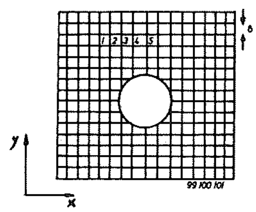

Fig. 6. Finite difference method of solution

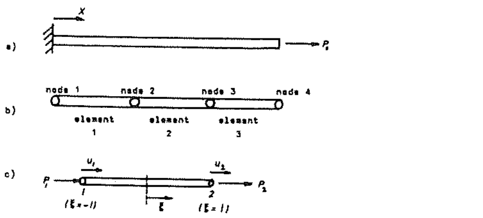

Fig. 7. a) one dimensional structure b) idealisation c) one - dimensional finite element with constant stress

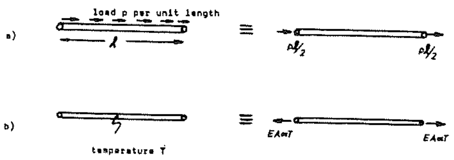

Fig. 8. Equivalent load as the lumping of physical loads onto the nodes

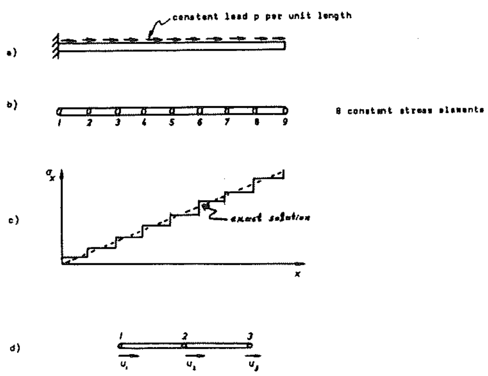

Fig. 9. a) to c) Solution of linearly varying stress with constant stress elements

d) Linear stress element requires three nodes

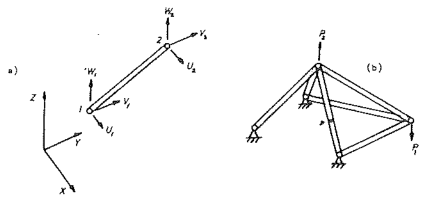

Fig. 10. A three dimensional flange element and its use in three - dimensional frame problem

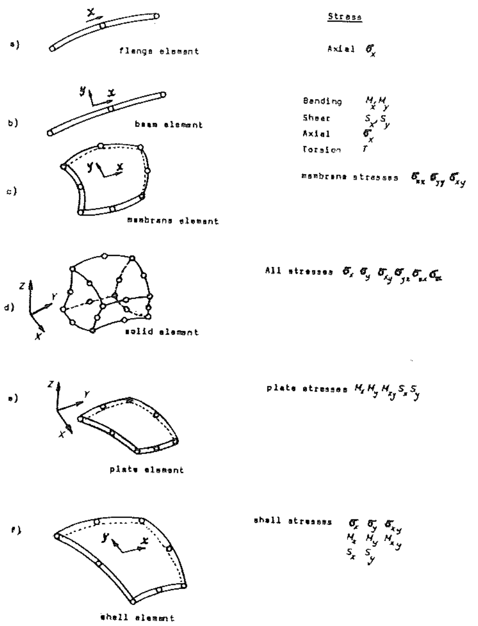

Fig. 11. Types of finite elements

START

↓

Read and check input data

↓

Generate element stiffness and load matrices

↓

Combine element stiffness and loads and solve for unknown displacements

↓

Solve for stresses in elements

↓

Output stresses

↓

STOP

Fig. 12. Sequence of steps in a finite element system static analysis

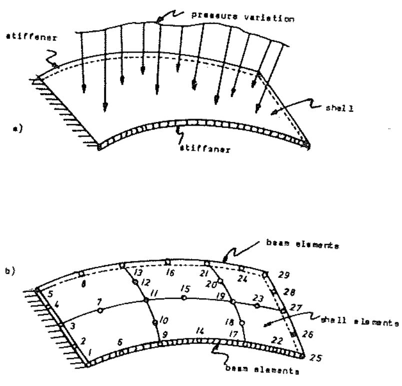

Fig. 13. a) Actual structure b) Idealised structure

UTILIZATION OF SOLAR ENERGY IN CYPRUS

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Inroduction

Due to the fact that research and development for utilization of solar energy in Cyprus was largely unco-ordinated, an Energy Research Group (ERG) has been established at the Higher Technical Institute to study energy problems and develop new systems applicable to Cyprus conditions.

Energy Research Group (ERG)

A research group to promote scientific activities related to energy matters was established in February 1979, by the academic staff of the HTI under the name of Energy Research Group (ERG).

The main objectives of ERG are to study the efficient utilization and conservation of energy in its conventional and uncoventional forms and to contribute to the worldwide effort for energy conservation.

As a means of achieving its objectives ERG has already established contact with similar organisations locally and abroad.

The main areas of study of ERG are the following :

(a) Conventional Energy
(b) Solar Energy
(c) Wind Energy
(d) Bio Energy
(e) Wave Energy

A multi-disciplinary team consisting of qualified engineers and technicians was formed for each area of study, whose task it is to collect related literature/state of the art, report on experimental work locally and abroad and propose and carry out suitable project work.

Following a recent Energy Planning Meeting organised by the Commonwealth Science Council in London, ERG undertoodk the formulation and proposal of a number of projects related to energy, to be financed and implemented in the near future.

Below is a report on **Utilization of Solar Energy in Cyprus,** prepared by members of ERG.

1. Background Information on the energy situation in Cyprus.

Cyprus, the third largest island in the Mediterranean, situated at a geographic latitude of 35°N and with total area of 9,251 square kilometres became an Independent Republic in 1960. A well geared economic and industrial development started with the First Five-year Plan, 1962—1966, and continued through the next two (The Second Five-Year Plan, 1967—1971, and the Third Five-Year Plan. 1972—1976). The implementation, however, of the Third Five-Year Plan was abruptly interrupted in July 1974 as a result of the Turkish Invasion. The occupation by Turkish troops of about 40% of the Island, the displacement of 200,000 people from their homes and the loss of some 70% of total gross output led to a general dislocation of the economy and the necessity for revision of the Third Five-Year Plan and the launching of the First and Second Emergency Economic Action Plans. These dramatic economic and social developments are reflected in the energy sector as follows :

	1962	1973	1975	1977	1978
Imported oil toe *	308,000	844,500	605,300	757,900	770,000
Installed electric capacity MW	75	204	234	264	264
Year electricity production GWh	248	782	698	849	839

The overall energy consumption of the country with the limited exception of that of non-commercial energy resources (primarily solar energy for domestic water heating and to a very minor degree fire-wood and agricultural residues) corresponds to the imported petroleum and petroleum derivatives. That means an almost total dependency on imported energy and a high annual expenditure of foreign currency for satisfying energy demands. For example in the year 1978 the imported petroleum products were valued at C£35 million (approx. US$90 million) which represents Yearly electricity production GWh approximately 13% of all imports into Cyprus and 27% of the total value of domestic products exported during the same year. In other words the energy consumption and expenditure per capita is quite high (approx. 1.5 toe and US$150 respectively).

The breakdown of consumption of the import oils in tonnes, for the years 1977 and 1978 is as follows :

	1977		1978	
Petrol	90,317	(12.92%)	101,146	(13,16%)
Kerosene	47,421	(6.79%)	67,044	(8.72%)
Gas oil (dieser)	126,575	(18.11%)	139,811	(18.19%)
Mazzut (fuel oils)	403,754	(57.78%)	429,401	(55,85%)
LPG	30,726	(4.40%)	31,340	(4.08%)
TOTAL	698,793	(100%)	768,742	(100%

The breakdown of usage of the imported oils for 1978 were as follows :

Domestic/Commercial	8%
Industry	26%
Transport	27%
Agriculture	4%
Electricity Generation	35%

In 1978 he structure of the electricity consumption was as follows :

Domestic	25%
Commercial	29%
Industry	40%
Irrigation	3%
Street Lighting	3%

2. National Policy.

The Cyprus Government being seriously concerned over the impact of the increasing cost of energy (due to both increased consumption and continuously rising prices) on the national balance of payments and in order to sustain the high rates of economic growth achieved so far and set as targets of the Second Emergency Economic Plan 1977—1978 has focussed its attention on the urgent need for appropriate action. Such action is aiming towards maximum energy conservation and the development of non-conventional energy resources. To this effect two major steps have been taken very recently :

Firstly, the setting-up of an Energy Committe with advisory capacity, whose primary objective is to act as the connecting link between Government, industry and people. This committee has already submitted its recommendations for measures to be taken to smoothen the effects of energy crisis.

Secondly, Government has, in the first instance, secured technical assistance through UNDP from UN—OTC for a project to be established on "Energy Conservation and Development". This project which covers a period of 18 months has already started this year.

3. Renewable Sources of Energy in Cyprus.

Alternative energy resources currently used in Cyprus are solar energy for water heating and wind energy for pumping water for irrigation purposes; however, there are promising prospects for other applications, these being the following :-

(a) Solar heating and cooling of buildings
(b) Solar heating of greenhouses
(e) Solar drying
(d) Solar desalination
(e) Solar pumping
(f) Bio energy applications.

Water pumping windmills were extensively used 20 years ago, especially in the South-eastern area of the island. With increasing electrification, however, their use has been diminished and replaced by electric pumps.

However, as a result of the 1973 energy crisis some of these windmills which were not pulled down or destroyed due to lack of maintenance have been put again into operation. Unfortunately, there are no figures which indicate the past, present (and future) utilisation of wind energy.

The story, however, with solar water heating is happily a different one. Solar water heaters were first produced in about 1960, modelled on an imported design. Their progress in the first 6 years was rather slow. This is attributed to the rather faulty initial design (leakages, low efficiency etc.) and to their rather high cost. With further developments in the construction of the collectors so that most technical problems were eliminated, and with rationalization of production so that costs if not decreasing at least remaining constant, more and more units were installed, with the result that by mid 1974 about 24,000 units, of a total collector area 57,600m^2 were in operation. This figure roughly means that about 20% of the population were satisfying their hot water needs through the use of solar water heaters. This represents about 1% of the total energy requirements of Cyprus, or about 28% of the present energy consumption for domestic and commercial uses.

It is very difficult to give any figures for the period after 1974 as to the contribution of solar energy to the total energy inputs. As a result of the Turkish invasion the whole picture was thrown out of balance during the years 1974—1976. However, production of solar water heaters has now been reactivated at a faster pace than before.

At present, there are 5 major manufacturers in Cyprus, with another 20 minor ones, all of them employing a total of about 400 workers and producing about 10,000 units per year, whereas prior to 1974 production was at the level of 4,000 units per year. This increase in production capacity came also as a result of Government's policy to install solar water heaters in all houses built for the accommodation of refugees (approx. 3,000 units per year).

Today, it is estimated that about 45,000 solar water heating units are in use having a total collector area of about 108,000 sq. metres. This means that approximately 35% of the population satisfy their hot water needs using solar energy.

Increasing fuel costs, however, led various users of hot water to consider using multiple unit installations to satisfy their needs. Thus, in 1977, an installation has been made in a mountain resort hotel to heat their open air swimming pool; the system utilises about 75m^2 of collectors and it is claimed that it is possible to expand the swimming season to include now May and September instead of only June—July and August.

Large-scale applications have been extended to hotels and blocks of flat apartments, mainly for the generation of domestic hot water and in some cases to assist the conventional central heating systems. Application of solar energy utilisation in hotels and hotel apartments is now a must and a necessary requirement for all hotels seeking financial support from the Government; According to a recent decision of the Government, all hotels and hotel apartments financed by the Cyprus Tourism Organisation should include solar heating systems for the generation of domestic hot water for their needs.

Solar energy is also extensively used for the generation of hot water in various industries.

4. Development of solar energy applications.

Up to now solar water heaters were extensively used in single or two-storey dwellings. The solar water heater used is of the thermosyphon type and consists of two flat-plate collectors of total absorbtion surface 2.4m^2, a hot water storage tank (boiler) and a cold water storage tank all assembled usually on a steel tower. (Fig. 1).

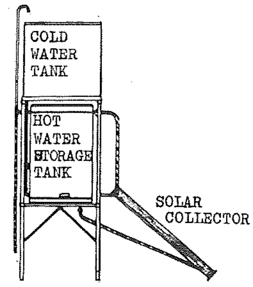


Fig. 1 : Thermosyphon solar water heater.

The boiler is usually positioned above the top of the collector panels, the latter being tilted to about 50 degrees from the horizontal facing south. The water heated in the collector, becoming lighter, will rise and colder (heavier) water will be drawn in its place from the bottom of the boiler. The greater the height difference between the top of the collectors and the bottom of the boiler, the larger the flow will be.

The collector panels used are of the header and tube construction; they consist of eight steels tubes ½'' diameter connected on two headers 1'' diameter, the whole structure fixed on the absorbing plate made of steel and painted black mat. The plate and tubes are assembled in an insulated casing and covered with a glazing. The usual dimensions of the collector are 1.8m x 0.8m.

The cost of such a unit, having a tank capacity of 1.5 tons of water and incorporating two panels of total collecting area 2.4m^2 is approximately US $415 in local market. A solar collector of the type described (1.2m^2) is priced at approximately US $65. Recently, a new development is marketed using copper piping in the collectors instead of the usual galvanised steel tubes. This increases the efficiency considerably but increases also the cost to about US $525. The cost for this type of collector is around US $100 (for 1.2$m^2$).

Research has been done in other fields mainly by the Higher Technical Institute (HTI), Nicosia. One of the projects initiated by the H.T.I. for the Ministry of Commerce and Industry constituted a pilot plant plant to dry washed sand for a proposed glass factory. Results were very encouraging, succeeding to dry about one ton per day from 5% moisture content to less than 1%.

Another successful project carried out jointly by the H.T.I. and the Agricultural Research Institute was the heating of a small greenhouse, in Nicosia. The greenhouse had a floor area of approximately $24m^2$ and was planted with tomatoes. In this system, now in operation, solar energy is collected by nine flat-plate collectors having a total absorption area of approximately $10m^2$ and is transferred through water by means of a circulating pump into the storage tank ($2m^2$). Another circuit distributes the hot water (45°C) through a fan convector installed in the greenhouse where heat is finally transferred to the space. In case of insuffcent solar energy an auxiliary electric heater is set on automatically to keep the water temperature at the required levels. The solar contribution recorded last winter was around 75%.

Work has also been done on a sun tracking system, a model desalination plant and space heating.

Due to the fact that research and development for utilisation of solar energy in Cyprus was largely unco-ordinated an Energy Research Group has been established at the Higher Technical Institute to study energy problems and develop new systems applicable to Cyprus conditions. Currently work is persued on collection of meteorogical and wind data to be used in projects aiming to improving the efficiency of solar collectors and utilization of solar energy for space heating and cooling.

A study has also been carried out by the Ministry of Commerce and Industry on bio-gas. The finding of the study were that bio-gas could possibly be used to satisfy the needs of organised farms.

5. Future plans.

Due to the pressing need for some action towards more exploitation of renewable energy resources, without, however, ignoring the more sophisticated research work (e.g. photovoltaics, heliostats, wave power etc.) currently carried out in developed countries it is felt that Cyprus should, at the present at least, follow the so-called soft energy path. Bearing also in mind the present conditions in Cyprus, the following may constitute a list of topics to which priority should be attached :

(i) Provision of hot water in large quantities for multi-storey blocks of flats, hotels, hospitals, industries, etc. on a larger scale.
(ii) Heating of Greenhouses.
(iii) Drying of Agricultural and Industrial products, such as tobacco, raisins, timber, clay products etc.
(iv) Space heating and cooling.
(v) Desalination.

To the above Biogas should be added. In Cyprus animal farming is well organised. This is especially so in the case of poultry and pig raising. Any developments in the production of biogas in Cyprus should be aiming towards satisfying the energy needs, mainly for lighting and heating of either individual farms or small groups of farms located close to each other.

However, some problems are encountered in formulating and implementing a plan for the exploitation and utilization of Alternative Energy Sources; a few of hese problems are outlined below :

(i) Information and Documentation

There is a pressing need for the means to be found so that documentation and technical information is disseminated quickly and efficiently through a central information unit. This need is enhanced also due to the very rapid technical developments in the field.

(ii) Research and Development Work

It must be admitted that due to lack of facilities the fundamental research that can be carried out is very limited. All efforts should be directed rather towards development work to produce quickly practical applications. Such work should be based on either endogeneous designs or on the adaptation to local conditions of imported technologies. However, training of suitable personnel is sought.

Closely related to this subject is the testing of prototypes. It may be that for testing purposes bik and expensive installations might be needed, which are at present lacking in Cyprus.

(iii) Standards

In connection with testing, there is also a need for the formulaion of Standard Specifications for any products that are either in use or are to emerge through development work. Such standards for equipment will ensure their marketability, especially since they are expected to boost public confidence in the utilisation of alternative energy resources.

Work has already been started by the Government for the formulation of suitable standards.

HTI Calendar of Events

Academic Year 1978 - 1979

By Miss D. Charalambidou, B.A. Hons (Lond.), Dip. (Cambr), M.A. (Birm) Lecturer HTI.

September:

Staff and students back from holidays. Classes commence on the 6th September. Freshers are trying to adjust themselves.

The total number of students in the three years of study amounts to 424 including 7 foreign students. The number of the 1st year students is 167 — 24 more than the previous year. The Electrical Engineering part-time course is continuing with 21 registered students.

This academic year saw the launching of a new course sponsored by the World Health Organization (WHO) for Medical Technicians. The course started with 13 students all holding a fellowship from WHO of which 11 are from abroad and 2 Cypriots.

The HTI Director, Mr. G. Christodoulides, goes to Belgrade as a member of a Government Team at the Conference of Ministers Responsible for Science and Technology (MINESPOL II).

October:

The second-to-third year Merchant Marine Officers in Engineering return after spending July - October on board for training. Experience valuable but difficulties in adjusting to the ship environment.

The HTI Amateur Radio Club participates and wins The Cyprus Multi-Operator High frequency Contest.

November:

8th November means UNESCO Day for HTI. This year both staff and students flocked to the Tekke Moslem shrine outside Larnaca. They cleared and tidied the surrounding area from scattered litter and listened to a talk on this historic and religious monument. The day was crowned with a picnic lunch on the nearby beach.

The Sub-Aqua Club, a branch of the Cyprus Sub-Aqua Club and a sub-division of the HTI Nautical Club, is founded by the Marine Officers.

The lecturing staff of HTI set up the Lecturers' League. The pub "Sinbad the Sailor" is chosen as their weekly "get-together" haunt.

The HTI Director attends the "20th General Conference of Unesco" held in Paris 1 - 11 November 1978: and participates in the work of the Commission on Natural Science.

December:

HTI experiences a new timetable whereby all time-tabled activities would be covered in five mornings (7.30 a.m. — 2 p.m.) and one afternoon (3.00 p.m. — 5.00 p.m.). The new timetable promises plenty of extra time for interaction between students and staff.

A Unesco expert, Mr. L. Polyakovski joined the H.T.I. Staff on a 12 month mission. His mission is to assist the Mechanical Engineering Department to revise its training syllabus in Production Engineering in order to include appropriate sections on the Technology and Practice of Gear Design and Manufacture.

The Nautical Club organises its first activity: a lecture on "Prospects of Cyprus Merchant Shipping" by Mr. P. Kazamias, Director General of the Ministry of Communications and Works.

HTI lecturers, Mr. N. Mantis and Mr. Th. Symeou, returned from abroad where they attended courses, the first in Business Administration and the second in Solar Energy.

Festivities mark the second half of the month because of the approaching Christmas vacations and celebrations. Staff and students try to enjoy themselves by holding Christmas parties and dances. Wine, music and dances drown down the tension and stress of the 1st Semester.

January:

Bacq to work. First semester exams at the end of the month keep busy both students and Staff.

February:

The HTI Director leaves for the U.K. on a 3-week study tour of Technical Institutions in G.B. as a guest of the British Council.

The Marines are active again. Mr. G. Kariolou, a Larnaca Marine Officer, talked on the "Objectives and Activities of Andreas Kariolou Marine Foundation" as a guest of the HTI Sub-Aqua Club.

March:

Suddenly the HTI life is interrupted by the students' three-week strike. The students abstained from classes in order to exercise pressure and raise public support for their claims for appropriate placement of HTI graduates with Government Technical Departments and for the revision of the law for the Registration of Civil Engineers and Architects in order to enable them to practice as Technicians.

The strike ended with the announcement of a decision of the Council of Ministers that a machinery would be set up to consider the students' demands and report back to the Council.

Members of the professional Staff of the Institute team together to form the Energy Research Group (ERG) for the purpose of initiating studies and applied research aiming at the efficient utilization of energy and the exploration of the unconventional energy resources.

April :

HTI lecturer, Mr. C. Loizou, Secretary of ERG, represents Cyprus at a 3-day meeting of the Commonwealth Science Secretariat. The purpose of the meeting is to plan a seminar on solar energy to be held in Tanzania or Kenya in September 1979.

The Institute was visited on 10th April by the Soviet Consmonaut Vladimir Zountof who, on the invitation of the Astronomy Club, gave a lecture on "Space Travels".

The Marines are active this month again :

(a) The Marine Bulletin makes its first praiseworthing appearance;

(b) the Nautical Club holds a talk on "Aphrodite the goddess of Cyprus" given by Mr. M. Louloupis, Archaelogical officer of the Cyprus Museum.

May :

May is highlighted by the celebrations of the HTI 10th anniversary, Sports day the publication of the "HTI, The First Ten Years 1968/69 - 1978/79".

As it is known, the Institute started operating in the academic year 1968 - 69. It was established as a joint project of the United Nations Development Programme and the Government of Cyprus. The Cyprus Ministry of Labour and Social Insurance and Unesco with assistance from the I.L.O. acted as executive agents for the project, which lasted till 1973, and entailed a total cost of $3,005,629.

On May 4th the Opening Ceremony for the WHO Sponsored Courses in the training of Technicians in the Repair and Maintenance of Medical and Hospital Equipment was held. The Ministers of Labour and Social Insurance, Mr. E. Theodoulou, of Health Dr. A. Mikellides, and the representative of the WHO Regional Office, Dr. G. Crespo spoke appropriately at the Ceremony.

With the setting up and operaion of the WHO course for Medical Technicians the Institute's regional character was enhanced as the present course is attended by 13 students from 8 different countries (Afhanistan, Pakistan, Iran, Jordan, People's Republic of South Yemen, Somalia, Sudan and Cyprus).

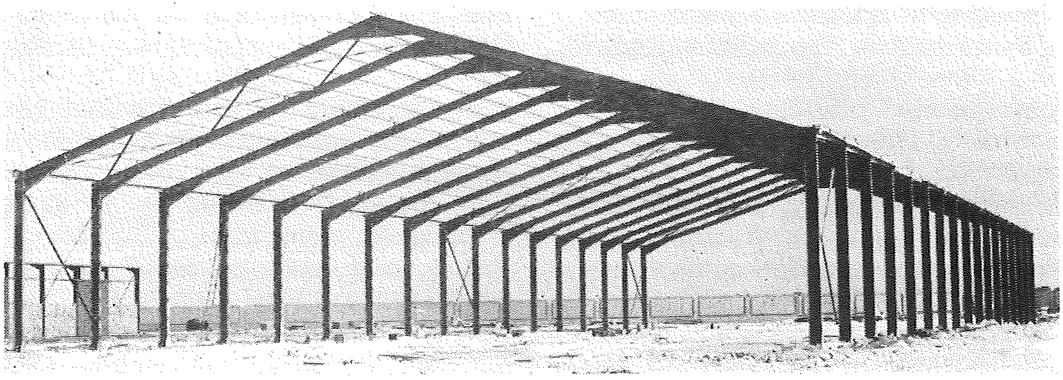
June :

An extremely busy time for both students and staff. Strain and anxiety reign in the air; 2nd - semester exams and final exams—an extremely trying period for students and academic staff but they both try to keep up their spirits by looking forward to summer holidays and the graduation ceremony and ball on 6th July.

The 1st year marines are preparing for their summer trip to Greece, while the 2nd year marines for their sea training on board and the 3rd-year Marines for their chozen profession at Sea.

ΜΕΤΑΛΚΟ

Ένα σύγχρονο συγκρότημα βιομηχανιών πού τιμᾶ τὴν Κύπρο.
Ἐδῶ καὶ 32 χρόνια πρωτοπορεῖ μὲ τὰ ἀσυναγώνιστα προϊόντα του τόσο στὴν Κύπρο ὅσο καὶ στὸ ἐξωτερικό.



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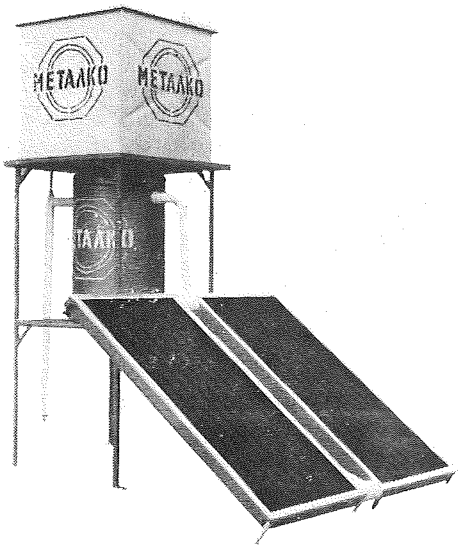

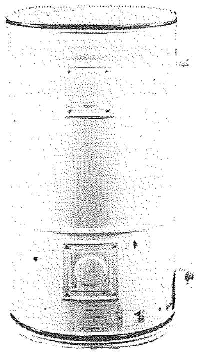

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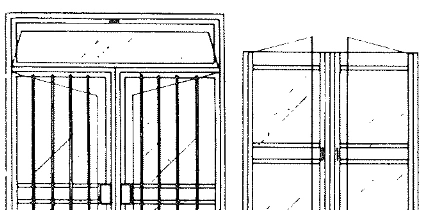
Ὅλα τὰ προϊόντα ΜΕΤΑΛΚΟ ἔχουν κατασκευασθῆ ἀπὸ ἔμπειρους καὶ εἰδικευμένους τεχνικούς, προσεγμένα καὶ στὴν πιὸ μικρὴ λεπτομέρεια.



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