

CAPE TECHNIKON  
SCHOOL OF MECHANICAL ENGINEERING

THERMOELECTRIC COOLING FOR  
MICROWAVE TRANSMITTERS  
LOCATED AT REMOTE SITES

BY  
RG PIETERSEN  
MAY 1992



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THERMOELECTRIC COOLING FOR  
MICROWAVE TRANSMITTERS  
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RICHARD GORDON PIETERSEN

This dissertation is submitted to the School of Mechanical Engineering at the Cape Technikon in part-fulfilment of the requirements for the Masters Diploma in Mechanical Technology.

CAPE TOWN      May 1992

## ABSTRACT

An investigation into the use of thermoelectric cooling energised by photovoltaic (PV) panels for removing sensible heat from electronic telecommunications equipment.

The thermoelectric cooler consists of a solid-state heat pump which operates on the principle of the Peltier effect. The thermoelectric device transfers heat through a cold sink to ambient outside air via a hot sink.

A major prerequisite was that the system should be self-sufficient in terms of power because the sites for the microwave transmitters are often remote. Solar power was the only alternative source of energy and the cooler was designed to accept direct current from PV panels which are usually used to power transmitters on distant locations. The cooling device had to be reliable, virtually maintenance-free and simple to repair.

The scientific theory of the Peltier effect was researched from the works of prominent scientists such as Goldsmid (1964) and Angrist (1977). The information gleaned from these authors was used to derive equations which were used to determine parameters for the thermoelectric materials. Equations together with the parameters were in turn used to analyse the heat pumps and estimate their cooling capacities. The requirements for the best thermoelectric materials for n and p semiconductors are described in the project. The best n-type material was found to be a mixture of 90 mole %  $\text{Bi}_2\text{Te}_3$ , 5 mole %  $\text{Sb}_2\text{Te}_3$ , and 5 mole %  $\text{Sb}_2\text{Se}_3$  doped with  $\text{SbI}_3$  to obtain a carrier density of  $3,5 \times 10^{19}$  per  $\text{cm}^3$ . The best p-type material was found to be  $\text{Bi}_2\text{Te}_3$ - $\text{Sb}_2\text{Te}_3$  comprising 72 mole %  $\text{Sb}_2\text{Te}_3$ . These materials were consistently found to produce figures of merit in excess of  $0,003/^\circ\text{C}$ . Other parameters produced by these materials were typically thermal conductance  $\alpha_n$  and  $\alpha_p$  in excess of  $200 \times 10^{-6}$  V/K and  $220 \times 10^{-6}$  V/K respectively and electrical resistivity  $\sigma_n$  and  $\sigma_p$  equal to approximately  $1,23 \times 10^{-3}$   $\Omega/\text{cm}$  and  $1,16 \times 10^{-3}$   $\Omega/\text{cm}$  respectively. A thermoelectric cooling system was developed

with heat pumps imported from Melcor in the United States of America. These prototype cooling devices were thoroughly tested in a scaled down container, mounted first on site in the open and then in a large climatic chamber. Tests were carried out with a microprocessor which recorded five temperatures and the on or off status of the system. Recordings were then analysed in the feasibility study discussed in the dissertation.

The scope of the project includes

i) Research and testing of a modified sol-air heat load estimating technique which proved to be suitable for predicting heat loads in small containers.

ii) Investigation of PV panels as a suitable energy source for thermoelectric cooling systems. It was finally concluded that it was feasible to supply power to the Peltier pumps from photovoltaic panels provided that the drawback of high capital cost was accepted. The rule of thumb method, tested for sizing the solar array and storage batteries, proved surprisingly accurate when compared with a sophisticated computer technique.

iii) Tubular storage batteries were chosen to provide autonomy because of their ability to operate under deep cycle conditions. Suitable methods of selection and comprehensive technical information on preferred charging and protection techniques are also documented in the dissertation.

iv) Digital constant current loads were designed to test an array of various photovoltaic panels available in South Africa. The same loads were adapted and used to inhibit ripple when testing thermoelectric heat pumps.

v) A digital thermostat was developed at the Telecom - communications Development Institute and used to regulate the inside ambient temperature on the prototype. Both the constant current loads and the digital temperature controller are discussed in the dissertation.

vi) Thermoelectric heat pumps were compared to conventional mechanical cooling systems and it was found that they held major advantages in special applications. Cost comparisons were also drawn and the thermoelectric cooling devices were found to become competitive in applications below  $\pm 60$  Watts.

vii) Passive cooling was considered to be the thermoelectric cooler's target competition. The photovoltaic energised Peltier cooler was financially rated against the passive cooler and was, unfortunately, found uncompetitive because of the cost of PV Power.

The final conclusion was that the Peltier cooling system had shown potential, despite the fact that the prototype was still in an early phase of development. After the brief period of research ( $\pm 2$  years) many possible areas of investigation were identified for improvement. Indications were that further research could result in a vastly improved, cheaper, and more efficient system.

## UITTREKSEL

'n Ondersoek na die gebruik van termoëlektriese verkoeling aangedryf deur fotovoltaiëse (FV) panele om voelbare hitte op elektroniese telekommunikasietoerusting te verwyder.

Die termoëlektriese verkoeler bestaan uit 'n vastestaathittepomp wat op die beginsel van die Peltier-effek werk. Die termoëlektriese toestel verplaas hitte deur 'n koue absorbeerder na omgewingsbuitelug via 'n warm absorbeerder.

'n Belangrike voorvereiste was dat die stelsel selfstandig moes wees wat krag betref aangesien die persele van mikrogolfsenders dikwels afgeleë is. Sonkrag was die enigste alternatiewe bron van energie en die verkoeler is ontwerp om direkte stroom van FV-panele aan te neem wat gewoonlik gebruik word om senders op afgeleë persele van krag te voorsien. Die koelstel moes betroubaar, bykans instandhoudingsvry en maklik herstelbaar wees.

Die wetenskaplike teorie van die Peltier-effek is aan die hand van die werke van prominente wetenskaplikes soos Goldsmid (1964) en Angrist (1977) nagevors. Die inligting wat van hierdie outeurs verkry is, is gebruik om vergelykings af te lei wat gebruik is om die parameters van die termoëlektriese materiale vas te stel. Die vergelykings en die parameters op hul beurt gebruik om hittepompe te ontleed en hulle verkoelingsvermoë te raam. Die vereistes vir die beste termoëlektriese materiale vir n- en p-semigeleiers word in die projek omskryf. Daar is bevind dat die beste n-tipe materiaal 'n mengsel was van 90 mol %  $\text{Bi}_2\text{Te}_3$ , 5 mol %  $\text{Sb}_2\text{Te}_3$  en 5 mol %  $\text{Sb}_2\text{Se}_3$  versterk met  $\text{SbI}_3$  om 'n draerdigtheid van  $3,5 \times 10^{19}$  per  $\text{cm}^3$  te verkry. Daar is ook vasgestel dat  $\text{Bi}_2\text{Te}_3$  die beste p-tipe materiaal was, wat bestaan het uit 72 mol %  $\text{Sb}_2\text{Te}_3$ . Hierdie materiale het deurgaans uitstekende resultate bokant  $0,003/^\circ\text{C}$  vir die figuur van meriete Z gelewer. Ander parameters wat deur hierdie materiale gelewer is, wat tipies termiese geleiding  $\alpha_n$  en  $\alpha_p$  bokant  $200 \times 10^{-6}$  V/K en  $220 \times 10^{-6}$  V/K onderskeidelik en elektriese resistewiteit  $\sigma_n$  en  $\sigma_p$  gelyk aan plus - minus  $1,23 \times 10^{-3}$   $\Omega/\text{cm}$  en  $1,16 \times 10^{-3}$  onderskeidelik. 'n Termoëlektriese verkoelingstelsel is ontwikkel met hittepompe wat vanaf Melcor in die Verenigde State van Amerika ingevoer is. Hierdie prototipe koeltoestelle is deeglik in 'n afgeskaalde houer getoets - eers op perseel in die buitlug en toe in 'n groot klimaatkamer. Toetse is gedoen met 'n mikroverwerker wat vyf temperature en die aan- of af-status van die stelsel geregistreer het. Opnames is daarna ontleed in die uitvoerbaarheidstudie wat in die verhandeling bespreek word.

Die bestek van die projek sluit die volgende in

- i) Navorsing en toetsing van 'n aangepaste son - lug - hitte - ladingberamingstegniek wat geskik is vir die voorspelling van hitteladings in klein houers.
- ii) Ondersoek na FV-paneel as geskikte energiebron vir termoëlektriese koelstelsels. Die finale besluit was dat dit lewensvatbaar was om krag vanaf fotovoltiese paneel aan die

Peltier-pompe te voorsien mits die nadeel van hoë kapitaalkoste aanvaar word. Die praktiese reël wat getoets is vir die groottebepaling van die sonpaneelinrigting en akkumulators was verbasend akkuraat gemeet aan gesofistikeerde rekenaartegniek.

iii) Buisakkumulators is gekies om outonomie te verskaf vanweë hulle vermoë om onder diepsiklustoestande te werk. Geskikte metodes van seleksie en omvattende tegniese inligting omtrent beskermings- en laaitegnieke is ook in die verhandeling vervat.

iv) Digitale konstante stroomladings is ontwerp om 'n reeks fotovoltaïese panele wat in Suid-Afrika beskikbaar is te toets. Dieselfde ladings is aangepas en gebruik om rimpel te beperk in die toetsing van termoëlektriese hittepompe.

v) 'n Digitale termostaat is by die Telekommunikasie - Ontwikkelingsinstituut ontwerp en gebruik om die benneomgewingstemperature van die prototipe te reguleer. Beide die konstante stroomladings en die digitale temperatuurreëlaar word in die verhandeling bespreek.

vi) Termoëlektriese hittepompe is vergelyk met konvensionele meganiese koelstelsels en daar is bevind dat hulle voordeliger is in spesiale toepassings. Kostevergelykings is ook gedoen en het getoon dat die termoëlektriese koeltoestelle meer mededingend is in toepassings onder  $\pm 60$  Watt.

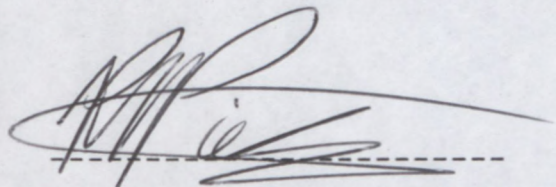
vii) Die mening is dat passiewe koeling die termoëlektriese verkoeler se teikenmededinger is. Die fotovoltaïes aangedrewe Peltier - koeler is finansieel vergelyk met die passiewe verkoeler; daar is ongelukkig bevind dat dit nie mededigend is vanweë die koste van FV-krag.

Die finale bevinding was dat die Peltier-koeler potensiaal toon hoewel die prototipe in 'n vroeë stadium van ontwikkeling was. Na die kort navorsingsperiode ( $\pm 2$  jaar) is heelwat moontlike ondersoekareas vir verbetering

geïdentificeer. Daar is aanduidings dat verdere navorsing 'n grootliks verbeterde en goedkoper, doeltreffender stelsel kan meebring.

## DECLARATION

I declare that this dissertation represents my own work and the opinions contained therein are mine and not necessarily those of the Cape Technikon.

A handwritten signature in black ink, appearing to read 'R. G. Pietersen', is written over a horizontal dashed line. The signature is fluid and cursive.

RICHARD GORDON PIETERSEN

1 May 1992

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I am grateful to my colleagues of Telkom's Telecommunications Development Institute who assisted me during the practical development of the prototype. In particular, I must mention my mentor Dr A E Prinn who spent time discussing the scientific aspects of the project with me. I also wish to acknowledge Messrs H Millar, and W Dersley who assisted me with the electronic controls.

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I am indebted to Mr N T Taute of Telkom's Professional Services who initiated and facilitated the project. Without his help the project would not have taken place.

## DEDICATION

To my wife Frances, who has patiently supported me through many years of study.

## PRINCIPAL SYMBOLS

$\epsilon$	=	Hemispherical emittance of surface.
$A$	=	Area of a heat sink fin.
$A$	=	Area of an elements n or p.
$a$	=	thickness of a heat sink fin.
$C$	=	A heat sink constant.
$C_g$	=	Electrical conductance.
$d$	=	Day numbered from the 1 st of January.
$D$	=	Diffused radiation.
$F$	=	Axial force.
$f$	=	$IR/\alpha$ - Group of terms.
$HL_{TR}$	=	Heat lost via thermal resistance.
$h_o$	=	Coefficient of heat transfer.
$H_p$	=	Heat pumped by thermoelectric cooler.
$HP_{TR}$	=	Thermal resistance of heat pump.
$I$	=	Electrical current.
$I_t$	=	Total solar radiation.
$J$	=	Polar moment of inertia.
$k$	=	Thermal conductivity related to elements n or p.
$K$	=	Total thermal conductance related to the n or p legs.
$l$	=	length of fin from root to tip.
$L$	=	Vertical length of heat sink fin.

$l_n, l_p$  = Length of couple leg n or p.  
 $m$  =  $(hp/kA)^*$  a heat sink constant.  
 $N$  = Number of coils in a spring.  
 $n$  = number of stages in a cascade.  
 $P$  = Power into the container.  
 $P_f$  = perimeter of a heat sink fin.  
 $q$  = Heat absorbed per unit time in Watts related to the n, p legs or the total ( $q_t$ ).  
 $R$  = Electrical resistance of element.  
 $r$  = Radius.  
 $R_f$  = Resistance to fluid flow.  
 $R_s$  = Direct solar radiation.  
 $\beta$  = Factor analogues to the figure of merit Z.  
 $S$  = Mean direct daily solar radiation.  
 $\beta_s$  = Angle of surface to the sun.  
 $t_e$  = Surface temperature.  
 $T$  = Absolute temperature.  
 $t$  = Thickness of a heat sink fin.  
 $T_c$  = Temperature of the Cold Junction.  
 $T_d$  = Temperature difference.  
 $T_h$  = Temperature of the hot junction.  
 $t_o$  = Outdoor air temperature.  
 $v$  =  $A/l$  related to the elements to facilitate convenient substitution in equations.

- V = E.M.F. or open circuit voltage.
- W = Electrical energy expended related to the n or p element and total ( $W_t$ ).
- $W_{TR}$  = Thermal resistance of container walls.
- X = Distance from source of heat.
- x =  $v_n/v_p$  used to facilitate convenient substitution in equations.
- Y = Deflection.
- z = Depth of heat sink fin as referred to by Holman(1981, p.41).
- Z = Figure of merit.
- zT = Dimensionless figure of merit.
- $\theta$  = A heat sink constant.
- $\Phi$  = Coefficient of performance.
- $\Phi_f$  = Fin efficiency.
- $\Phi_L$  = Latitude.
- $\alpha$  = Seebeck coefficient related to the n or p elements.
- $\alpha_{ab}$  = Relative or differential Seebeck coefficient of material a and b.
- $\alpha_f$  = Couple coefficient.
- $\alpha_N$  = Noon Time angle of the sun.
- $\alpha_x$  = Absorptance of the surface for solar radiation.
- $\alpha_s$  = Angle of surface to the sun.

- $\delta R$  = Difference between the long-wave radiation incident on the surface from the sky and the surroundings and the radiation emitted by a black body.
- $\pi$  = Peltier coefficient related to the n and p elements.
- $\pi_{ab}$  = Relative or differential Peltier coefficient of materials a and b.
- $\sigma$  = Electrical resistivity related to the n or p legs.
- $\tau$  = Thomson coefficient.
- $\tau_s$  = Shear force.

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CHAPTER 1

INTRODUCTION

## 1 . 1 GENERAL BACKGROUND

Telkom operates a large number of microwave installations on remote sites all over South Africa. Typical microwave transmitter sites are on high hills at Springbok and Upington, far away from the main engineering depots. Cooling is required for these transmitters which are housed in containers and erected on remote sites. Total cooling load requirements for electronic transmission equipment are moderate, and have been specified as 500 Watts at a maximum inside air temperature of 38 °C. This temperature limit is suitable for the electronic transmitter equipment. The engineers that researched the cooling load requirements for the microwave transmitters for passive cooling determined that the total load was made up of a constant equipment load of 300 Watts and a variable climatic load of 200 Watts. Passive cooling is the term used for an absorption refrigeration system that relies on natural convection to move liquid refrigerant.

Internal dimensions of the container used for field testing were specified as follows:

Height - 2,791 m  
Width - 2,288 m  
Length - 2,841 m

Rigid polyurethane, with a conduction factor (k) of not greater than 0,025 W/m°C, was specified for the container. In an effort to overcome cooling problems at the microwave transmission stations, Telkom engineers carried out a great deal of research on alternative cooling systems. They have developed passive cooling to an advanced stage and the system is presently undergoing field tests.

Climatic conditions experienced on typically exposed microwave sites are characteristically harsh. Rugged terrain surrounding the sites limits access to utility vehicles equipped with four-wheel drive. Modern transmission

equipment is usually extremely reliable, resulting in little demand for maintenance. Power on site is provided by storage batteries charged by diesel driven generators or photovoltaic (PV) panels. Most of the sites are now, in fact, powered by PV panels via industrial storage batteries.

## 1.2 FORMULATING THE PROBLEM

The following scenario has emerged from the special circumstances surrounding microwave equipment:

(i) On these remote transmission sites, maintenance is carried out only when necessary. A typical example is the site near Springbok, which is visited routinely only once a month. Services are also carried out when breakdowns occur or adjustments have to be made. The number of visits to microwave towers varies, depending on the number of microwave systems operating. Thirty times per annum would be a rough estimate of the number of site visits to the average installation.

(ii) Well-trained technical personal used to service the transmitters are limited in number.

(iii) Man hours lost and extra wages paid in subsistence allowances, makes it expensive to move maintenance staff to microwave sites. Hidden costs also arise in the form of risk of injuries, wear and tear on vehicles, stress on staff separated from families, etc.

(iv) Continual operation of electronic equipment at higher than rated temperatures for extended periods of time may cause a drop in reliability and hence latent system malfunction can occur.

(v) Microwave technicians employed by Telkom have usually specialised in electronics and are not trained to maintain and repair air conditioning (AC) equipment. Microwave electronic specialists also do not usually carry specialised equipment normally used to maintain AC machinery. This often

means that AC specialists have to be called in when electronics technicians find AC machinery breakdowns.

Apart from the normal maintenance work which has to be done on conventional AC installations, periodic checks also have to be carried out to ensure that the optimum coefficient of performance (COP) is maintained.

Equipment installed on sites, often situated on hills in exposed positions is inclined to be damaged by rain and high winds. Corrosion in these circumstances is high.

### 1.3 PLACING THE PROBLEM IN CONTEXT

The total project can be viewed on two levels, that is that Telkom has to find an AC system capable of eliminating the problems formulated in section 1.2 and once a solution is proposed there will be engineering problems within that system that have to be resolved. This section (1.3) only deals with the initial situation.

The challenge presented is to provide adequate cooling for electronic equipment housed in small containers on remote sites open to inclement weather where

- (a) reliability is a priority;
- (b) maintenance is expensive because of a high level of corrosion, and is also time-consuming because of the remote nature of the sites. The maintenance should also preferably be done by microwave electronics technicians.
- (c) sites are far away from service depots; and
- (d) power is supplied by storage batteries charged from a photovoltaic array.

#### 1.3.1 ALTERNATIVE COOLING SYSTEM

It has been found that conventional air-conditioning systems do not perform well under the rigorous conditions normally

experienced on these exposed sites. For this reason, Telkom has sought to find alternative cooling methods. Passive cooling is an example of one such arrangement currently undergoing development. Field tests have proved encouraging but the capital cost is high. Hence the search continues for less expensive alternatives.

#### 1.4 AIMS & OBJECTIVES

The overall short-term aim was to develop an alternative cooling system to cool the electronics components on microwave radio sites. It was eventually realised that the system that was developed could be used for sensible cooling any electronic device. The following goals were identified as being key to the viability of the project:

(i) The cooling system should operate on direct current (DC), to be compatible with the existing on-site power. Generally, the power supply is only adequate for the existing installations. A power source that would not require fuelling or power cables, would have to be included in the design. Most remote Telkom sites are energised by a PV power system and it is considered highly desirable that any additional equipment should also be fed by the same power. High costs of PV panels and storage batteries compelled Telkom to select a cooling system that would draw power at an amperage and voltage that was suited to the PV power supply.

(ii) Low maintenance and excellent reliability.

(iii) A modular cooler to fulfil the variable needs of an electronic system that could be extended from time to time.

(iv) Radio signals should not be distorted by the operation of the cooling system.

(v) Adjustments or maintenance work should fall within the technical capability of the microwave technicians. Spares should be inexpensive and compact, so that it would be convenient to equip the personnel with them. Tools needed

for repairs should preferably be part of the technicians standard tool kit.

## 1.5 PRELIMINARY INVESTIGATION

A cooling system designed to comply with all of the requirements mentioned in Section 1.4, would present a series of development problems. Thus Telkom has initiated preliminary investigations into thermoelectric cooling using PV power as a possible viable alternative.

Preliminary reading and theoretical investigations revealed that substantial research had been carried out by engineers using thermoelectric cooling based on the Peltier effect. It was apparent from such references that Peltier cooling has proved successful in specialised industrial applications in many parts of the world but evidently not yet in South Africa. A number of successful industrial applications of thermoelectric cooling have been documented in paragraph 5.3.2.1. The Peltier cooling effect mentioned above occurs when a current is passed through the junction between two dissimilar conductors. One side of the coupling heats up and the other side cools down. This phenomenon is labelled Peltier effect and will be comprehensively analysed in Chapter 2 of this project.

### 1.5.1 POTENTIAL OF THERMOELECTRIC COOLING

The following possibilities for practical application of thermoelectric cooling emerged:-

(i) If thermoelectric systems were correctly designed they would make a meaningful contribution to the problem of cooling electronic equipment in cases where the loads were light.

(ii) From the outset of research of thermoelectric effective cooling, it was perceived that such devices would be suited to the cooling of electronic components. The reason for this was that compact coolers were sometimes needed for

specialised applications where economy was not an overriding factor (Goldsmid, 1964, p214).

(iii) Indications were that thermoelectric cooling systems would be capable of operating indefinitely without maintenance or adjustment, provided that they are properly assembled and installed. The preliminary literature survey revealed that the US Weather Bureau had operated weather information transmitters, located above the Arctic circle, charged with power from direct energy conversion devices, fuelled by nuclear energy. The weather information transmitters were cooled using the same principle as Peltier coolers. The weather stations operated on six-hour daily schedules without any services required except for the need to refuel every ten years (Angrist, 1977, p176-177). Judging from prefatory analysis by this author there seemed to be a reasonable possibility that thermoelectric coolers would provide effective cooling, without maintenance for indefinite periods.

(iv) The installed system is such that minimal maintenance or adjustment would be required. In the event of maintenance or adjustment becoming necessary, the work would be well within the skill of the microwave technician. Initial investigation indicated that standard tools would be adequate and spares would be comparatively inexpensive and compact. To emphasise this point heat pumps with dimensions of 30mm x 30mm x 4,5mm were imported at a cost of R122 each (GST excluded, 1990).

(v) Peltier devices are solid state and thus have no moving parts. As such they are expected to have the same life expectancy as other electronic devices which have been found to last indefinitely.

(vi) Unlike other standard cooling systems, no fluids or chemicals are used to remove heat, resulting in no internal corrosion.

(vii) If possible heat sinks were going to be used to replace conventional condensers. In comparison with condensers, heat

sinks were expected to have greater resistance to external corrosion and wind damage.

(viii) Thermoelectric coolers have to be operated from a DC power source. This, together with the fact that Peltier coolers can be designed to operate at fairly low amperage (approx. 3 A), implies that they could easily be adapted to PV panel power.

#### 1.5.2 NEGATIVE ASPECTS OF THERMOELECTRIC COOLERS

Certain negative characteristics of thermoelectric cooling emerged during preliminary analysis. These attributes were identified as follows:

(i) The coefficient of performance (COP) of thermoelectric cooling systems (TEC) tended to be low and generally below unity (Angrist, 1977, p163; Goldsmid, 1964, p9).

(ii) Initial capital cost was high at approximately R1400 per 100 Watts. For a detailed analysis of the cost of a TEC see Section 4.7.

(iii) Thermoelectric coolers are manufactured from specialised components and there are no manufacturers of the components or the materials used in their production in SA to date (August, 1991).

(iv) The capital cost of PV power is high at R1200 per 55 Watt panel. Tubular stationery batteries had to be used with the panels to provide storage. They are supplied at approximately R470 per 490 ampere hour 2 volt cell. A minimum of 12 cells would be used at an approximate cost of R5880, further increasing the initial capital cost (1991 GST excluded on all costs). A complete cost breakdown can be found in Section 4.7.1.2.

#### 1.5.3 PRELIMINARY RESOLUTION

Preparatory investigations revealed that Thermoelectric cooling due to Peltier effect, could provide a solution to

Telkom's problems. Telkom management indicated that they were prepared to sponsor a six month period of practical research including the cost of providing electric test equipment and components for the manufacture of a Peltier cooling device.

It is important to note that up to now the introductory discussion has focused on the general problems which initiated the research. The rest of this chapter will concentrate on problems peculiar to the application of thermoelectric cooling to the particular circumstances arising in Telkom.

## 1.6 OBJECT OF RESEARCH

The general aim is to design a simple solid state thermoelectric cooling system that could provide cooling for containers housing microwave transmitters.

The following factors were considered to be important and attainable:

(i) A life expectancy that compares favourably with other electronic equipment and has a high degree of reliability.

(ii) Maintenance and adjustment should be minimal but if repairs or maintenance work were to become necessary, it should be easily executed by microwave technicians. From the outset of the project, one limitation placed on the design was that no fans, pumps or other mechanical devices were to be permitted. This restriction was considered necessary to decrease the overall maintenance requirements and to improve the reliability of the system.

(iii) Designers of the system should ensure that there would be no chemical fluid corrosion from within or climatic element corrosion from without.

(iv) The cooling device should be compatible with direct PV power or power supplied from storage batteries.

Telkom also had, as a major goal, the attaining of a general understanding of the principles and procedures of thermoelectric cooling. Principles learned in the application of Peltier cooling could then be relevant to other telecommunications cooling designs.

## 1.7 RESEARCH METHODS

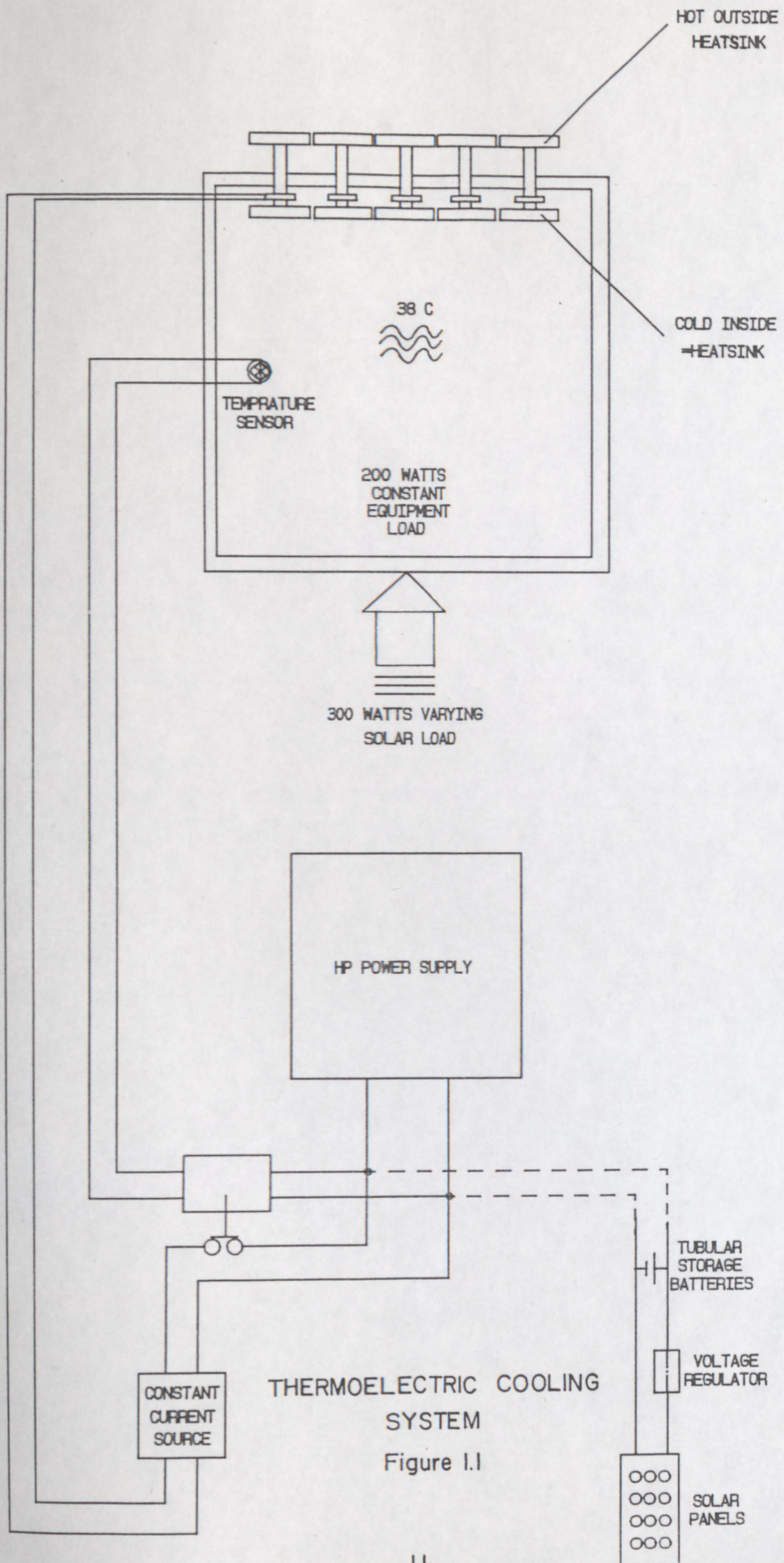
The project naturally divided into the following six sections :-

- (a) HEAT LOADS
- (b) HEAT PUMPS
- (c) HEAT SINKS
- (d) SOLAR PANELS
- (e) BATTERIES
- (f) ELECTRICAL CONTROLS

The general approach in this dissertation, has been to discuss these sections in the order shown above. The major thrust of the project was, however, towards the development of Peltier heat pumps.

### 1.7.1 PROTOTYPE

It was decided from the outset of the investigation that a prototype or model had to be built to test the practical application of the theory that would be researched. The prototype would take the form of a scaled down model of the container normally used by Telkom. No attempt was made to scale down the insulation material, but the U factor of the existing container insulation was matched. Based on experience, a 1m<sup>3</sup> container was considered suitable for the model. Figure 1 shows a schematic diagram of the prototype.



## 1.7.2 HEAT LOADS

A 100W constant heat load was chosen to represent the equipment load. The equipment heat load generated by a microwave transmitter does not vary (Prinn, Pers. Com., 1990). The container was manufactured from 1,0mm mild steel, white painted to reflect heat and insulated with IM24 fibreglass. See drawing number 1 for details and figure 1 for a schematic layout.

When considering the equipment load, it is interesting to note that telecommunications equipment is almost 100% inefficient in terms of heat load. That means, for example, that if 10 watts of power is used, almost 10 watts of heat is rejected. As the equipment load is constant, any variation in heat load is due to the diurnal fluctuation in solar irradiation. Due to the high permissible internal temperature (38°C) heat will, at times, be conducted outwards, especially at night.

### 1.7.2.1 Problems Encountered - Heat Loads

The fluctuating solar load became the main focus of analysis during the design phase as the electronic heat load was considered to be constant. High permissible internal temperatures prevented the use of standard methods to determine heat loads.

### 1.7.2.2 Research - Heat Loads

Established heat load assessment methods were investigated to discover if they were applicable to this case. The procedure chosen would need to be suitable for various sites in a wide range of climatic conditions. Finally a series of readings was taken in a climatic chamber and compared with on site readings. These readings were used to check the validity of methods and formulae applied.

## 1.7.3 HEAT PUMPS

Peltier heat pumps and the underlying thermoelectric principles are examined in this part of the dissertation.

#### 1.7.3.1 Practical Limitations - Heat Pumps

No suitable thermoelectric materials could be obtained from the manufacturers of the Peltier device, with the result that the materials could not be evaluated.

#### 1.7.3.2 Problems Encountered - Heat Pumps

Peltier devices were required to be compatible with power supplied from storage batteries charged by PV panels. This specification means that the mechanism design was limited in ampere and voltage supply. A current of less than 3 amps at 24 volts was eventually chosen so as to allow for a minimum cost battery - panel combination.

Constant pressure had to be maintained on the cooling device, in spite of the fact that it would be expanding and contracting as its temperature fluctuated.

Sufficient heat had to be dissipated notwithstanding the restriction that no fans or pumps be used in the design.

The heat had to be conveyed through the insulated wall of the container

#### 1.7.3.3 Theoretical Development - Heat Pumps

A substantial theoretical component has been included in this section embracing all the technical and the theoretical aspects of thermoelectric cooling. Discussion on grown alloys and sintered compounds is also incorporated in the dissertation. This part of the study is confined to bismuth telluride and selenide as these elements have outperformed all other materials on coolers operated at room temperature (Goldsmid, 1964, p100).

#### 1.7.3.4 Research - Heat Pumps

Theoretical features of the project were based upon research papers and books written by various engineers and scientists like Goldsmid (1964), Angrist (1977), and Horst (et al)(1980). This information has been supplemented by information from suppliers, such as, Melcor and Peltron.

A prototype of the Peltier cooling system was manufactured, based on knowledge discovered during research. The test model was operated on an open site and in a climatic chamber, where temperature readings were taken while the current and climatic conditions were varied. Six temperature probes were mounted on strategic points where temperatures were simultaneously read at 10 minute intervals. Graphs generated from the tabulated results were then used to predict the performance of the system. Changes in the operating temperature of the cooling device, caused the resistance across the chip to vary. A specially designed power source, that maintained a constant current, was used during experimentation to place tests carried out onto a scientific basis. This electronic system held the current constant while the voltage modulated on demand. Power and performance calculations could eventually be made because the current was fixed and maximum voltage could be measured.

#### 1.7.4 HEAT SINKS

Heat sinks took the place of the evaporator on the cool side and the condenser on the hot side.

##### 1.7.4.1 Problems Encountered - Heat Sinks

The heat sinks had to absorb fairly large quantities of heat on the inside of the container and dissipate the heat to ambient air on the outside. The challenge was to develop a heat sink combination that could reject heat efficiently, enough to keep the temperature rise across the sinks within limits, in spite of high ambient temperatures.

A conductive link had to be established between the heat pump inside the container and the outside heat sink, so that heat could be adequately conveyed through the container insulation.

A method also had to be devised to insulate the hot sink from the cold sink and the hot sink from the container.

#### 1.7.4.2 Research Methods - Heat Sinks

Heat transfer theory from handbooks and textbooks was used to derive formulae, which in turn were applied to predict the performance of the heat sinks. Data disseminated by suppliers, was used to select the most efficient heat sink for the application under consideration. A test was carried out with a cooling chip clamped between two heat sinks in a temperature controlled environment. Temperatures were then tabulated, while the cooling effect was varied by adjusting the current on the chip. The results were then used to predict the heat sink performance.

#### 1.7.5 PHOTOVOLTAIC PANELS

The power for the system would be supplied by PV panel charged storage batteries. It was only deemed essential to gain sufficient knowledge to determine the size, type and number of panels needed to power the system.

##### 1.7.5.1 Problems Encountered - Photovoltaic Panels

Panel angles had to be found which would maximise the power of available solar insolation when climatic conditions were demanding maximum cooling load.

##### 1.7.5.2 Practical Limitations - Photovoltaic Panels

Since PV panels were extremely expensive, the budget for the prototype did not cover the cost of purchasing and installing panels (approx R1200 ea in 1990 exc GST). This limitation was however not considered a problem, as there sufficient data was already available to predict the PV panel output.

##### 1.7.5.3 Research Methods - Photovoltaic Panels

Research was based on publications by recognised authorities, computer programs from Arco Solar (Atlantic Richfield Company) and tables from energy research institutions such as the CSIR and SA Weather Bureau. Information obtained thus was used to calculate the most satisfactory panel angles and the expected solar hours, so that power output per panel could be predicted. In this way the number of PV panels needed to charge the storage batteries was determined.

Eight PV panels including examples of most of the popular makes available in South Africa, were mounted in direct sunlight at an angle of 15°. Constant current loads were connected across the terminals and the voltage was then tabulated at uniform time intervals throughout the day. These readings were taken for various current settings and used to corroborate the validity of the suppliers' estimates of the output of their PV panels.

#### 1.7.6 BATTERIES

Industrial storage batteries had to be used to store power for operation during times of low solar irradiation.

##### 1.7.6.1 Problems Encountered - Batteries

The problems that were experienced with batteries were caused more by the lack of information or publications on the subject than by actual engineering problems. Autonomy for the PV system was provided by batteries which had to be compatible with the trickle charging capacity of the PV panels. The word autonomy in this dissertation is considered to mean operation without insolation. Charging rates had to be selected in such a way that neither stratification nor overheating of cells would occur.

##### 1.7.6.2 Practical Limitations - Batteries

As with the PV Panels, the batteries were expensive and the prototype was not operated from batteries. The present (1991) cost of a 24 V 490 amp hr battery is R5640 excluding GST. This limitation was not expected to effect the results adversely, as accurate experimental data would be gathered while operating the prototype from constant current charged from a DC source.

##### 1.7.6.3 Research Methods - Batteries

Research was once again confined to information from publications and data distributed by suppliers. Although information was limited, no research was judged necessary as there was already sufficient expertise available to make a sound battery selection. Telkom is a long term user of

storage batteries and the project benefited from this experience.

#### 1.7.7 ELECTRICAL SYSTEM

The electronic system that was used to provide constant current electricity for the thermoelectric system, was discussed here together with the electronics involved in the heat sensor used to switch the cooler on and off. The constant amperage electrical supply was also used as a constant current load, when the PV panels were evaluated. Constant current supplies used during research were developed by Hilton Millar in consultation with Dr AE Prinn. The sensor/temperature control was designed by Wayne Dersley with assistance from Hilton Millar. Both systems were assembled and tested by Wayne Dersley.

##### 1.7.7.1 Practical Limitations - Electrical Systems

Melcor, the suppliers of the heat pumps, recommended a maximum of 10% current ripple. The prototype was operated from 5 constant current sources supplied with direct current from a direct current power supply, manufactured by Hewlet Packard. This system smoothed the direct current and enabled the heat pumps to deliver optimum performance. There were no real limitations in this part of the project, except that the constant current loads would be replaced by PV panels and batteries in the final design. No ripple will have to be overcome in the storage battery current supply.

##### 1.7.7.2 Problems Encountered - Electrical Systems

No difficult problems were encountered here but the electronic system was used to overcome problems that were encountered in the prototype and facilitate the operation of the Peltier cooler (See Paragraph 1.7.3.4 for information).

##### 1.7.7.3 Research - Electrical Systems

No research was carried out on electrical systems but they were evaluated while being used on the project.

## 1.8 HISTORY OF THERMOELECTRIC COOLING

### 1.8.1 SEEBECK

In 1891 Thomas Johann Seebeck reported his observation that a magnetic needle was deflected when held near a circuit made up of two different conductor materials. Seebeck considered this to be due to the temperature difference which he had detected between the two conductors. He unfortunately then tried to explain terrestrial magnetism as being the difference in temperature between the North and South poles. Some of Seebeck's contemporaries did, however, recognise that a current was induced in a circuit comprising two dissimilar semiconductors in contact. This phenomena was due to the temperature difference in the materials. Ironically Seebeck evidently spent a lot of time trying to prove them wrong (Angrist, 1977, p129) (Goldsmid, 1964, p1).

### 1.8.2 PELTIER

In 1834, 13 years after Seebeck made his discovery, Peltier, a French watchmaker and amateur scientist, had his breakthrough. He observed a temperature difference across a junction of two dissimilar metals through which he was passing a direct current. He noted a cooling effect on one side of the coupling and a heating effect on the other side, beyond the normal influence of joule heating. Peltier, unfortunately also misunderstood his discovery (Angrist, 1977, p130).

### 1.8.3 LENZ

Four years after Peltier's discovery in 1838, Emil Lenz, a member of the St Pietersburg Academy, clarified Peltier's work. Lenz passed a direct current through a bismuth antimony junction and froze water placed on it. On reversing the current, the ice melted (Angrist, 1977, p5).

#### 1.8.4 THOMSON (Lord Kelvin)

In 1855 William Thomson noted the relationship between Seebeck effect and Peltier effect. Thomson derived the relationship between the two effects using thermoelectric principles. He also discovered a third effect which is now known as the Thomson effect (Goldsmid, 1964, p1).

The Thomson effect is a lateral heating or cooling effect that takes place in a homogeneous conductor when an electric current passes in the direction of a temperature gradient (Angrist, 1977, p130).

#### 1.8.5 ALTENKIRCH

Altenkirch, who delivered papers in 1909 and 1911 (p920), was the first scientist to consider Peltier effect as a possible means of refrigeration (cited by Goldsmid 1964, p4). He derived formulas and developed the basic theory for generators and refrigerators. Scientific properties for materials which would be suitable for thermoelectric devices, were also identified by him. He placed special emphasis on a high Seebeck coefficient and a high electrical conductivity to minimise Joule heating. Altenkirch also recognised that a material with a low thermal conductivity, would reduce heat transfer through the junction (Angrist, 1977, p130).

#### 1.8.6 ADVENT OF SEMICONDUCTORS

The advent of semiconductor technology in 1949 with the development of the transistor in 1950, revived interest in thermoelectricity. It was perceived that semiconductors could have a much larger Seebeck coefficient than metals and this led to the use of bismuth telluride in Peltier cooling. First as a positive thermoelectric element and later for both positive and negative branches of thermocouples ( Goldsmid & Douglas, 1954, p386-p390; Cited by Goldsmid, 1964, p4).

Abraham Ioffe (et.al) cited by Goldsmid (1964, p4) progressed the semiconductor science further with the important proposal that semiconductor alloys, as opposed to compounds, could

have a reduced lattice thermal conductivity. Today the materials that are almost invariably adopted for thermoelectric elements, are isomorphous compounds of bismuth selenide and antimony telluride. A flood of interest followed the research of the late 1950s in the early 1960s and numerous scientists became involved in research. Such information will be discussed and referenced in the dissertation (See Section 3.3 for further information).

CHAPTER 2

LITERATURE STUDY

## 2.1 HEAT PUMPS

### 2.1.1 FUNDAMENTAL THEORY

The approach used here is the classical thermodynamic route as opposed to the irreversible technique.

The simple theory assumes:

i) relevant parameters are independent of temperature. ( $\alpha$  Seebeck effect,  $\sigma$  electrical resistance,  $k$  conduction resistance)

ii) the contact resistance is negligible. Contact resistance is the resistance between the strips or bus bars and the elements. Resistance of a connecting strip is also assumed to be insignificant.

iii) heat exchange occurs only between the hot and cold junctions and not between the junction and the environment.

Although, in this approach, contact resistance is considered to be inconsequential, it is important to bear in mind that the properties of semiconductors are highly temperature dependant and that it is difficult to avoid contact resistance when jointing materials. Surprisingly, notwithstanding this fact the simple theory proves reasonably accurate in practice when working with real conductors.

#### 2.1.1.1 Seebeck Coefficient ( $\alpha$ )

Lead is used as a reference material for determining the absolute Seebeck coefficient  $\alpha$ . Borelius (et al) cited by Goldsmid (1964, p3) determined the Seebeck coefficient of lead relative to temperature, from absolute zero to 18°K. This he did by using readings taken on a junction between lead and the super conductor compound  $Nb_3Sn$  (niobium/tin alloy). Experiments by Borelius made it possible to find the Seebeck coefficient of any material by using measurements on a junction between it and lead. Figure 2.1 is used to illustrate Seebeck effect.

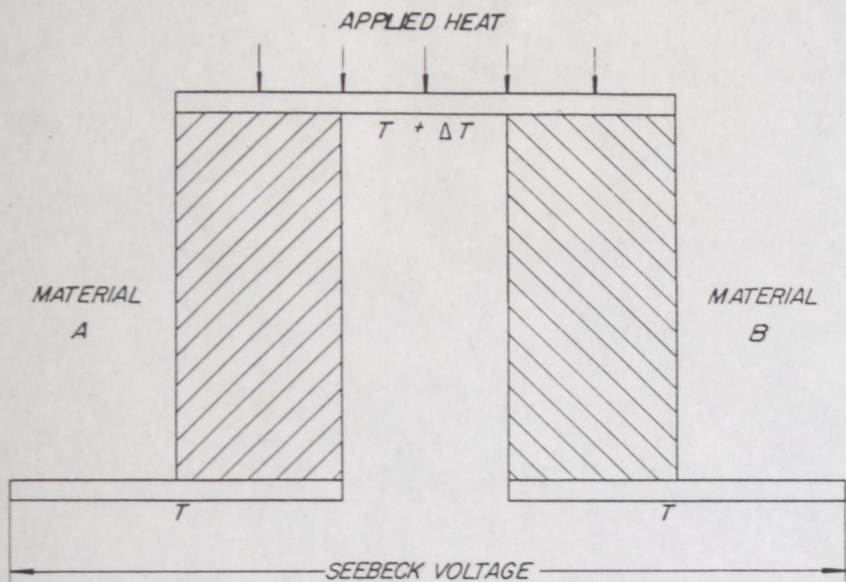


FIG. 2.1 SEEBECK EFFECT

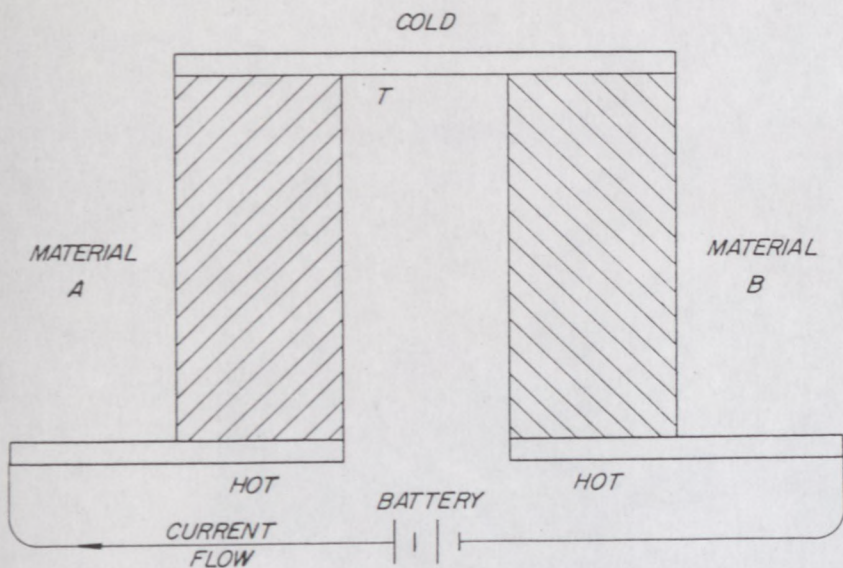


FIG. 2.2 PELTIER EFFECT

Figure 2.1 & 2.2

Consider Figure 2.1 and assume that a temperature difference ( $T_d$ ) is established between the two junctions of conductor material a and b inducing an e.m.f. (V). The open circuit voltage is proportional to the temperature difference.

Seebeck coefficient  $\alpha_{ab} = V/T_d \dots \dots \dots 2.1$

V = Open circuit voltage developed.

$\alpha_{ab}$  = Relative Seebeck coefficient. This is the difference between the absolute Seebeck coefficient for materials A and B.

Typical  $\alpha$  in metals does not exceed 0,00005V/°C.

Typical  $\alpha$  in thermoelements up to about 1980 was 0,0002 - 0,0003V/°C. (ASHRAE, 1981, p 1.27)

2.1.1.2 Peltier Coefficient ( $\pi$ )

Consider Figure 2.2 as having the same circuit as before but introducing a current (I) which cools the circuit to its original- temperature.

Peltier coefficient  $\pi_{ab} = q/I$ .....2.2

q = Heat absorbed or evolved per unit time in watts at the junction between two different metals.

$\pi_{ab}$  = Relative or differential Peltier coefficient for materials a and b.

I = Direct current.

2.1.1.3 Thomson Coefficient ( $\tau$ )

To define the Thomson coefficient  $\tau$  for one of the conductors make the assumption that in addition to the current I there is a temperature gradient dt/dx which causes a cooling effect dq/dx per unit length, then

$$dq/dx$$

Thomson coefficient  $\tau = \frac{dq/dx}{I dt/dx}$ ..... 2.3

2.1.1.4 Kelvin Relationship

Thomson assumed a reversible system although he knew his approach was not strictly correct because of the irreversibility of joule effect and thermal conduction. It must however be noted that he did obtain the same results as an irreversible analysis would have given. Lord Kelvin performed a thermodynamic analysis of a simple circuit (Figure 2.2), by applying the first and second laws of thermodynamics to it. Two equations known as Kelvin

relations were derived. These equations connected the three thermodynamic coefficients.

$$\pi_{ab} = \alpha_{ab}T \dots \text{important} \dots 2.4$$

T = Absolute temperature K

This equation is particularly important because through it the rate of cooling due to Peltier effect can be expressed in terms of the Seebeck coefficient which is easier to measure than the Peltier coefficient (Goldsmid, 1964, p3).

$$\tau_a - \tau_b = T(d\alpha_{ab}/dT) \text{ important} \dots 2.5$$

Due to Kelvins third law of thermodynamics the Seebeck coefficient between any two conductors must be zero at 0°K (Goldsmid, 1964, p3).

Equation 2.5 can therefore be written

$$\tau = T dx/dt \dots 2.5a$$

For a single conductor, standard metal has zero Thomson coefficient at all temperatures. Equation 2.4 written in terms of absolute coefficients becomes

$$\pi = \alpha T \text{ important} \dots 2.7$$

#### 2.1.1.5 Cooling Effect/Heat Flow

Now consider 2.2  $\pi_{ab} = q/I$  and substitute  $\pi_{ab}$  from equation 2.4.

Kelvins 1st Law is therefore  $\alpha_{ab}T = q/I$

$$\text{and therefore } q = \alpha_{ab}IT \dots 2.8$$

The Peltier heat flow equation has now been derived using Kelvin's 1st law.

The question that now comes to mind is what causes the Peltier effect or what is the Peltier effect. To quote Angrist (1977, p133) "in a semiconductor/metal junction, energy is absorbed or liberated as electrons or holes are forced to change their energy levels because of continuity of the Fermi level". The index as to how much energy is absorbed or released is given by the Peltier coefficient  $\pi$ .

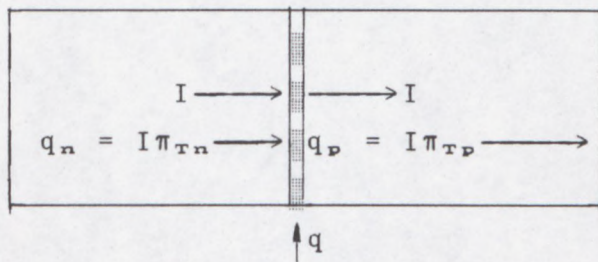


Figure 2.3  
Junction of Two Conductors

Consider Figure 2.3 showing a junction of two conductors maintained at a uniform temperature with a current passing through the junction. The current flow causes an exchange of heat with the environment. If this quantity of heat is measured it will be greater or less than the Joule heating normally experienced by a conductor. The difference between the heat rejected in this example and that due simply to the Joule effect in a homogeneous conductor is dependant on two factors. One, the types of material used in the junction and two, the magnitude and direction of the current. This phenomena is labelled Peltier effect.

Consider conduction for an n type material. (It will be useful to refer to Figure 2.4 while reading the proof.)

Rate of heat flow  $q_n = \pm(\text{heat flow per unit time due to Seebeck effect when a current is induced}) + (\text{The heat flow due to conduction within the material})$

It is important to note that both the Peltier and Seebeck coefficients are bulk properties although their effect is only apparent at the junction.

The rate of heat flow,  $q_n$ , within one of the conductors n at a distance X from the source of heat is given by

$$q_n = \pm\alpha_n IT - k_n A_n \frac{dt}{dx} \dots \dots \dots 2.9$$

- A = area of element
- $\alpha$  = Seebeck coefficient
- k = thermal conductivity (W/Cm<sup>2</sup>/°C Cm)

$T$  = absolute temperature over the plane at a distance  $X$   
from the heat source

$\alpha_n IT$  = Peltier heat flow from equation 2.8

Goldsmid (1964, p6) stated that the rate of heat generated per unit length due to Joule effect is given by

$$dq/dx = I^2/\sigma_n A_n - k_n A_n d^2T/dx^2 \dots \dots \dots 2.10$$

$\sigma$  = Electrical conductivity.

Equation 2.10 is not effected by thermoelectricity. Goldsmid explained this as follows, the rate of change of Peltier heat flow along the conductor is almost equal to the rate of working e.m.f. there being no Thomson effect when  $\alpha$  is independent of temperature. To clarify what is meant here

$$q_\pi = \alpha_{ab} T \text{ in units } V/K \times K = V$$

$$V_\alpha = dT \alpha_{ab} \text{ in units } K \times V/K = V$$

$\tau = dq/dx / dt/dx$  The  $dt/dx$  term falls away when  $\alpha=0$  and  $\tau=0$ .

From equation 2.10

$$dq = I^2 dx / \sigma_n A_n - k_n A_n dt/dx \text{ and}$$

$$q_n = I^2 X_d / \sigma_n A_n - k_n A_n T_d / X$$

Solving (2.10) with boundary conditions  $(T=T_c)_{x=0}$  and  $(T=T_H)_{x=l}$  Therefore

$$q_n = I^2 [X - (1/2)] / \sigma_n A_n - k A_n (T_H - T_c) / l \dots \dots \dots 2.11$$

(Reference to Figure 2.4 to will assist with understanding 2.11.)

$T_c$  = temperature of the cold junction or source °K

$T_H$  = temperature of hot junction °K

The derivation shown is for the n type material but the derivation will remain the same for the p type material.

- Note
- a.  $q_t = q_n + q_p$  at  $X = 0$
  - b. The current flows in the opposite directions in the two elements.
  - c. The current direction is assumed to be in the right direction to give cooling of the source.
  - d.  $\alpha_p > \alpha_n$
  - e. The n type material has a negative Seebeck

coefficient and an excess of electrons.

f. The p type material has a positive Seebeck effect and a deficiency of electrons.

$$q_t = (\alpha_p - \alpha_n)IT_c - I^2R/2 - K(T_H - T_c) \dots \dots \dots 2.12$$

$\alpha_p$  = Seebeck coefficient p type

$\alpha_n$  = Seebeck coefficient n type

R = electrical resistance of leg or element ( $\Omega$ )

(Derivation of R will follow)

K = total thermal conductance (Derivation of K will follow.)

The heat removed  $q_t$  (W) is then due to the Peltier effect ( $\alpha T_c I$ ) minus one half of the Joule heat that flows back to the cold junction, minus the conduction heat due to the temperature difference of the cold and hot junction. This equation can also be written:

$$q_t = \alpha T_c I - \frac{I^2 R}{2} - K T_d \dots \dots \dots \text{important} \dots \dots \dots 2.13$$

$\alpha$  = difference between the absolute Seebeck effects p and n type

$T_d = (T_H - T_c) =$  operating temperature difference  $^{\circ}C$

Equation 2.13 is an important equation derived by Goldsmid (1964, p7) and used by ASHRAE (1981, p1.28).

### 2.1.1.6 Resistance

The electrical resistance of the couple legs can be calculated as follows:

$$R_n = \sigma_n (l_n / A_n) \dots \dots \dots 2.14$$

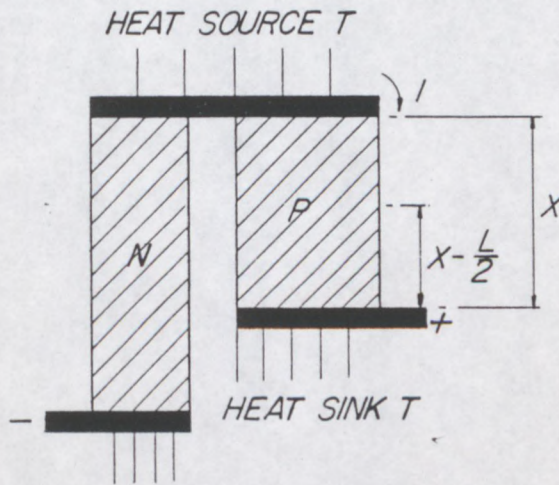
$$R_p = \sigma_p (l_p / A_p) \dots \dots \dots 2.15$$

$R_n, R_p$  = resistance of n and p elements ( $\Omega$ )

$\sigma_n, \sigma_p$  = electrical resistivity of n and p elements ( $\Omega/cm$ )

$l_n, l_p$  = length of n and p couple legs (cm)

$A_n, A_p$  = cross section area of n and p elements ( $cm^2$ )



SIMPLE THERMOELECTRIC REFRIGERATOR

Figure 2.4

Similar To Goldsmid (1964, p6)

2.1.1.7 Conductance

The conductance of the couple legs can be calculated as follows:

$$K_n = k_n(A_n/l_n) \dots \dots \dots 2.16$$

$$K_p = k_p(A_p/l_p) \dots \dots \dots 2.17$$

$K_n, K_p$  = thermal conductance of the n, and p elements W/°C.

$k_n, k_p$  = thermal conductivity of n and p elements W/Cm<sup>2</sup>/(°C/Cm)

2.1.1.8 Total Conductance

The total thermal conductance of branches in parallel.

$$K = k_n(A_n/l_n) + k_p(A_p/l_p) \dots \dots \dots 2.18$$

Thermal conductance is the rate of heat conduction per unit temperature difference between opposite parallel faces of the rectangular or cylindrical sections of the material.

2.1.1.9 Total Electrical Resistance

The total electrical resistance is in series.

$$R = \sigma_n l_n / A_n + \sigma_p l_p / A_p \dots \dots \dots 2.19$$

It is also interesting to note that the loss from the cold junction in spite of the non-linear temperature gradient is the total of the heat conduction in the absence of an

electrical current and half the Joule effect. The temperature is non linear because of the Joule heat in each leg.

2.1.1.10 Energy Expended

The rate of electrical energy expended in say the n leg is determined as follows

$$w_n = \int_{T_c}^{T_H} (\alpha_n I) dT + \int_0^{l_n} (I^2 / \sigma_n A_n) dx$$

$$w_n = \int_{T_c}^{T_H} \alpha_n I dT + \int_{x_1}^{x_2} (I^2 / \sigma_n A_n) dx$$

$$w_n = \alpha_n I (T_H - T_c) + I^2 l_n / \sigma_n A_n \dots \dots X_2 - X_1 = l_n \dots \dots 2.20$$

Likewise for p Leg.

$$w_p = \alpha_p I (T_H - T_c) + I^2 l_p / \sigma_p A_p \dots \dots 2.21$$

The total energy expended for both legs and therefore the power needed to provide the cooling rate shown in equation 2.13

$$w_t = (\alpha_n - \alpha_p)(T_H - T_c)I + I^2 R$$

$$w_t = I \alpha T_d + I^2 R$$

$$w_t = I (IR + \alpha T_d) \dots \dots \text{important} \dots \dots 2.22$$

2.1.1.11 Applied Voltage

Consider equation 2.22.

Voltage  $V = w_t / I$  therefore

$$V = IR + \alpha T_d \dots \dots 2.23$$

It is interesting to note that the applied voltage is a combination of two terms, the normal voltage drop due to Joule heating which occurs in a conductor and the voltage to provide Peltier cooling.

2.1.1.12 Coefficient of Performance

The dimensionless coefficient of performance for a thermoelectric cooler is the power expended divided into the cooling rate.

The equation for the coefficient of performance is equal to equation 2.13 divided by equation 2.22.

$$\Phi = (q_t/w_t) = (\alpha T_c I - I^2 R / 2 - K T_d) / I (I R + \alpha T_d) \dots \dots \dots 2.24$$

Equation 2.24 can be written

$$\Phi = \frac{\alpha T_c I - I^2 R - K T_d}{I^2 R + \alpha I T_d} \dots \dots \dots \text{important} \dots \dots \dots 2.25$$

2.1.1.13 Maximising the COP

Angrist (1977, p162) took the following approach to maximise the COP.

He defined a new group of terms ,

$$f = IR/\alpha \dots \dots \dots 2.26$$

equation 2.25 can then be written

$$\Phi = \frac{\alpha f T_c I \alpha / IR - f^2 / 2 (\alpha^2 I^2 R / I^2 R^2) - K T_d}{f (\alpha I T_d \alpha / IR) + f^2 (I^2 R \alpha^2 / I^2 R^2)} \dots \dots \dots 2.27$$

$$\Phi = \frac{f T_c (\alpha^2 / R) - f^2 / 2 (\alpha^2 / R) - K T_d}{f T_d (\alpha^2 / R) + f^2 (\alpha^2 / R)} \dots \dots \dots 2.28$$

Assuming optimum geometry for p and n elements and multiplying 2.28 x R/α²

$$\Phi_{max} = \frac{f T_c - f^2 / 2 - K T_d (R / \alpha^2)}{f T_d + f^2} \dots \dots \dots \text{important} \dots \dots \dots 2.29$$

To maximise equation 2.28 we must minimise the RK component.

To derive the K term refer to equation 2.18

$$K = k_n (A_n / l_n) + k_p (A_p / l_p)$$

Let  $A_n / l_n = v_n$  And  $A_p / l_p = v_p$

$$K = k_n v_n + k_p v_p$$

To derive the R term refer to equation 2.19

$$R = (l_n / A_n) \sigma_n + (l_p / A_p) \sigma_p$$

Let  $A_n / l_n = v_n$  and  $A_p / l_p = v_p$

$$\text{Then } R = \sigma_n / v_n + \sigma_p / v_p$$

$$RK = [\sigma_n / v_n + \sigma_p / v_p] [k_n v_n + k_p v_p]$$

$$RK = \sigma_n k_n + \sigma_p k_p + (\sigma_p k_n) (v_n / v_p) + (\sigma_n k_p) (v_p / v_n) \dots 2.30$$

The product is minimised by taking the derivative of 2.30 and setting the results equal to zero obtaining the equation

as follows.

$$\text{Let } X = v_n/v_p$$

$$RK' = dx[\sigma_n k_n + \sigma_p k_p + \sigma_p k_n X + \sigma_n k_p (1/X)]$$

$$RK' = dx(\sigma_n k_n + \sigma_p k_p) + dx(\sigma_p k_n X) + dx(\sigma_n k_p)(1/X)$$

$$RK' = dx(\sigma_n k_n + \sigma_p k_p) + dx\sigma_p k_n + \sigma_n k_p(-1/X^2)$$

$$RK' = \sigma_p k_n + \sigma_n k_p(-1/X^2)$$

$$0 = \sigma_p k_n + \sigma_n k_p(-1/X^2)$$

$$X^2 = \sigma_n k_p / \sigma_p k_n$$

$$v_n/v_p = (\sigma_n k_p / \sigma_p k_n)^{1/2} \dots \dots \dots 2.31$$

Substituting for  $v_n/v_p$  in 2.30 and simplifying to find (RK)min:

$$(RK)_{\min} = [(\sigma_n k_n)^{1/2} + (\sigma_p k_p)^{1/2}]^2 \dots \dots \dots 2.32$$

Angrist (1977, p483) cited Osterle who in an analysis of electrokinetic energy found the coefficients that described the electrokinetic energy converter in terms of  $C_e, R_e, \alpha_e$ .

Where  $C_e$  = electrical conductance

$R_e$  = resistance to fluid flow

$\alpha_e$  = couple coefficient. In the case of a pump the pressure rise per unit volume.

$$\text{He derived a factor } \beta = \alpha_e^2 / R_e C_e \dots \dots \dots 2.33$$

(Angrist, 1977, p448)

Angrist considered that the quantity  $\beta$  was in some respects analogous to the figure of merit of a thermoelectric generator and therefore applicable to the thermoelectric cooler. The same formula (2.33) can be used to yield a performance figure of merit for the thermoelements. Seebeck effect  $\alpha$ , and RK are substituted for  $\alpha_e, C_e$  and  $R_e$ . A group of properties called the figure of merit(Z) was found.

$$Z = \alpha^2 / RK \dots \dots \dots 2.34$$

To maximise the figure of merit, (RK)min as above from 2.32 is substituted in formula 2.34

$$Z_{\max} = \alpha^2 / [(\sigma_n k_n)^{1/2} + (\sigma_p k_p)^{1/2}]^2 \dots \dots \dots 2.35$$

Refer to formula 2.29 and substitute for Z as derived in formula 2.34

$$\Phi = \frac{fT_c - f^2/2 - T_d/Z_{max}}{fT_d + f^2} \dots\dots\dots 2.36$$

Consider formula 2.36 and differentiate  $\Phi$  with respect to  $f$  to find the value of  $f$  that maximises  $\Phi$ . Set the formula equal to zero and solve for the value of  $f$  that will give the maximum COP ( $\Phi_{max}$ )

$$0 = \frac{d\Phi/df = \frac{[(fT_d + f^2)(T_c - f)] - [(fT_c - f^2/2 - T_d)(T_d + 2f)]}{(fT_d + f^2)^2}$$

$$0 = fT_d T_c + f^2 T_c - f^2 T_d - f^3 - fT_c T_d - 2f^2 T_c + f^2 T_d/2 + f^3 + T_d^2/Z_{max} + 2fT_d/Z_{max}$$

$$0 = f^2(T_c + T_d/2) - 2fT_d/Z_{max} - T_d^2/Z_{max}$$

$$f = \frac{T_d/Z_{max} \pm [(T_d/Z)^2 + (T_c + T_d^2/2)Z_{max}]^{1/2}}{T_c + T_d/2} \dots\dots\dots \text{(Quadratic formula)}$$

$$T_c + T_d/2 = T_c + (T_H - T_c) = T_H + T_c = T_{av}$$

$$f = \frac{T_d/Z_{max} \pm [(T_d/Z_{max})^2 + (T_{av})T_d^2/Z_{max}]^{1/2}}{T_{av}}$$

$$f = T_d/Z \left[ \frac{1 + (1 + T_{av} Z_{max})^{1/2}}{T_{av}} \right]$$

$$f = \frac{T_d}{Z_{max}} \left[ \frac{1 + (1 + T_{av} Z_{max})^{1/2}}{T_{av}} \right] \times \left[ \frac{(1 + T_{av} Z_{max})^{1/2} - 1}{(1 + T_{av} Z_{max})^{1/2} - 1} \right]$$

$$f = \frac{T_d}{Z_{max}} \left[ \frac{1 + T_{av} Z_{max} - 1}{(1 + T_{av} Z_{max})^{1/2} - 1} \right]$$

$$f_{\Phi_{max}} = T_d / [(1 + Z_{max} T_{av})^{1/2} - 1] \dots\dots\dots 2.37$$

The maximum coefficient of performance may now be determined by substituting  $f_{\phi_{max}}$  found in 2.37 in 2.36.

$$\phi_{max} = \frac{T_c/T_d \left[ \frac{(1 + Z_{max} Tav)^* - T_H/T_c}{(1 + Z_{max} Tav)^* + 1} \right]}{\dots} \dots \text{important.. 2.38}$$

2.1.1.14 Optimum Current

Substitute in 2.26 for the value of  $f_{\phi_{max}}$  as derived in 2.37 and solve for  $I_{\phi_{max}}$ . This equation will give the current required to maximise the COP ( $\phi_{max}$ ) as calculated in equation 2.38.

$$I_{\phi_{max}} = \frac{\alpha T_d}{R[(1 + Z_{max} Tav)^* - 1]} \dots \dots \text{important} \dots \dots 2.39$$

2.1.1.15 Optimum Voltage

The voltage ( $V_{opt}$ ) drawn across a couple operating at maximum COP is the result of the sum of  $I_x R$  rise across the junction and the e.m.f. to create the Seebeck effect. The voltage equation can then be written as follows

$$V_{\phi_{max}} = I_{\phi_{max}} R + \alpha T_d \dots \dots \dots 2.40$$

To derive an equation for the voltage that will give optimum COP ( $V_{\phi_{max}}$ ) substitute  $I_{\phi_{max}}$  found in equation 2.39 for  $I$  in equation 2.40.

$$V_{\phi_{max}} = \alpha T_d \left[ \frac{(1 + Z_{max} Tav)^*}{(1 + Z_{max} Tav)^* - 1} \right] \dots \dots \dots \text{important} \dots \dots 2.41$$

2.1.1.16 Optimum Power

Power input for maximum COP is obtained by substituting  $I_{\phi_{max}}$  for  $I$  in equation 2.22

$$W_{\phi_{max}} = \frac{(1 + Z_{max} Tav)^*}{R} \left[ \frac{\alpha T_d}{(1 + Z_{max} Tav)^{0.5} - 1} \right]^2 \dots \dots \dots 2.42$$

important

2.1.1.17 Maximum Heat Pumping Rate

The first step to determine the maximum heat pumping rate is to determine the equation for the current (Iqmax) that will give the maximum heat pumping rate. This current is found by taking the derivative of the heat flow equation 2.13 with respect to I and setting the results equal to zero.

$$q_t = \alpha T_c I - RI^2/2 - KT_d$$

$$dq_t/dI = \alpha T_c - RI \text{ Setting the equation to zero therefore:}$$

$$I_{qmax} = \alpha T_c / R \dots \dots \text{important} \dots \dots \dots 2.42$$

The voltage (Vqmax) to produce Iqmax is found by substituting Iqmax found in equation 2.42 in equation 2.40:

$$V_{qmax} = \alpha T_c + \alpha T_d$$

$$V_{qmax} = \alpha T_H \dots \dots \dots 2.43$$

The maximum heat pumped for a given temperature difference (Td) is determined by substituting Iqmax in equation 2.13.

$$q_{max} = (\alpha^2 T_c^2 / 2R) - KT_d \dots \dots \dots 2.44$$

It follows that the power to produce the maximum cooling is the product of Vqmax and Iqmax:

$$P_{qmax} = \alpha^2 T_c T_H / R \dots \dots \dots 2.45$$

2.1.1.18 Maximum Temperature Difference

The maximum temperature difference is obtained by considering equation 2.44 and allowing zero heat to be rejected

$$T_d = \alpha^2 T_c^2 / 2RK \dots \dots \dots 2.46$$

Then substituting the minimum value of RK

$$T_{dmax} = \frac{\alpha^2 T_c^2}{\alpha^2 T_c^2 / [(\sigma_n k_n)^* + (\sigma_n k_n)^*]^2} \dots \dots \dots 2.47$$

Substituting Zmax from 2.35:-

$$T_{dmax} = \alpha T_c / Z_{max} \dots \dots \dots 2.48$$

HEAT PUMPED AT MAXIMUM COP  $q_{\phi_{max}}$

The heat pumped at maximum COP is obtained by substituting the current as found in equation 2.39 in equation 2.13 which is the total heat removed equation.

$$q_{\phi_{max}} = KT_d \left[ \frac{ZT_c(1+Z_{max}T_{av})^{\frac{1}{2}} - Z_{max}T_{av}}{[(1+Z_{max}T_{av})^{\frac{1}{2}} - 1]^2} - 1 \right] \text{ important. 2.49}$$

An estimation of the figure of merit for a couple can be obtained by measuring the maximum temperature difference produced by the junction and the cold side temperature. It must be noted that all of the above maximum equations and other calculations in the dissertation assume optimum couple geometry as proved in equation 2.31 where

$$(A_p/l_p)/(A_n/l_n) = (k_n\sigma_p/k_p\sigma_n)^{\frac{1}{2}} \dots \dots \dots 2.50$$

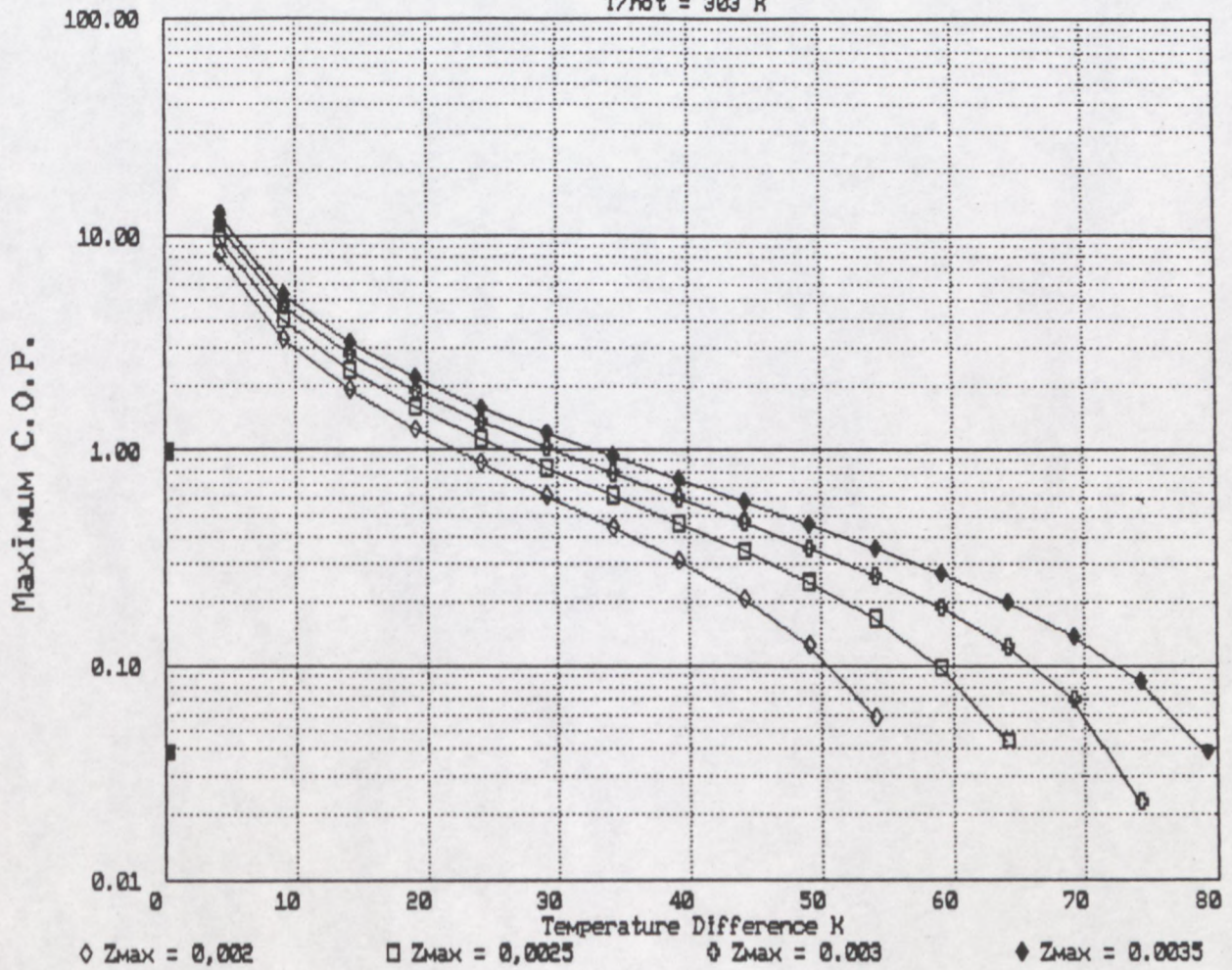
Useful graphs for Zmax can be plotted using equation 2.38 and varying the  $T_d$  value to give the  $\phi_{max}$  value. Figure 2.5 shows a graph plotted for some realistic values of Zmax.

2.1.1.19 Figure of Merit

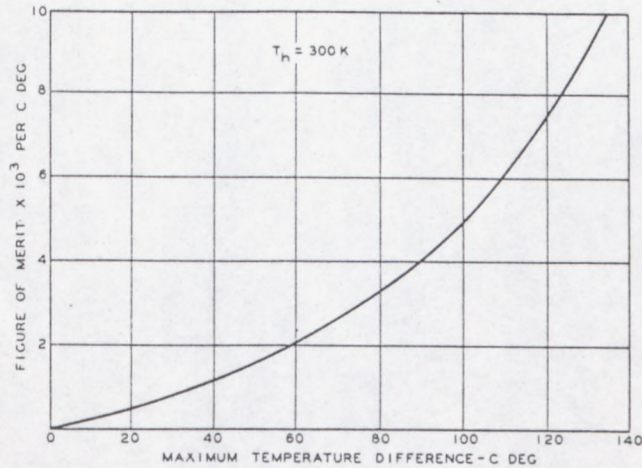
It can be seen from from equation 2.38 that by far the most dominant factor in the performance of thermoelectric coolers is the figure of merit. Use of the formulas indicated that even a small increase in the figure of merit resulted in a significant improvement in thermal efficiency. This factor is obviously of major importance when selecting suitable materials for thermoelements. Of course the figures of merit for the n and p materials cannot be viewed in isolation from each other. The question as to whether a material is the best for one branch depends to an extent on the properties of the other material. Happily progress has been parallel in positive and negative thermoelectric materials operated at room temperature. Figure 2.6 shows a typical figure of merit against maximum temperature difference graph (ASHRAE Fundamentals Handbook ,1981 pl.30).

### MAXIMUM C.O.P./Z<sub>max</sub> GRAPH

T/hot = 303 K



Max. COP Graph  
 Source: Personal Work  
 Figure 2.5



Maximum Temperature Difference from Room Temperature Produced by a Thermoelectric Couple as a Function of the Figure of Merit

Figure 2.6

Source: ASHRAE Fundamentals (1981, p1.30)

## 2.1.2 MATERIALS

This section gives a very brief description of the important characteristics effecting the behaviour of materials suitable for thermoelectric elements.

### 2.1.2.1 Crystal Lattice

The crystal lattice is the framework through which the carriers of energy and charge move. The crystal structure preferred by a particular element depends on the way in which the atoms are bound together.

#### 2.1.2.1.1 Covalent bonds

In many semiconductors the bond results from the sharing of atoms in the incomplete outer shell. A covalent bond arises from sharing electrons between adjacent atoms in the outer shell of neighbouring atoms. These types of bonds are extremely strong.

#### 2.1.2.1.2 van der Waals bond

The van der Waals bond is a weak bond that exists between electrically neutral atoms resulting from small dipole moments.

### 2.1.2.1.3 Lattice Imperfections

Kittel (1967,p12) defines a lattice point group as a collection of the symmetry operations which when applied about a lattice point leaves the lattice invariant (uniform). Lattice structures are not perfect, some of the lattice sites may be vacant while others may be occupied by impurity atoms. This is called a point defect. Another point defect occurs when atoms inhabit interstitial positions between lattice sites. Line defects also occur where periodicity of the lattice is interrupted. These defects effect the transport characteristics of the solid.

### 2.1.2.2 Heat Conduction

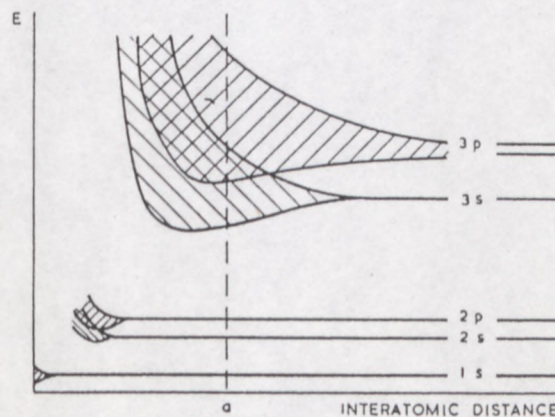
Thermal conductivity is due to the sum of the lattice vibration and the component of the electrical charge carriers. Heat applied to the lattice increases the vibration energy of the atoms. Increasing the temperature of a body increases the amplitude of vibration of the body. Increased vibration due to heat is passed on to adjacent atoms and eventually to the rest of the crystal by the chemical bonds. Vibrations are projected through the crystals in waves. Peierls cited by Goldsmid (1964, p19) saw these waves as phonon wave packets originating from quantised vibrational waves. These packets are called phonons and are normally scattered by collision with each other. Scattering of phonons also occurs because of impurities and this phenomena is particularly important at low temperatures.

### 2.1.2.3 Free Electron Theory

The free electron theory postulated that all except the outer electrons of the atoms forming the metal are tightly bound. The outer electrons form a free electron gas having many of the properties of real gas described in the kinetic theory. Although this theory had a number of successes in explaining some of the properties of metals, it is now considered invalid due to certain inconsistencies in the approach which indicated that electrons really do not behave as a classical gas.

#### 2.1.2.4 Energy Bands

Considering that electrons do not move in free space nor in a random arrangement of isolated atoms but in arrays of atoms that are coupled together it is not surprising that the free electron theory fails to explain all their properties. To explain the energy band theory each electron is considered in isolation. This is called the one-electron model. The effect of all the other electrons and of the atom nuclei is to provide a periodic potential. Energy bands appear to arise through the periodic nature of the lattice. It is however better to consider the energy bands as arising from the broadening of the electron energy levels as the atoms approach each other when a vapour condenses to form a solid or liquid. Figure 2.7 shows this phenomenon.



Schematic Diagram of the Broadening of the Energy Levels of Sodium Atoms as the Interatomic Distance is Reduced- $\alpha$  is the Interatomic Spacing in the Metal

Figure 2.7

Source: Goldsmid (1964, p28)

#### 2.1.2.5 Insulation

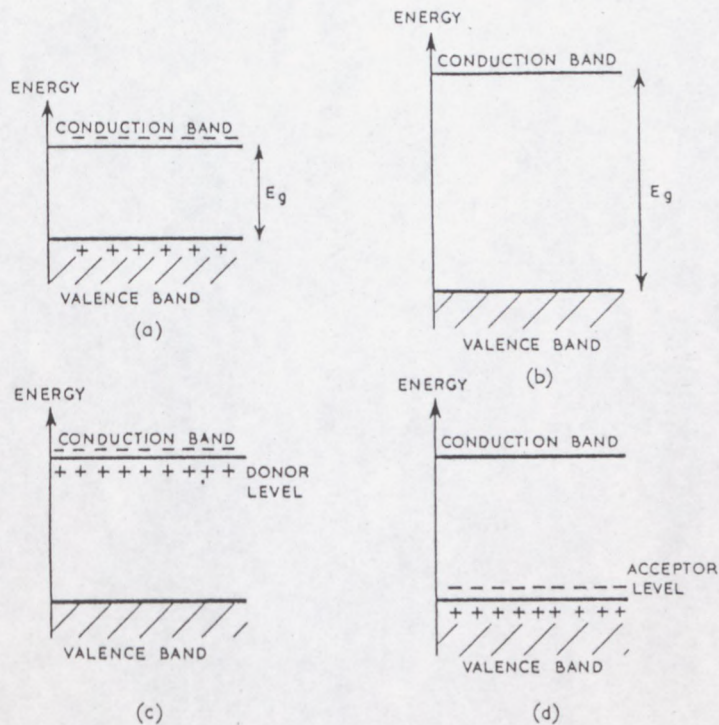
At temperatures above 0°K, no solid is a perfect insulator because there is at least some movement of electrons from the highest full band to the next highest empty band across the energy gap. When the conductivity due to excitation of carriers across the forbidden band is no longer negligible the material is said to be an intrinsic semiconductor. Each electron excited into the upper band leaves behind a positive

hole in the lower band. In an intrinsic semiconductor the number of quasi-free electrons and positive holes are equal. A solid that is normally a poor conductor can be made to conduct electricity more readily by adding impurities. Impurities that tend to donate electrons to the upper or conduction bands are termed donors. If an impurity semiconductor is taken up to a high enough temperature a certain number of electron-hole pairs are excited across the forbidden gap.

Materials that contain donor impurities and conduct electricity by means of quasi-free electrons are known as n-type impurity semiconductors.

Impurities that take up electrons from the lower valence band are known as acceptors. Conduction in materials that contain acceptors is due to positive holes in the valence band. Materials that conduct electricity by means of acceptors are known as p-type semiconductors. Impurity semiconductors are also known as extrinsic semiconductors.

See Figure 2.8 for energy diagrams.



Energy Diagrams for  
 (a) Intrinsic Semiconductor,  
 (b) Insulator  
 (c) n-Type impurity semiconductor  
 (d) p-Type impurity semiconductor

Figure 2.8

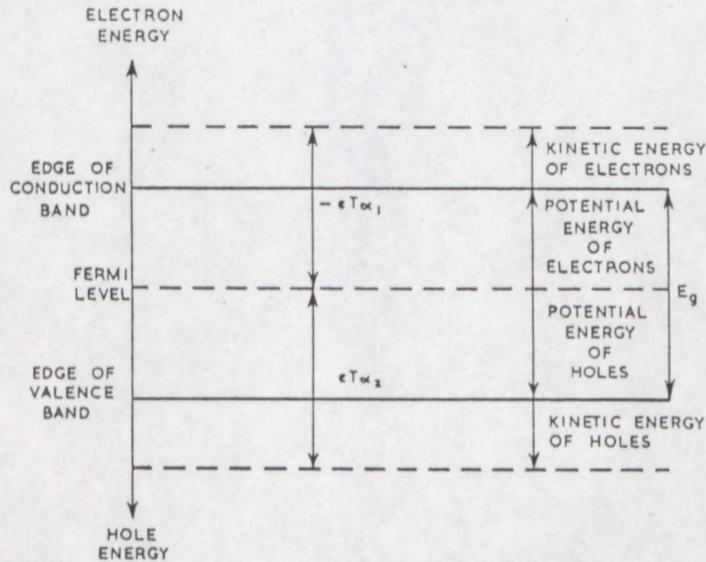
Source: Goldsmid (1964, p30)

Intrinsic semiconductors differ from insulators in terms of the width of their energy bands. In more impure semiconductor conductors with which this project deals these bands are so wide that they overlap. These materials differ from ordinary semiconductors in that their electrical conductivity does not fall off at very low temperatures. When impurity bands overlap the main bands remain ionised even at 0°K and the carrier concentration is temperature independent. Semiconductors differ from metals in having a positive energy gap between a more or less full valence band and a more or less empty conduction band. Semimetals are materials in which there is slight overlap between the valence and conduction band. There is otherwise little

difference between the the properties of semimetals and narrow-gap semiconductors.

2.1.2.6 Mixed Condition

When there is an appreciable number of both negative quasi-free electrons and positive holes but with their concentrations unequal, the semiconductor is said to be of mixed conduction. The enhanced transport of heat in a mixed semiconductor is known as bipolar thermodiffusion. This behaviour is most readily observed in narrow-gap materials since the electrical conductivity in the intrinsic region is reasonably large. Figure 2.9 shows a diagrammatic representation of this phenomenon (Goldsmid, 1964, p40).



Energy Diagram Showing the Relationship Between the Partial Seebeck Coefficients for Electrons and Holes in a Mixed Semiconductor

Figure 2.9

Source: Goldsmid (1964, p40)

2.1.2.7 Scattering

Electrons in a perfect periodic lattice would not be scattered. In an electric field they would be continually accelerated until reaching the boundaries of the sample. At temperatures above 0°K the perfect periodicity of the lattice structure is disturbed. Disturbance of periodicity causes effective scattering centres to be developed. A rise in

temperature increases the amplitude of thermal vibrations and a more pronounced scattering of charges takes place. The inverse occurs when temperature is decreased.

#### 2.1.2.8 Transport In a Single Band

Application of an electric field and a temperature gradient to a conductor lead in general to flows of heat. The electrical field alters the distribution of electrons without effecting the phonon distribution. This occurs in such a way that the average velocity is no longer zero. The temperature gradient however changes both the electron and phonon distribution.

#### 2.1.2.9 Material Selection

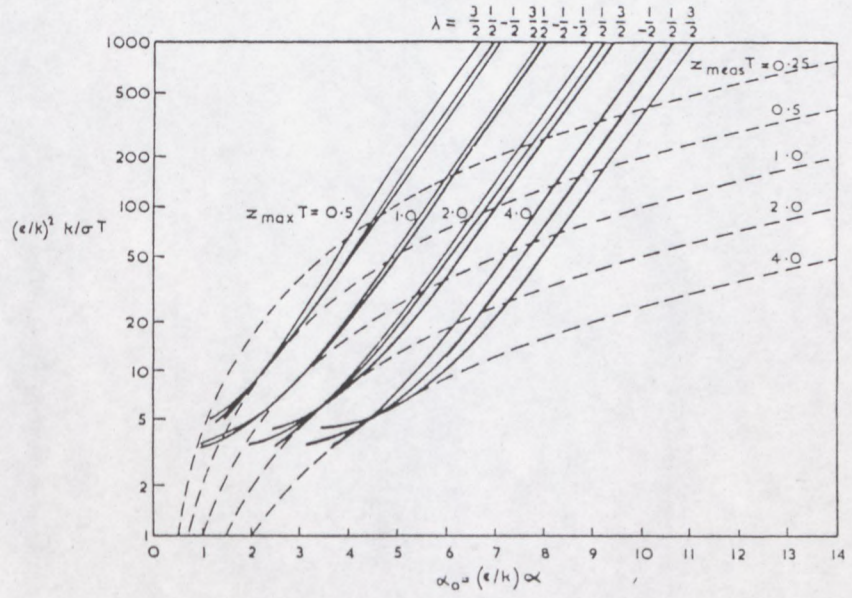
Metals are not suitable for thermoelectric cooling systems as it is well known that when working at room temperature, high Seebeck coefficients can usually only be obtained using semiconductors. This is probably because the lattice component of conductivity is usually negligible in metals due to the fact that phonons are scattered by electrons and the electronic component is so great (Goldsmid, 1964, p43). In semiconductors the conduction of heat is primarily due to lattice vibrations and is not directly dependant on electrical conductivity. The electrical conductivity may be very low while the thermal conductivity may be high. Goldsmid (1964, p43) found that in certain semiconductors the higher Seebeck effect more than compensated for the inferior ratio of electrical to thermal conductivity, but in spite of obtaining Seebeck coefficients in excess of  $300\mu\text{V}/^\circ\text{C}$  favourable figures of merit were never achieved.

#### 2.1.2.10 Extrinsic Semiconductor (Impurity, p-type)

Goldsmid (1964, p45) determined that for high figures of merit the semiconductors should have high carrier mobility, high effective mass, and low lattice thermal conductivity.

A number of useful and practical curves have been plotted by Simon (Figure 2.10) who was cited by Goldsmid (1964, p50 & p51). These graphs can be used in the following way. Find the solid curve for the appropriate value of  $\lambda$  that

passes through the point that corresponds to the values of  $K/\sigma T$  and  $\alpha$  measured from the sample (Goldsmid, 1964, p50).



Simon's Curves of  $Z_{max}T$  and  $Z_{mean}T$  as Functions of lambda and Measured Values of  $\alpha$  and  $k/\sigma T$

Figure 2.10

Source: Goldsmid (1964, p50)

Who cited Simon

Simon prepared more complete graphs shown in Figure 2.11, Figure 2.12, Figure 2.13 and Figure 2.14. In these curves it is possible to immediately see the optimum Seebeck coefficient corresponding to a selected  $Z_{max}$  and also the reduction in the figure of merit if the Seebeck coefficient does not have the optimum value (Goldsmid, 1964, p51-54).

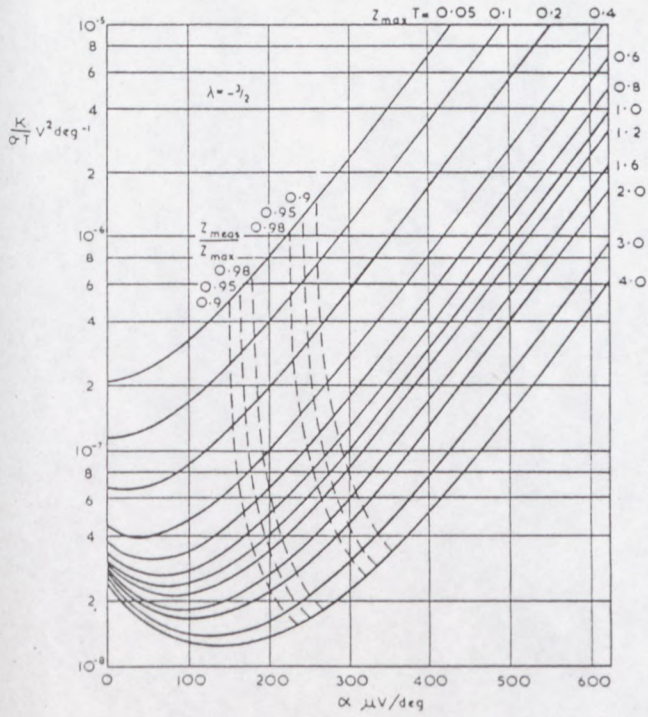


Figure 2.11  $h = -3/2$

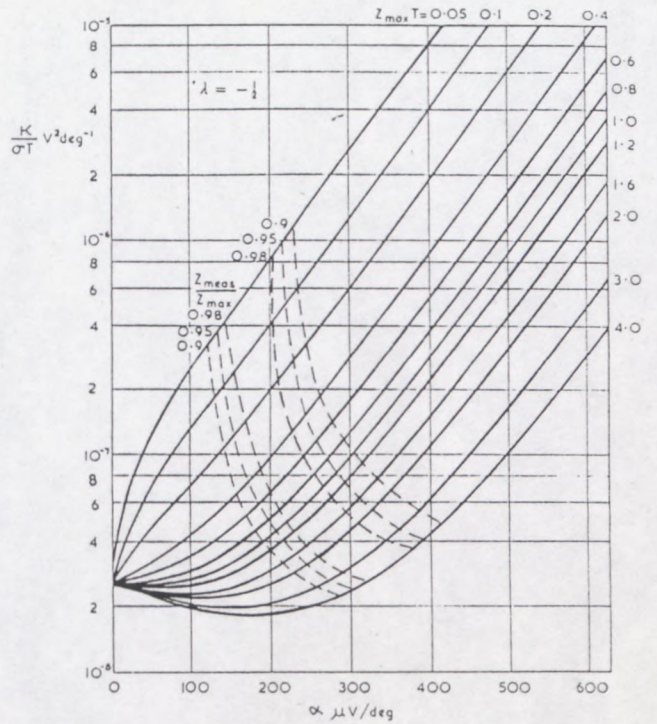


Figure 2.12  $h = -1/2$

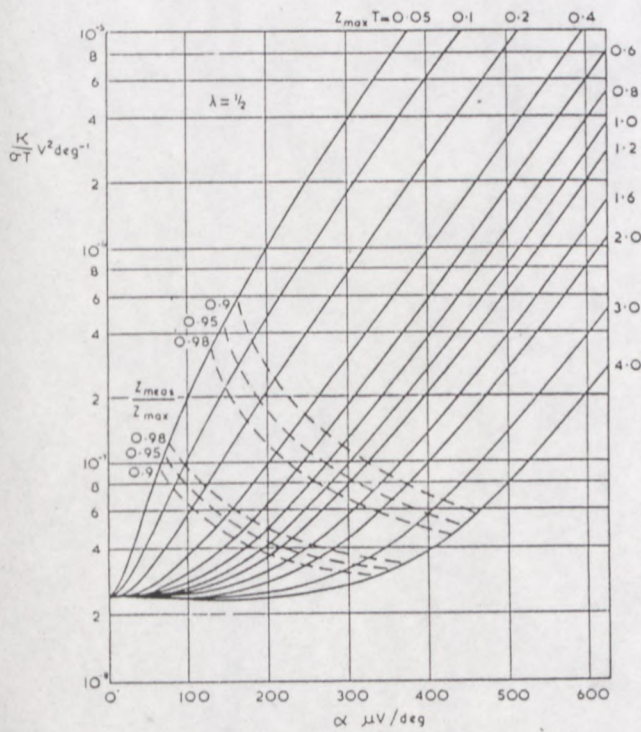


Figure 2.13  $h = 1/2$

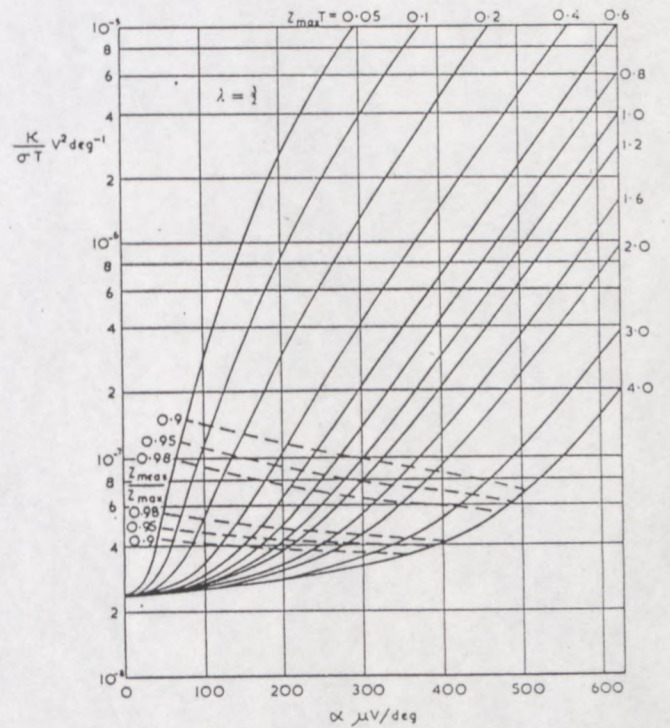


Figure 2.14  $h = 3/2$

Simon's Curves of Constant  $Z_{max}T$

The Broken Lines Represent Constant Values of  $Z_{max}/Z_{mean}$

Source: Goldsmid (1964, p51-54)

Who cited Simon

#### 2.1.2.11 Mixed and Intrinsic Semiconductors

Most of the best thermoelectric materials are narrow-gap semiconductors, as at room temperatures the energy gap is not many times greater than  $kT$ . The effect of mixed conduction is to lower the figure of merit although, if the reduced energy gap is equal to 8 or more, the figure of merit is not appreciably reduced.

#### 2.1.2.12 Modes of Lattice Scattering

Two modes of lattice scattering are encountered in semiconductors, acoustic mode and optic mode. In very pure crystals the scattering of the charge carriers is due to the vibration of the lattice and this form of scattering imposes an upper limit on the mobility of any material. Acoustic-mode lattice scattering can be attributed to the local change in density brought about by the thermal vibrations which in turn, leads to fluctuation in the periodic potential through which the charge carriers move. Covalent rather than ionic crystals tend to be used for thermoelectric applications and it is normally hoped that all forms of lattice scattering excepting acoustic modes will be negligible. Intrinsic semiconductors are not usually very good thermoelectric materials. Goldsmid (1964, p59) stated that when bonds are ionic, scattering by the optic modes is due to the polarisation of the lattice that results from the ionic movement.

#### 2.1.2.13 Scattering By Static Imperfections

As intrinsic semiconductors do not make very good thermoelectric elements it is desirable to make the semiconductors extrinsic. This is achieved by introducing donor or acceptor impurities which act as scattering centres. In materials used for TECs all impurities are usually ionised. The associated electrons or holes take part in the conduction processes.

#### 2.1.2.14 Alloy Scattering

Alloy scattering is very important since the best forms of materials for TEC systems are alloys as opposed to compounds

or pure elements. Brooks, cited by Goldsmid (1964, p48), showed that lattice scattering in alloys is due to the local variation in the potential energy at the band edge. The theory of alloy scattering is therefore similar to the deformation-potential theory of acoustic-mode scattering.

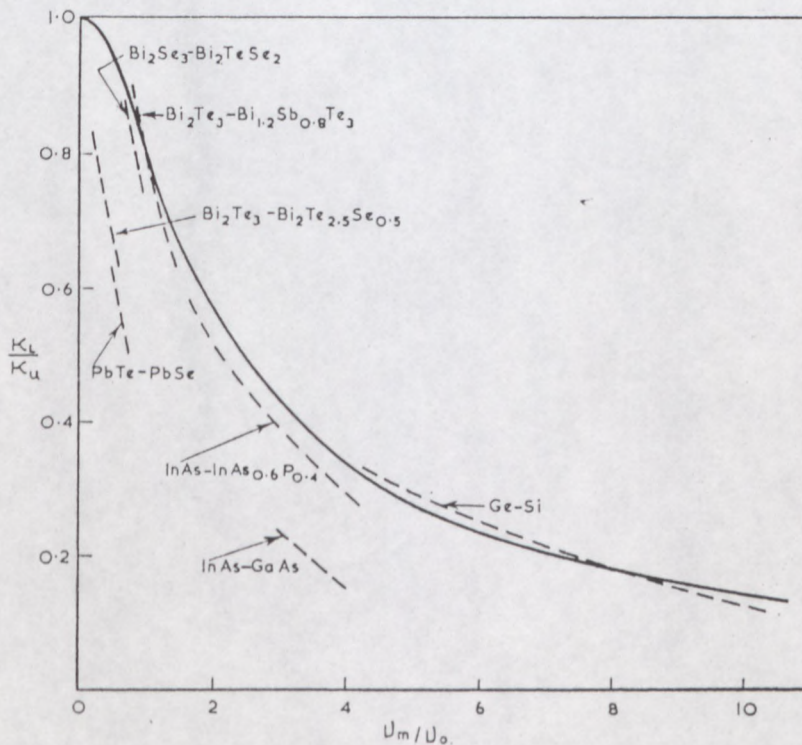
#### 2.1.2.15 Multi-Valley

When there is more than one valley the charge carriers can be scattered not only to different energy states within their own valley but also to energy states in other valleys. There is evidence to indicate that it is advantageous to employ multivalley semiconductors in TEC applications. Bismuth telluride compound's behaviour is exemplary of a noncubic multi-valley semiconductor.

#### 2.1.2.16 Semiconductor Alloys

Ioffe (et al) cited by Goldsmid (1964, p67) pointed out that solid solutions of isomorphous semiconductors might have higher figures of merit than the pure crystals. He expected that more intense scattering of phonons than electrons would result from the alloy and this occurrence would raise the ratio of mobility to lattice thermal conductivity. Goldsmid (1964,p68) stated that the wavelength of phonons that are responsible for the transport of heat are only of the order of a few interatomic spacings so they are scattered most effectively by local variations in the properties of the lattice on the atomic scale. In depth studies by Goldsmid (1964, p70) indicated that semiconductor alloys as opposed to pure elements or compounds, should have the highest figures of merit. He indicated that the ideal thermoelectric material seemed to be a semiconductor alloy of high mean atomic weight having a multivalley band structure with a low inertial effective mass for the charge carriers. The energy gap should be large enough to allow a reasonably high Seebeck coefficient without appreciably mixed conduction effects. Higher mean atomic weight alloys normally indicate smaller energy gaps. Goldsmid (1964, p73) plotted a graph comparing his theoretical calculations of thermal conductivity with experimental results (See Figure 2.15). The broken curve in

the diagram shows experimental values of lattice thermal conductivity  $K_L$  divided by the umklapp lattice thermal conductivity  $K_U$  plotted against Debye frequency  $V_m$  divided by the optic mode frequency  $V_o$ . The solid curve represents the theoretical variations of the same curve.



Comparison of the Theoretical Behaviour of the Lattice Thermal Conductivity in Alloys at High Temperatures with Experimental Results.

Figure 2.15

Source: Goldsmid (1964, p73)

#### 2.1.2.17 Phonon-Drag

It is normally assumed that the transport of charge and heat by electrons can be considered independently of the transport of heat by the phonons. In most situations that arise in practice this is a valid approach. In certain materials, however, it is necessary to deal with electrons and phonons simultaneously. Effects resulting from the interdependence of flow are termed phonon-drag. It may be assumed that phonon-drag is absent at the temperatures that are used in

this project because this effect is only a factor at the very lowest of temperatures which are not used here.

### 2.1.3 SPECIFIC MATERIALS

The foregoing sections have very briefly covered the aspects that influence selection of good TEC materials. This section deals with the best materials suited to the purpose of cooling in the region of room temperature. These are the materials used in the project. The study will also be confined to alloys rather than compounds.

Goldsmid (1964, p100) found that the best materials for use at room temperature were alloys of bismuth telluride with antimony telluride and bismuth selenide. It is important to note that bismuth telluride has a narrow energy gap implying that it is unsuitable for use in applications where elevated ambient hot sink temperatures are encountered. Goldsmid (1964, p100) felt that lead telluride may have inherent characteristics which would be advantageous when the hot sink of the cooling unit operated at a high ambient temperature.

#### 2.1.3.1 Bismuth Telluride

The crystals of bismuth telluride,  $\text{Bi}_2\text{Te}_3$ , are made up of atoms forming the following sequences.

$\text{Te}^{[1]}-\text{Bi}-\text{Te}^{[2]}-\text{Bi}-\text{Te}^{[1]}-\text{repeat}$

The tellurium and bismuth layers are connected by strong covalent-ionic bonds. The neighbouring telluride layers are held together by weak van der Waal forces. Bismuth telluride can be very easily cleaved along the basal planes. Apart from the mechanical anisotropy of this material there exists an anisotropy of the semiconductor attributes. This anisotropy is a peculiar property of some semiconductor materials worth noting (Goldsmid, 1964, p101).

The following table determined by various scientists give the structural cell data for  $\text{Bi}_2\text{Te}_3$  and some other general properties.

PROPERTIES OF BISMUTH TELLURIDE

-----  
 Hexagonal unit cell a(binary) 4,3835 ± 0,0005 Å 20°C  
 dimensions c(trigonal) 30,487 ± 0,001 Å  
 (Francombe)

-----  
 Density 7,8587 ± 0,002g/cm<sup>3</sup> 20°C  
 (Goldsmid)

-----  
 Thermal expansion a(binary) 12,9 x 10<sup>-6</sup>deg<sup>-1</sup> 20°C  
 coefficients c(trigonal) 22,2 x 10<sup>-6</sup>deg<sup>-1</sup>  
 (Francombe)

-----  
 Elastic constants C<sub>11</sub> 6,46 x 10<sup>11</sup> dyne/cm<sup>2</sup> 20°C  
 C<sub>12</sub> 3,58 x 10<sup>11</sup> dyne/cm<sup>2</sup>  
 C<sub>33</sub> 4,73 x 10<sup>11</sup> dyne/cm<sup>2</sup>  
 C<sub>44</sub> 2,50 x 10<sup>11</sup> dyne/cm<sup>2</sup>  
 C<sub>13</sub> not determined  
 C<sub>14</sub> not determined

(Ilisavskii)

-----  
 Latent heat of fusion 29,0 ± 1,0 kcal/mole  
 (Bolling)

-----  
 Specific heat (high c 36,0+1,30x10<sup>-2</sup>T- to 550°C  
 temperatures) 3,11x10<sup>-5</sup>T<sup>2</sup>cal  
 deg<sup>-1</sup>-mole

(Bolling)

-----  
 Specific heat (low c (20±9)x10<sup>-5</sup>T+ bellow 2,3K  
 temperatures) 556(T/θ<sub>0</sub>)<sup>3</sup>cal/deg-mole

(Itskevich)

-----  
 The above researchers were cited by Goldsmid. (1964,p102)

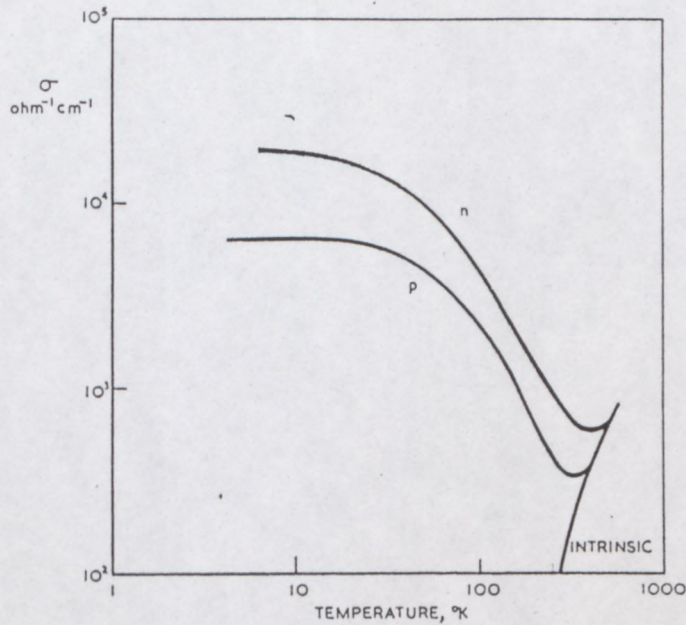
2.1.3.1.1 Bismuth Telluride Band Structure

Drabble working alone and with Groves and Wolfe observed that both the n-type and p-type bismuth telluride materials fitted the 6 valley model with the valley centred on the reflective

planes. Testardi (et al) bore out Drabble's findings that both the conduction bands and the valance bands were of the 6 valley type. Austin discovered that the forbidden energy gap was 0,13eV at a temperature of 20°C and the temperature coefficient between -155°C and 20°C was  $-9,5 \times 10^{-5}$  eV/deg. These scientists were cited by Goldsmid (1964,p104-106).

#### 2.1.3.1.2 Bismuth Telluride Electrical Properties

Figure 2.16 shows temperature against conductivity graphs plotted by Yates for both n and p samples of  $\text{Bi}_2\text{Te}_3$  (Cited by Goldsmid, 1964, p106). It can be seen from the graph that the conductivity falls from a maximum value at 20°K. The fact that the graph is so steep close to the temperatures at which the test system was operated is to be noted. It was expected that this would cause significant increases in resistance in the cooling system when ambient temperatures above room temperatures ( $\pm 20^\circ\text{C}$ ) were experienced. Since the conductivity does not become positive at low temperatures it is postulated that carriers originate from impurity bands which overlap the valance bands. It is important to note that Goldsmid (1964, p107) attributed the change in conductivity with temperature in the extrinsic region to change in mobility of electrons. At temperatures below the intrinsic range the electrical properties are controlled by impurities. Goldsmid (1964, p107) felt that some form of imperfection scattering must predominate at below 20°K to keep  $\sigma$  constant. At liquid-nitrogen temperature and above he thought that only scattering of charge carriers by lattice vibration was significant. Figure 2.16 is a reproduction of a graph plotted by Yates cited by Goldsmid (1964, p106) which shows the normal characteristics for nondegenerate  $\text{Bi}_2\text{Te}_3$ . If the product of conductivity and temperature is less than the fermi-energy then electron gas is termed degenerate.



Variation With Temperature of the Electrical Conductivity  
in Typical Samples of p and n Type  $\text{Bi}_2\text{Te}_3$

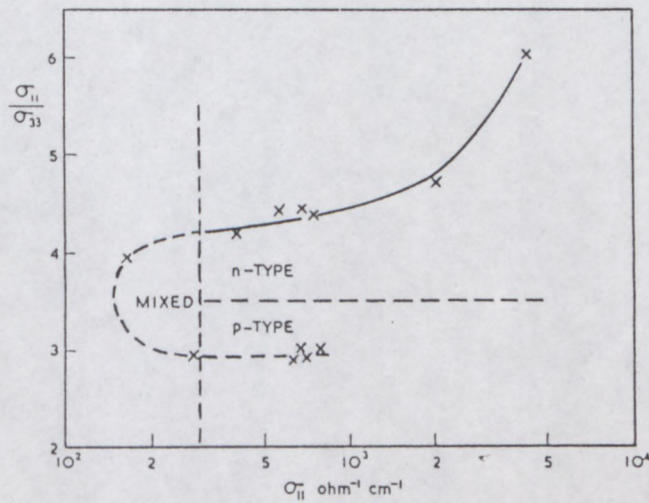
Figure 2.16

Source: Goldsmid (1964, p106)

Who cited Yates

#### 2.1.3.1.3 Anisotropy of Electrical Conductivity

An unusual property of this material is that the conductivity parallel to the basal plane ( $\sigma_{11}$ ) is greater than it is perpendicular to the plane ( $\sigma_{33}$ ). Figure 2.17 shows a graph of the anisotropy of electrical conductivity of bismuth telluride plotted by Delves (et al). The graph indicates the ratio of perpendicular conductivity to parallel conductivity for the p and n materials.



Anisotropy of the Electrical Conductivity  
of Bismuth Telluride at 20°C

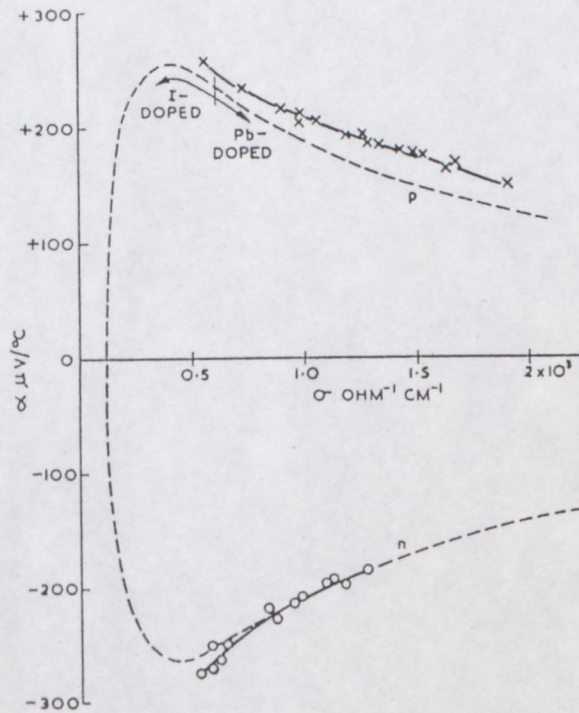
Figure 2.17

Sourced from Goldsmid (1964, p107)

Who Cited Delves (et al)

#### 2.1.3.1.4 Seebeck Coefficient

Particularly useful graphs were plotted by Goldsmid (1964, p109) for bismuth telluride and its alloys showing Seebeck coefficient against electrical conductivity (See Figure 2.18). Anisotropy is evidently not a factor with the Seebeck coefficient for n and p type materials that are truly uniform.



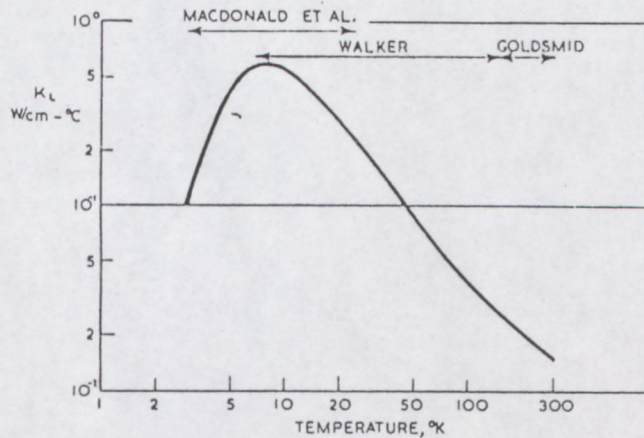
Seebeck Coefficient Plotted Against Electrical Conductivity for Bismuth Telluride and its Alloys at 20°C  
 -----  $\text{Bi}_2\text{Te}_3$ , x--x  $\text{Bi}_{0.5}\text{Sb}_{1.5}\text{Te}_3$ , o-o  $\text{Bi}_2\text{Te}_{2.7}\text{Se}_{0.3}$ .

Figure 2.18

Sourced from Goldsmid (1964, p109)

#### 2.1.3.1.5 Thermal conductivity

Figure 2.19 shows a graph for the lattice thermal conductivity of  $\text{Bi}_2\text{Te}_3$  at a temperature of 300°K. (Goldsmid, 1964, p112) The graph compares information from MacDonald (et al), Walker and Goldsmid.



Variation with Temperature of the Lattice  
Thermal Conductivity of Pure Bismuth Telluride

Figure 2.19

Source: Goldsmid (1964, p112)

#### 2.1.3.1.6 Figure of Merit

Since the anisotropy of electrical conductivity is more marked than thermal conductivity it follows that the Figure of merit is higher along the basal plane. Goldsmid (1964, p113) plotted graphs of Figure of merit against Seebeck coefficient at 20°C for bismuth telluride and its alloys. Goldsmid makes the interesting observation that  $Z_n$  and  $Z_p$  reach a maximum at  $\pm 15^\circ\text{C}$  and falls off rapidly to room temperature at  $\pm 25^\circ\text{C}$ . He also noted that other thermoelectric materials performed better than  $\text{Bi}_2\text{Te}_3$  at higher than room temperatures.

#### 2.1.3.2 Bismuth Telluride Alloys

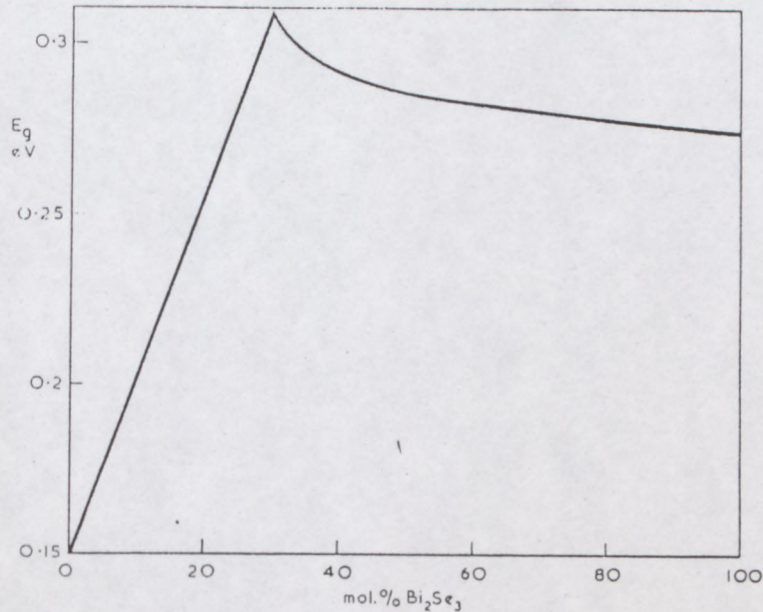
##### 2.1.3.2.1 Seebeck effect

The addition of antimony telluride ( $\text{Sb}_2\text{Te}_3$ ) to bismuth telluride  $\text{Bi}_2\text{Te}_3$  caused the Seebeck coefficient to fall from  $\pm 220\mu\text{V}/\text{deg}$  for the undoped material to  $\pm 140\mu\text{V}/\text{deg}$  for  $\text{Bi}_{0.5}\text{Sb}_{1.5}\text{Te}_3$ . If bismuth selenide ( $\text{Bi}_2\text{Se}_3$ ) is added to bismuth telluride ( $\text{Bi}_2\text{Te}_3$ ) the acceptor concentration is decreased and if sufficient selenium is added to the alloy the material becomes n-type. Bennet cited by Goldsmid (1964, p114) found that undoped  $\text{Bi}_2\text{Te}_{2.1}\text{Se}_{0.9}$  was almost intrinsic.

It must be remembered that the number of quasi-free electrons and holes are equal in an intrinsic semiconductor.

#### 2.1.3.2.2 Band structure

Airapetyants and Efimova cited by Goldsmid (1964,p115) implied that the energy gap for  $\text{Bi}_{0.5}\text{Sb}_{1.5}\text{Te}_3$  fell to 0,1eV and that  $\text{Sb}_2\text{Te}_3$ 's energy gap was reduced to zero, but Goldsmid (1964, p115) felt that the energy gap of the bismuth telluride doped with  $\text{Sb}_2\text{Te}_3$  does not fall since Seebeck coefficients as high as  $260\mu\text{V}/\text{deg}$  at room temperature for  $\text{Bi}_{0.5}\text{Sb}_{1.5}\text{Te}_3$  were found. Austin and Sheard cited by Goldsmid (1964, p115) plotted a graph for the dependence of the energy gap on doping of  $\text{Bi}_2\text{Te}_3$  with bismuth selenide ( $\text{Bi}_2\text{Se}_3$ ) (See Figure 2.20). The graph shows that the energy gap rises on doping, reaching a maximum of 0,31eV at a composition of  $\text{Bi}_2\text{Te}_{2.1}\text{Se}_{0.9}$ . If more tellurium is replaced by selenium the energy gap decreases. Goldsmid (1964, p114) considered that the sharp discontinuity at  $\text{Bi}_2\text{Te}_{2.1}\text{Se}_{0.9}$  probably indicated a change in band structure. If his assumption was correct the band structure at the lower selenium levels possibly resembles that of  $\text{Bi}_2\text{Te}_3$  in the number of energy extrema and their symmetry.



Dependence of Energy Gap on Composition  
in the  $\text{Bi}_2\text{Te}_3$ - $\text{Bi}_2\text{Se}_3$  System

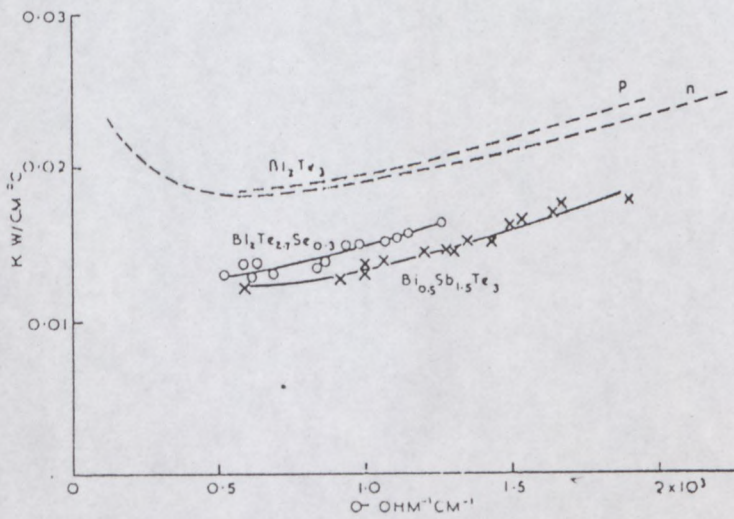
Figure 2.20

Source: Goldsmid (1964, p115)

Who Cited Austin and Sheard

#### 2.1.3.2.3 Electrical and Thermal Conductivity

Both Hall and Seebeck effects indicate that hole mobility rises on the addition of  $\text{Sb}_2\text{Te}_3$  to  $\text{Bi}_2\text{Te}_3$ , on the other hand Airapetyants (et al) cited by Goldsmid (1964, p116) indicated that electron mobility falls when some bismuth is replaced with antimony. The addition of more than 20 mol.%  $\text{Bi}_2\text{Se}_3$  to  $\text{Bi}_2\text{Te}_3$  leads to a reduction in both electron and hole mobility. The relationship of Seebeck coefficient to electrical conductivity when doping with up to 10 mol.%  $\text{Bi}_2\text{Se}_3$  is not very different from  $\text{Bi}_2\text{Te}_3$ . Goldsmid (1964, p117) cited Gordyakova, his own earlier research, and work which he did with Delves to prove these facts. Hole electron mobility is not appreciably altered over this range. A graph of the variation in thermal conductivity plotted against the electrical conductivity at  $20^\circ\text{C}$  is shown in Figure 2.21 (Goldsmid, 1964, p117).



Thermal Conductivity Plotted Against Electrical Conductivity for  $\text{Bi}_2\text{Te}_3$  and its Alloys at  $20^\circ\text{C}$

Figure 2.21

Source: Goldsmid (1964, p117)

Another interesting graph where the effect on lattice thermal conductivity with the addition of bismuth selenide or bismuth telluride is shown in Figure 2.22. The results of work by Birkholz, Rosi (et al) and Goldsmid's own work done in 1971 is shown on the graph (Goldsmid, 1964, p116). Examination of the graph emphasises the reduction of thermal conductivity on addition of  $\text{Sb}_2\text{Te}_3$  or  $\text{Bi}_2\text{Se}_3$  to bismuth telluride.

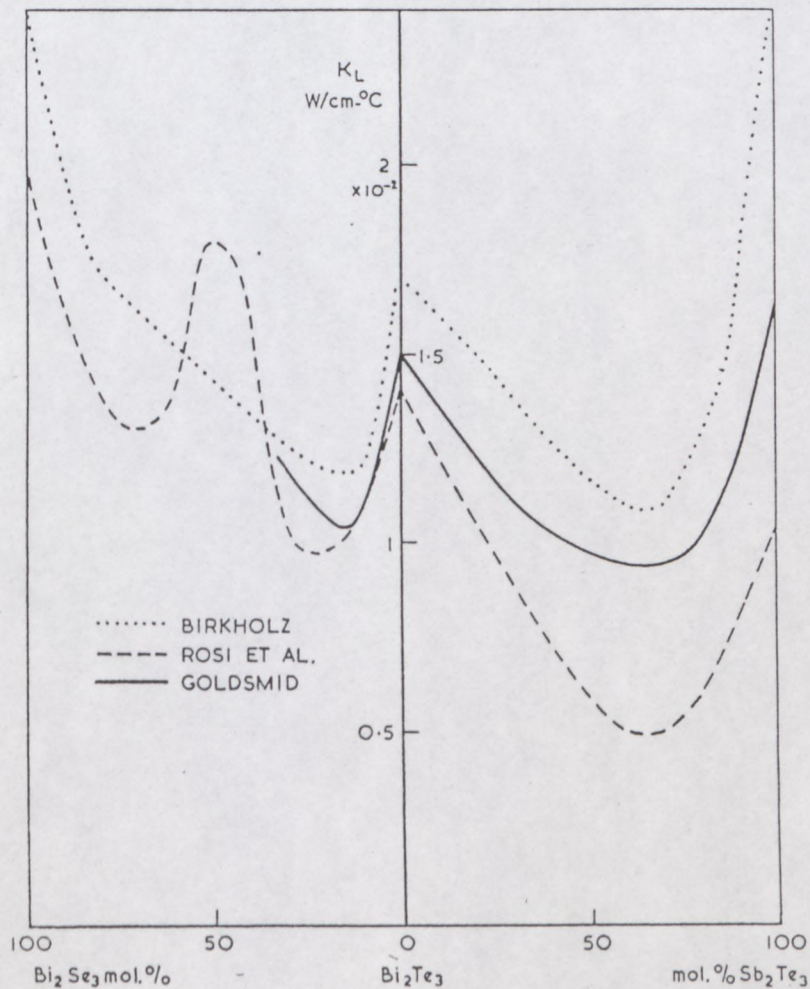


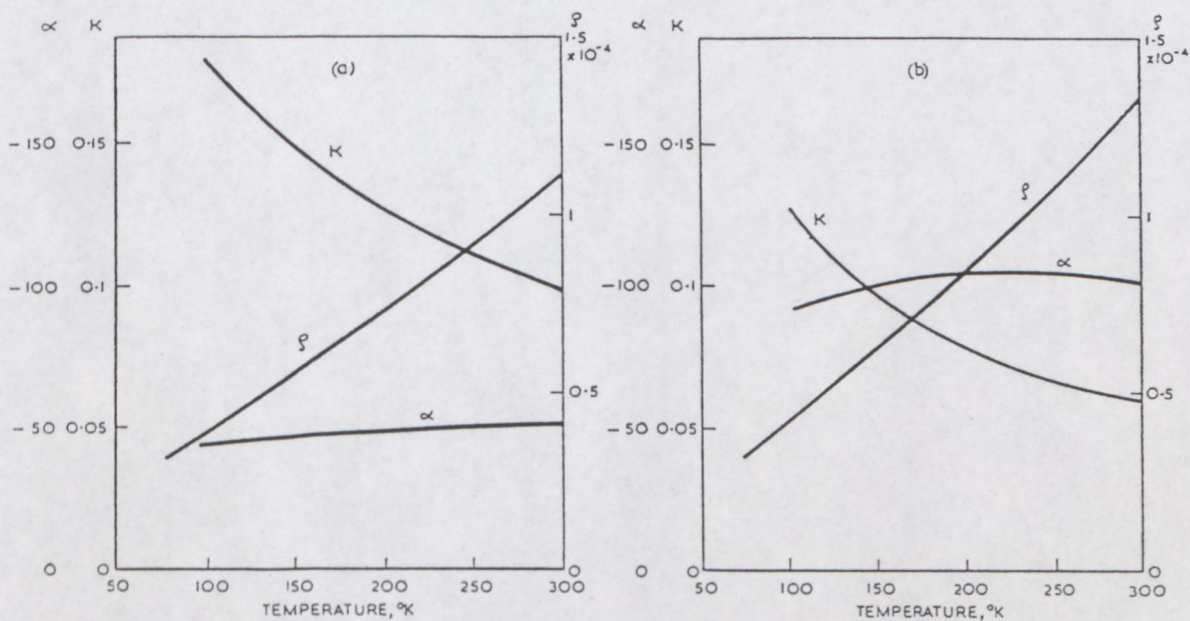
Figure 2.22

Source: Goldsmid (1964, p116)

Goldsmid cited Birkholz, Rosi (et al), Goldsmid, 1961

#### 2.1.3.2.4 Figure of Merit

The effects of the Seebeck coefficient, electrical conductivity and thermal conductivity are all represented globally in the figure of merit. The best p-type alloy is  $Bi_{0.5}Sb_{1.5}Te_3$  and n-type  $Bi_2Te_{2.7}Se_{0.3}$  (Goldsmid, 1964, p117-118). The highest figures of merit obtained for the alloys at  $20^\circ C$  were  $3,3 \times 10^{-3} deg^{-1}$  and  $3,0 \times 10^{-3} deg^{-1}$  respectively. Graphs for Seebeck coefficient, electrical resistivity and Seebeck coefficient plotted against temperature are shown in Figure 2.23 (Gallo cited by Goldsmid, 1964, p120).



Seebeck Coefficient Electrical Resistivity and Thermal Conductivity of Bismuth Plotted Against Temperature

(a) Flow Along Basal Planes. (b) Flow along Trigonal Axis.

Units; Seebeck Coefficient  $\alpha$  in  $\mu\text{V}/\text{deg}$ . resistivity  $\rho$  in Ohm-cm. and thermal conductivity  $\kappa$  in  $\text{W}/\text{cm-deg}$ .

Figure 2.23

Source: Goldsmid p120

Who Cited Gallo (et al)

### 2.1.3.3 Bismuth-Antimony Alloys

Little or no improvement in the figure of merit can be achieved by doping bismuth telluride with elements like lead or tin as these elements act as acceptor impurities and tellurium acts as a donor impurity. This is because an increase in the number of electrons decreases their partial Seebeck coefficient while an increase in holes strengthens their bipolar effects (Goldsmid, 1964, p119).

The addition of antimony to bismuth is beneficial in thermoelectric cooling applications for two reasons. Firstly the increase of the energy gap or decrease of band width allows a higher Seebeck coefficient to be reached. Secondly, the formation of a solid solution leads to a reduction in the lattice thermal conductivity. For alloys containing up to

12% antimony the energy gap is too small to allow a high figure of merit at room temperature. Smith and Wolfe cited by Goldsmid (1964, p121) showed that a 12% alloy will attain a figure of merit of  $5,2 \times 10^{-3} \text{ deg}^{-1}$  with current flowing along the trigonal axis at  $80^\circ\text{K}$ . The figure of merit falls off rapidly at lower temperatures and slightly slower at higher temperatures reaching a Z of  $2 \times 10^{-3}$  at  $200^\circ\text{K}$  and a Z of  $1 \times 10^{-3}$  at  $300^\circ\text{K}$ . A 5% antimony alloy obtained a Z of  $1,8 \times 10^{-3}$  at  $300^\circ\text{K}$ . At temperatures less than  $220^\circ\text{K}$   $\text{Bi}_{0,95}\text{Sb}_{0,05}$  it performs better than bismuth selenotelluride as an n-type thermoelectric material. As temperatures far higher than  $220^\circ\text{K}$  are used in most cooler applications it is not felt that this material would hold any advantages over alloys of bismuth telluride in standard cooling applications.

#### 2.1.3.4 Compounds

Considerable interest was generated in the late 1950,s in compounds of bismuth telluride and compounds of lead telluride as thermoelectric materials. Both materials were of a high density low lattice thermal conductivity mixture. Thermal conductivity for lead telluride was higher at  $0,0215 \text{ W/cm-deg}$  compared to bismuth telluride's  $0,0150 \text{ W/cm-deg}$ . Lead telluride also has a higher mobility of electrons and holes ( $1620\text{cm}^2/\text{V-sec}$ ;  $750\text{cm}^2/\text{V-sec}$ ) in comparison with bismuth telluride ( $1200\text{cm}^2/\text{V-sec}$ ;  $510\text{cm}^2/\text{V-sec}$ ). Surprisingly enough since the density of states effective masses of the carriers are lower for lead telluride the compound has a poorer  $\alpha^2\sigma$  value at near optimum doping. The optimum figures of merit at room temperature of the n and p type compounds of lead telluride ( $z_n=1,5 \times 10^{-3}$   $z_p=1,2 \times 10^{-3}$ ) are considerably inferior to alloys of bismuth telluride under similar conditions (Devyatkova, Cited By Goldsmid, 1964, p127).

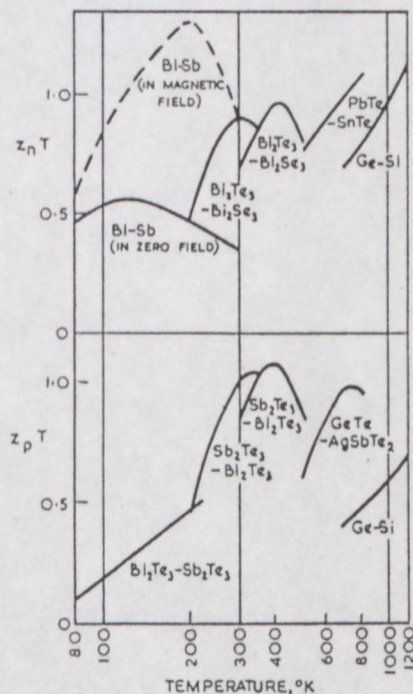
##### 2.1.3.4.1 Compounds of Lead Telluride

Compound - lead - telluride manifests certain advantages at higher temperatures. It remains chemically stable at the higher temperatures. The energy gap of  $\pm 0,3 \text{ eV}$  is approximately twice that of bismuth telluride allowing the material to remain extrinsic at high temperatures. These

characteristics make lead telluride and other IV-VI compounds preferred materials at temperatures of 500K and above. This material is not suitable for the thermoelectric application involved in this project because the temperatures used on this project did not exceed  $\pm 340\text{K}$  even on the hot sink side of the apparatus.

### 2.1.3.5 Figure of Merit Upper Limit

Intense research has resulted in a number of specialised p-type and n-type alloys which perform well over specific temperature ranges. Figure 2.24 shows a graph for the dimensionless figure of merit ( $zT$ ) plotted against temperature for various materials (Goldsmid, 1964, p131). The graph shows that the n-type alloy  $\text{Bi}_2\text{Te}_3\text{Bi}_2\text{Se}_3$  and the p-type alloy  $\text{Sb}_2\text{Te}_3\text{Bi}_2\text{Te}_3$  appear to perform best in the 300K to 400K range. Goldsmid (1964, p132) considered that in the light of present trends, the dimensionless figure of merit would not exceed unity by much.



The Dimensionless figure of merit  $zT$  plotted against absolute temperature for selected p- and n-type materials.

Figure 2.24

Source: Goldsmid (1964, p131)

#### 2.1.4 MULTISTAGE THERMOELECTRIC UNITS

It is possible to achieve greater temperature differences by using a multistage or cascade system. In this type of system the first stage of the system provides a cold sink junction for the hot junction of the second stage. It is possible for the second stage to provide a cold junction for the third stage. In theory this system could be repeated an infinite number of times, but it is unlikely that it would be repeated more than three times as the coefficient of performance tends to drop as more stages are added.

Goldsmid (1964, p162) looks at the problem of determining the performance of a cascade in this way.

$$T_d = (T_H - T_c)/n$$

$T_d$  = temperature difference per stage

$T_H$  = temperature at the hot junction

$T_c$  = cold junction temperature at the nth stage

$n$  = number of of stages

$$\phi_s = n(\phi_1 + \frac{1}{2})^{-\frac{1}{2}}$$

$\phi_s$  = COP per stage

$\phi_1$  = COP per stage working over the whole temperature difference

The rate at which cooling at the final stage is assumed to be  $q_c$  and  $W_n$  is the work that must be done at the nth stage.

$W_n = q_c/\phi_s$  and the rate of cooling at the (n-1)th stage is  $q_c(1+1/\phi_s)$  and the rate of cooling at the (n-2)th stage is  $q_c(1+1/\phi_s)^2$ . Therefore rate of heat that is finally delivered to the first stage is  $q_c(1+1/\phi_s)^n$  and the overall COP for an n-stage unit is

$$\phi_n = 1/[(1+1/\phi_s)^n - 1] \dots \dots \dots 2.51$$

$$\phi_s = n(\phi_1 + \frac{1}{2})^{-\frac{1}{2}}$$

From 2.38

$$\Phi_1 = \frac{T_c/T_d \left[ (1 + Z_{\max} T_{av})^{1/2} - T_H/T_c \right]}{(1 + Z_{\max} T_{av})^{1/2} + 1}$$

Considering the above three equations the coefficient of performance for a two stage cascade will be found to be:

$$\Phi_2 = \Phi_1 + 1/8(2\Phi_1 + 1) \dots \dots \dots 2.52$$

For a three stage cascade

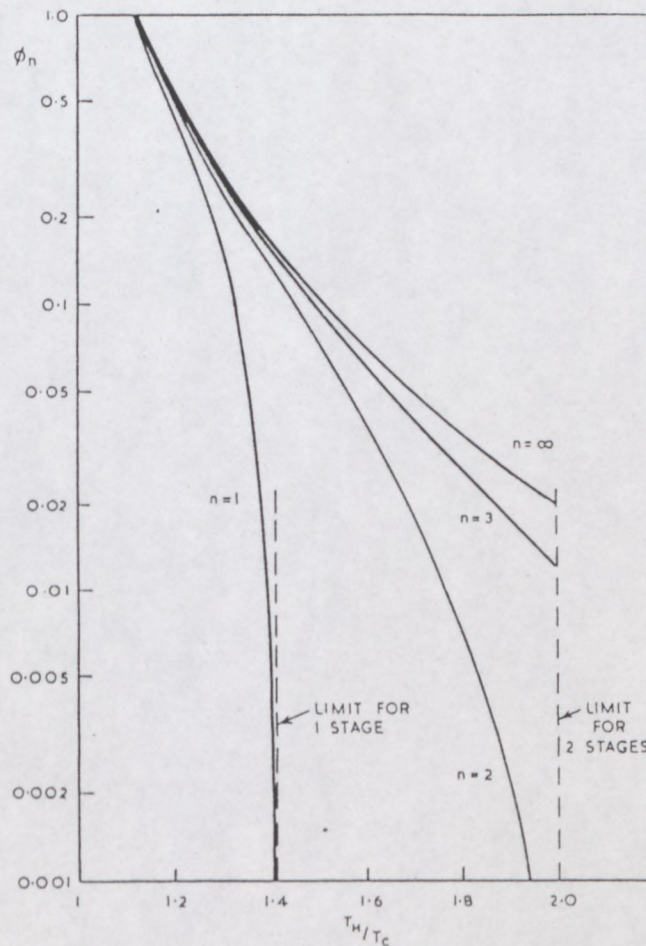
$$\Phi_3 = \Phi_1 + \frac{2\Phi_1 + 1}{27\Phi_1^2 + 27\Phi_1 + 7} \dots \dots \dots 2.53$$

For an infinity stage cascade

$$\Phi_\infty = 1/\{\exp[1/(\Phi_1 + \frac{1}{2})] - 1\} \dots \dots \dots 2.54$$

An infinity stage cascade is obviously only used to make theoretical comparisons.

Goldsmid (1964, pl64) plotted graphs of  $T_H/T_c$  against  $\Phi_n$  for one, two, three and infinitesimal stage cascades (See Figure 2.25).



Coefficient of Performance of Multi-stage Cooling Units  
( $zT = 1$ ).  $n$  = number of stages in cascade.

Figure 2.25

Source: Goldsmid (1964, p164)

On examining the graphs it can be seen that no significant improvement in  $T_d$  can be obtained by increasing the number of stages if the COP is above 0,5. It is probably not worth the effort of building a cascade if the COP is above 0,2. The graph shows the diminished improvement as more than 3 stages are added to the cascade. For this reason practical cooling units seldom employ more than three stages. It is evident that little would be accomplished if an attempt was made to utilise cascade principles on this project. This is because

the effects of the advantages of using a cascade are only significant at reduced coefficients of performance.

### 2.1.5 TEMPERATURE-DEPENDENT THERMOELECTRIC PARAMETERS

Now that thermoelectric cooling systems are able to operate at high temperature differentials between hot and cold junctions, parameters such as thermal conductivity can vary substantially. This is especially the case in cascade systems. Some researchers have felt justified in using averages.

#### 2.1.5.1 Thomson Effect

Ioffe cited by Goldsmid (1964, p168) suggested that it is better to use an average of the  $k/\sigma$  over the whole range of temperatures as compared to using the product of the average of  $k$  and  $1/\sigma$  to calculate the figure of merit.

What is interesting is that although it might appear that the Seebeck coefficient  $\alpha$  at the cold junction should be used as the Peltier effect is only felt at the junction between two dissimilar conductors, this is not the case due to the fact that both Seebeck and Peltier effects are bulk characteristics. It is therefore not surprising that  $\alpha$  average is used to calculate thermoelectric behaviour. Using this approach Thomson cooling is

$$q_{\tau} = I \int \tau dT$$

Half of this heat is experienced at the cold junction. The total cooling at the cold junction, which is the sum of the Peltier cooling effect  $\alpha TI$  and

$$\frac{1}{2} q_{\tau} = \frac{1}{2} I \int_{\alpha_c}^{\alpha_H} T d\alpha$$

Where  $\alpha_H$  and  $\alpha_c$  refer to the Seebeck coefficients at the hot and cold junctions.

Since the Thomson term is only a small fraction of the Peltier term it is reasonable to put

$$\int_{\alpha_c}^{\alpha_H} T d\alpha \approx T_c \int_{\alpha_c}^{\alpha_H} d\alpha = (\alpha_H - \alpha_c) T_c$$

Therefore

$$\alpha_c T_c I + \frac{1}{2} I \int_{\alpha_c}^{\alpha_H} T d\alpha \approx \frac{(\alpha_H + \alpha_c)}{2} T_c I$$

In this way the Thomson effect can be taken into account by using the average Seebeck coefficient. Combining this approach with Ioffe's suggestion of averaging out the electrical resistivity and thermal conductivity, the figure of merit can be approximated by.

$$Z \approx \frac{\langle \alpha_n - \alpha_p \rangle^2}{(\langle k_n / \sigma_n \rangle^{1/2} + \langle k_p / \sigma_p \rangle^{1/2})^2} \dots \dots \dots 2.55$$

Note that the angle brackets denote average values. This equation is almost identical to equation 2.35 except that average values are adopted.

Sherman (et al) (1960, p1) cited by Goldsmid (1964, p170) tested this theory on a specific example where the electrical resistivity and the Seebeck coefficient rose with temperature. Actual values of coefficients were based on alloys of bismuth telluride. Approximate calculations using the theory that has been discussed here yielded the following results.

- (i) Cross-section area predictions for a given cooling power were within 4%
- (ii) Applied voltage to within 1%
- (iii) Current to within 1%
- (iv) Coefficient of performance to within approximately 14% to small

These results indicate that the method of using the average of the Seebeck coefficient divided by conductivity yields a reasonably accurate figure of merit.

#### 2.1.6 AN IDEAL COOLING UNIT

In the specifications of a TEC unit it is normal to require a certain cooling effect for a given temperature difference between the hot and the cold faces. In this instance the assumption is made that there is no electrical resistance at the junction and no thermal resistance at the junction and between the element-source and the cold sink- element junctions.

For practical reasons cooling units usually consist of an array of cooling elements connected in series. In this section it will be shown how the number of junctions and the length and cross-section of the elements can be calculated.

##### 2.1.6.1 Possible Design Approach

It must be once again emphasised that it is essential to adhere to the geometry of equation 2.50. The required cooling, the cold junction temperature and the hot junction temperature must be known.

- I) Equation 2.49 is used to determine the cooling effect of one junction at the most favourable COP
- II) Equation 2.41 is employed to find the potential drop across one junction for the maximum COP.
- III) The cooling effect of one junction is divided into the total cooling effect required. The answer is the total number of junctions required.
- IV) The necessary voltage can then be determined by multiplying the potential across one junction calculated in step (ii) by the number of junctions determined in step (iii).

#### 2.1.7 NONIDEAL TEC

The aim when designing a TEC is to provide a required rate of cooling for a specified temperature differential at minimum

cost and maximum operating efficiency. In an ideal T.E.C. the cooling attributes are not altered if the length or the cross section area of the elements is reduced provided that their  $l/A$  ratio is maintained. In a real cooling unit however the COP falls as the volume of material decreases since the electrical resistance at the contacts becomes an increased fraction of the total resistance. As the cross-section area is reduced the thermal resistance between the cold and hot junction and the source and sink rises (Goldsmid, 1964, p173).

#### 2.1.7.1 Contact Resistance

The COP improves without variation as the length and the cross-section area increases. Goldsmid (1964, p174) considered that the preferred thermoelement design would have a length which would be not less than that which would yield the greatest ratio of cooling power to material volume. In this section it is necessary to assume that the Peltier coefficient  $\pi$ , the electrical conductivity  $\sigma$  and the thermal conductivity  $k$ , are constant for both positive and negative materials or alternatively that equation 2.50 has been satisfied. For practical reasons the lengths of both branches are usually equal.

It is also important to note that the electrical contact resistance at the cold junction has a greater effect on the efficiency of a cooling device than the other above mentioned factors. This phenomenon occurs because the electrical resistance at the hot junction only draws more power. The resistance at the cold junction, however, uses more power and also produces a heating effect which decreases the cooling effect. Parrott and Penn cited by Goldsmid (1964, p175) did in depth research into the effects of contact resistance and derived equations and graphs which can be used when contact resistance is expected to have a significant effect on TEC performance.

It is vital that designers of thermoelectric cooling devices should be aware of the fact that, in practice, the contact

resistances are usually low enough to be negligible if the thermoelements are greater than 1mm in length (Goldsmid, 1964, p179). The branches used in the devices which were employed in the development of this project were approximately 1,5mm in length and most manufacturers are using lengths of 3mm to 5mm, so an in depth study of these factors is not included in this dissertation.

#### 2.1.7.2 Thermal Resistance

Thermal resistance is another factor which has to be taken into account in a practical thermoelectric cooler. A typical cooler design would consist of the cooling elements and their little busbars clamped between two copper plates which act as hot and cold sinks. Electrical insulation must be sandwiched between the busbars and the copper plates to prevent short circuiting. The electrical insulation normally has a limited thermal resistance which effects performance, the physically smaller the unit is for a predetermined cooling effect the larger the temperature differential across the insulation. One way used in the past to overcome this problem was spacing of elements. This method increased the cross-section area but the spaces between the elements have to be filled with insulation material to prevent conduction of heat through the gaps. Metallised ceramic plates are used instead of copper in the case of the thermoelectric devices which were imported for the prototype. The manufacturers have by this method apparently overcome the problem of having to use electrical insulation which diminishes the thermal conduction. Special epoxies that have minimal thermal resistance and high electrical resistance are now also available and these materials could be used to effectively overcome this problem. For the above reasons only brief comment has been made in the dissertation on this point.

#### 2.1.8 CURRENT RIPPLE

A thermoelectric cooling unit operates at its highest efficiency when the electrical current is an absolutely steady direct current. This situation is often not achieved

in cases where current is supplied by rectified AC. In the case of the test system, a direct current power source was used in conjunction with other smoothing devices, and in proposed site operation the system would be operated from industrial storage batteries. For this reason the ripple was not a big factor in the design. The steady component of current is designated  $I_0$  in the formula. The ripple current adds to the joule heating the term  $\langle I^2 \cos^2 \omega t \rangle R$  which is equal to  $\frac{1}{2} I^2 R$ . Half of this heat will appear at the cold junction. Equations 2.13 and 2.22 still apply with  $I=I_0$  and  $R = R(1+\frac{1}{2}\delta^2)$ , where  $\delta=I/I_0$  and  $Z=Z/(1+\frac{1}{2}\delta^2)$ . A current ripple of 10% ( $\delta=0.1$ ) or less is the accepted recommendation for TEC systems and this percentage would cause a decrease in the figure of merit of  $\pm\frac{1}{2}\%$ . A ripple as high as 25% ( $\delta=0.25$ ) would only result in a 3% reduction in the figure of merit. It seems that the deleterious effect of ripple current may have been overemphasised in the past.

#### 2.1.9 MANUFACTURE

The performance of cooling units is usually calculated on the assumption that all the positive and negative thermoelements have the same dimensions and thermoelectric properties. It is impossible to actually manufacture thermoelectric components identically both in terms of physical proportions and electronic characteristics. This means that the optimum current will no longer yield ultimate performance. Ioffe investigated these effects as early as 1957 and developed equations to predict them (Cited by Goldsmid, 1964, p187).

##### 2.1.9.1 Variation of Electrical Conductivity

Goldsmid (1964,p188) used Ioffe's equations to prove the following statement "If the most probable departure of the conductivity from its optimum value is as high as 10%, the reduction in coefficient of performance is no more than about 2,5%. Even if  $(\sigma_d/\sigma_0)$  is as large as 20%, the coefficient of performance falls by only about 10% below its maximum value. Where  $\sigma_d$  is the deviation from the nominal conductivity given the term  $\sigma_0$ .

Goldsmid (1964, p189) made a further statement based on calculations that "If a cooling unit is composed of thermoelements with an electrical conductivity that differs from the optimum value by 10% and if it is operated so as to maintain the cooling power of a unit composed of the optimum materials, then the deterioration in the coefficient of performance is little more than 1%".

Goldsmid's conclusions based on calculations are ample proof that small deviations from mean conductivity values will not affect thermoelement performance substantially.

#### 2.1.9.2 Dimensional Tolerance

As most designers base their design on equation 2.50 there may be a question as to what effect small deviations from the ratio would have on the performance of the cooling unit. Goldsmid (1964, p190) indicated that in practice strict tolerance control would normally be exercised with a view to the use of assembly jigs, rather than because of fear of deterioration of COP.

#### 2.1.9.3 Material Preparation

As previously mentioned bismuth telluride has anisotropic characteristics and its highest figure of merit is obtained when the current flows parallel to the basal planes. The material will have to be manufactured so that the basal planes all lie in the same direction. The elements need not necessarily consist of single crystals and in practice partially-oriented polycrystalline material is usually utilised. Crystals of bismuth telluride align themselves with their basal planes in the direction of growth. Goldsmid (1964, p191) believed that this characteristic was owing to the fact that the thermal activity of bismuth telluride was appreciably higher along the basal planes.

##### 2.1.9.3.1 Directional Freezing

Horizontal directional freezing is reputed to be the simplest technique used to align bismuth telluride. In this method a tube which contains the molten compound is maintained in a horizontal furnace that has a temperature gradient from one

end to the other. The power input to the furnace is then reduced resulting in a freezing effect which gradually moves across the molten material.

#### 2.1.9.3.2 Vertical Double Furnace

In the Bridgeman vertical double furnace method, the top of the furnace is maintained at above the melting point temperature of the compound while the bottom of the furnace is held below freezing point. The molten compound is contained in a vertical capsule that is lowered into the bottom compartment of the furnace. Steep temperature gradients are maintained at the liquid interface and the drop rate is approximately  $3 \times 10^{-4}$  cm/sec.

Directional freezing is suitable for undoped bismuth telluride but in doped material the segregation of impurities into the continually decreasing volume of molten material leads to non-uniformity. This results in a material that gradually becomes richer in impurities as the process progresses. The other problem prevalent when using zone melting is that movement of the liquid - solid interface, leads to segregation of one of the constituents of the binary alloys. This problem must be regarded in the light that the best thermoelectric materials are binary or pseudobinary in nature. The situation can be improved if the compound is zone melted as opposed to directly frozen.

#### 2.1.9.3.3 Zone Melting

Only a very short section of the ingot is melted in this process and this melting process is moved along the ingot. There is still a tendency to segregate but the molten region is so short that equilibrium is quickly reached.

#### 2.1.9.3.4 Zone Levelling

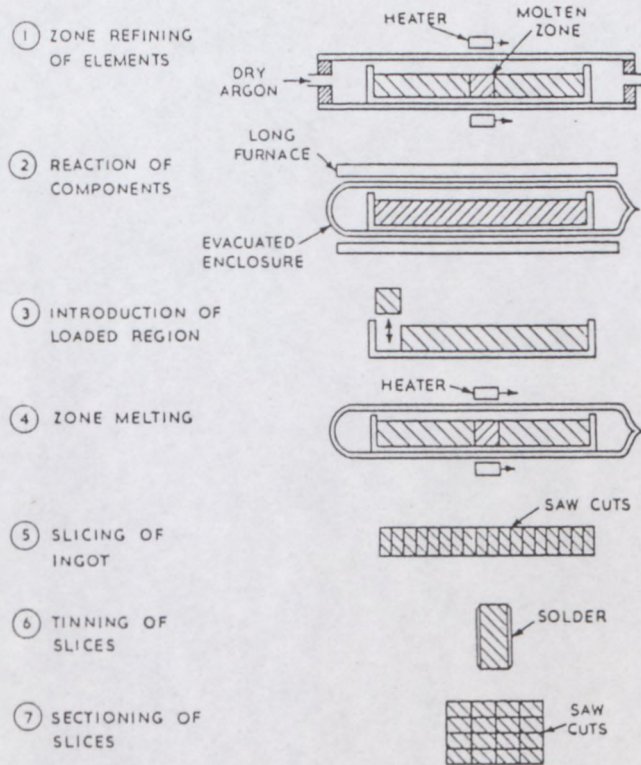
A further improvement in the uniformity of the crystal can be obtained by the process of zone levelling. In this method the molten zone is traversed back and forth a number of times.

#### 2.1.9.3.5 Loaded Zone Melting

When the segregation coefficient is less than unity further impurities are added so that the required constitution is maintained. This process is known as zone loading. Purity of material depends on a number of factors such as whether the manufacturer is prepared to compensate for donor impurities by adding acceptor impurities. Impurities representative of lead or iodine in bismuth telluride are reduced to about ten parts per million where as non doping impurities can be found in greater concentrations.

#### 2.1.9.3.6 Zone Melting Process

Pure material together with any doping agent is melted in a vacuum into a silica or graphite boat. The ingot is then rapid frozen in such a way as to inhibit segregation. A volume of material is removed from the ingot and replaced by a similar volume of doped material. Following this step a molten zone is formed and passed through the material. The ingot is removed from the crucible and the Seebeck coefficient is checked to make certain that the process has been successful. The ingot is accurately sliced into thermoelement branches with a fine toothed circular saw. Sections are tinned and fine cut again with a circular saw. Tinning prevents damage of the surface of the element. Goldsmid (1964,p196) found in experimentation with  $\text{BiSbTe}_3$  that a temperature gradient of  $50^\circ/\text{cm}$  allowed a speed of  $10^{-4}\text{cm}/\text{sec}$  in the absence of stirring. Where temperature gradients of  $250^\circ/\text{cm}$  have been adopted at the molten interface feed speeds of in excess of  $10^{-3}\text{cm}/\text{s}$  were possible. Goldsmid (1964, p195) showed the process in a diagram reproduced in Figure 2.26.



Steps in the Production of Thermoelements  
Using a Typical Zone-melting Process

Figure 2.26

Source: Goldsmid (1964, p195)

### 2.1.9.3.7 Sintering Process

The sintering process has distinct disadvantages one of them being that the process normally leads to randomly or imperfectly oriented thermoelements. It is not always possible to avoid pressing faults which may take the form of cracks vertical to the press direction. Goldsmid (1964, p200) felt that these faults may be responsible for some of the anisotropy of electrical conductivity detected in sintered bismuth telluride samples. This characteristic is more prevalent in n-type than p-type materials. The n-type figure of merit for sintered alloys drops to  $0,0025\text{deg}^{-1}$  in comparison with  $0,0031\text{deg}^{-1}$  for crystal orientated samples. Positive-type samples drop to  $0,0031\text{deg}^{-1}$  as compared to  $0,0033\text{deg}^{-1}$ . These disadvantages may be balanced by the

obvious advantages of the method for manufacturers involved in large scale production.

There are three main steps in this process, powder stage, pressing process and heat treatment. The powder may consist of a mixture of unreacted compound/alloy or it could be made up of partly reacted materials. Suitable bismuth telluride alloys have been produced by cold pressing, with maximum densities being reached at 5 to 6 tons/cm<sup>2</sup> (Schreiner and Wendler, cited by Goldsmid, 1964, p199). Heat treatment in hydrogen for one hour at 380°C was found to be suitable for bismuth telluride and the ideal temperatures for its alloys is not expected to be far from that temperature.

#### 2.1.9.4 Cutting and Tinning

Cutting is necessary when the zone melting manufacturing process has been used. Thermoelectric alloys with oriented or partially oriented crystals are brittle and therefore special care has to be taken when cutting. The material is generally mounted on a steel block held in a magnetic chuck. Liberal quantities of shellac are used with slitting saws of typically 0,5mm width and 70mm diameter. The saws are diamond impregnated or have fine teeth. Saw speeds of the order of 3000rpm are used with feed rates of ±10mm/min. Sawing always disturbs the surface and it is generally necessary to clean up by etching. A mix of 1 part nitric acid, 1 part hydrochloric acid and 2 parts distilled water has proved successful. Bismuth telluride dices have to be specially tinned with bismuth - tin alloys before soldering with conventional lead - tin eutectic (Goldsmid, 1964, p201).

#### 2.1.9.5 Construction

Five main goals are borne in mind when construction is in progress, viz

- (i) Negligible resistance at the contacts.
- (ii) Flat and parallel end faces to facilitate heat transfer between heat sinks.
- (iii) Minimum heat transfer between the source and the sink other than through the thermoelements.

- (iv) No damage to thermoelements due to mechanical stress.
- (v) Economy of time and materials.

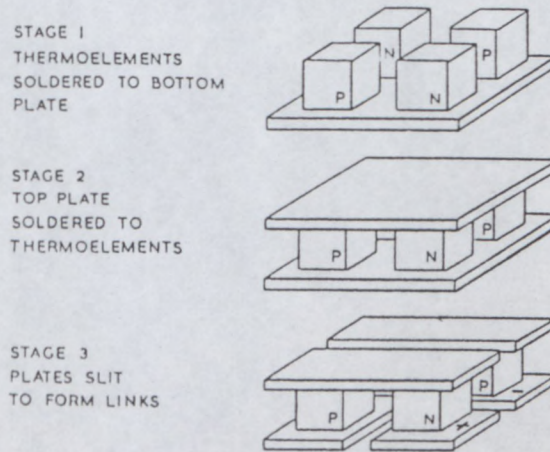
#### 2.1.9.5.1 Links

Copper is the most useful metal available when it comes to high electrical conduction. It does, however, have some distinct drawbacks when it comes to thermoelectric units. The main disadvantage being that copper diffuses very rapidly through bismuth telluride effectively doping it with an impurity and changing its characteristics. Many manufacturers have utilised copper successfully by limiting the duration for which the solder remains molten. This danger of contamination does not exist with non or partly aligned sintered elements.

Some manufacturers have started to employ aluminium links to enable them to overcome the copper contamination problem. This solution does however pose soldering and tinning problems which necessitate the adoption of special soldering techniques.

Copper is still the most popular material for links which are usually thin because of the good conductivity of the material. It is impractical to apply these delicate connectors to the elements individually so other solutions have evolved. One patent method used to keep the junctions coplanar involves the soldering of a copper plate on each side of an array of elements. Links are then cut apart along appropriate lines. Spark erosion has proven to be the most suitable method for slitting the copper plates into links as this method overcomes the problem of burrs which are created when using ordinary fine saws. Figure 2.27 shows the basic steps applied in this method (Goldsmid, 1964, p203). Printed-circuit techniques are also used to create links for thermoelements (Sochard, Cited by Goldsmid, 1964, p203). This method has in the past had the advantage that it is manufactured with the insulation block in place. There are other methods like the shared stalk, linkless stalk, wrapped

stalk, separate link, and slotted-plate techniques that have been pioneered and patented by various manufacturers.



#### Assembly of a Cooling Unit Soldering Flat Plates to the Thermoelements

The Plates Are Subsequently Slit to Form Separate Links

Figure 2.27

Source: Goldsmid (1964, p203)

#### 2.1.9.5.2 Heat Transfer

The cooling units almost invariably have flat heat exchange surfaces with the links between the thermoelements exposed. The heat has to be transferred from the links to the heat sinks. This is normally accomplished by using aluminium receptacle blocks to clamp the units between thin (20µm) mica insulation plates. The mica insulation of course prevents short circuiting of links. Some manufacturers like Melcor have ingeniously overcome this problem with metallized ceramic plates which evidently give good electrical resistance while affording good thermal conductivity. Close tolerances are maintained on thermal contact surfaces (depth of roughness < 0,01mm). The blocks are in turn clamped between conventional aluminium heat sinks. The Peltier cooling units are brittle and can easily be damaged if the clamping system does not allow for limited expansion of the unit. Figure 2.28 shows a typical clamping set up patented by Peltron GMBH and sourced from one of their pamphlets.

Silicon grease is used on heat sink interfaces to minimise the temperature rise across the interfaces.

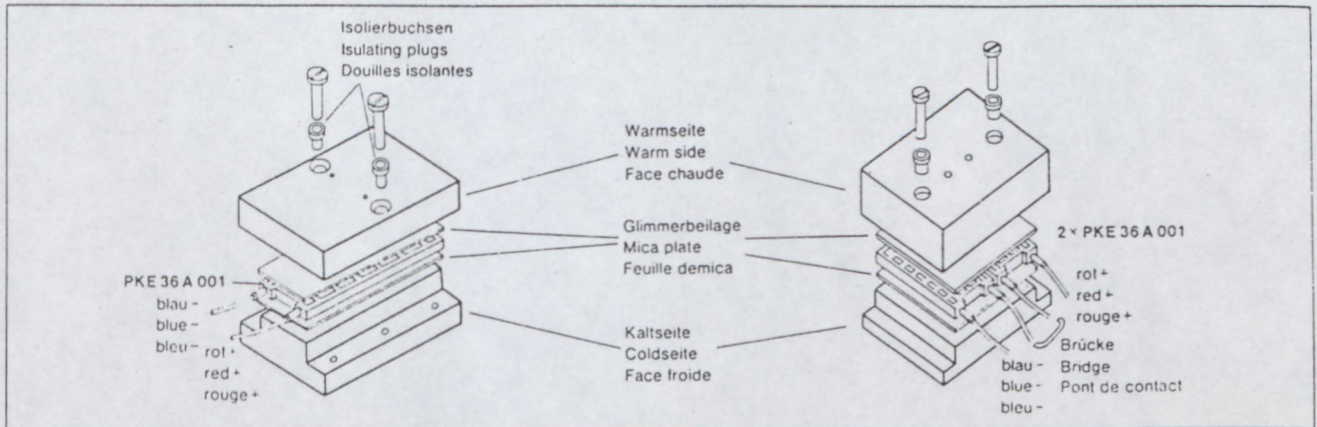


Figure 2.28

Peltier Cooling Unit Clamping Systems

Source: Peltron GMBH Technical Information Brochure

2.2 HEAT LOADS

Three popular conventional approaches were investigated to ascertain whether they would yield reasonable heat load estimates for the solar heat absorbed through the walls and roof of the test container. If one of these techniques proved accurate they would form the basis for actual load estimation of heat loads on future sites. The three methods were as follows

- (I) CLTD/CLF Method (ASHRAE, 1989, p26.33 to 26.49).
- (II) TETD/TA Method (ASHRAE, 1989, p26.49 to 26.54).
- (III) Carrier Program Method.

2.2.1 CLTD/CLF METHOD

The CLTD method is a direct one-step approach for calculating cooling loads from conduction heat gained through sunlit walls, roofs and glass exposures. Tables have been developed for various types of walls for different times of the year on certain latitudes. Two main problems were encountered when this procedure was applied to the container.

(i) The tables which had to be used were designed for an indoor temperature of 23°C, whereas a temperature of 38°C was permissible in the container.

(ii) The tables were developed for overseas conditions and building materials which differed from the materials used in the manufacture of the test container.

#### 2.2.2 TETD/TA METHOD

TETD stands for "total equivalent temperature difference". This method was originally presented in a manual giving tables for time - lags, decrement factors and TETD values for various wall and roof types. All the calculations were based on an indoor temperature of 24°C which meant that the system could not be used on the container when an indoor temperature of 38°C was required. No test calculations were made using this method. Useful information on sol-air equivalent temperature was found during reading up on this method and this information will be reviewed later in this section.

#### 2.2.3 THE CARRIER PROGRAM METHOD

The Carrier Corporation has designed the E20-II Carrier Software System for commercial load estimation. Version 2.14 was applied to the heat load problem and the results of these calculations are discussed in the next chapter.

#### 2.2.4 SOL-AIR METHOD

After calculations were made using the above three conventional heat load methods, it became clear that further investigation was called for. Hence the consideration of the sol-air method.

##### 2.2.4.1 Definition of Sol-air Temperature

Sol-air temperature is defined as the value of the outside air temperature that would, in the absence of all radiation exchanges, give the same rate of heat flow into the outer surface of the wall as the actual combination of temperature

difference and radiation exchange really does (Jones, 1985, p192).

#### 2.2.4.2 Heat Gain Through Exterior Surfaces

ASHRAE (1989, p26.3-26.4), Jones (1985, p192) and IHVE (1970, pA5-A6) all document this method. The ASHRAE handbook approach seemed most suitable for the project and is laid out in this section.

The heat balance at a sunlit surface gives the flux into the surface  $q/A$  in  $W/m^2$

$$q/A = \alpha I_t + h_o(t_o - t_s) - \epsilon \delta R \dots \dots \dots 2.56$$

Where the symbols are equal to the following

- $\alpha_x$  = absorptance of the surface for solar radiation
- $I_t$  = total solar radiation incident on the surface,  $W/m^2$
- $h_o$  = coefficient of the heat transfer by long-wave radiation and convection at the outer surface,  $W/m^2 \text{ } ^\circ C$
- $t_o$  = outdoor air temperature,  $^\circ C$
- $t_s$  = surface temperature,  $^\circ C$
- $\epsilon$  = hemispherical emittance of surface
- $\delta R$  = difference between the long-wave radiation incident on the surface from the sky and surroundings and the radiation emitted by a black body at outdoor air temperature,  $W/m^2$

Assuming that the rate of heat transfer can be expressed in terms of the sol-air equivalent temperature  $t_s$

$$q/A = h_o(t_s - t_s) \dots \dots \dots 2.57$$

From equations 2.56 and 2.57

$$t_s = t_o + \alpha_x I_t / h_o - \epsilon \delta R / h_o$$

Bliss cited by ASHRAE (1989, p26.5) found that  $63 W/m^2$  was a suitable figure for the horizontal surface correction term ( $\delta R$ ).

The authors of the ASHRAE Handbook (1989,p26.4) used their experience to assume a figure of 1 for the surface emittance  $\epsilon$ , and  $3,8^{\circ}\text{C}$  for the horizontal correction term  $\epsilon\alpha_{\text{r}}R/h_{\text{o}}$ .

The ASHRAE Handbook emphasises the fact that when solar radiation intensity is high, the surface of terrestrial objects emits long-wave radiation which compensates for the sky's low emittance. Based on this fact the authors considered the vertical surface correction term  $\delta R$  to be equal to zero which effectively negated the correction term.

A surface finish of glossy white paint was specified for the container. The ASHRAE Handbook indicated that a figure of 0,026 for the absorption coefficient  $\alpha/h$  would be suitable for a clean light colour surface.

This figure can also be calculated thus

$\alpha = 0,5$  For a dirty surface. Table A6.14 (IHVE Guide ,1970 pA6-15)

$h_{\text{o}} \approx 17 \text{ W/m}^2\text{ }^{\circ}\text{C}$  (ASHRAE Handbook ,1989 ,p26.5)

$\alpha_{\text{r}}/h = 0,5/17 = \pm 0,029$

This figure is very close to the figure of 0,026 found in ASHRAE.

#### 2.2.4.3 Outdoor Ambient Air Temperature ( $t_{\text{o}}$ )

The outdoor ambient air temperatures ( $t_{\text{o}}$ ) were taken from the NBRI (Van Deventer, 1971, p160) tables which are considered to be the most carefully researched and comprehensive tables available on South African conditions.

#### 2.2.4.4 Solar Radiation ( $I_{\text{t}}$ )

There are a number of well-documented scientific methods for calculating the direct and scattered effects of solar radiation on surfaces at various orientations. An investigation was made into the methods which were documented by Jones (1985, p154-168), Wentzel (1985, p23), and ASHRAE (1989, p22.8). All of the methods relied on calculation which estimated the solar radiation conditions at specific times of the year. A decision was finally taken to use actual readings taken by Van Deventer (1971) which were gathered over an extended period. In most of the

calculations a probability rating of 2,5% was selected. The tables give the global radiation ( $I_t$ ) for the horizontal, north vertical, south vertical, west vertical and east vertical. The radiation readings are calculated on an hourly basis.

The late night and early morning temperatures between 19:00 and 06:00 are not affected by solar radiation. The black vault absorption effect is also ignored as this effect is normally cancelled by other factors such as radiation from the surroundings heated by the day time sun. The time lag was not considered to be a big factor since there were no windows and the u-factor was constant for the walls and the roof of the container. The lag time is not expected to be great because of the mass of the walls of the container. This fact will be investigated and discussed in the next section.

#### 2.2.5 SOL-AIR RESEARCH

Heat load calculations were made using Sol-air equivalent temperatures and the results were investigated by taking readings on site and in the TDI climatic chamber. The results of these calculations will be discussed in the next chapter.

### 2.3 HEAT SINKS

Heat sinks were used to absorb heat on the cold side and reject heat on the hot side of the thermoelectric cooler. The heat sinks in-fact took the place of the condenser on the hot side outside the container and the evaporator on the cool side inside the container. A standard multiple fin comb shaped heat sink was selected because of its good heat rejection ability, availability and reasonable cost. Heat sinks were favoured above other more efficient heat transfer systems like radiators because they had no moving parts and would be effected minimally by the elements. The actual shape of the sink was also dominated by physical aspects, for

example the fact that the thermoelectric device had to be clamped between the two heat sinks.

### 2.3.1 HEAT SINK SELECTION

Heat sinks are normally used to protect electronic components where high active junction temperatures would result in drastically reduced device life. In the case of the project the heat sinks were mainly to act as heat exchangers. The goal when selecting the heat rejection sink was to keep the hot junction of cooling device as close to the ambient air temperature as possible. Perhaps it would be easier understood to say that the temperature rise across the heat sink was to be kept to a minimum.

Most companies who supply heat sinks are able to supply performance graphs. These graphs have been developed by experimentation and are reasonably accurate under most conditions. They show thermal resistance plotted against the variation in length of the particular heat sink under consideration. The other approach is by calculations and this method will be briefly discussed in this section. A graph of the TB 200 comb type heat sink which is similar to the PDH13 heat sink used in the project is shown in Figure 2.29. No heat dissipation graphs were available for the PDH13.

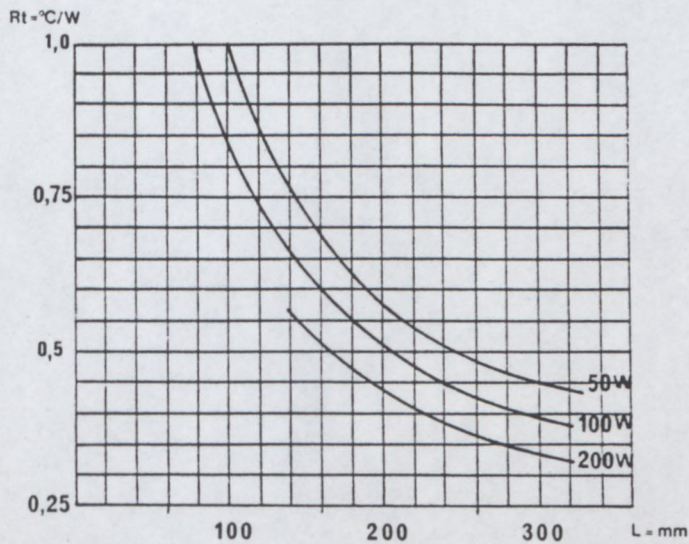


Figure 2.29  
Heat Dissipation Curves  
Source: SGE Bósari catalogue.

### 2.3.2 HEAT SINK DESIGN THEORY

Convection from a solid surface to the surrounding fluid is limited by the area of that surface and the extension of the surface will result in an overall gain in total heat transferred. This is simply accomplished by adding fins. Heat transfer results from conduction along the fins and convection from the fins. The surface convection coefficient is altered by the addition of fins owing to the new flow pattern and the uneven surface temperature of the fins. Although the average surface temperature is reduced, the total heat transfer is increased.

To explain the theory of heat sinks an energy balance has been carried out on a fin which is considered to be one dimensional. Fin length is equal to  $L$  and the fin is assumed to be thin compared to the length, a width of  $a$  is assumed.

straight fin area  $A = La$

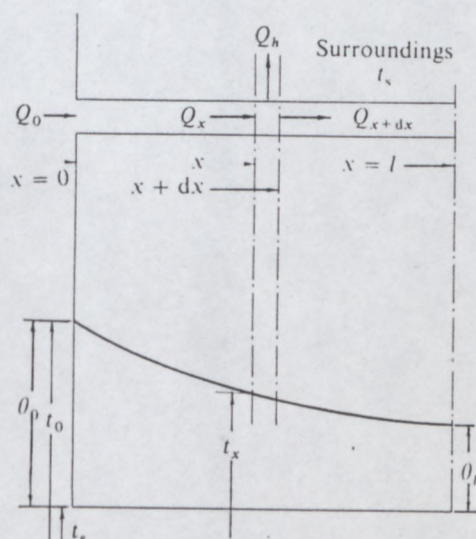
perimeter  $P = 2L$

$a$  = thickness of fin

$L$  = vertical length of fin

$l$  = length of fin from root to tip

Simonson (1983, p163) showed a graphic representation of the heat transfer from an extended surface which has been reproduced in Figure 2.30.



Heat Transfer From an Extended Surface

Figure 2.30

Source: Simonson (1983,p162)

Consider an element of the fin, conduction at  $x=Q_x$ . This must be equal to the sum of the conduction out of the element at  $x+dx$  and the convection from the edge of the element. Therefore

$$Q_x = -kA \, dt/dx$$

$$Q(x+dx) = -kA \, dt/dx - kA \, (d^2t/dx^2)dx$$

$$Q_h = hP \, dx(t-t_\infty)$$

$$Q_x = Q(x+dx) + Q_h$$

Therefore

$$-kA \, (d^2t/dx^2)dx + hP \, dx(t-t_\infty) = 0$$

Therefore

$$d^2t/dx^2 - hP/kA(t-t_\infty) = 0$$

Since  $t_\infty$  is assumed to be a constant, surroundings temperature,  $(t-t_\infty)$  may be replaced by  $\theta$ , and  $d^2t/dx^2$  becomes  $d^2\theta/dx^2$ .

Therefore

$$d^2\theta/dx^2 - (hP/kA) \theta = 0$$

This equation has the following solution

$$\theta = C_1 e^{mx} + C_2 e^{-mx} \dots\dots\dots 2.58$$

where

$$m = (hP/kA)^{1/2} \dots\dots\dots 2.59$$

and  $C_1$  and  $C_2$  are constants of integration to be determined from boundary conditions.

The first boundary condition is  $\theta = \theta_0$  at  $x=0$  therefore from equation 2.58

$$\theta_0 = C_1 + C_2 \dots\dots\dots 2.60$$

The second boundary condition depends on the heat transferred from the tip of the fin. In the case of a thin fin it is assumed to be zero, therefore

$$(d\theta/dx)_{x=1} = 0$$

Therefore

$$mC_1 e^{m1} - mC_2 e^{-m1} = 0 \dots\dots\dots 2.61$$

Solving equations 2.60 and 2.61 yield the following values:

$$C_1 = \theta_0 e^{-m1}/e^{m1} + e^{-m1}, \text{ and } C_2 = \theta_0 e^{m1}/e^{m1} + e^{-m1}$$

Substituting for  $C_1$  and  $C_2$  in 2.58 gives

$$\theta = \theta_0 [e^{m(1-x)} + e^{-m(1-x)} / e^{m1} + e^{-m1}]$$

Therefore

$$\theta/\theta_0 = \cosh m(1-x)/\cosh m1 \dots\dots\dots 2.62$$

The temperature at the end of the fin is above  $t_a$  and is obtained by letting  $x=1$  and is given by

$$\theta_t = \theta_0/\cosh m1 \dots\dots\dots 2.63$$

The total heat transferred from the fin is determined by considering the conduction into the fin at the root. Then

$$Q_0 = -kA(d\theta/dx)_{x=0}$$

$$Q_0 = mkA\theta_0 [\sinh m(1-x)/\cosh m1]_{x=0}$$

$$Q_0 = mkA\theta_0 \tanh m1 \dots\dots\dots 2.64$$

In the case of a comparatively short fin the assumption of no heat rejected at the tip is not reasonable. With short fins the heat transfer at the tip is given by

$$-kA(d\theta/dx)_{x=1} = +hA\theta_1$$

Therefore

$$-k(mC_1 e^{m1} - mC_2 e^{-m1}) = +h\theta_1 \dots \dots \dots 2.65$$

The constants  $C_1$  and  $C_2$  may now be obtained by solving equations 2.60 and 2.65. Substituting for  $C_2$  in 2.65 and eliminating  $\theta_x$  by using 2.58

$$-k[mC_1 e^{m1} - m(\theta_o - C_1)e^{-m1}] = +h[C_1 e^{m1} + (\theta_o - C_1)e^{-m1}]$$

which gives

$$C_1 = \frac{\theta_o [e^{-m1} - (h/km)e^{-m1}]}{(e^{m1} + e^{-m1}) + (h/km)(e^{m1} - e^{-m1})}$$

$$C_2 = \frac{\theta_o [e^{m1} + (h/km)e^{m1}]}{(e^{m1} + e^{-m1}) + (h/km)(e^{m1} - e^{-m1})}$$

Substituting back into 2.58

$$\theta = \frac{e^{m(1-x)} + e^{-m(1-x)} + (h/km)[e^{m(1-x)} - e^{-m(1-x)}]}{(e^{m1} + e^{-m1}) + (h/km)(e^{m1} - e^{-m1})}$$

Which may be expressed as

$$\theta = \frac{\cosh m(1-x) + (h/km)\sinh m(1-x)}{\cosh m1 + (h/km)\sinh m1} \dots \dots \dots 2.66$$

The temperature difference at the end of the fin is given by

$$\theta_x = \theta_o / \cosh m1 + (h/km)\sinh m1 \dots \dots \dots 2.67$$

The heat transfer from the fin is obtained as before by considering  $(d\theta/dx)_{x=0}$ . Therefore

$$Q_o = -kA(d\theta/dx)_{x=0}$$

$$Q_o = -kA\theta_o \left[ \frac{-m \sinh m(1-x) - (h/k)\cosh m(1-x)}{\cosh m1 + (h/km)\sinh m1} \right]_{x=0}$$

$$Q_o = mkA\theta_o \left[ \frac{\sinh m1 + (h/km)\cosh m1}{\cosh m1 + (h/km)\sinh m1} \right]$$

$$Q_o = mkA\theta_o \left[ \frac{\tanh m1 + h/km}{1 + (h/km)\tanh m1} \right] \dots \text{important} \dots \dots \dots 2.68$$

2.3.2.1 Fin Effectiveness

Fin effectiveness is defined by relating the actual performance of a fin to the performance of an ideal fin which has a uniform temperature all along its surface equal to the temperature at its root.

The heat transfer from an ideal fin neglecting the heat from the end is equal to

$$Q_1 = Plh\theta_o \dots\dots\dots 2.69$$

If the heat transfer from the actual fin is considered to be given by equation 2.64. then

$$\text{Fin effectiveness } \eta_f = Q_o/Q_1 = mkA\theta_o \tanh ml/Plh\theta_o$$

$$Q_o/Q_1 = A*k*\tanh ml/h*P*1$$

$$Q_o/Q_1 = \tanh ml/ml \dots\dots\dots \text{important} \dots\dots\dots 2.70$$

Holman (1981, p41) stated that the expression for heat could be written.

$$ml = (hP/kA)*1 = [h(2z+2t)/kzt]l$$

z = depth of fin.

t = thickness of fin. (t is used here instead of a)

Remember that l = length of tooth from root to tip.

If the fin is sufficiently deep then 2z term will be large compared to 2t and

$$ml = (2hz/ktz)*1 = (2h/kt)*1$$

Multiplying the numerator and the denominator by l\*.

$$ml = (2h/kl)t l^{3/2}$$

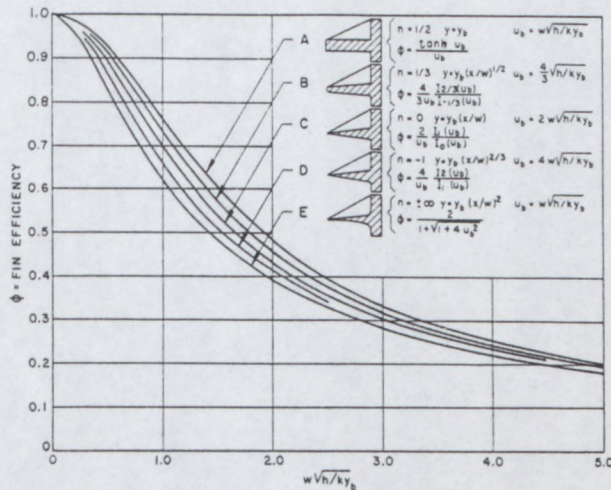
lt = A Therefore

$$ml = l^{3/2} (2h/kA)* \dots\dots\dots 2.71$$

In the case of a fin that has a significant end heat transfer

$$\eta_f = \frac{Q_o}{Q_1} = \frac{\tanh ml + h/km}{ml + (h1/k)\tanh ml} \dots\dots\dots \text{important} \dots\dots\dots 2.71$$

Figure 2.31 shows useful graphs of efficiency sourced from the ASHRAE Handbook (1989,p3.16).



Efficiency of Several Types of Straight Fin

Figure 2.31

Source: ASHRAE (1989, p3.16, Figure 14)

The calculations and graphs discussed in this section will be used in the next chapter to determine the characteristics of the heat sink.

## 2.4 PHOTOVOLTAIC POWER

As mentioned in the introduction, power is supplied to many of the microwave transmission sites by PV panels and the decision was taken to power the thermoelectric cooling system with photovoltaic panels. No attempt has been made in this project to furnish specialised knowledge covering the cells and panels. An effort has however, been made to find and discuss generally reliable ways to predict the panel performance and anticipate expected insolation so that panel output could be predicted. The power requirements in the case of the project were different to a standard panel application where the panel tilt on fixed cells is selected to give an overall maximum average monthly output for the year. This is done by selecting a panel tilt angle to favour winter sun conditions. In thermoelectric cooling applications the maximum power demand arises in summer when the heat load is at a maximum. It may therefore be advantageous to tilt the panels to an angle that will give more power in summer. Serious consideration was given to

using a two-way or single latitude following system to make maximum use of solar radiation. In the light of advice from experienced users however a fixed tilt system was decided on because it was considered to be more economical, practical and reliable.

#### 2.4.1 SIZING PHOTOVOLTAIC SYSTEMS

South Africa has a great deal of well-researched information on solar radiation for virtually every main centre in this country. Dr Eberhard (1990) has recently published an up to date set of readings recorded in South Africa's main centres. His publication includes useful graphs and data on radiation. Numerous approaches have been employed when sizing arrays and storage batteries and a convenient method which appears to suit the needs of this project has been adopted. Radiation data is usually given for horizontal surfaces and so it is important to be able to make corrections for tilt and also to find the most beneficial tilt angles. Fixed cells are set up facing north and then their tilt angle is varied depending on their latitude.

##### 2.4.1.1 Solar Insolation Incident on PV Panels

The mean direct daily solar radiation  $S$  on a horizontal plane is given by the formula

$$S = R - D \dots\dots\dots 2.72$$

$R_s$  = direct radiation

$D$  = diffused radiation

Consider combined radiation  $S$  on a surface inclined at an angle  $\beta_s$

$$S_{\beta_s} = S \sin(\alpha + \beta_s) / \sin\alpha \dots\dots\dots 2.73$$

$\alpha_N$  = noon time altitude of the sun

$$\alpha_N = 90^\circ + \phi_L - \delta \dots\dots\dots 2.74$$

$\phi_L$  = latitude

$$\delta = 23.45^\circ \sin 360/365 (d-81) \dots\dots\dots 2.75$$

$23.45^\circ$  is the summer solstice

$d$  = day numbered from 1 January

The total radiation  $R_{\beta_s}$  becomes

$$R_{\beta_s} = S \sin(\alpha_N + \beta_s) + D / \sin\alpha$$

As only total mean daily solar radiation is usually available, this formula is used to obtain the tilt correction (Mack, 1979, p12-20).

#### 2.4.1.2 Optimum Array Tilt

The optimum panel tilt angle depends both on the load demand through the year and the charge requirements of the storage batteries. The optimum tilt is usually regarded as the angle which provides the most effective radiation throughout the year (Mack, 1979, p13). The optimum tilt (OT) can be determined by using a looped calculation in a computer, but as with almost all PV information the data is readily available from suppliers. The OT angle for Pretoria is 25° obtained from data supplied by Siemens. Figure 2.32 shows a reproduction of information supplied by Siemens.

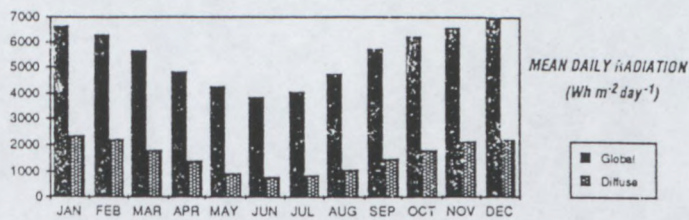
Station	Worst month	Optimum tilt	Design PHE	Years on record	No. of failures	Loss in PHE if panel is misaligned
	Note: 1	2	3	4	5	6
Alexander Bay	Jun	55°	4,79	26	0	- 4,2 %
Bloemfontein	Jun	40°	5,00	26	1	- 9,6 %
Cape Town	May	55°	3,26	30	0	- 4,9 %
Durban	Sep	30°	3,83	30	2	-12,3 %
Grootfontein	Jun	55°	5,74	13	0	- 5,6 %
Keetmanshoop	May	40°	6,96	12	0	- 8,3 %
Nelspruit	Sep	30°	4,31	9	0	- 5,8 %
Port Elizabeth	Jun	60°	4,51	24	0	- 4,4 %
Pretoria	Mar	25°	4,38	30	0	- 3,7 %
Upington	Jun	50°	5,36	15	0	- 6,2 %
Windhoek	Dec	10°	5,11	24	0	- 10,6 %

Notes:

1. The month with the least mean daily gain of solar energy.
2. The tilt that results in maximum gain in the worst month.
3. Peak Hour Equivalent (PHE) is the mean daily gain of a panel, in langleys, multiplied by 0,011624. (The result is in hours of peak performance of the panel). The design PHE is  $0,011624 (M - 1,96.S)$  where M is the average of the mean daily gains, for a given month, as calculated from the records for n years. S is the corresponding standard deviation.
4. Years of records on radiation as available from the Weather Bureau in July 1986.
5. Number of years in which the global radiation for the worst month fell below  $M - 1,96.S$ .
6. Misaligned panel is a panel facing  $15^\circ$  away from the true North and having a tilt of  $15^\circ$  less than the optimum.

Figure 2.32  
Solar Panel Design Data  
Source : Siemens

Figure 2.33 shows a copy of tables for global radiation on tilted surfaces sourced from Dr A Eberhard, s handbook (1990, p51).



MEAN DAILY GLOBAL RADIATION ON TILTED SURFACES ( $Wh\ m^{-2}\ day^{-1}$ )

Degrees	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual Mean
5	6592	6323	5813	5139	4664	4277	4485	5142	5911	6298	6516	6885	5670
10	6528	6353	5955	5408	5025	4676	4873	5491	6121	6370	6479	6784	5839
15	6428	6342	6059	5642	5354	5043	5229	5804	6291	6402	6401	6651	5971
20	6289	6291	6124	5840	5647	5377	5550	6079	6420	6392	6283	6477	6064
25	6111	6201	6150	5999	5902	5674	5834	6313	6507	6341	6126	6262	6118
30	5896	6072	6137	6118	6118	5933	6079	6505	6552	6249	5931	6010	6133
35	5646	5906	6083	6197	6292	6152	6282	6654	6553	6118	5700	5722	6109
40	5363	5703	5991	6235	6423	6328	6442	6757	6511	5948	5434	5400	6045
45	5052	5466	5861	6232	6511	6461	6558	6815	6426	5740	5136	5058	5943
50	4729	5196	5693	6187	6554	6549	6628	6826	6299	5496	4821	4701	5807
55	4382	4897	5489	6101	6552	6592	6654	6792	6131	5219	4484	4318	5634
60	4011	4581	5251	5974	6505	6589	6633	6711	5924	4909	4123	3914	5427
65	3623	4240	4980	5808	6413	6540	6566	6585	5677	4575	3741	3493	5187
70	3221	3877	4679	5604	6278	6446	6454	6414	5395	4221	3343	3084	4918
75	2848	3496	4350	5363	6100	6307	6298	6200	5078	3845	2945	2690	4627
80	2474	3101	3996	5088	5881	6125	6099	5945	4730	3449	2568	2295	4313
85	2124	2709	3621	4780	5622	5901	5858	5650	4353	3040	2191	1964	3984
90	1821	2338	3228	4441	5325	5636	5577	5318	3951	2624	1862	1689	3651

MEAN MONTHLY GLOBAL RADIATION ON TILTED SURFACES ( $KWh\ m^{-2}\ month^{-1}$ )

Degrees	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual Total
5	204	177	180	154	144	128	139	159	177	195	195	213	2068
10	202	177	184	162	155	140	151	170	183	197	194	210	2130
15	199	177	187	169	165	151	162	179	188	198	192	206	2178
20	194	176	189	175	175	161	172	188	192	198	188	200	2213
25	189	173	190	179	182	170	180	195	195	196	183	194	2233
30	182	170	190	183	189	178	188	201	196	193	177	186	2239
35	175	165	188	185	195	184	194	206	196	189	171	177	2230
40	166	159	185	187	199	189	199	209	195	184	163	167	2207
45	156	153	181	186	201	193	203	211	192	177	154	156	2170
50	146	145	176	185	203	196	205	211	188	170	144	145	2120
55	135	137	170	183	203	197	206	210	183	161	134	133	2058
60	124	128	162	179	201	197	205	208	177	152	123	121	1982
65	112	118	154	174	198	196	203	204	170	141	112	108	1895
70	99	108	145	168	194	193	200	198	161	130	100	95	1797
75	88	97	134	160	189	189	195	192	152	119	88	83	1691
80	76	86	123	152	182	183	189	184	141	106	77	71	1576
85	65	75	112	143	174	177	181	175	130	94	65	60	1456
90	56	65	100	133	165	169	172	164	118	81	55	52	1335

Figure 2.33

Mean Monthly and Mean Daily Global Radiation Figures  
For Roodeplaat

Source: Eberhard (1990, P51)

#### 2.4.1.3 P.V. Suppliers Information.

All of the panel suppliers are prepared to supply useful information to assist users in power output prediction. Figure 2.34 shows a typical supplier's graph from AEG. The graph indicates amperage plotted against voltage for varying radiation. Readings are taken at the bends on the graph. Power is calculated using the product of the amperage and voltage read from the graph. Telkom's policy has been to favour high quality monocrystalline silicon panels on their installations and any panel selections will therefore be confined to that type of system.

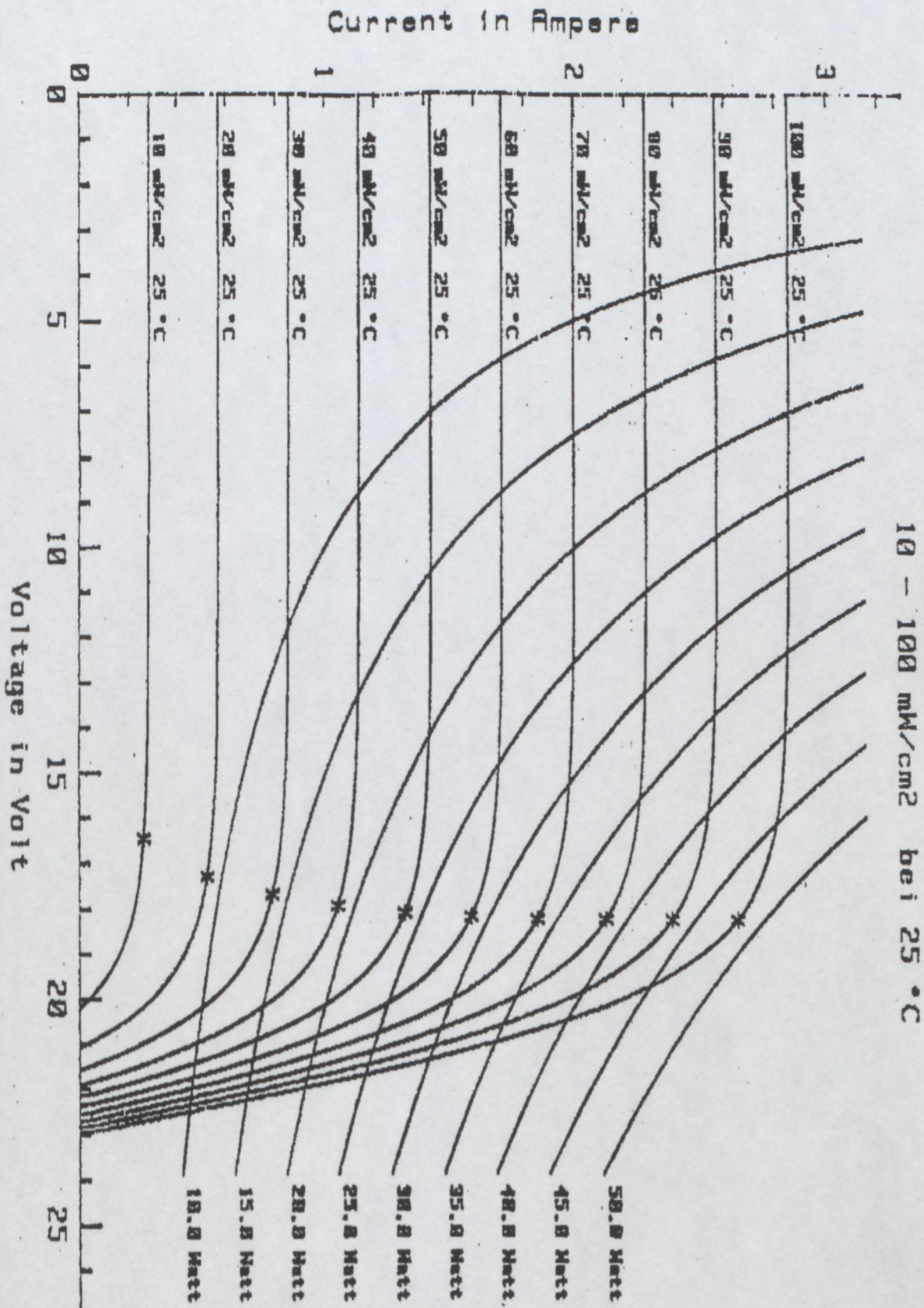


Figure 2.34

Typical PV Panel Performance Graph

Source: AEG Technical Specification

Supplied to Telkom 21:07:89

#### 2.4.1.4 Simplified Method of PV Panel Calculation

Capacity of photovoltaic systems have to be calculated by taking sunshine duration, amount of insolation, meteorological conditions and other factors into account. It is however possible to make reasonable approximations by applying simplified methods of calculation. An example of one such approach is as follows

Add the mean daily global radiation  $I_g$  for a tilted surface found in tables (eg. Eberhard, 1990, p51) for December, March and June. If Roodeplaat is considered with a tilt of  $25^\circ$  then the following information can be obtained from figure 2.32.

December = 6262 Wh  $m^2$ /day

March = 6150 Wh  $m^2$ /day

June = 5674 Wh  $m^2$ /day

Find the average from the total of the 3 values  $I_m$ .

$I_m = 18,09 \times 10^3 / 3 = 6,029 \times 10^3$  Wh  $m^2$ /day.

The figure is then divided by 1000 and multiplied by the amperage output read from the 1000 W/ $m^2$  curve. The answer is the ampere/hour output of the panel. Assume that the AEG panel PQ10/40H48D is used and the amperage read from the manufacturers graph in fig 2.32. A possible supply of 2,63A at 19,3 volts delivers a power output of 50,76 Watts. The total ampere hour output per day can then be determined.

$6,029 \times 2,63 = 15,86$  A/hrs.

Provision which is made for hours without insolation due to overcast conditions for instance is termed autonomy and will be discussed in the section on batteries. In the case of the project it will be advantageous to consider the heat load in conjunction with the estimated power demanded by the cooling system during specific months. This rule of thumb method will be compared with the ARCO computer program method in Chapter 3.

## **2.5 BATTERY**

Solar power panels are able to convert solar radiation into direct current power. It is obvious that there will not be

power when radiation is interrupted, for example at night or in overcast conditions. For this reason a storage facility is a most important part of any PV power system. Energy from PV panels is used to feed DC power to the load and to charge storage batteries. Batteries for storage of solar energy have to fulfil the following requirements:

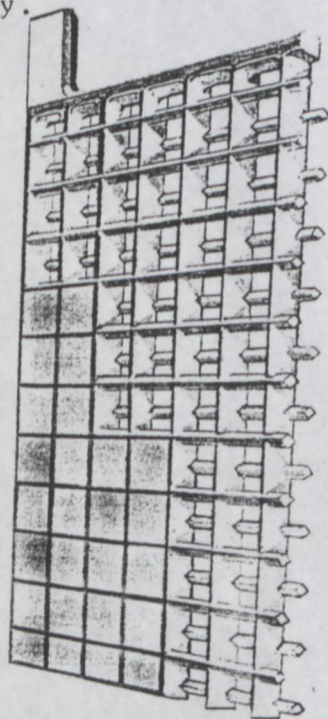
- i) low self-discharge;
- ii) long life in the peculiar solar charge mode;
- iii) low maintenance;
- iv) transportability;
- v) high charge efficiency;
- vi) reasonable cost; and
- vii) cycleability.

All batteries have some form of loss of accessible capacity. Self-discharge within a battery and inefficiency in the charge cycle must be overcome by using more solar power. The state of charge of the battery drops gradually to  $\pm 50\%$  during winter or overcast months and then has to recover during high radiation months. Solar batteries have to be low maintenance as they are typically installed on unmanned sites. The storage batteries will have to be transported long distances over rough roads. Long life lead-acid batteries designed for float duty often have soft pure-lead positive plates which have to be specially supported during transportation to prevent damage.

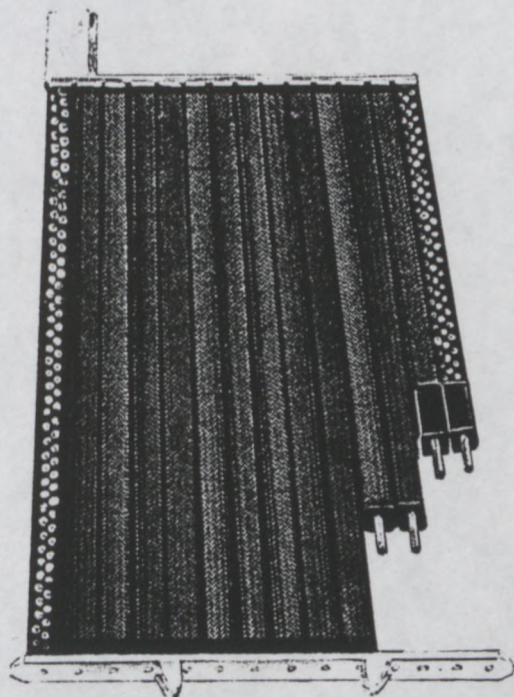
#### 2.5.1 TUBULAR BATTERY

The Tubular positive plate lead acid battery has proven superior under cycling conditions. The negative plate of this battery is of a normal flat plate construction consisting of a lead antimony alloy frame or grid supporting the active lead. Willard has developed a special frame for the negative plates manufactured from strips and rods. They have also developed a special alloy called Silvium which they claim is 98,7% more corrosion resistant than lead antimony alloy. The positive plate, however, is made up of a series of tubes. Antimonial lead spines are cast in one piece with

the upper end of the lug. Seamless braided fibre-glass sleeves of high stability are held concentric round the spine by means of fins cast onto the spine. The space between the spine and the tube is filled with active material. Fine pores in the sleeve allow the electrolyte to have uninhibited contact with the lead dioxide. Excessive sedimentation is also effectively inhibited by the fibre-glass sleeve. Perforated PVC tubes encase the fibreglass sleeves adding strength and preventing mechanical damage. The outer halves of the end tubes are not perforated to avoid short circuits. Plastic mouldings are used to insulate and seal the tubes in the positive plates. The design of the batteries and the corrosion resistance of the alloys used for spines allow a service life of in excess of 15 years under float conditions. The cycle life of this type of battery often exceeds 1200 cycles. Figure 2.35a shows a typical spine-in-tube construction positive plate battery from Exide and Figure 2.35b shows the negative plate construction for a Willard battery.



Cutaway of Negative (b)  
Grid Construction



Square Tubular Positive (a)  
Plate Construction

Figure 2.35

Source: Willard

Tubular Stationary Batteries

## 2.5.2 ELECTROCHEMICAL REACTION

In the lead acid cell lead peroxide (dioxide) ( $\text{PbO}_2$ ) on the positive plate and sponge lead (pb) on the negative plate is acted upon electrochemically by a solution of diluted sulphuric acid( $\text{H}_2\text{SO}_4$ ).

### 2.5.2.1 Discharge

On discharge the electrolyte ( $\text{H}_2\text{SO}_4$ ) divides into  $\text{H}_2$  and  $\text{SO}_4$ . The  $\text{H}_2$  combines with some of the oxygen at the positive plate to form water ( $\text{H}_2\text{O}$ ) which effectively reduces the percentage of electrolyte in the water because the volume of the water increases. The  $\text{SO}_4$  combines with lead (Pb) of both plates to form lead sulphate ( $\text{PbSO}_4$ ). During discharge acid is drawn out of the electrolyte and the specific gravity gradually falls.

### 2.5.2.2 Charge

When charging this chemical process is reversed and the lead sulphate ( $\text{PbSO}_4$ ) on the positive plates is converted back to lead peroxide while the lead sulphate on the negative plate is transformed to sponge lead (Pb). At the same time the strength of the electrolyte increases since the volume of the water decreases as the sulphate  $\text{SO}_4$  from the plates forms sulphuric acid ( $\text{H}_2\text{SO}_4$ ) with hydrogen from the water. The specific gravity of the electrolyte progressively rises until all the acid is driven out of the plates back into the electrolyte. After all the acid has been returned to the electrolyte, additional charging will not increase the gravity. Batteries in photovoltaic cycling applications have specific gravity ranging between 1,200 and 1,220 and 1,210 is recommended.

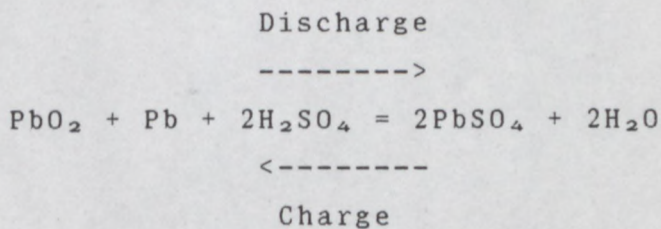
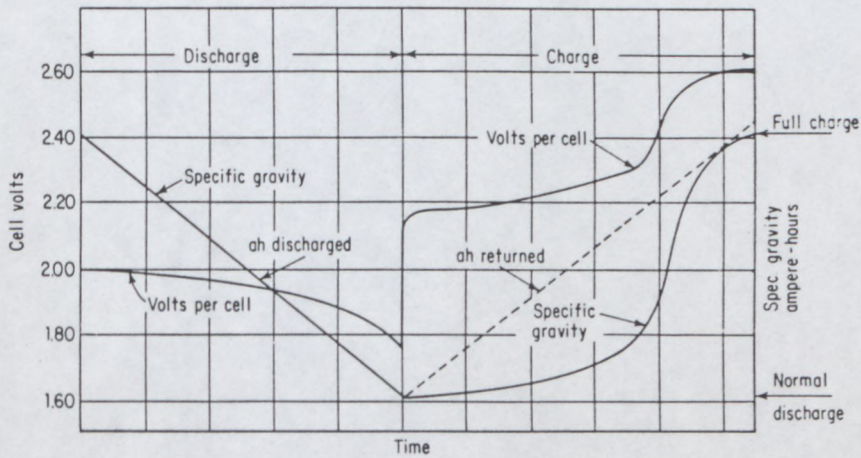


Figure 2.36 shows a typical voltage - gravity graph for a storage battery from Willard.



Typical Voltage and Gravity Characteristics  
During A Constant Rate Discharge and Recharge

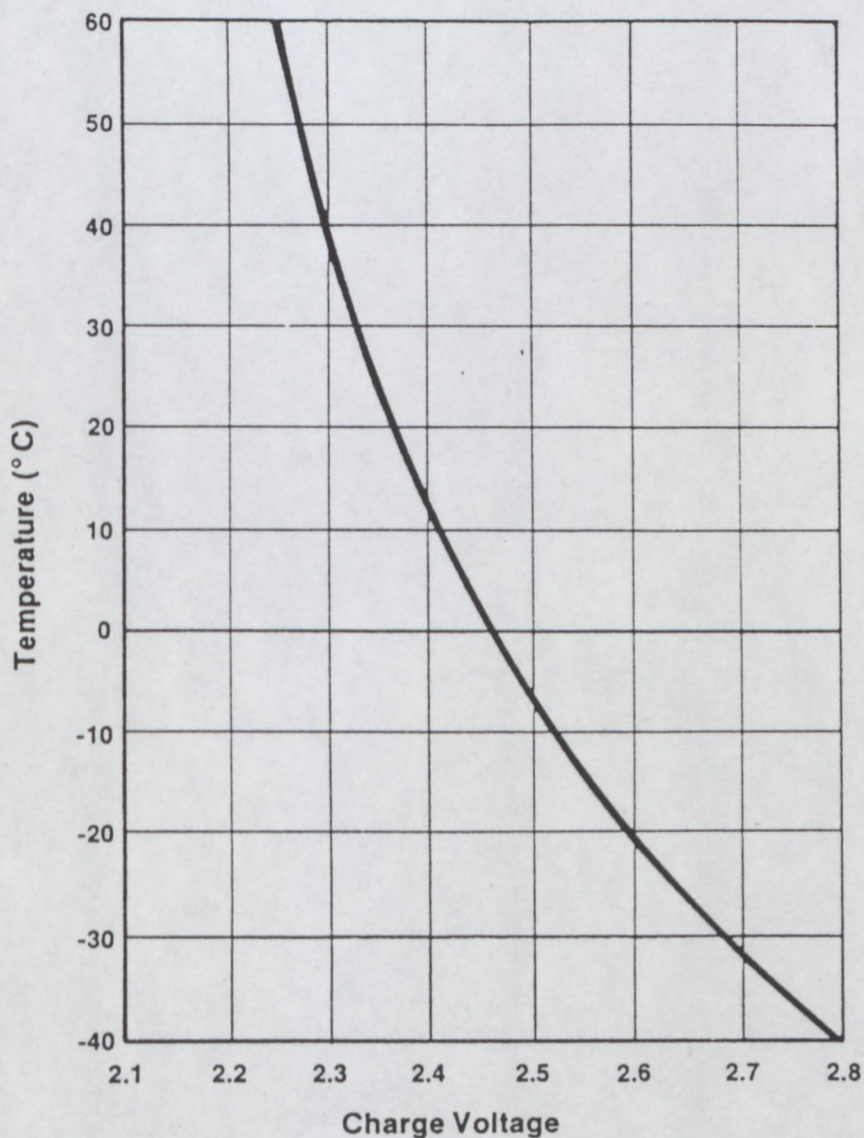
Figure 2.36

Source: The Willard Storage Battery  
Its Fundamental Principles and, Operation And Care  
(1982, p8)

### 2.5.3 CHARGING RATES

There are certain problems experienced with solar storage batteries not normally encountered in standard battery applications. The risk of stratification is high in storage batteries held on float charge. Float charge voltage is between 2,17 and 2,26 volts per cell and the current will vary between 30 and 50 milliamperes per 100 AH (Willard Storage Battery Handbook, 1982, p22). The charging cycle used on solar is what is sometimes termed a partial float cycle. This charge is adopted since maximum use has to be made of available solar insolation. It is usual to allow a certain amount of gassing to overcome stratification. Gassing usually commences at between 2,3 Vpc and 2,35 Vpc (The Willard Storage Battery Handbook, 1982, p 27). High temperatures accelerate the rate of the chemical reaction in a cell and at higher temperatures the voltage necessary to

maintain a full charge is reduced. Gates Energy Products recommend a reduction of 2,5 mV/°C per cell at a temperature significant from 25°C. For this reason most regulators are now temperature compensated to prevent overgassing which results in a loss of electrolyte or a risk of other battery damage. Figure 2.37 is a reproduction of a temperature compensation graph sourced from the Gates Battery Application Manual (Barcus (et al), 1982, p31).



Recommended Temperature Compensation

Figure 37

Source: Barcus (et al)(1982, p31)

Typical solar chargers allow the voltage to rise to a high of 2,40 Vpc. This charge is held constant until the battery starts to warm up to a temperature of 30°C at which time the charge rate is decreased to between 2,25Vpc and 2,3 Vpc as the temperature increases from 30°C to 35°C. At this temperature the charge is reduced to 2,2 Vpc and at 40°C the regulator closes down. A limiting voltage of 1,85Vpc is usually assumed. Batteries give greater discharge amp hours per cell when lower rates of discharge are accepted. This is adequately demonstrated in figure 2.38 which shows typical constant current discharge curves for an A600 Sonenschein solar battery. It is customary for Telkom to select their batteries from the 10h curves. This adds a safety factor into the selection of batteries and facilitates longer battery life.

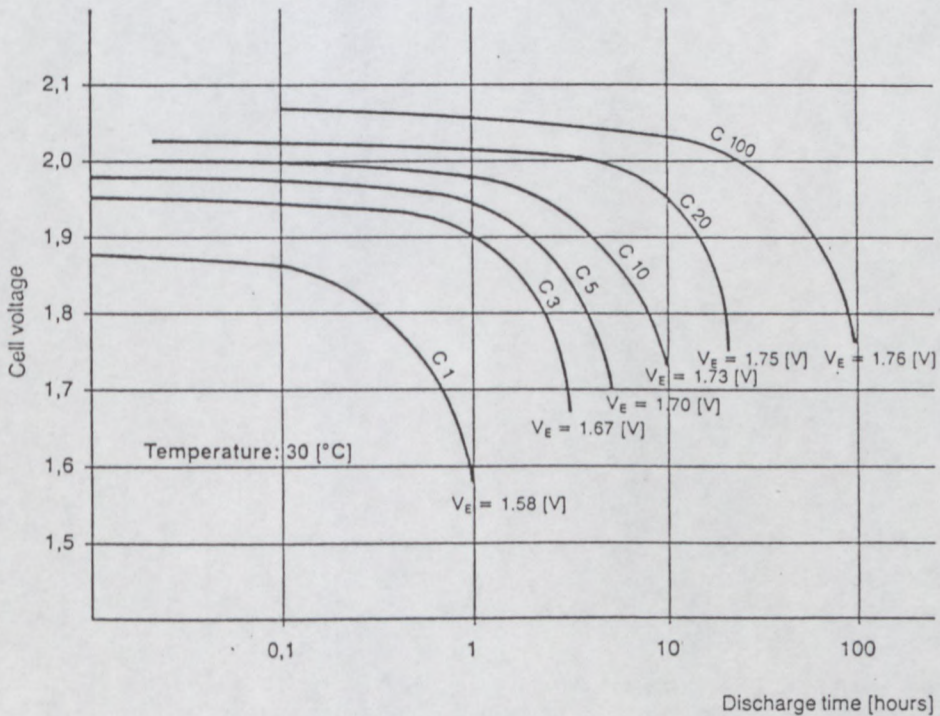
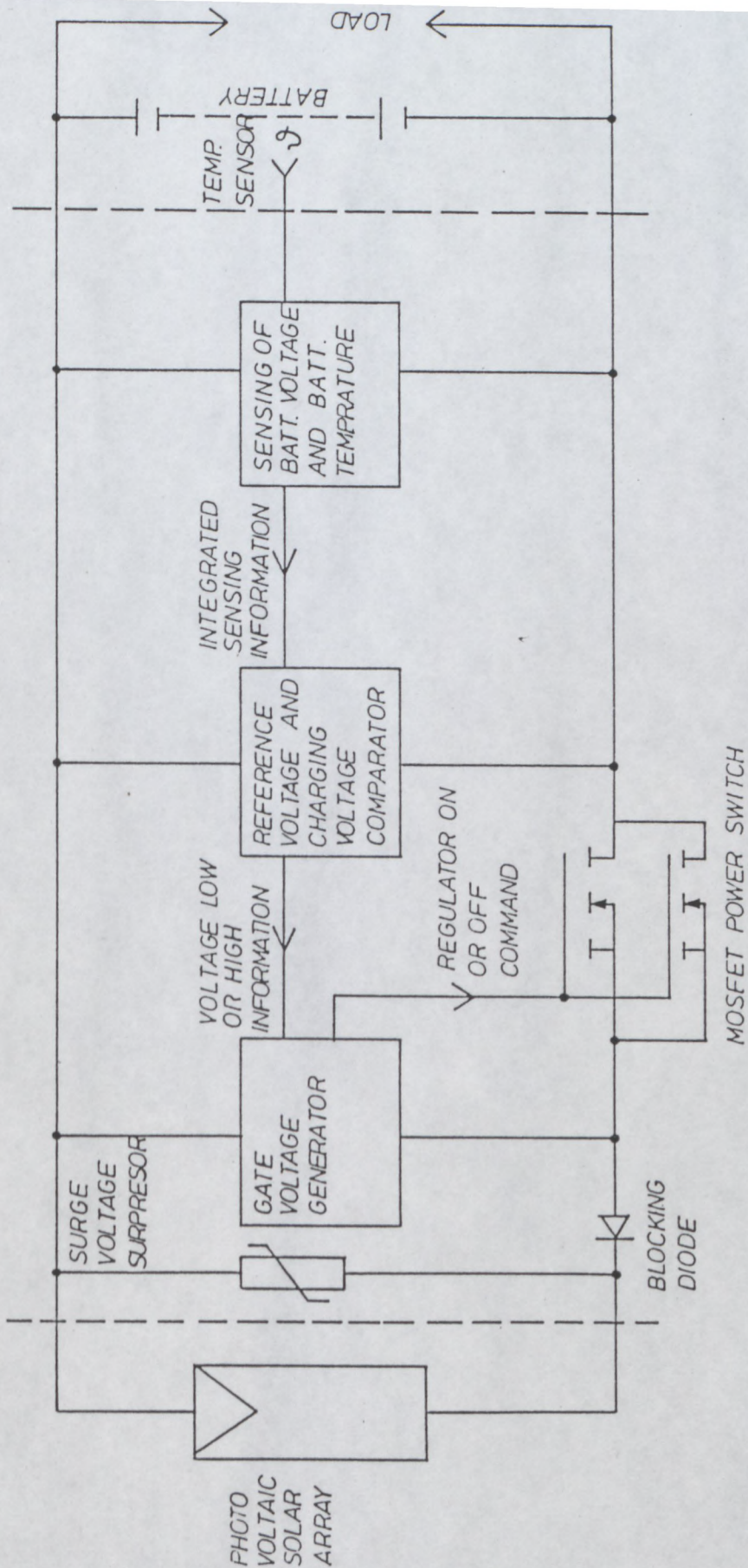


Figure 2. 38  
 Battery Performance Curves  
 Source: Sonenschein Sales Brochures

2.5.3.1 Electronic Pulse Type Regulator

A number of patent battery temperature compensated voltage regulators suitable for PV applications are available today. Siemens, for instance, supplies the sr-9, a system that is

specially designed for PV application. Their electronic pulsing type regulator is operated in series and can be set to any battery operating temperature. Important aspects of their chargers are that they only draw 5mA and will provide the right amount of charge to storage batteries in temperature conditions between  $-30^{\circ}\text{C}$  and  $65^{\circ}\text{C}$ . Battery voltage and temperature is sensed by a voltage sensing and reference voltage supplying circuit. This circuit automatically compensates the sensed voltage according to the battery temperature. The ratio of compensation is adjustable. Information from the circuit is fed to a charging pulse length forming circuit which tests the reference voltage and the temperature compensated sensed current. On this information a command is sent to the gate voltage generator causing it to provide or stopping it from providing the gate voltage to power MOSFET switch. The length variation of the charging pulse depends on the load current, battery state, current available from the PV array and pre-adjustment of the circuit. The pre-adjustment offsets the sensed voltage and creates hysteresis between the on and off voltage of the regulator. It is possible to match this regulator to different sizes of solar arrays, batteries and load requirements through this adjustment facility. The gate voltage generator supplies the required gate voltage to the MOSFET switch on the command of the charging pulse length circuit. The MOSFET transistor switch enables the actual switching of the charging current to the battery. The SR-9 can be designed to take 6 M55-Siemens modules in 12V form or 8 M55-modules in 24V form. It is marketed at a price of  $\pm\text{R}400$  (1992). Figure 2.39 shows the schematic diagram of the SR - 9 circuit supplied by Siemens.



Siemens SR-9 Battery Temperature Compensated Solar Voltage Regulator

Figure 2.39  
Source: Siemens

#### 2.5.4 BATTERY SELECTION

Prediction of the mode of solar battery operation is difficult as the performance of the battery is dependant on site climatic conditions which do not conform to regular patterns. Batteries are either operated on a constant potential, sometimes called float mode or on a cycling mode where the battery undergoes deep discharge and recharge. The thermoelectric cooling system will probably function on both cycles at different times of the year. For instance, research indicated that during summer months in Pretoria's thunder storm conditions full solar charge was typically delivered between 08:30 and 02:00. Ambient temperatures on the other hand remained high right up to 22:00 (See solar panel voltage related to temperature graphs in Appendix 3.16). These conditions would result in a cycle represented by a deep discharge followed by a short recharge. In cool winter conditions with very little cloud cover the batteries may, however, operate under float mode conditions. It is important to keep the battery state of charge above 50% in spite of climatic conditions that are difficult to predict. Batteries normally remain in a state of discharge for up to 5 months in the year, and it is the performance of the battery during this time of the year that is usually critical to the life and performance of a battery (Mack, 1979, p21). For this reason battery researchers at the Energy Research Institution of Cape Town University have developed programs to assist them in predicting "battery depth of discharge" and this will be discussed in the next chapter. Charge rates are normally slow in PV charged systems, say 50 to 100 hours compared to 10 hour rates normally employed. The steps that are typically followed to determine the size of a battery are as follows

i) Actual ampere hours consumed per day are multiplied by the number of days autonomy. In Telkom's case in Pretoria three days. If a rate of 159Ah per day at 24V is assumed for three days then a 477Ah battery is required that will discharge in 72h ( $24 \times 3 = 72h$ ).

ii) Refer to figure 3.39 which shows Raylite's battery selection curves for solar batteries. The 72h point on the graph yields a figure of 1,425. If a 6RST600 Raylite battery is selected we find that a factor of

$$600 \times 1,425 = 855\text{Ah}$$

The charge state of the battery at the end of three days will be

$$477/855 = 55\%$$

Since each cell supplies 2V, twelve fully charged cells would supply 24V.

iii) When charging the battery, a figure of 90% efficiency is usually accepted which yields a multiplication factor of 1,11. The charging rate per 24h will then be

$$159 \times 1,11 = 176,49\text{Ah}$$

IV) If the solar day is found to be 6,3 hours the recharging current will be

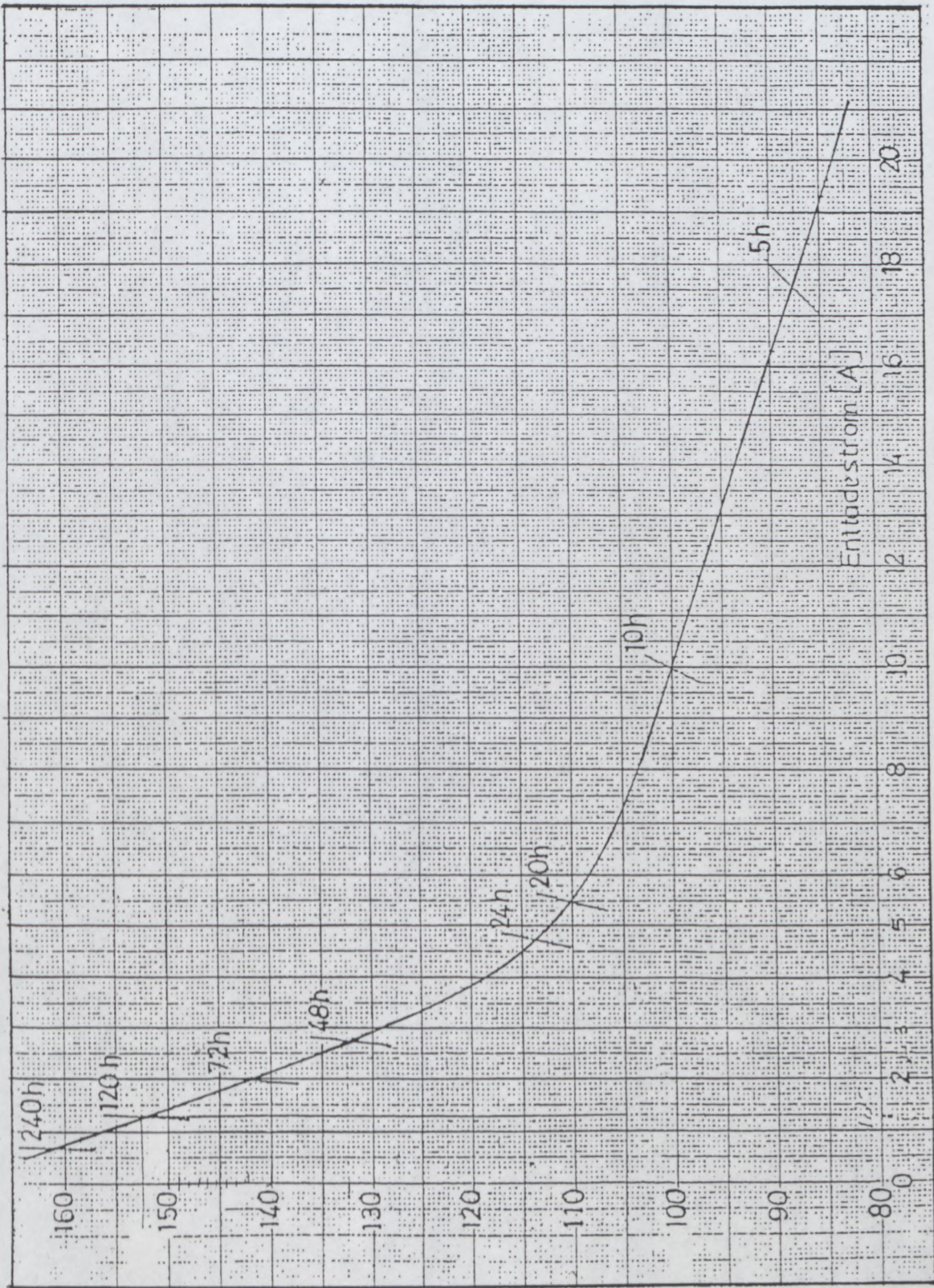
$$176,49/6,3 = 25\text{A}$$

If the PV panels was assumed to supply 2,5A per panel then an array of 10 panels would have to be used. As there would be 12 cells at an ideal optimum voltage of 2,4 Vpc the array would have to give a minimum of

$$2,4 \times 12 = 28,8 \text{ V}$$

## 2. 6 ELECTRICAL SYSTEM

No literature research was carried out in this field and the operation of the circuit is discussed with diagrams in Chapter 3.



Battery Selection Curve

Figure 2.40

Source: Raylite

CHAPTER 3

RESEARCH

### 3 . 1 . GENERAL

A suitable scaled down container was designed, developed and built at the Telecommunications Development Institution (TDI) for testing the thermoelectric cooling system. Drawing No.1 shows details of the Test Container while paragraphs 1.7.1 introduces the prototype and paragraph 1.7.2 gives some preliminary discussion on heat loads. Figure 3.1 shows a photograph of the container that was manufactured for the project.

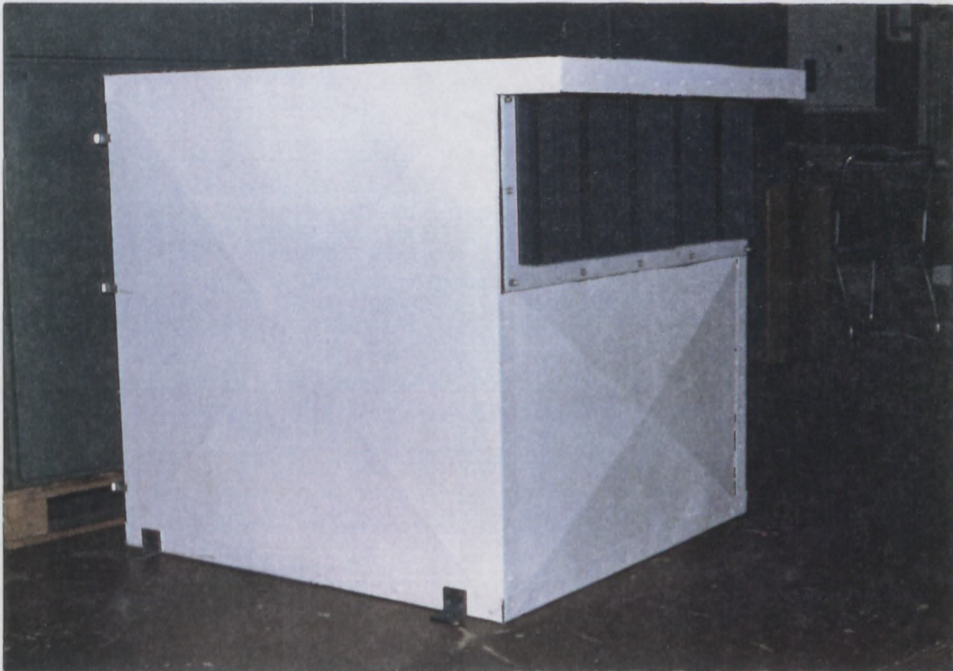


Figure 3.1  
Test Container

### 3 . 2 . HEAT LOADS

A 100W load was considered suitable for the size container concerned. The challenge was to predict the heat load where a high inside temperatures ( $38^{\circ}\text{C}$ ) was permitted. The severe summer weather conditions found in Roodeplaat Pretoria, were used for the prototype as this station was close to the TDI test site.

### 3.2.1 CLTD METHOD

A test calculation was made using the CLTD method based on the Trane Air Conditioning Manual (1979, p16-54). The closest available latitude in the tables was 40 north and the 22nd of December at 14:00 was considered to be the time that would yield close to maximum heat load conditions. Walls and roof materials were selected (in the tables) that had U factors similar to the test container. Appendix 3.2 shows the calculations that were made using this procedure. Heat loads were considered too high here as the technique assumes an indoor condition of 23°C. No calculations were made utilising the TETD approach as this system would have similar disadvantages to the CLTD method.

### 3.2.2 CARRIER PROGRAM METHOD

Calculations were developed employing the E20-II Carrier program. Climatic data from the CSIR tables with a probability level of 5% was loaded into the program (See Appendix 3.3 for computer readout). A selection of worst conditions was automatically made by the program and it was predicted that the worst conditions would arise during January at 17:00. Two test runs were made using the computer program. In the first set of calculation the same inside temperature of 23°C which was used in the Trane manual was adopted. It is worth noting that the Trane manual method yielded an answer very close to the computer method at a 23°C indoor temperature. It is also important to note that the U-factor for fibreglass was originally found using tables from the ASHRAE Handbook but that a more accurate U-factor was later obtained from the fibreglass suppliers. Appendix 3.4 shows the original calculation of the fibreglass U-factor. The U-factor calculated using the k-factor found in the chart was 0,5742 W/m<sup>2</sup>/°C compared to 0,661 W/m<sup>2</sup>/°C later obtained from the insulation suppliers. If a factor of 1,151 is used to cancel the discrepancy in the U-factor, then the computer method gives a maximum heat load of 42,61W (37 x 1,151) compared to the CLTD method of 48,46W, which is not a

totally unreasonable error. In the second computer run the permissible inside temperature was lifted to 30°C and a total heat load of 16W was calculated. It was readily noted that as the permissible temperature was lifted towards a temperature of 38°C, the heat load diminished to zero. Since it was felt that there was going to be a radiation heat load owing to solar insolation effect there was concern that this method would not be accurate under these special conditions. It became clear that conventional methods were not going to yield useful information and other load estimating methods had to be discovered. Hence the application of the Sol-air technique.

### 3.2.3. SOL-AIR METHOD

The sol-air method was applied to develop suitable heat loads. Climatic data from the CSIR which show summer design conditions for Pretoria. Tables with a probability level of 2,5% were used to find suitable ambient temperatures (Van Deventer, 1971, p65). The same tables were used to determine total radiation for north, south, west, east, and horizontal surfaces and these figures were substituted in the sol-air formula to give the total solar heat load entering the container for every hour of the day. Heat is assumed to be conducted outwards where the sol-air temperature is below the indoor temperature and total solar heat load is assumed to be the sum of the radiation into and the conduction out of the container. Situations arose at certain times of the day where one or two of the walls were thought to be conducting heat outwards while the other walls were conducting heat inwards. This phenomenon is illustrated in Appendix 3,5. At 14:00 the loads in the La column are as follows: roof 7,51W, north wall -0,27W, east wall -2,01W, south wall -2,01W, and west wall 2,89W, which gives a total solar load for the container of 6,11W. The total solar load La is added to the equipment load of 100W to give a grand total load of 106,1W at 14:00. There is no solar radiation in the night and only ambient temperatures were used to determine loads between 20:00 and 05:00.

### 3.2.3.1 Lag Time

With the above approach lag time is considered to be a problem but in this case it was not considered to be a big factor because the container's roof and walls were manufactured from the same material and there were no windows in the container. From experience, average lag time was estimated to be short. Site testing proved the assumption correct. Appendix 3.6.1 contains readings and graphs which were taken on the container with no cooling operating and no equipment load. Reading number 281 on 24th February at 15:20 in Appendix 3.6.1 shows the maximum outdoor temperature reached in the container to be 31,65°C. Reading number 284 shows that the maximum temperature of 34,74°C inside the container was reached approximately 20 minutes later at 15:50. The lag time was therefore calculated to be ±20 minutes which is negligible.

### 3.2.4 CLIMATIC CHAMBER READINGS

The test container was sited at TDI Pretoria and readings were taken at 10 minute intervals with a Grant 1206 temperature recording micro-processor. Readings were read down into a PC at suitable intervals and graphs were plotted. Five probes were mounted on strategic points of the container and one probe was mounted in a wooden louvered holder to sense the shaded ambient temperature. When the container was mounted on site, probes were mounted as follows:

probe 1 = outside on the east against the skin of the container

probe 2 = on the outside heat sink near the top between the fins

probe 3 = on the inside cold sink near the bottom between the fins

probe 4 = inside the container at floor level

probe 5 = inside the container at heat source level  
approximately half way up the container

probe 6 = outside in a shaded louvered reciprocal  
manufactured from wood

The column Ch 19 on the data sheets indicated 255 when the cooler was switched off and 254 when the cooler was working. Site readings were taken to determine performance in natural climatic conditions and then the container was placed in a climatic chamber where most of the important data was gathered. The following sets of readings were taken on site:

- Appendix 3.6.1 File 7. No heat load. No cooling.
- Appendix 3.6.2 File 14. 100W heat load. No cooling.
- Appendix 3.6.3 File 18. 60W heat load. No cooling.
- Appendix 3.6.4 File 19. 60W heat load. 2,5 A cooling.
- Appendix 3.6.5 File 20. 100W heat load. 2,25 A cooling.
- Appendix 3.6.6 File 22. 60W heat load. 2,25 A cooling.
- Appendix 3.6.7 File 23. 100W heat load. 2,5 A cooling.

Appendices 3.7.1 to 3.7.17 contain series of tests performed in the climatic chamber. These tests will be fully discussed in section 3.6.5 but they have to be briefly discussed in this section because they will be used here. Two temperature programs were used in the climatic chamber, a sol-air series and a stepped series. In the case of the sol-air series the temperatures that were used were an average of the sol-air temperatures for the different walls and the roof of the container. To explain exactly what is meant by this examine Appendix 3.5 at a time of 07:00 column Te. The average sol-air temperature at 07:00 will be

$$\text{sol-air} = \frac{20,19 + 20,22 + 34,02 + 23,94 + 20,27}{5} = 23,73^{\circ}\text{C}$$

5

This was considered to be a reasonable approach because the area and the U-factor of each side of the container was constant. The temperature graph representing an average of sol-air temperatures is shown in appendix 3.8. Appendix 3.9 shows the stepped temperature graph which was also used in the climatic chamber. These graphs will be discussed in the next section of this chapter.

#### 3.2.4.1 Validity of Sol-Air Temperatures

How valid was the sol-air approach. Turning to Appendix 3.6.1 reading 281, it can be seen that a maximum outdoor ambient temperature of 31,65°C was reached at 15:20 which caused the inside temperature to rise  $\pm 3,55^\circ\text{C}$  above ambient temperature to 35,2°C approximately 20 minutes later. These outdoor conditions can be compared with the artificial conditions created in the climatic chamber by examining Appendix 3.7.12 reading 85, where a temperature of 38,85°C inside the chamber caused the temperature inside the container to eventually rise to 37°C. This temperature was only 1,8°C higher than the temperature obtained in the container when readings were taken on site. This seems to indicate that the sol-air temperature results in a slightly higher heat load in the container than would normally be caused by site conditions. Factors like wind, cloud cover and humidity might have contributed to the discrepancy. While the difference in heat load is probably not very great, remember that climatic chamber results and heat loads will probably err on the pessimistic side.

#### 3.2.5 ELECTRONIC HEAT LOADS

The constant 100W heat load representative of an electronic load was provided by a 100W electric light bulb. This 100W load was later varied to 60W so that the system could be tested under varying conditions. There was initially concern that high radiation from the globe heat load would give false readings and the globe was covered with a 1,6mm thick matt black sheet metal cover. The cover was subsequently discarded when no difference in temperature readings could be detected after the system was operated without it.

#### 3.2.6 HEAT LOADS SUMMARY

A reasonable schedule of heat loads was now available in Appendix 3.5. For most of the day it would appear that the heat would flow out of the container because it would be hotter inside the container than outside. At 01:00 as much as 65,11W could flow out of the container; an average ambient

temperatures of 18,3°C was predicted for that time of the morning. At 14:00 an extra 6,1W of heat load could come into the container and have to be added to the the 100W of equipment load. These figures were all worst summer condition temperatures from a 2,5% probability level climatic table (Van Deventer, 1971, p35). Although it may appear to an air-conditioning engineer that only the 14:00 worst design condition was important, that was not the case. The amount of energy that the system was going to use had to be established so that the PV panels and batteries could be designed.

### 3.3. HEAT PUMPS

In this section both the theoretical and the practical aspects of the design of the thermoelectric cooling system are discussed. A purely theoretical approach will first be taken in which it is considered that units can be ordered with element sizes and numbers to Telkom's specifications. In the second case the actual thermoelectric units which were imported from the USA are discussed with suitable mounting arrangements. A number of tests were also carried out on the imported thermichips and the container with the chips mounted.

#### 3.3.1. THEORETICAL THERMOELECTRIC COOLING UNIT DESIGN

As mentioned above it is assumed here that a unit could be ordered to specification. The maximum heat load for the container was 106W so a 110W system will be examined for interest. The n and p elements are assumed to be 0.005m cubes. It is felt that the system should be powered by a 24V battery system charged by PV panels and because it is acknowledged that the batteries will not at all times produce optimum power a voltage of 20 is adopted for the theoretical system. It was eventually discovered that the temperature of the inside heat sink had to be kept at least 10° below the target inside ambient temperature and the outside heat sink temperature rose to extremely high temperatures in testing. Temperatures of 60°C and higher occurred in the outside

heat sink. These facts about the temperatures were only discovered after intensive testing of the prototype. In a most superb research paper on the production of thermoelectric materials delivered by Horst and Williams (1980) all the thermoelectric parameters are excellently laid out. For the n-type alloy Horst and Williams used a mixture of 90 mole %  $\text{Bi}_2\text{Te}_3$ , 5 mole %  $\text{Sb}_2\text{Te}_3$ , and 5 mole %  $\text{Sb}_2\text{Se}_3$  which he doped with  $\text{SbI}_3$  to obtain a carrier density of  $3,5 \times 10^{19}$  per  $\text{cm}^3$ . For p-type materials he obtained the best results from an alloy of  $\text{Bi}_2\text{Te}_3$ - $\text{Sb}_2\text{Te}_3$  comprising 72 mole %  $\text{Sb}_2\text{Te}_3$ . He found that he was measuring figures of merit (Z) in the region of  $0,003/^\circ\text{C}$  and he concluded that Zs of that order could be readily available on a production basis. Page 1871 which is a summary of his results has been reproduced in Figure 3.2. Module C2 is a typical example of the type of thermoelectric parameters that a good Peltier couple might poses and those values have been adopted for the calculations.

### Couple Results

The impact of the radiative loading on the couple  $\Delta T_{\max}$  performance is illustrated in Fig. 12. Data on a number of couples are summarized in Tables 2 through 4. Table 2 shows the performance obtained with the first material produced, Table 3 during the study, and Table 4 shows the performance obtained with the more carefully grown and doped materials. From these results, we conclude that couple Z's  $\geq 3 \times 10^{-3}/K$  are readily achievable on a production basis. Furthermore, additional materials effort will provide additional performance from this pseudo-binary system.

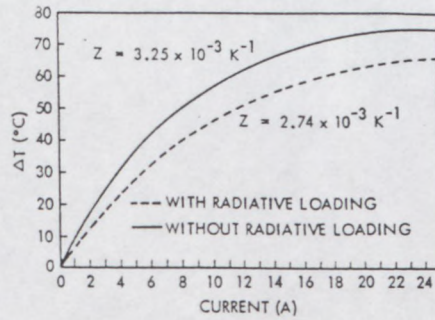


Fig. 12 The maximum  $\Delta T$  obtained from a thermoelectric module.

Table 2 Thermoelectric modules - Lot A

Module Number	$\alpha_n$ ( $\mu V/K$ )	$\alpha_p$ ( $\mu V/K$ )	$\rho_n$ (m $\Omega$ cm)	$\rho_p$ (m $\Omega$ cm)	$T_h$ ( $^{\circ}C$ )	$T_c$ ( $^{\circ}C$ )	$\Delta T$ ( $^{\circ}C$ )	Calculated <sup>(a)</sup>		
								Measured $Z \times 10^3$ ( $K^{-1}$ )	$Z_n \times 10^3$ ( $K^{-1}$ )	$Z_p \times 10^3$ ( $K^{-1}$ )
A2	180	190	0.73	0.70	15	-48	63	2.51	2.9	3.3
A3	175	170	0.62	0.59	15.5	-46	61.5	2.38	3.0	2.9
A4	180	190	0.73	0.70	14	-49	63	2.51	2.9	3.3
A5	170	167	0.60	0.57	14.5	-45	59.5	2.29	2.9	2.8
A6	182	187	0.74	0.73	15	-48	63	2.51	3.0	3.2
A7	187	187	0.75	0.73	15	-50	65	2.63	3.1	3.2

(a) Values of  $\kappa_L$  from Ref. 6.

Table 3 Thermoelectric modules - Lot B

Module Number	$\alpha_n$ ( $\mu V/K$ )	$\alpha_p$ ( $\mu V/K$ )	$\rho_n$ (m $\Omega$ cm)	$\rho_p$ (m $\Omega$ cm)	$T_h$ ( $^{\circ}C$ )	$T_c$ ( $^{\circ}C$ )	$\Delta T$ ( $^{\circ}C$ )	Calculated <sup>(a)</sup>		
								Measured $Z \times 10^3$ ( $K^{-1}$ )	$Z_n \times 10^3$ ( $K^{-1}$ )	$Z_p \times 10^3$ ( $K^{-1}$ )
B1	210	237	0.985	1.97	17.5	-51.5	69	2.82	3.2	2.6
B2	207	270	0.994	1.45	20	-50.5	70.5	2.84	3.0	3.3
B3	229	245	0.942	1.20	19	-50	69	2.78	4.0	3.8
B4	207	257	0.915	1.49	18.5	-53.5	72	3.00	3.3	3.7
B5	214	260	0.952	1.58	18	-48	66	2.60	3.4	3.6
B6	199	222	0.970	0.96	18	-51.5	69.5	2.84	2.9	3.6
B7	201	261	0.925	1.41	19	-53	72	2.98	3.1	3.7
B9	210	222	0.971	0.940	17	-52	69	2.84	3.2	3.7
B10	206	220	1.00	0.908	18	-50	68	2.74	3.0	3.8
B11	208	215	1.05	1.14	19	-50	69	2.78	2.9	3.1
B12	205	205	1.06	0.957	17	-50.5	70.5	2.93	2.8	3.1
B13	232	203	1.03	0.925	16.5	-51.5	68	2.80	3.7	4.0

(a) Values for  $\kappa_L$  from Ref. 6.

Table 4 Thermoelectric modules - Lot C

Module Number	$\alpha_n$ ( $\mu V/K$ )	$\alpha_p$ ( $\mu V/K$ )	$\rho_n$ (m $\Omega$ cm)	$\rho_p$ (m $\Omega$ cm)	$T_h$ ( $^{\circ}C$ )	$T_c$ ( $^{\circ}C$ )	$\Delta T$ ( $^{\circ}C$ )	Calculated <sup>(a)</sup>		
								Measured $Z \times 10^3$ ( $K^{-1}$ )	$Z_n \times 10^3$ ( $K^{-1}$ )	$Z_p \times 10^3$ ( $K^{-1}$ )
C1	221	225	1.27	1.12	13.5	-58	71.5	3.09	3.0	3.5
C2	216	223	1.23	1.16	14.5	-56	70.5	3.00	2.9	3.3
C3	216	223	1.25	1.23	14	-56	70.0	3.00	2.9	3.1
C4	210	232	1.15	1.17	13.5	-57	70.5	3.04	2.9	3.5
C5	210	224	1.10	1.25	14.5	-56	70.5	3.04	3.1	3.1
C6	209	231	1.13	1.19	13.5	-57	70.5	3.04	3.0	3.4

(a) Values for  $\kappa_L$  from Ref. 6.

Thermoelectric Parameters for  
n-type =  $Bi_2Te_3$   $Sb_2Te_3$   $Sb_2Se_3$ , Doped with  $SbI_3$   
p-type =  $Bi_2Te_3$   $Sb_2Te_3$

Figure 3.2

By Horst and Williams (1980)

#### 3.3.1.1 Theoretical Calculation

The first step is to ensure that the couple complies with equation 2.50. Assume that the lengths of both elements are kept the same and that the area is varied if necessary.

$$A_p/A_n = (k_n \sigma_p / k_p \sigma_n)^{1/2}$$

$$k = \alpha^2 / \sigma Z \dots\dots\dots 3.1$$

$$k_n = (216 \times 10^{-6})^2 / 1,23 \times 10^{-3} \times 2,9 \times 10^{-3}$$

$$= 13,08 \times 10^{-3} \text{ W/cm}^\circ\text{C}$$

$$k_p = (223 \times 10^{-6})^2 / 1,16 \times 10^{-3} \times 3,3 \times 10^{-3}$$

$$= 12,99 \times 10^{-3} \text{ W/cm}^\circ\text{C}$$

$$A_p / A_n = (13,08 \times 10^{-3} \times 1,23 \times 10^{-3} / 12,99 \times 10^{-3} \times 1,16 \times 10^{-3})^{\frac{1}{2}}$$

$A_p / A_n \approx 1,033$  which is negligible and can be treated as a 1 to 1 ratio.

The next step is to find the maximum figure of merit for the combination of the p and n materials which are being used. Applying equation 2.35.

$$Z_{max} = \alpha^2 / [(\sigma_n k_n)^{\frac{1}{2}} + (\sigma_p k_p)^{\frac{1}{2}}]^2 \dots\dots\dots 2.35$$

$$[(216 + 223) \times 10^{-6}]^2$$

$$Z_{max} = \frac{\dots\dots\dots}{[(1,23 \times 10^{-3} \times 13,08 \times 10^{-3})^{\frac{1}{2}} + (1,16 \times 10^{-3} \times 12,99 \times 10^{-3})^{\frac{1}{2}}]^2}$$

$$Z_{max} = 3,094 \times 10^{-3} / ^\circ\text{C}$$

The  $Z_{max}$  calculated is very close to the  $Z$  measured by Horst and Williams (1980, p1871) in Figure 3.2. The total thermal conductance for a junction between elements of  $0,5\text{cm}^3$  is calculated using equation 2.18.

$$K = k_n (A_n / l_n) + k_p (A_p / l_p) \dots\dots\dots 2.18$$

$$K = 13,08 \times 10^{-3} \times 0,5^2 / 0,5 + 12,99 \times 10^{-3} \times 0,5^2 / 0,5$$

$$K = 13,04 \times 10^{-3} \text{ W/}^\circ\text{C}$$

The total electrical resistance for the junction is calculated using equation 2.19.

$$R = \sigma_n l_n / A_n + \sigma_p l_p / A_p \dots\dots\dots 2.19$$

$$R = 1,23 \times 10^{-3} / 0,5 + 1,16 \times 10^{-3} / 0,5$$

$$R = 4,78 \times 10^{-3} \Omega$$

The average operating temperature of the couple:-

$$T_{av} = \{[273+(38-10)] + [273+60]\}/2 = 317^\circ K$$

The material - temperatures quantity that is used to calculate the optimum current is:-

$$(1 + Z_{max} T_{av})^{\frac{1}{2}} = (1 + 3,094 \times 10^{-3} \times 317)^{\frac{1}{2}} = 1,407$$

The optimum current can now be calculated from formula 2.39 so that the device can operate at maximum COP

$$I_{\phi_{max}} = \frac{\alpha T_d}{R[(1 + Z_{max} T_{av})^{\frac{1}{2}} - 1]} \dots\dots\dots 2.39$$

$$I_{\phi_{max}} = [(216+223) \times 10^{-6} \times (333-301)] / [4,78 \times 10^{-3} (1,407-1)]$$

$$I_{\phi_{max}} = 439 \times 10^{-6} \times 32 / 4,78 \times 10^{-3} \times 0,407$$

$$I_{\phi_{max}} = 7,221 \text{ amps}$$

Equation 3.13 will give the rate at which each couple will pump the heat from the cold junction

$$q_t = \alpha T_c I - RI^2/2 - KT_d \dots\dots\dots 2.13$$

$$q_t = 439 \times 10^{-6} \times 301 \times 7,221 - 4,78 \times 10^{-3} \times 7,221^2 / 2 - 13,04 \times 10^{-3} \times 32$$

$$q_t = 0,9542 - 0,1246 - 0,4123$$

$$q_t = 417,3 \times 10^{-3} \text{ Watts per couple}$$

The number of junctions that would have to be used to remove 110W of heat

$$\text{Number of Junctions} = 110 / 0,4173 = 263,6$$

Assuming that five devices or units were used with 10 heat exchangers then each unit would have 53 junctions.

The voltage for maximum COP is found by substituting in formula 40.

$$V_{\phi_{max}} = I_{\phi_{max}} R + \alpha T_d \dots\dots\dots 2.40$$

$$V_{\phi_{max}} = 7,224 \times 4,78 \times 10^{-3} + 439 \times 10^{-6} \times 32$$

$$V_{\phi_{max}} = 46,58 \times 10^{-3} \text{ volts per junction}$$

$$V_{\phi_{max}} = 12,87 \text{ volts total}$$

The 12,87 V system would be more than adequately supplied from the 24V power source which was originally specified in the introduction to the problem.

The maximum COP can be determined by using equation 2.38.

$$\phi_{max} = \frac{T_c/T_d \left[ \frac{(1 + Z_{max} T_{av})^{\frac{1}{2}} - T_H/T_c}{(1 + Z_{max} T_{av})^{\frac{1}{2}} + 1} \right]}{\dots\dots\dots} \quad 2.38$$

$$\phi_{max} = \frac{301/32 \left[ \frac{1,407 - 333/301}{1,407 + 1} \right]}{\dots\dots\dots}$$

$$\phi_{max} = 1,175$$

It stands to reason that the power input will be the cooling effect (qt) divided by the COP.

$$W_t = qt/\phi_{max} = 417,3 \times 10^{-3} / 1,175 = 355,1 \times 10^{-3} \text{ Watts per couple}$$

For 265 couples the power would be 94,1 Watts, which is the same as dividing the total required cooling power by the COP.

$$W_t = 110 / 1,175 = 93,62 \text{ Watts.}$$

The power can also be calculated by multiplying the voltage by the amperage.

$$W_t = I_{\phi_{max}} \times V_{\phi_{max}} = 12,87 \times 7,224 = 92,97 \text{ Watts.}$$

If each thermoelectric device was made up of seven rows of eight elements, each little device probably would not exceed  $\pm 40\text{mm} \times \pm 45\text{mm} \times \pm 10\text{mm}$  in size. These small appliances would of course have to be sandwiched between heat exchangers once they were assembled. Materials could unfortunately not be imported into SA otherwise the device could have been purpose made to the above specifications.

### 3.3.2 THEORY ON IMPORTED DEVICES

Although thermoelectric materials were not available, Peltier heat pump modules could be imported from Melcor. A device with the catalogue number Cp 1.0-127-06L was selected with the following overall specifications stated by the manufacturer.

maximum current input = 3,0 A

cooling output at 25°C hot face = 26,0 Watts

maximum EMF = 15,4 Volts

maximum  $T_d$  = 67°C

number of couples = 127

element size = 1mm x 1mm x 1,524mm

size of device = 30mm x 30mm x 3,6mm

weight = 12,0 grams

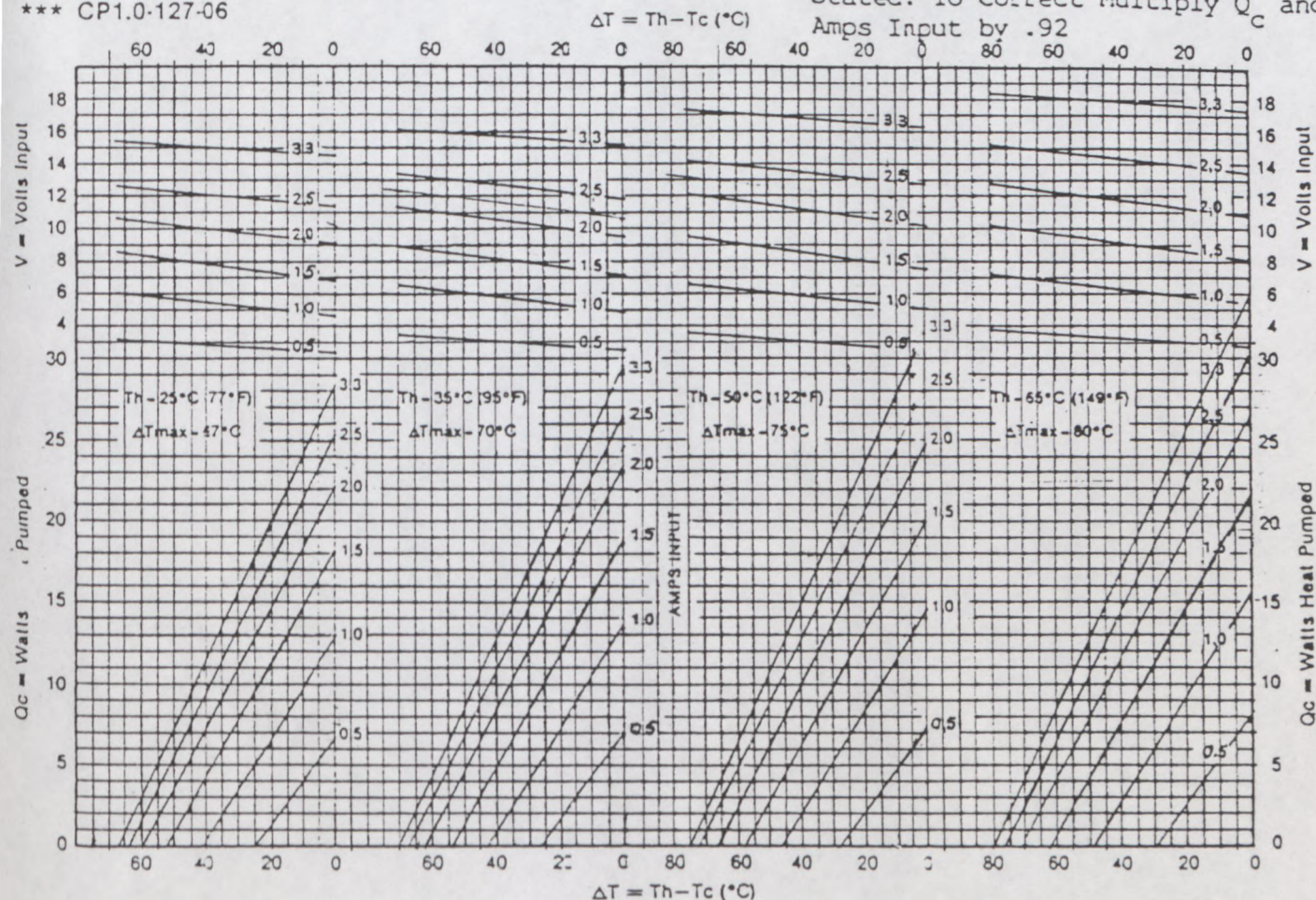
material =  $\text{Bi}_2\text{Te}_3$  (crystal growth, alloying and doping could not be obtained from the company)

face plates = metallised ceramic plates.

Melcor supplied a catalogue with a set of performance graphs in it. The relevant graph can be seen in Figure 3.3

\*\*\* CP1.0-127-06 Values are Incorrectly Stated. To Correct Multiply  $Q_c$  and Amps Input by .92

\*\*\* CP1.0-127-06



Performance Graphs for Melcors CP1.0-127-06 Heat Pump

Figure 3.3

Source: Melcor thermoelectrics catalogue of 1985.

As Melcor graphs were inconvenient for the type of calculations which were going to be made in the project an attempt was made to use the graphs to determine the main thermoelectric parameters of the imported heat pumps.

### 3.3.2.1 Analysing Melcor Device

The device, was analysed by selecting values from the manufacturers graphs (see Figure 3.3), substituting them into equations and solving the equations simultaneously. A confusing statement on the graphs stated that the  $Q_c$  and

ampere input had to be multiplied by 0,92 to correct an error in these values. It was assumed that the actual values on the graph had to be multiplied by 0,92 and not the values which were being used on the graphs. In that case 2,5 A on the graph should be read as 2,3 A and 25 Watts on the graph should be read as 23 Watts.

Assume the following values:

- $T_d = 30^\circ\text{C}$
- $T_H = 50^\circ\text{C}$
- Input current = 2,3 A

Reading from graphs

- $q_t = 15,18 \text{ Watts}$   $Q_t \text{ per couple } 15,18/127 = 0,1195 \text{ Watts}$
- volts input = 13,2 V

From experience it is fairly safe to assume that the p and n elements comply with formula 2.50 on a 1 to 1 ratio.

From equations 2.14 and 2.15

- $R_n = \sigma_n (0,1524/0,1 \times 0,1) = 15,24 \sigma_n \Omega\text{cm}$
- $R_p = \sigma_p (0,1524/0,1 \times 0,1) = 15,24 \sigma_n \Omega\text{cm}$

From equation 2.13

- $q_t = \alpha IT_c - I^2R/2 - KT_d \dots \dots \dots 2.13$
- $0,1195 = \alpha \times 2,3 \times 293 + 2,3^2R/2 - K \times 30$
- $0,1195 = 673,9\alpha - 2,645R - 30K \dots \dots \dots (3a)$

To develop the second equation the following values were assumed

- $T_d = 30^\circ\text{C}$
- $T_H = 65^\circ\text{C}$
- Input current = 2,3 A

Reading from graphs

- $q_t = 17,02 \text{ Watts}$   $Q_t \text{ per couple } 17,02/127 = 0,134 \text{ Watts}$

Volts input = 14 V

$$0.134 = \alpha \times 308 \times 2,3 - 2,3^2 R / 2 - K \times 30$$

$$0.134 = 708,4\alpha - 2,645R - 30K \dots\dots\dots (3b)$$

Equation 3a - 3b

$$14,52 \times 10^{-3} = 34,5\alpha$$

$$\alpha = 420,7 \times 10^{-6} \text{ V}/^\circ\text{C}$$

This is a perfectly reasonable answer.

To develop a third equation assume the following values

$$T_a = 20^\circ\text{C}$$

$$T_H = 65^\circ\text{C}$$

Input current = 2,3 A

Reading from graphs

$q_t = 20,7$  Watts  $Q_t$  per couple  $20,76/127 = 0,163$  Watts  
volts input = 14 V

$$0,163 = \alpha \times 318 \times 2,3 - 2,3^2 R / 2 - K \times 20$$

$$0,163 = 731,4\alpha - 2,645R - 20K \dots\dots\dots (3c)$$

Substitute for the value of  $\alpha$  in (3b) and (3c) and deduct (3b) from (3c).

$$28,99 \times 10^{-3} = 23 \times 420,7 \times 10^{-6} + 10K$$

$$K = 1,931 \times 10^{-3} \text{ W}/^\circ\text{C}$$

This seemed like a feasible answer.

Substitute K and  $\alpha$  in (3a) and solve R

$$0,1195 = 673,9\alpha - 2,645R - 30K \dots\dots\dots (3a)$$

$$0,1195 = 673,9 \times 420,7 \times 10^{-6} - 2,645R - 30 \times 1,931 \times 10^{-3}$$

$$R = 40,11 \times 10^{-3} \Omega\text{cm}$$

Substitute K and  $\alpha$  in (3b)

$$0.134 = 708,4\alpha - 2,645R - 30K \dots\dots\dots (3b)$$

$$0,134 = 708,4 \times 420,7 \times 10^{-6} - 2,3R - 1,931 \times 10^{-3} \times 30$$

$$R = 46,13 \times 10^{-3} \Omega\text{cm}$$

Substitute K and  $\alpha$  in (3c) and solve R

$$0,163 = 731,4\alpha - 2,645R - 20K \dots\dots\dots (3c)$$

$$0,163 = 731,4 \times 420,7 \times 10^{-6} - 2,645R - 20 \times 1,931 \times 10^{-3}$$

$$R = 40,11 \times 10^{-3} \Omega\text{cm}$$

Although the value of R found in (3b) deviates slightly from the value found in equations (3a) and (3c) the resistance value of  $40,11 \times 10^{-3} \Omega \text{cm}$  appeared to be an excellent value. The above parameter values were substituted in equation (2.40) and they yield a very plausible input voltage value. To demonstrate consider the first set of values sourced from the Melcor graphs

$$\begin{aligned}
 V &= IR + \alpha T_d \dots\dots\dots 2.40 \\
 V &= 2.3 \times 40,11 \times 10^{-3} + 420,7 \times 10^{-6} \times 30 \\
 V &= 104,9 \times 10^{-3} \text{ volts per couple} \\
 V_t &= 13,32 \text{ volts}
 \end{aligned}$$

This is extremely close to the answer of 13,2 volts obtained in the graph.

When calculations were made with the above parameters, answers were obtained which were consistent with readings taken from the graph. It is, however, readily admitted that at the best parameters deduced from graph readings would only provide approximations of real values because of the unavoidable errors that occurred when reading graphs. These approximate values did however prove useful when spread sheets were eventually used to predict the performance of the devices.

### 3.3.3 TEST CALCULATIONS

Sufficient information was now developed to build tables for determining cooling load and power required to maintain the cooling load. A spread sheet which can be found in Appendix 3.10 was used for this purpose. This initial spread sheet was built up before running the prototype. The spread sheet was labelled, "Preliminary". The sheet was divided into 17 vertical columns and 24 horizontal columns. Each horizontal column indicated hours of the day. The vertical columns were used in the following way.

Column 1 - time of day

Column 2 - cooling load from Appendix 3.5

Column 3 - Equivalent sol-air temperature ( $T_e$ ) from Appendix 3.5

Column 4 - it was considered that the hot side of the device would rise to 16K above ambient. The hot side temperature ( $T_h$ ) of the thermoelectric device was therefore estimated by adding 16K to the sol-air temperature ( $T_e$ ). This figure of 16K was placed in this column of the spread sheet to facilitate the operation of the spread sheet. This estimate was found to be inaccurate after test running the prototype and later revised accordingly.

Column 5 - the hot side temperature ( $T_h$ ) found by adding the estimated 16K mentioned above to the sol-air temperature. As mentioned above, the figure of 16K was merely an estimate and the figures in column 5 were later revised when more detailed information on expected temperature differences came to light.

Column 6 - the temperature difference ( $T_h - T_c$ ). The cold side temperature as well as the hot side temperatures also had to be revised after test runs.

Column 7 - the Seebeck coefficient is listed in this column to facilitate calculations.

Column 8 - the electrical resistance of the elements is also listed in this column to facilitate calculations.

Column 9 - the conductance is once again listed to allow for the operation of the spread sheet formulas.

Column 10 - the amperage of 2,25 was chosen because it appeared that this amperage was most suited to the combination of the power output from the photovoltaic panels and the battery storage system. It was also noticed during testing of the thermoelectric device that an increase in current above 2,25 A resulted in very little return in cooling power. These aspects will be further discussed at other stages in the project.

Column 11 - this column shows the hot junction temperature in Kelvin.

Column 12 - equation 2.13 is applied here and the heat rejected per junction is determined and recorded here.

Column 13 - the heat rejected by 127 junctions and therefore for one device is recorded in this column.

Column 14 - the heat rejected or the cooling effect for five devices is recorded here.

Column 15 - equation 2.40 is applied here to determine the voltage required by the device to operate at 2,25 A.

Column 16 - this column shows how long the cooling system would have to be operated during the hour of the day indicated assuming that the heat load and the temperature remained constant for the duration of an hour. The cooling system would be operated on an off or on-basis using a current of 2,25 A. Although the temperature and heat load vary constantly, this method would still give an accurate assessment of the operating time. It must also be remembered that the prediction of climatic conditions is not an exact science. To clarify what is being done in this column the cooling system was switched on at 37°C when cooling was needed and switched off when the inside temperature approached 35°C. If for instance 91,67 watts of cooling was needed at 11:00 and the five devices that were used on the prototype could produce 108 Watts at that ambient temperature then the devices would be operated for 50,93 minutes during that hour of the day.

Column 17 - The power obtained here is the input power for the 5 devices under the particular operating conditions involved at that time of the day.

Column 18 - This is the COP for the system representative of the conditions at that particular time of day.

### 3.3.3.1 Ordering From Preliminary Calculations

The above calculations tabulated in the spread sheet (Appendix 3.10) were used to determine the size and number of Peltier cooling chips to be ordered from Melcor. The devices were imported from America at this early stage in the progress of the project as the suppliers could not commit themselves to delivery dates and there were fears of the company refusing to export to SA because of trade embargoes. Although indications were that only five CP 1.0 - 127 - 06L devices were needed for the project one spare device was imported in case of a breakdown. The Melcor thermichips cost R122 each excluding 13% G.S.T. (1990). Readings taken later on the prototype appeared to indicate that some of the assumptions made on the preliminary spread sheets were not entirely correct and revision of the calculations indicated that it would have been advantageous to have ordered larger capacity cooling chips. The specifications for the tiny devices have already been documented in section 3.3.2. Figure 3.4 shows a photograph of the device leaning against a 50mmx50mmx50mm aluminium cube.

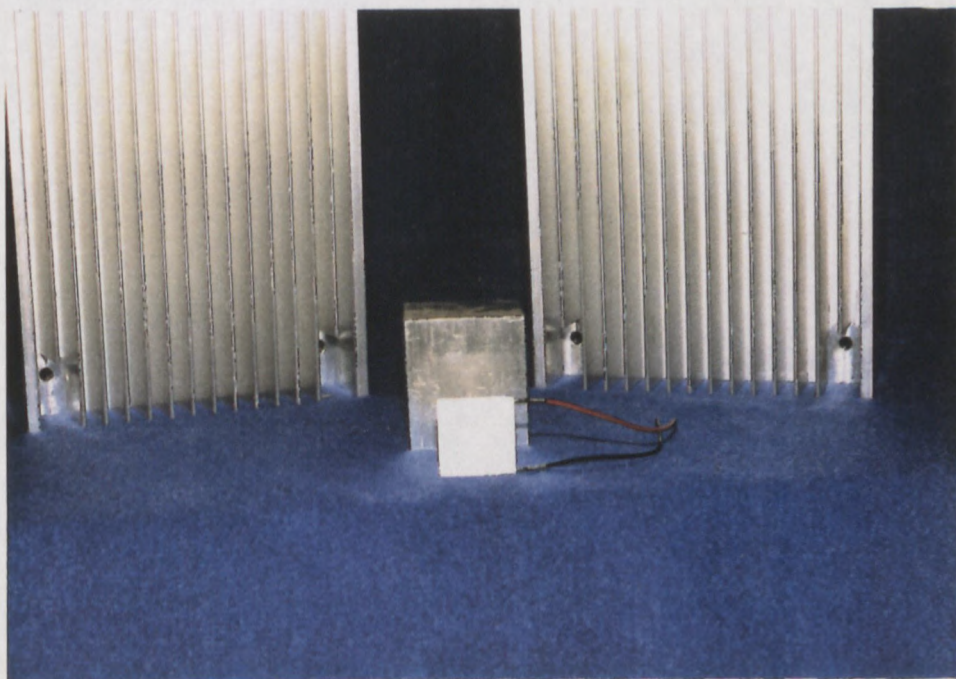


Figure 3.4  
Melcor Peltier Heat Pump.

### 3.3.4 REVISION OF PRELIMINARY SPREAD SHEETS

#### 3.3.4.1 Cold Junction Temperature

It was at first assumed that the inside heat sink would operate at the temperature of the inside of the container because it was felt that all the cooling effect would be discharged into the container. This erroneous assumption was later discovered when it was realised that the inside heat sink normally functioned between  $\pm 6,95$  K (App 3.6.5, File 20, 6th March, reading 32) and  $\pm 9,2$  K (App. 3.6.5, File 20, 6th March reading 119) lower than the inside temperature when the container was maintained at  $38^{\circ}\text{C}$ . These temperature differences were for 100W load conditions with a 2,25 A input. Higher amperage input did increased the temperature differential significantly. This phenomenon was adequately demonstrated when the temperature differential rose to 14,05 when running the system on a 100W load at 3 amp input and  $38^{\circ}\text{C}$  (Appendix 3.7.16, file 44, 8 July, Reading 20). A decrement in equipment heat load from 100W to 60W led to a reduction in the temperature difference. Typical temperature differences were 9,2 K for the 100W load (Appendix 3.6.5, File 20 6th March Reading 119) and 2,95 K for the 60W load (File 22, 7th March, Reading 116  $\pm 2,95$  K). The temperature difference when running with a 60W load on a 2,25 A input was invariably close to 3 degrees at  $38^{\circ}\text{C}$  and the temperature difference with a 100W load on a 2,25 A input was constantly close to 9 K. This factor was brought into reckoning by reducing the inside junction or heat sink temperature to  $29^{\circ}\text{C}$  which increased the value in column 4 on the revised spread sheet (See Appendix 3.11).

#### 3.3.4.2 Hot Junction Temperature

It was a surprise record that the temperature of the hot sink rose to as high as 27K above the ambient temperature (Appendix 3.6.5, File 20, 6th March, reading 148, 27,05 K) when the system was operated on site with a 100W heat load on a 2,25 A input (see also Figure 3.5). Temperatures as high as this were not obtained in the climatic chamber where the temperature difference did not exceed 13 degrees (Appendix

3.7.2, File 30, 13th May, reading 180, 13K). The temperature differences in the climatic chamber were very similar to the night time temperature differences developed in outdoor conditions which were of the order of 9 K to 13 K. Similar temperature differences were encountered when operating on a 60W load and a 2,25 A input (Appendix 3.6.6, File 22, 19 March, 25,05 K). These temperature differences obviously developed with time as the hot sink was first cold and then warmed up with the operation of the system. A type of cooling inertia effect. Review of the test figures indicated the following pattern. Cooling demand came on at about 7:30 and the temperature difference rose quickly to 22,75 K where it stayed constant till 11:20. It then increased to 24,95 K at 12:00, 27,4 K at 14:00 and 28,15 K at 14:40, from which time it began to drop to 27,05 K at 13:20, 22,05 K at 18:00 and 9,05 K at 19:20, again increasing to 14:75 K and remaining almost constant during the night. Figure 3.5 shows the temperature graphs with temperature differences and reading numbers noted. Apart from indicating that there was a temperature gradient in the heat sink Appendix 3.14 also indicated that there was a temperature rise of at least 4 degrees in the spigot that had to be consideration (Appendix 3.14 will be discussed in the heat sink section). This pattern was used to replace the constant temperature difference of 16 K used to develop the hot sink temperature in column 4 of the preliminary spread sheet. Appendix 3.11 shows the revised spread sheet incorporating the changes discussed. The revised spread sheet is identical to the preliminary spread sheet except for 3 revisions. Column 4 has been added to indicate the predicted difference in temperature between the ambient temperature and the hot sink, column 5 is now used to add the figure in column 4 to the sol-air equivalent temperature in column 3, and the cold sink temperature which is subtracted from the hot sink temperature in column 6 has been changed from 38°C to 29°C. These changes alter the values found in columns 11 to 18. The ability of the system to handle full load is adversely effected between 13:00 and 15:00 where the system would have

to operate for more than one hour shown in column 16. The revised chart goes some way to explain the loss of control which occurred between 12:00 and 16:00. Figure 3.5 is a graph sourced from Appendix 3.6.5 which was used to obtain temperature differences discussed in this section.

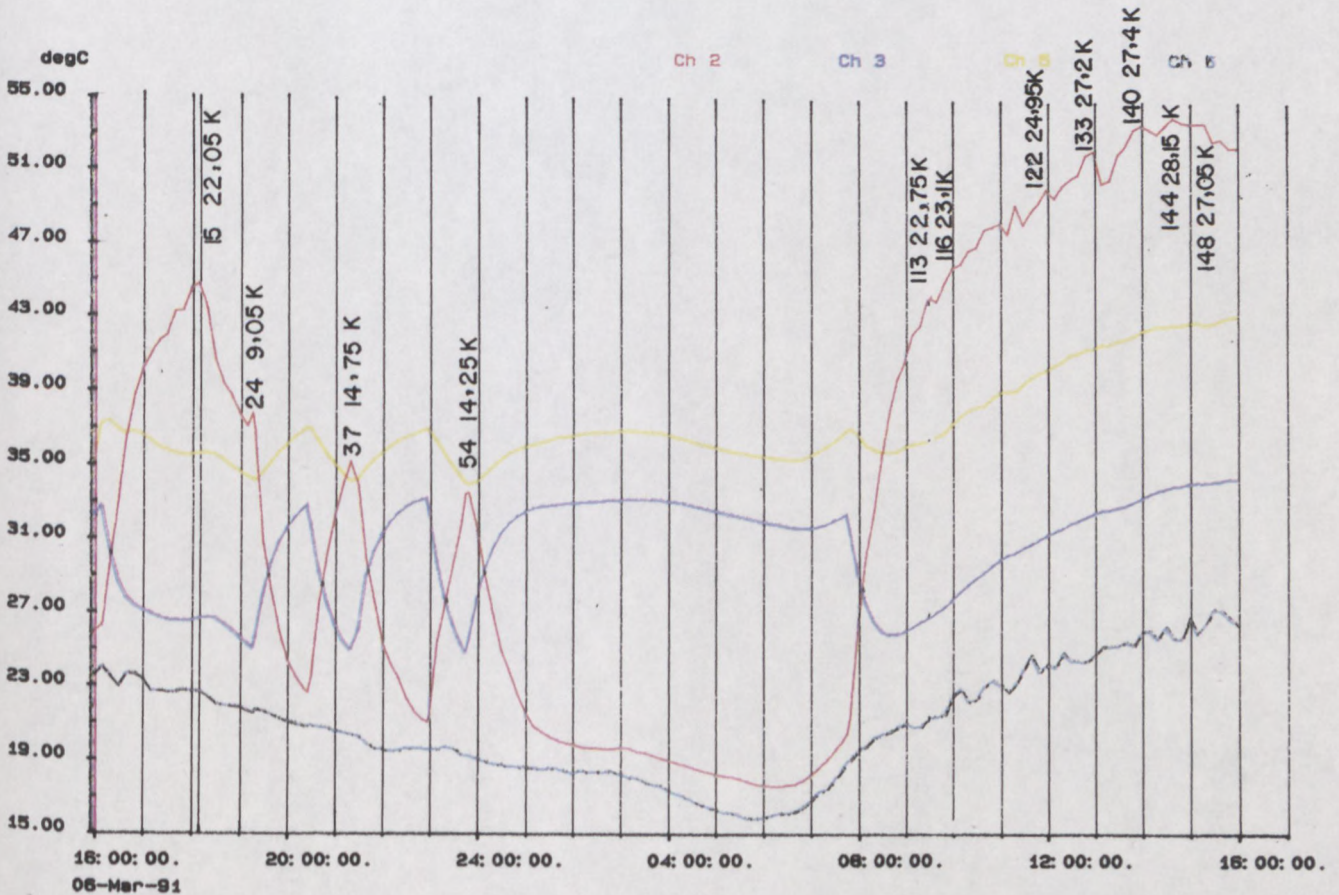


Figure 3.5  
 A Graph Sourced from Appendix 3.6.5  
 Used to illustrate Temperature differences  
 discussed in this section.

### 3.3.5 EXPERIMENTAL VOLTAGE AGAINST TIME READINGS

Early in experimental operation of the cooling devices it was observed that resistance rose with the temperature which increased with operating time. For this reason two sets of

readings were taken so that this phenomenon could be investigated. The methods used for taking the readings are discussed below.

#### 3.3.5.1 Varying Voltage / Constant Amperage (Appendix 3.12)

The Melcor device was mounted between a hot and a cold sink in the normal way. Fifty millimetres thick insulating material having a similar U-factor to the material used on the prototype was used to insulate the two sinks from each other. The system was mounted in an atmosphere that was held at approximately 23°C. A Hewlett Packard power source was then used to keep amperage constant while the voltage was allowed to vary as the resistance gradually increased. Voltage required to keep the amperage constant was recorded at 5, 10, 15, 30, and 60 minute intervals. Amperage settings were varied between 0,5 and 3. These readings were recorded in Appendix 3.12. The voltages calculated in Appendix 3.11 column 15 were remarkably close to the voltages measured in the 2,25 A column in Appendix 3.12.

The 60 minute reading from Appendix 3.12 for instance shows that a voltage of 13.31 was drawn in comparison with 13.246 the highest voltage of the day from column 15 Appendix 3.11 at 15:00. This adequately corroborated the feasibility of the voltage calculations made in Appendix 3.11.

#### 3.3.5.2 Constant Voltage / Varying Amperage (Appendix 3.13)

The same set-up as above was used. In this case however the voltage was held constant at 12 volts while the amperage was allowed to vary. Readings were taken at intervals from 5 to 140 minutes at which time stability of amperage was reached. These readings were taken to determine the amperage that would result from a constant potential drop of 12 volts across the cooling device. The predicted amperage could then be used to predict the cooling which would be expected from the devices if they were operated from a 12 volt power source.

### 3.4 HEAT SINKS

Calculations were made in this section applying formulas derived in section 2.11. These calculations were mainly used to predict the temperature rise on the hot sink.

#### 3.4.1 HOT SINK TEMPERATURE RISE GRAPH PREDICTION

It is possible to predict the hot sink temperature rise using manufacturers' graphs. The heat that one heat sink rejects is assumed to be the heat transferred by one cooling device divided by the COP:

Heat Rejected at 15:00 =  $19,397/0,645 = 30,07$  Watts

A 160mm wide comb type imported aluminium heat sink was selected for the prototype. Power Devices SA (Pty) Ltd sold Telkom 10 - 300mm long lengths at R225-50 each (1990). The cost included epoxy bonding a 50mmx50mmx50mm aluminium spigot in the centre of five of the heat sinks and anodising the heat sinks to increase heat dissipation. Telkom did their own machining to prepare the heat sinks and the spigots for bonding. There was no curve for a 30 Watt and the 50 Watt graph was used instead (see Figure 2.28). Unfortunately no performance graphs were available for the imported heat sinks which were purchased from Power Devices SA. Mike Burger, Power Devices SA, indicated that in this case the heat dissipated would be approximately proportional to the surface area as the fins on both heat sinks were identical (Per Com, 1992). Only the area of the fins that was exposed to the open atmosphere was taken into consideration in the proportional calculations.

Imported 160 wide heat sink

Peripheral length of fins =  $30 \times 2 + 2 + 5 = 67$ mm

Peripheral length of end fins =  $2(40 + 6 + 30) = 152$ mm

Peripheral length total =  $(67 \times 14 + 5) + 152 = 1095$ mm

South African TB 200 Heat sink 200 wide.

Peripheral length total =  $(67 \times 18 + 5) + 152 = 1363$ mm

Ratio =  $1095/1363 = 0,803$

A length of 300mm was assumed on the prototype because it appeared to be close to the optimum length point on the graph. Reading from the 50W graph in Figure 2.28 a temperature rise over ambient coefficient (Rt) of 0,45°C/W was found.

Temperature rise coefficient for imported heat sinks

$$R_t = 0,45/0,803 = 0,560 \text{ } ^\circ\text{C/W}$$

$$\text{Temperature rise} = 0,560 \times 30,07 = 16,84 \text{ K}$$

To this figure must be added the temperature rise in the 50mm x 50mm x 50mm aluminium spigot that was used to conduct the rejected heat through the side of the insulated container.

$$\text{Resistance } R = X/kA \dots\dots\dots 3.2$$

$$R = 0,050/233,6 \times 0,050^2$$

$$R = 85,62 \times 10^{-3}$$

$$Q = T_d/R \dots\dots\dots 3.3$$

$$T_d = 30,07 \times 85,62 \times 10^{-3} = 2,575 \text{ K}$$

$$T_d \text{ Total} = 16,84 + 2,575 = 19,42 \text{ K}$$

This figure fell well short of the actual maximum figure of 32 K which was later reached on the prototype. The  $T_d$  was estimated at an early stage in the project using the above method and the figure of 16 K arrived at was used in column 4 of the preliminary spread sheet. Both the surfaces of the spigots and the heat sinks were ground to a high tolerance before the low thermal resistant single-component epoxy was used as the bonding agent. The epoxy was imported and Power Devices could not release details of the chemical make-up as it was a trade secret. They were however prepared to release the following statistics.

Thermal conductivity = 1,5 - 1,8 cal/sec/cm<sup>2</sup>/cm/°C

Thermal expansion = 17,5 x 10<sup>-6</sup> cm/cm/°C

Shear strength at right angles to the direction of force = 1,5 - 1,8 kg/cm.

Temperature stability -60°C to + 175°C

(Burger,IM, Power Devices SA (Pty)Ltd.)

A junction of this nature prepared as mentioned is considered to be of negligible thermal resistance. Figure 3.6 shows a

photograph of the heat sinks, spigot and the thermoelectric device.

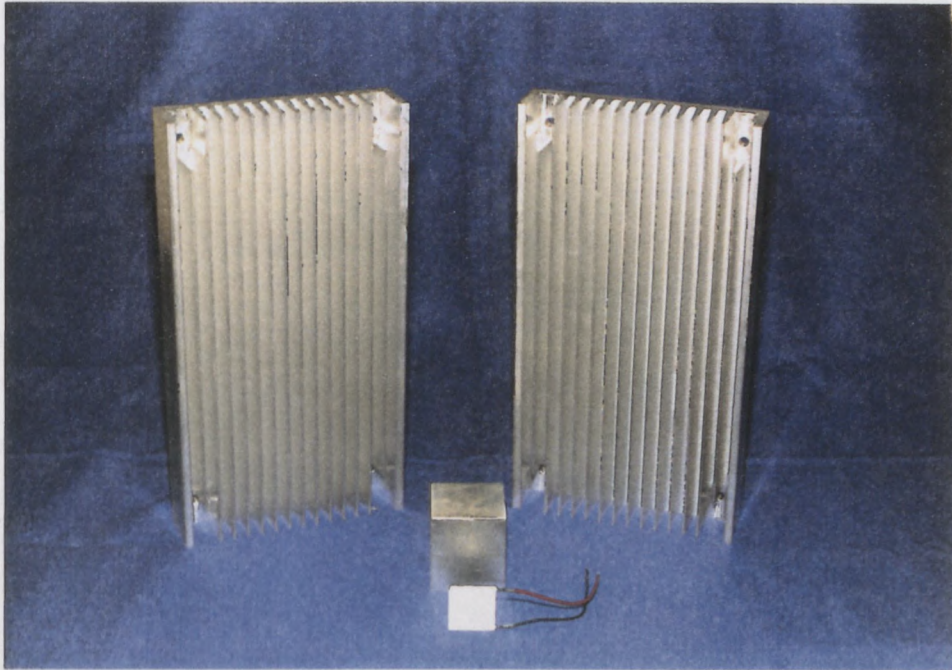


Figure 3.6  
Heat Sinks, Spigot and Device.

### 3.4.2 HOT SINK TEMPERATURE RISE PREDICTION BY CALCULATION

An iteration method was devised to solve the heat transfer calculations on the heat sinks. This method was chosen because there was no information available on any of the coefficients usually used to analyse vertical plate heat sinks. For instance, the temperature rise across the heat sinks would have had to be known before the heat transfer coefficient could be determined and the temperature rise across the sink was still to be found.

Applying formula 2.59 to the problem to find m.

$$m = (hP/kA)^{1/4} \dots\dots\dots 2.59$$

$$P = 2L + 2a = 2 \times 0,300 + 2 \times 3,5 \times 10^{-3}$$

$$P = 0,607m$$

P is the perimeter of the vertical cross-section of the fin.

$$A = L \times a = 0,300 \times 3,5 \times 10^{-3} = 1,05 \times 10^{-3}m$$

A is the vertical cross-section area.

$$A_m = 3,5 \times 31 \times 10^{-6} = 108,6 \times 10^{-6}$$

An operating temperature of 325 K was assumed for the heat sink therefore

$$k = 234 \text{ W/m}^\circ\text{C} \text{ (Simonson, 1975, p223)}$$

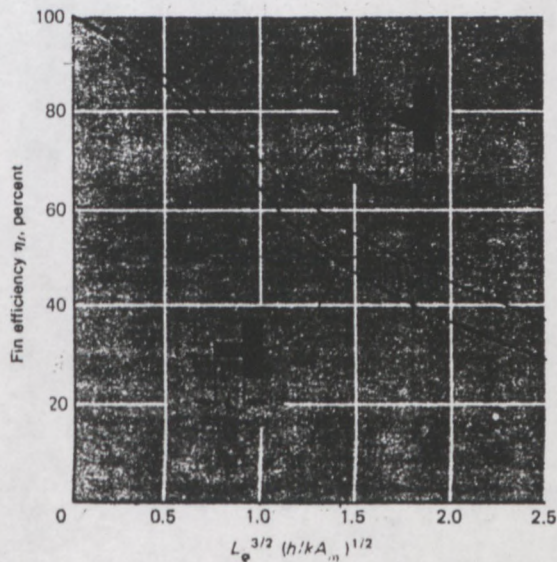
Assume  $h=20$  to obtain a departure point for the iteration method and substitute in equation 2.71.

$$m_1 = L^{3/2} (h/kA_m)^{1/2} \dots\dots\dots 2.71$$

$$m_1 = 0,031^{3/2} (20/234 \times 108,5 \times 10^{-6})$$

$$m_1 = 160,7 \times 10^{-3}$$

The efficiency is then read from the graph sourced from Holman (1981, p42) shown in Figure 3.7.



Fin Efficiency Graph

Fig 3.7

Source: Holman (1981, p42)

$$\eta_e = 97\%$$

This efficiency is used in equation 2.70 to determine  $m$ .

$$\eta_e = \tanh m_1/m \dots\dots\dots 2.70$$

$$0,97 = \tanh (m \times 0,031)/m \times 0,032$$

$$m = 9,85$$

This quantity is used in formula 2.59 to find a new value for  $h$ .

$$m = (hP/kA)^{1/2} \dots\dots\dots 2.59$$

$$9,85 = (h \times 0,607/234 \times 1,050 \times 10^{-3})^{1/2}$$

$$h = 39,27$$

39,27 is now substituted in equation 2.71 and the whole process is repeated until h eventually stays constant. The value eventually found for h was 102,7 W/m<sup>2</sup> and for m was 16,1.

These values are substituted in equation 2.68 to find  $\theta_o$ .

$$Q_o = m k A \theta_o \left[ \frac{\tanh ml + h/km}{1 + (h/km) \tanh ml} \right] \dots\dots\dots 2.68$$

$$= 16,1 \times 234 \times 1,05 \times 10^{-3} \times \theta_o \left[ \frac{\tanh 16,1 \times 0,031 + 102,7 / 234 \times 16,1}{1 + (102,7 / 234 \times 16,1) \tanh 16,1 \times 0,031} \right]$$

$Q_o = 1,909 \theta_o$  (This figure differs only slightly to a figure of 1,825  $\theta_o$  found when the tip of the fin was assumed to reject no heat and equation 2.64 was applied.)

The heat rejected for the heat sink was 29,33 Watts therefore the heat rejected for one fin was found to be 30,07/16 = 1,879 Watts

$$\theta_o = Q_o / 1,909 = 1,879 / 1,909 = 0,985^\circ$$

This temperature gradient on the heat sink proved completely unsatisfactory even in the light that the tips of the fins would be at a higher temperature than ambient.

### 3.4.3 EXPERIMENTAL TEMPERATURE READINGS

Two sets of experimental temperature readings were taken on the heat sinks both with the spigot bonded in place. These readings were taken in the hope that they would assist in the accurate prediction of the temperature rise across the heat sinks. This was important because the operating temperature of the heat sink had a direct influence on the temperature of the hot junction of the thermoelectric cooling device.

#### 3.4.3.1 Temperature Readings Using Device Heat Load (Appendix 3.14)

The cooling device was clamped between the hot and cold sink with the hot side of the device against the heat sink that had a spigot attached. 50 mm of insulating material was placed around the spigot between the two heat sinks as shown in the sketch included in Appendix 3.14. The experiment was

conducted in an atmosphere that was controlled at approximately 24°C. It was considered that these readings gave a true idea of actual operating temperatures of both sinks. The temperature readings were taken after an hour of operating time at various set amperages. Voltage even under these no heat load conditions, had to be varied as the resistance on the TEC systems tended to creep up with time operated. All readings were taken after an hour of operation starting with both the heat sinks at ambient temperature. Although a number of readings were taken during this test the most meaningful readings were taken on points 8, 9, and 10. These readings give an insight into the temperature rise through the heat sink and the spigot.

Examination of the 2.25 A readings after an hour of operation showed the following results.

(a) Temperature rise above ambient.

$$T_a \text{ Ambient} = 52,9 - 24,1 = 28,8 \text{ K}$$

This once again corroborated deductions made on the strength of readings made in the climatic chamber and used in the spread sheets.

(b) Temperature rise through the heat sink.

$$T_a \text{ Across Heat Sink} = 53,4 - 46,3 = 7,1\text{K.}$$

Temperature rise through aluminium spigot.

$$T_a \text{ Spigot} = 52,9 - 47,8 = 5,1\text{K.}$$

This calculation throws doubt on the feasibility of using calculations to predict temperature differentials through the heat sinks.

#### 3.4.3.2 Temperature rise Using Resistor Heat Load

(Appendix 3.15)

Two resistors with a total resistance of 2,7Ω were mounted on the spigot. Thermal grease was used to improve conduction between the spigot and the resistors and the resistors were insulated from the atmosphere to insure that the heat was conducted through the spigot to the heat sink. Calculations were made to determine the current that would give the required heat loads. Sets of temperature readings were taken after 5, 10, 15, 30 and 60 minutes of operating time for 10,

20, 30, 40, 50 and 60 watts of heat load. Readings were taken on the (9) and (10) positions on the heat sink up to 30 minutes but all points were recorded at the 60 minute reading. Ambient temperature was held constant at close to 24°C. The aim was to determine how much heat was being rejected through the heat sink when the Peltier device was attached to the heat sinks by comparing these resistor temperature readings with the temperature readings at the same points. This can be explained by comparing the temperature obtained on Appendix 3.14 reading 10 at 2,25 A and the 60 minute reading taken from Appendix 3.15.4 reading 10. From this comparison it would appear that the heat load rejected from the hot sink is closer to 40 Watts than it is to the expected 29,33 Watts.

#### 3.4.4 CONCLUSION

After critically looking at heat sinks it was apparent that the best method for determining the temperature rise through the heat sink and therefore the temperature of the hot junction was by measuring an operating system under expected operating conditions. Even these measurements would at best yield approximate answers.

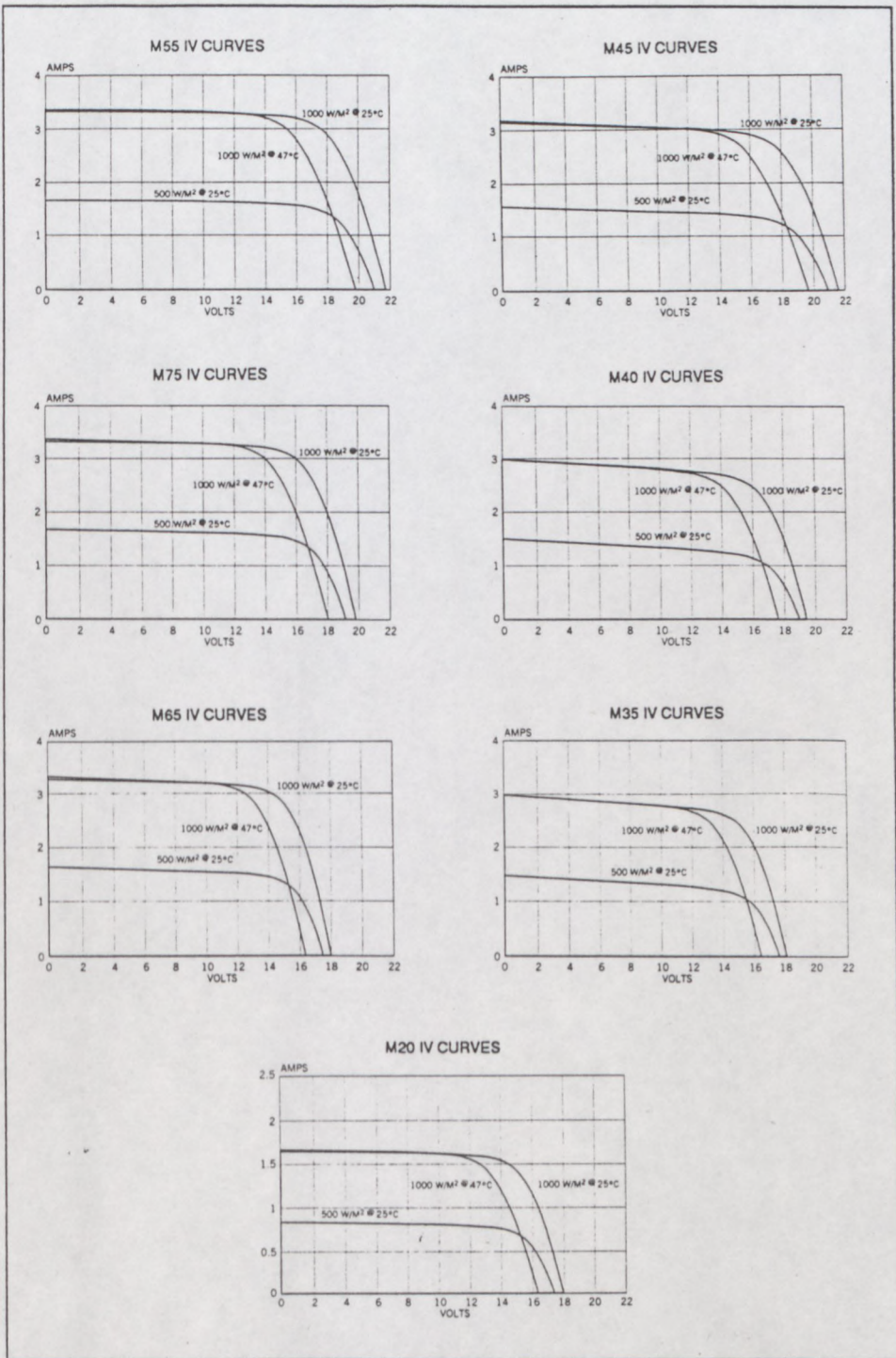
### 3.5 . PHOTOVOLTAIC POWER AND STORAGE BATTERIES

The practical aspects of this section embraced two areas, firstly monitoring of an array of solar cells under load and, secondly performing calculations to determine the number of PV panels needed to supply the system.

#### 3.5.1 LOADED PV PANEL MONITORING

In this experiment 9 - PV panels were set up in a north facing direction tilted to an angle of approximately 25°. Constant current loads were designed by TDI to allow the PV panels to be tested under load. These same devices were used to supply constant current to the Peltier cooling devices when they were tested. The electronics of the constant

current supplies will be discussed later in section 3.6. The constant current loads were set at 1 A and 2 A during testing. Voltage was measured across the load at hourly intervals to determine the panel output at different times of the day. Panel temperature and in some cases ambient temperature was also recorded. Graphs showing a summary of this information can be found in Appendix 3.16. Examination of the 2 A graphs show that full power is reached at about 9:00 and this power would be maintained until it clouded over at approximately 15:30. The measurements were taken during the Pretoria summer rainy season and cloudy conditions normally occurred during the afternoon. The graphs appeared to indicate that the PV Panels would supply close to their optimum voltage for approximately  $5\frac{1}{2}$  hours during the average summer day. This fitted in with the figures quoted by researchers like Dr Eberhard (1990). There was therefore justification for using figures from his tables. Another interesting fact was that very few of the deleterious effects caused by heat could be detected during the panel tests. This was probably because the increase in solar radiation during the hotter times of the day tended to overcome any effects of the heat. Siemens shows IV curves for both 25°C and 47°C surface temperatures at a thousand Watts. These graphs indicate that there is a voltage reduction of  $\pm 13\%$  on a 3 A load. (See Figure 3.8 for copies of the Siemens graphs sourced from Siemens Installation Guide p4, reference no. 233-701500-20, Rev.G. 1990)



Graphs for IV Curves

Figure 3.8

Source: Siemens Installation Guide p4

### 3.5.2 PANEL AND BATTERY SIZE ESTIMATION

Calculations for these two sections have to be treated together because the battery size has to be selected before the number of solar panels are selected and the batteries provide autonomy for the system.

It can be seen from Appendix 3.11 that the cooling system will operate for  $\pm 14,712$  hours. There are five devices each drawing 2,25 A.

Ampere hours of operation =  $14,712 \times 5 \times 2,25 = 165,5$  Ah

Allowing for 3 days of operation.

Ampere hours consumed in 3 days =  $165,5 \times 3 = 496,5$  Ah

Battery Type - Raylite 6 RST 600

Battery capacity - 600 Ah at 10 h to 1,85 volts per cell.

Refer to Figure 2.38 which shows curve HV 32 - 100 h supplied by Raylite.

The factor at 72 h = 142,5%

The 600 Ah battery discharging at 72 hr rate will give

$600 \times 142,5\% = 855$  Ah

Therefore depth of discharge after 3 days

$496,5/855 = 58,07\%$

This is a borderline case as the depth of discharge exceeds the goal of 50%.

Retry using a Raylite 7 RST 700.

$700 \times 142,5\% = 997,5$  Ah

Depth of discharge after 3 days

$496,5/997,5 = 49,77\%$

This looks like a fine selection. Although it can be seen from the spread sheet presented in Appendix 3.11 that a 12 volt battery is almost sufficient for the devices, a 24 volt system will be selected here so that the system will still operate at more than the minimum 13,25 volts even after the batteries have been operating for some time on autonomy. The other electronic components like the sensors also need more than 16 volts to operate efficiently.

It is therefore recommended that 12 - 7 RST 700 Cells be used.

The actual A/h consumed per day = 165,5 Ah  
 Battery efficiency = 90% = 1/1,11  
 The Ah recharge required is therefore = 165,5 x 1,11  
 = 183,7 Ah

Refer to Figure 2.32 and remember that this load will most likely occur during December. The mean monthly global radiation for December on a surface facing North and tilted to an angle of 30° is 186 KWh/m<sup>2</sup>. This works out at 6kWh/m<sup>2</sup> per day. One rule of thumb method used to obtain an average figure was to divide the 6kWh/m<sup>2</sup> by 1000W, find the maximum power point on the voltage - current characteristics curve and multiply this by the answer of 6 to obtain the total power per day. Specifications have been shown in Figure 3.9 for a variety of Siemens' PV panels. [Siemens Installation Guide p3 (Ref No 233-701500-20),1990]

**SPECIFICATIONS**

	MODEL M55	MODEL M45	MODEL M75	MODEL M40	MODEL M65	MODEL M35	MODEL M20
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**ELECTRICAL CHARACTERISTICS:**

Max. Power, Watts	53 Wp	48 Wp	48 Wp	40 Wp	43 Wp	37 Wp	20 Wp
Open Circuit Voltage (Voc)	21.7	21.6	19.8	19.5	18.0	18.0	18.0
Short Circuit Current (Isc)	3.35	3.2	3.35	3.0	3.32	3.0	1.60
Voltage at Load	17.4	17.3	15.9	15.7	14.6	14.5	14.5
Amperage at Load	3.05	2.78	3.02	2.55	2.95	2.56	1.38

- NOTES: 1. Rated electrical characteristics are within 10% of measured values at Standard Test Conditions of: 1000 W/m<sup>2</sup>, 25°C cell temperature and solar spectral irradiance per ASTM E 892.
2. Under normal conditions, a photovoltaic module may experience conditions that produce more current and/or voltage than reported at standard test conditions. Accordingly, the values of Isc and Voc marked on UL Listed modules should be multiplied by a factor of 1.25 when determining component voltage ratings, conductor capacities, fuse sizes, and size of controls connected to the module output. Refer to Section 690-8 of the National Electric Code for an additional multiplying factor of 1.25 which may be applicable.

Electrical Characteristics for Various Siemens PV Panels

Figure 3.9

Source: Siemens Installation Guide p3

If this approach is taken the amperage at the haunch of the curve given by the Siemens Installation Guide was 3,05 A at 17,4 volts under load. Allowing a total of  $3,05 \times 6 = 18,3$  Ah per panel per day.

The number of panels needed on site would then be  $183,7/18,3 = 10,04$  Panels

The system would therefore run on 11 panels in parallel to make up the amperage and 2 panels in series to make up the desired ideal voltage of approximately 2,3 volts per cell and 12 cells would be used. To explain this, the battery requires :

$$12 \times 2,3 = 27,6 \text{ volt}$$

Referring to Figure 3.5 and examining the 47°C curve for the M55 PV panel it can be seen that the panel will deliver at best  $\pm 14,5$  volts 15 A. Two panels in series will deliver current at 29 volts, which is only a little bit more than the ideal battery requirement of 27,6 volts.

This is an overoptimistic way of looking at the power that a PV Panel produces as the currents displayed on the graph appear to be short circuit currents and the voltages are open circuit voltages. From measurements taken on a typical 55W cell under a 2,5 A load about 14 V was given from 10:00 to 15:00 when cloud cover would usually cut the reading short. Although there would not be enough solar power to produce a voltage drop across the load there would often still be a heat load until late in the evening. Even under tests where lower loads such as 2 A were used it was unlikely that there would be power from the panels after 15;00. For this reason it is felt that a much more reasonable expectation from the average 55 Watt solar panel would be 2,5 A for five hours at 14 volts. This would mean that one panel would produce

$$2,5 \times 5 = 12,5 \text{ Ah per panel}$$

$$183,7/12,5 = 14,7 \text{ panels}$$

If the ideal charging rate per cell was taken to be 2,3 volts the required voltage of

$$2,3 \times 12 = 27,6 \text{ volts}$$

30 PV panels would suffice with 15 panels in parallel and 2 in series. If the supply amperage on the cooling system was

dropped slightly to 2,2 A at 12 volts only one row of panels would have been sufficient. The number of PV Panels would therefore reduce to 15, presenting a more positive scenario in terms of capital expenditure. The number of cells in the battery would also be halved resulting in a further reduction in price. As this is an illustrative calculation no recalculation of spread sheets has been done at this stage. This last approach is in no way considered conclusive as it goes contrary to what experienced PV Panel suppliers have found in their research. (See Siemens computer calculations in Appendix 3.17.1 and 3.17.2.)

#### 3.5.2.1 Computer Program PV Panel Selection

Optitron a Siemens PV panel supplier ran a computer analysis on the cooling system load requirements. It is more than surprising to see that the rule of thumb calculations yielded exactly the same answer in the case of the number and size of PV panels that were selected. The battery selection also proved very close. In the manual battery selection the Raylite 6 RST600 battery was found to be marginal and the next size up was the Raylite 7 RST700. The computer program on the other hand accepts a 620 AH battery. Appendices 3.17.1 and 3.17.2 contain copies of the computer analysis for both 24 A and 12 A systems respectively.

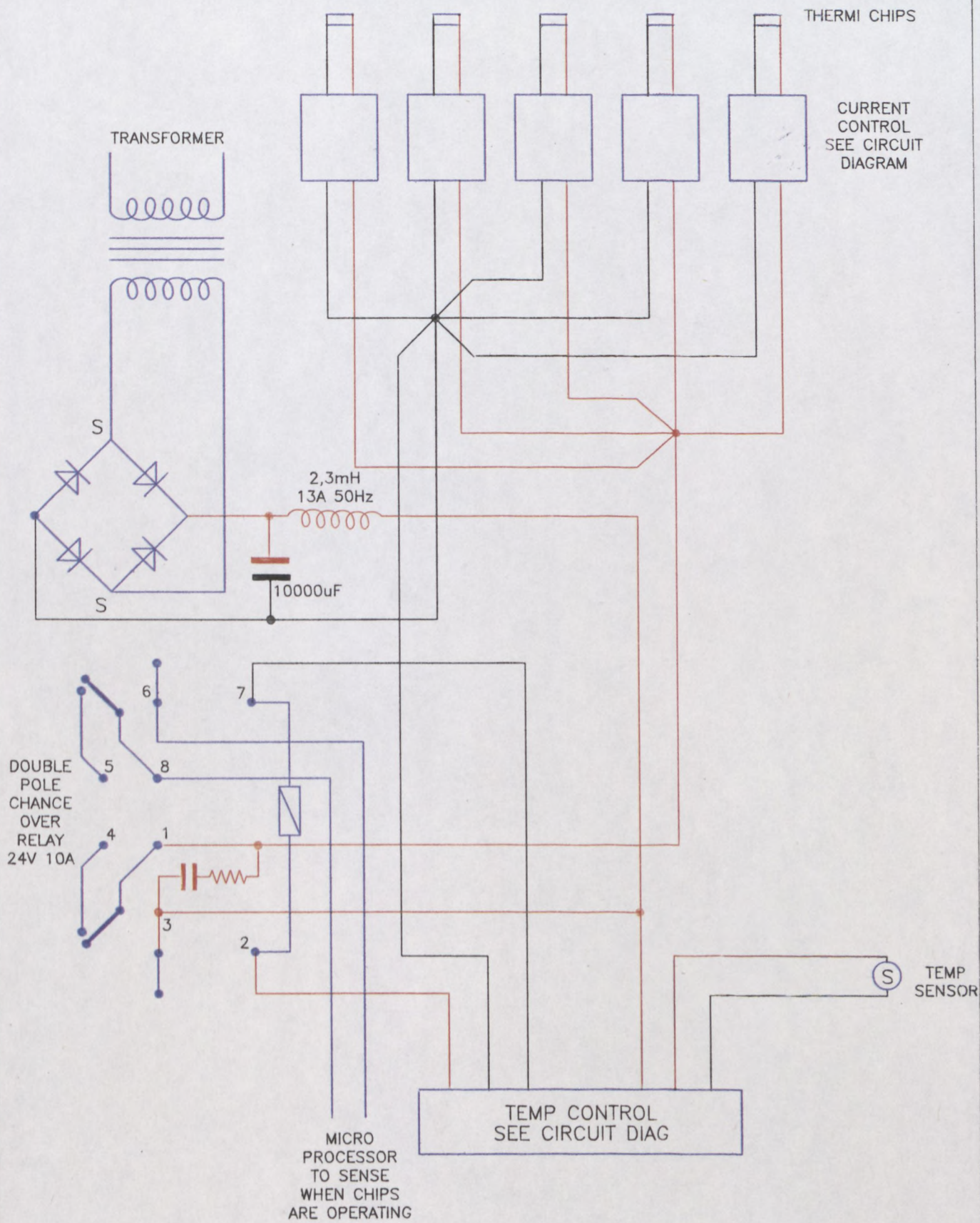
### **3.6 ELECTRICAL SYSTEM**

This section is confined to a discussion of the operation of the circuits used on the prototype. Two circuits are discussed, the constant current circuit and the temperature sensor circuit. During the test period the devices were powered from a Hewlett Packard DC power package through constant current power sources. This method was used to avoid any of the deleterious effects of ripple. The constant current devices would only be necessary during testing as the batteries would produce a non-rippling DC under actual operation conditions. A constant current was used as a basis for testing the system and the voltage was allowed to rise on demand from the devices. The voltage required to maintain the amperage increased as the devices warmed up. The

increase in voltage tended to level off after approximately 60 minutes. The sensor system on the other hand was used in the same form as it was used on the prototype.

### 3.6.1 THE GENERAL ELECTRICAL SYSTEM

The complete circuit is shown in Figure 3.10. The sensor switches the double pole 10 A relay in on demand and the Hewlett Packard direct current power source was used to supply the current for the devices. Voltage was allowed to vary on demand while the amperage was held constant at various settings.



SCHEMATIC LAYOUT OF THERMO – ELECTRIC COOLING SYSTEM

LÊER NAAM/FILE NAME DRW.No 5	© SAPT 1990 HIERDIE TEKENING IS DIE EIENDOM VAN TOI. GEEN GEDEELTE VAN HIERDIE TEKENING MAG GEREPRODUSEER OF GEBRUIK WORD SONDER SKRIFTELIKE TOESTEMMING VAN TOI NIE.	© SAPT 1990 THIS DRAWING IS THE PROPERTY OF TDI. NO PART OF THIS DRAWING MAY BE USED OR REPRODUCED WITHOUT WRITTEN PERMISSION FROM TDI.
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GOEDGEKEUR/APPROVED		
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FIGURE 3.10		

### 3.6.2 CONSTANT CURRENT SOURCE

A brief explanation of the circuit and component operation follows. Figure 11 shows a photograph of an assembled Constant Current Source. Figure 3.12 shows the circuit diagram for the Constant Current Source.

The output voltage across VCC and Tpl is five times the voltage across Tpl and ground (GND). This was designed to allow readings to be taken on a computer linkage at a 1:5 ratio. This facility was not used in this project.

When the current flows from VCC through the Zener diode D1 to GND the Zener acts as a blocking diode until a potential of 33 volts shorts the circuit out.

In the event of reversal of polarity and current flowing from GND to VCC which shorts the circuit out when the voltage exceeds 0,7 V.

IC 1 is a precision 2,5 V shunt regulator diode. Being a monolithick IC voltage reference it operates as a low temperature coefficient 2,5 V Zener diode with a dynamic impedance of  $0,2\Omega$ . The third terminal on IC 1 allows the reference voltage and the temperature to be trimmed. This is accomplished in the following way. Both diodes D1 and D2 have negative temperature coefficients to IC 1 and they function as follows. If the temperature on IC 1 rises by a temperature of  $T_a$  the voltage will tend to increase by a voltage  $V_a$ . This results in an increase in temperature in the diodes which in turn results in an increased voltage across the diodes which compensates for the drop in voltage across IC 1. In this way the voltage is kept constant across IC 1.

Resistors R1 and R2 were used to divide the voltage and to establish a 4 volt drop across VCC and TP1. Variable resistor R3 is used to establish a 1V drop from TP1 to GND. It is also used to give the circuit flexibility so that an exact voltage could be established in the circuit.

Variable resistors R5 and R6 are used to vary the constant voltage output from the IC 1 (LM336). R5 allows fine adjustment from  $\pm 2,1V$  TO  $2,7V$  while R6 adjusts the output from  $\pm 0$  to  $2,7$  volts.

IC2 is an operational amplifier. The stable voltage signal that comes in on terminal 3 is inverted on terminal 1 and capacitor C1 allows only the AC component to pass through. The signal that passes to terminal 8 is a rise or fall in voltage and the operational amplifier stabilises the signal before it reaches terminal 6.

R7 is a current limiting resistor and prevents IC 2 from being damaged by noise spikes.

Diode D3 stops the voltage from dropping too low on IC 2. There is a risk of a short circuit occurring on IC 2 if the voltage drops below zero and becomes negative.

Resistances R8, R9, and R10 make up an infinitely variable switch. Transistor T1 is a 90W device which switches through transistors T2 and T3. T2 and T3 are both 115W devices which operate in unison. The signal is measured through resistor R10 to ground and this resistor prevents the voltage from rising to high. Resistors R8 and R9 operate as a divider chain and balance the output from the transistors. In this case then

$$I_{T2} + I_{T3} = I_T$$
$$\text{and } I_{T2} = I_{T3}$$

In summary the circuit was able to control the output current to an exact setting. Each thermoelectric device was linked to terminal TP2 and IOUT. The current was varied successfully at constant currents of 2 A, 2,25 A, 2,5 A, and 3 A. One limitation that was however discovered was that large variations of 2 or more volts on the supply to the constant current loads would have an effect on the current setting of the constant current devices. This limitation was not considered a problem during testing as the Hewlett Packard power source was stable and could be accurately set. It was customary to turn the voltage on the HP power source

up when the system was initially set up to allow for the increase in voltage demand when the resistance rose as the device heated up.

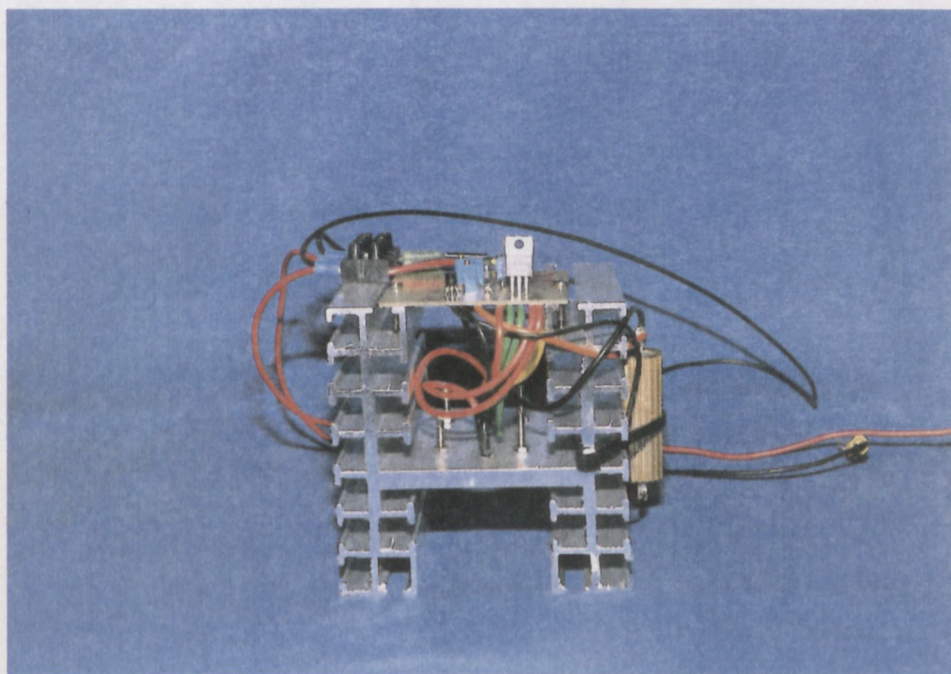
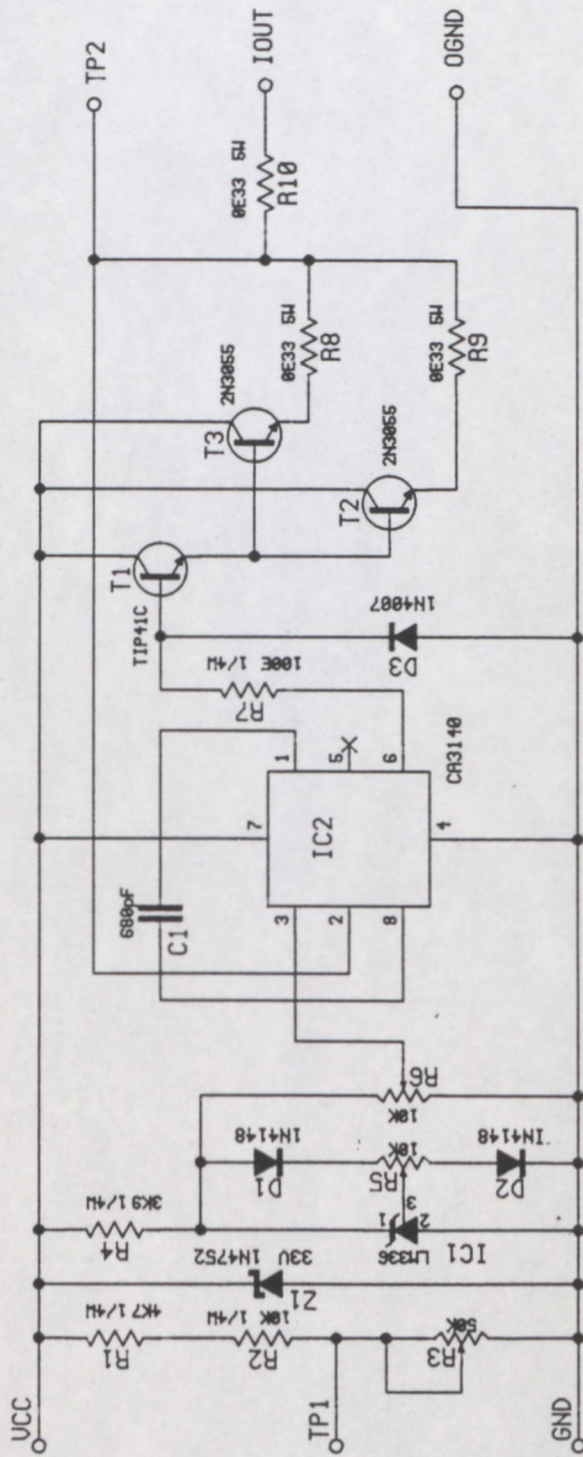


Figure 11  
Constant Current Source



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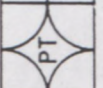
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CONSTANT CURRENT SOURCE  
FOR THERMO-ELECTRIC COOLING SYSTEM



### 3.6.3 THE THERMOSTAT

The circuit diagrams for the temperature control can be seen in Figure 3.13 and circuit diagram for the temperature sensor can be seen in Figure 3.14. Figures 3.15 and 3.16 are photographs of the electronic thermostat. Figure 3.15 shows the assembled thermostat opened so that the circuit can be seen and 3.16 shows the circuit housing closed.

The following is a brief explanation of the circuit and component operation. The thermostat was designed for a 24 V direct current power supply but it was operated efficiently on voltages as low as 16V. The power supply was connected to the P1 positive and P2 negative terminals.

Capacitors C1 and C2 smooth the DC entering the system. One capacitor smooths the high frequency component and the other the low frequency component.

IC 1 is a 3 terminal positive regulator with a fixed voltage output of 8V (LM7808). The output voltage is controlled to  $\pm 5\%$  with an output current in the order of 100mA. The IC has internal thermal overload protection and provision is made for internal short-circuit current limitation.

Capacitor C3 stabilises the 8V output from IC1.

IC2 (LM334) is a 3 terminal adjustable current source. Current is established through the external resistor R1 and held constant by IC2 once it has been adjusted. R1 is therefore used to drive IC2 and the current from the resistor is used to adjust the current on IC2.

IC3 and VR1 make up the remote sensor circuit. VR1 is used to adjust the reference voltage on IC3. The sensor is calibrated with a voltage of 2,982V at 25°C.

VR2 is used to set the switching limit on IC4 and VR3 sets the switching limit on IC5. The setting procedure will be discussed later in this section.

R2 and R3 make up the voltage divider circuit on IC4. R4 and R5 make up the voltage divider circuit on IC5. These resistors are used to establish the correct voltage and to make it possible to choose a reasonable size variable resistor on which to make adjustments.

Resistor R9 used with IC4 and resistor R10 used with IC5 are both used to establish control on feedback to prevent high current damage to the integrated circuits.

R6 and R7 resistors are used to adjust the current on the logic circuit to +0 or +1.

The logic circuit is made up of the three IC6s and three IC7s. IC6 is an inverter and IC7 acts first as a norgate and then as an inverter.

IC8 is a gate which switches with the following switching characteristics.

Preset	Clear	
0	0	Q = 0
0	1	No effect
1	0	No effect
1	1	Q = 1

When the gate is closed 8 volts are switched onto the MOSFET (T1) and it switches 24 volts onto the terminals P3 and P4. The load is connected to P3 and P4.

D1 is a blocking diode which prevents back emf when the circuit is switched off.

Capacitors C4, C5 and C6 are decoupling capacitors connected across the terminals of the logic circuit which is made up of CMOS integrated circuits which need a stable supply.

### 3.6.3.1 The Switching Process

When the maximum temperature or switch on point is reached IC4 and IC5 produces an 0 0 logic. This is applied to the digital circuit formed by IC6 and IC7 which resets the JK

flipflop switch on IC8. This turns the MOSFET T1 on which switches the current through P3 positive and P1 negative.

When the minimum temperature or switch off point is reached the IC4 and IC5 produces a 1 1 which again resets the JF flip flop. MOSFET (T1) is turned off which switches the current of.

The 0 1 and 1 0 output from the logic circuit will have no effect on the JK flip-flop.

#### 3.6.3.2 Setting Up Procedure

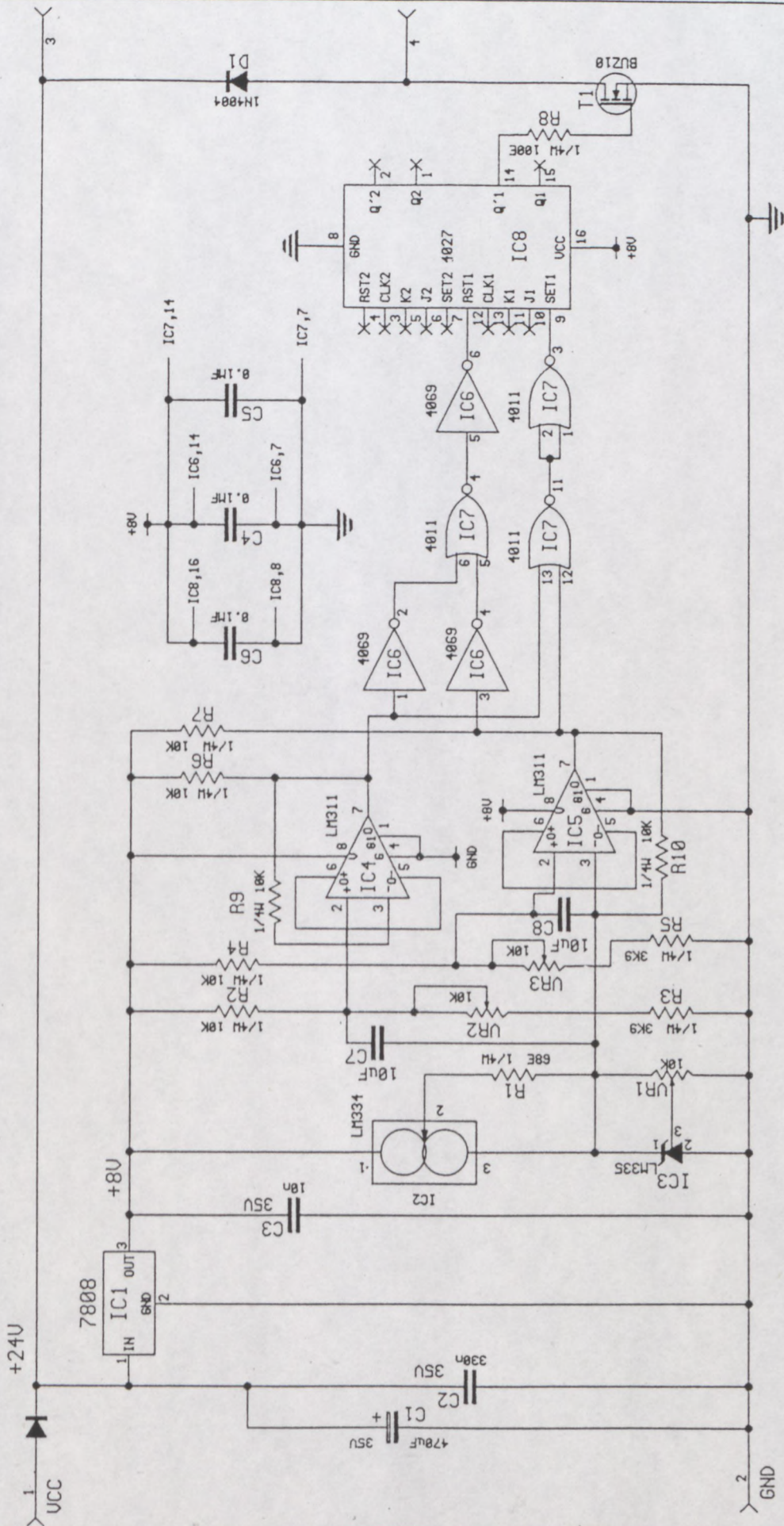
The remote sensor is held at 25°C and the voltage across IC3 (LM335) is set on resistor VR1 to 2.982V. The switch-on and turn-of voltage can now be calculated using the reference voltage of 2,982V at 25°C. For every 1°C above or below 25°C 10mV is added to or subtracted from the 2,982V reference. VR2 is used to adjust IC4 and VR3 is used to adjust IC5. The voltage is measured on pin 2 of both integrated circuits. In its application to the project the sensor output was wired to the coil of a 10 A 24V double pole change over relay which switched the system on or off.

#### 3.6.3.3 Limitations of the Circuit

The switch operated well after it was set up. Only a small error of less than 0.1°C on either side of the setting temperature was apparent. The switching sensor was taped to the sensor number Ch5 attached to the microprocessor. This method was adopted in an effort to get an accurate idea of the sensor switching error.

The only accurate way to set up the sensor was to use a climatic oven. This was necessary as each sensor tended to vary slightly in its characteristics. The most accurate settings were obtained by taping the thermostat sensor to a calibrated electronic digital thermometer sensor. Even after these precautions final adjustments often had to be made when testing the prototype. The necessity of resetting was probably owing to the heating and cooling system in the climatic oven. Final adjustments during testing were easily

carried out by comparing column Ch5 and column Ch19 after an initial run of temperature readings had been taken. Appendix 3.6.5 illustrates very clearly how this check can be made. Reading 2 shows Ch5 at 37°C and the switch indicator in column Ch19 shows 254 indicating that the sensor switched the system on when the temperature reached 37°C. The system stayed on until the temperature had dropped close to 34°C whereupon the sensor switched the cooler off (Reading 22). The temperature again rose to 36,9°C and the thermoelectric cooler switched off (Reading 30). It can clearly be seen that the two settings were working accurately at 34°C and 37°C.

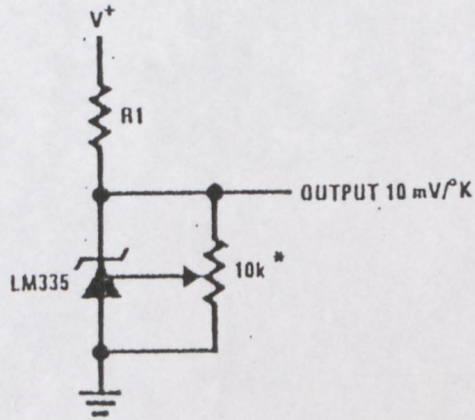


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CD BKA FB PPP				Fig. 3.13	

### Calibrated Sensor



\* Calibrate for 2.982V at 25° C.

Figure 3.14  
Temperature Sensor

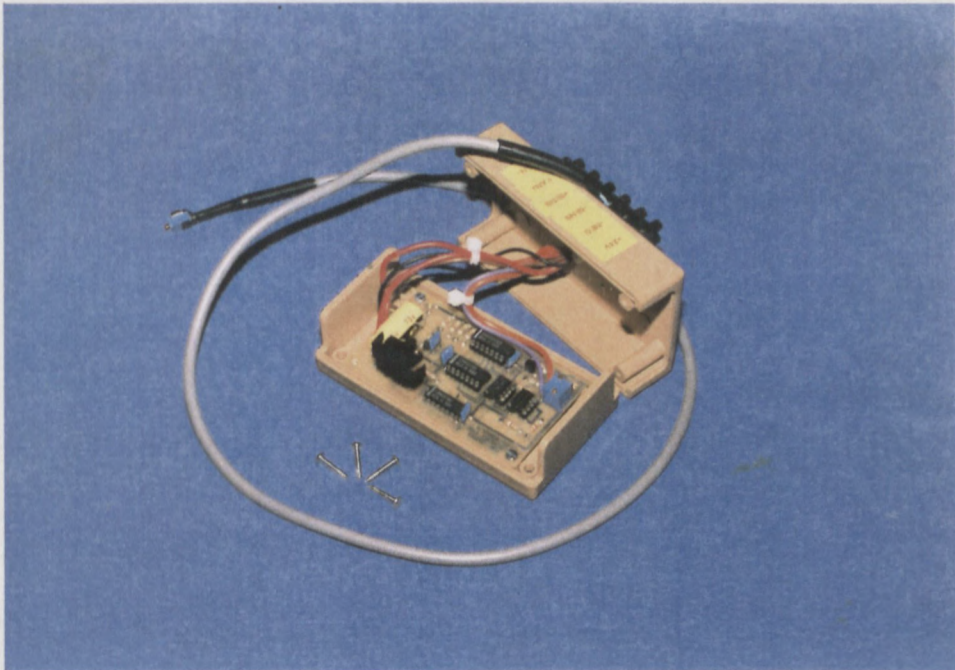


Figure 3.15  
Thermostat  
with the Housing open

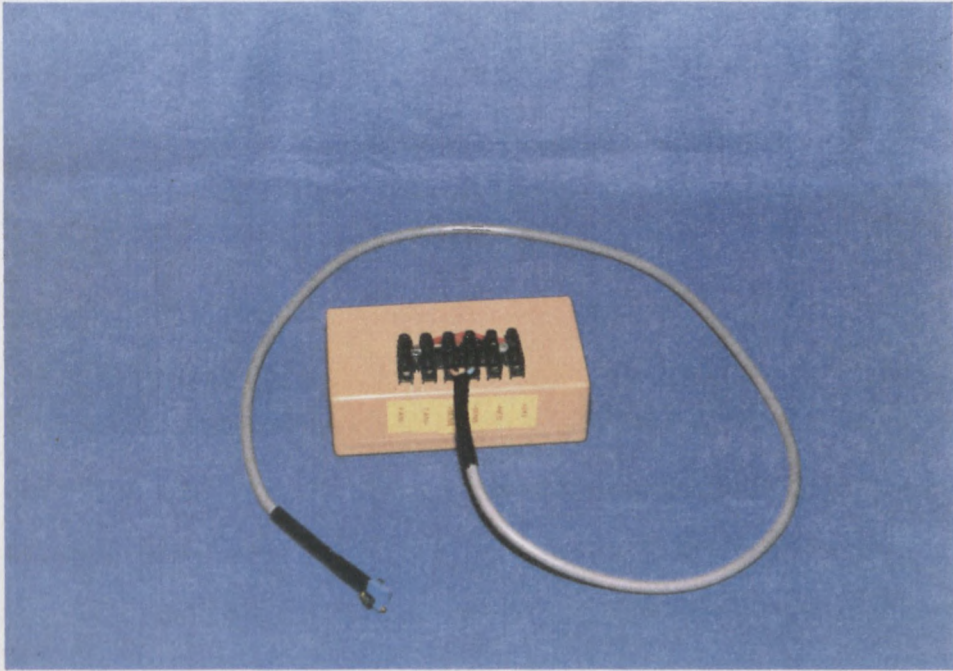


Figure 3.16  
Thermostat  
with the Housing closed

### 3.7 ASSEMBLY

The discussion on this phase of the work should be read in conjunction with drawing 2 which is self explanatory (drawing 2 is bound into the back of the dissertation). Five MELCOR CP 1.0-127-06L thermoelectric heat pump modules were mounted between 10 - 160mm wide anodised aluminium heat sinks. The mounting plate consisted of two sheets of 3mm white opal 068 perspex. Initially only one 3mm sheet had been used but this was found too weak to support the system and a second sheet was bonded to the first to strengthen it. These two sheets will be replaced by single 6mm sheets on any future production models. Fifty millimetre thick Sondor white EPX 33 was used to insulate the hot sink from the cold sink. A 50mm x 50mm x 50mm aluminium spigot was used to make the connection from the hot sink through the insulation. The outside heat sink is screwed in place with M6 stainless steel screws. A 3mm stainless steel spacer creates an air gap between the outside heat sink and the perspex. In the

initial design the M6 screws were screwed into threaded brass bosses cast into 16mm diameter Acetal spacers. These patent Acetal spacers were eventually discarded because of the problem of procuring small quantities for the prototype. They were replaced with 16mm diameter Ertalyte PETP - thermoplastic polyester. It was felt that Ertalyte would better resist the operating temperatures of the outside heat sink and the tensile stresses that would be exerted on it. Maizey Plastics supplied the material at R13,81/m (1990). According to the suppliers' catalogue a maximum long term service temperature of 100°C, and a tensile stress of 80 N/mm<sup>2</sup> at 23°C was permitted. This non-metallic material was favoured in preference to metal to prevent heat from being conducted from the hot sink through the spacer to the cold sink. The stainless steel screws effectively clamped the outside heat sink to the perspex mounting. The inside cold sinks were also mounted with stainless steel screws on the other side of the spacers. But instead of being firmly held in place they are clamped against the Peltier heat pump with springs. This was a necessary precaution as heat conduction is only at a maximum when there is pressure between the devices and the mating surfaces. Thermal grease was also used to further increase heat conduction. The springs were specially designed to maintain a safe load on the heat pumps when expansion and contraction took place as the temperature varied during operation. The perspex plate with its 10 heat sinks and 5 thermoelectric devices was mounted on the back of the 1m<sup>3</sup> container. Drawing 1 shows details of the container with the heat sinks mounted in place (this drawing is bound into the back of the book). Figure 3.17 shows the five heat sinks mounted in place on the perspex sheets.

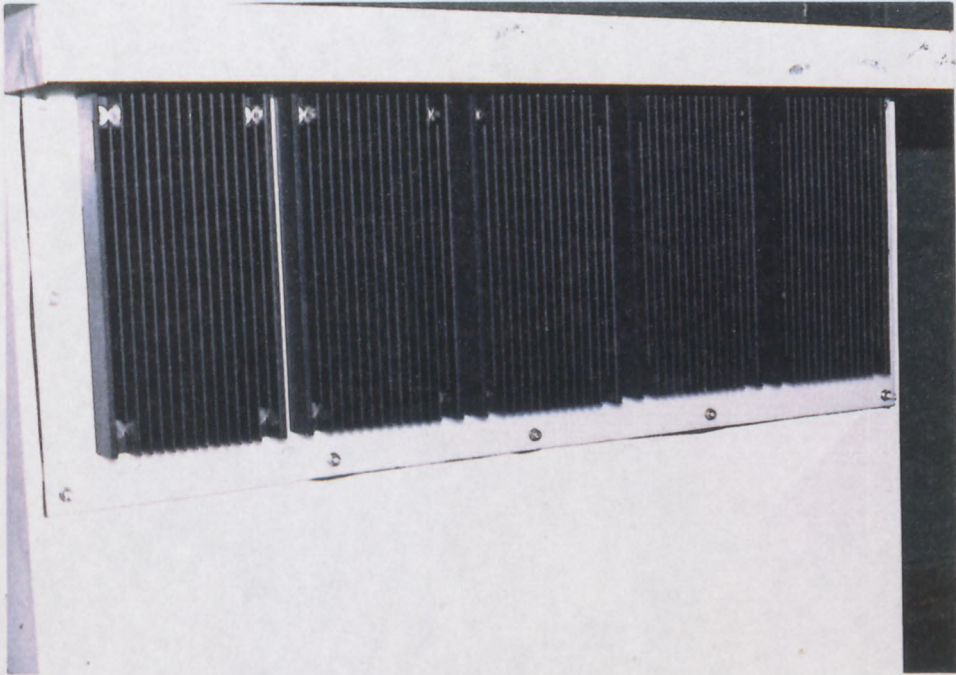


Figure 3.17  
Mounted Heat Sinks

### 3.7.1 SPRING DESIGN

The Melcor catalogue stated that "the design stress was 500 lbs compression". Two assumptions were made on the strength of this information, firstly that they were referring to a force of 500 lbs and not to a stress, secondly that the makers were referring to an ultimate load and not a safe load.

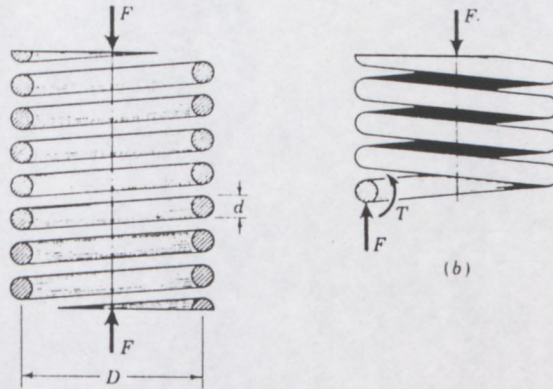
The force was converted to Newtons thus

$$500 \times 9,81 / 2,2046 = 2225 \text{ N}$$

$$\text{Safe load} = 2225/4 = 556,2 \text{ N}$$

$$\text{Load per spring} = 556,2/4 = 139,1 \text{ N}$$

The spring design formula was developed based on Joseph Shigley's (1988, p359) approach and the development of the formulas is best understood in the light of Figure 3.18.



Spring Diagram Showing Symbols Used

Figure 3.18

Source: Shigley p359 Figure 10-1

$$\tau_{max} = \pm(T \times r) / J + F/A$$

Where

$\tau_s$  = Shear force

F = Axial force

A =  $\pi d^2/4$

J =  $\pi d^4/32$

r = d/2

T = FD/2

$$(T \times r)/J = 32/\pi d^4 \times (F \times d)/2 \times d/2 = 8FD/\pi d^3$$

$$A = \pi d^2/4 \quad \text{Therefore : } F/A = 4F/\pi d^2$$

Therefore

$$\tau_{s \max} = 8FD/\pi d^3 + 4F/\pi d^2 \dots\dots\dots 3.4$$

Preliminary Selection was made using the following substitutions

F = 139,1N , d = 1,6mm diameter , D = 8mm diameter.

$$\tau^{max} = 8 \times 139,1 \times 0,008 / \pi \times 0,0016^3 + 4 \times 139,1 / \pi \times 0,0016^2$$

$$= 691,8 \times 10^6 + 69,18 \times 10^6$$

$$= 761 \times 10^6 \text{ MPa}$$

The permissible shear stress for 1,6mm corrosive resistant steel wire was found to be 115Lb/sq inch (792,9 Mpa). Reference the Machinery's Handbook working stress graph for ASTM A313 material at an average service intensity (Machineries Handbook, Oberg (et al), 1992, p393). Indications are therefore that the design is safe.

Deflection (Y) is given by Shigley as

$$Y = 8FD^3N/d^4G \dots \dots \dots 3.5$$

N = number of active coils.

In this case 4 coils are assumed to be active.

$$Y = 8 \times 139,1 \times 0,008^3 \times 4 / 0,0016^4 \times 68,95 \times 10^9$$
$$= 5,044\text{mm}$$

These non-corrosive springs were manufactured by Starco Spring and Wire Works (PTY) Ltd to a 10N tolerance at a cost of R2-65 each (1990).

### 3.8 TESTS CONDUCTED

Two sets of tests were conducted on the prototype. Brief readings were taken on site at Telkom's TDI site near Wonderboom in Pretoria and then a second set of tests were conducted in a climatic chamber at TDI. The first test involved taking a series of readings while running the system on site. The second set of test covered readings taken in the climatic chamber. In these tests the chamber computer was loaded either with a sol-air temperature graph or with a stepped temperatures graph. The sol-air temperature approach has been discussed in sections 2.3.10 and 3.2.3. The sol-air graph used in the tests can be found in Appendix 3.8 and the stepped graph in Appendix 3.9. The readings that were taken were used to establish the effectiveness of the system.

#### 3.8.1 SITE READINGS

Although a number of readings were taken on site only seven of the most relevent readings were included in the write-up in Appendix 3.4. Six temperature sensors were connected in the following positions

- Ch1 = outside east side of the container on the surface
- Ch2 = outside heat sink on the top at the base of the fins
- Ch3 = inside heat sink on the bottom at the base of the fins
- Ch4 = inside temperature floor level
- Ch5 = inside temperature at globe level approximately 500mm from the floor
- Ch6 = outdoor ambient temperature in the shade

Ch19= this column is only shown on some of the Appendices  
and indicates that the system is on (254) or off (255).

The following sets of readings were included in the  
Appendices below

Appendix 3.6.1 = no heat load and no cooling

Appendix 3.6.2 = 100 Watt heat load no cooling

Appendix 3.6.3 = 60 Watt heat load and no cooling

Appendix 3.6.4 = 60 Watt heat load with the cooling system  
operating on 2,5 A

Appendix 3.6.5 = 100 Watt heat load with the cooling system  
operating on 2,25 A

Appendix 3.6.6 = 60 Watt heat load with the cooling system  
operating on 2,25 A

Appendix 3.6.7 = 100 Watt heat load with the cooling system  
operating on 2,5 A

Temperatures were recorded at 10 minute intervals and graphs  
were later plotted. These readings were useful for comparing  
temperature rises within the container under different load  
conditions. They were however limited because the outdoor  
environment could not be controlled and readings had to be  
taken on different days in greatly varying weather  
conditions.

The readings from the site tests were used to make some  
rather unscientific comparisons. It can be seen from App.  
3.6.1 reading 137 that the indoor temperature rose to 34,25°C  
when the outdoor ambient temperature reached 32,05°C as  
compared to Appendix 3.6.2 reading 284 where the indoor  
temperature rose as high as 51,35°C when the outdoor  
temperature only reached 30,45°C. The 100 Watt heat load  
appeared to make quite a substantial difference to the heat  
rise in the container. It can also be seen from Appendix  
3.6.5 reading 118 that the cooling system lost control of the  
target temperature of 38°C when the outdoor temperature  
reached approximately 22,15°C. This must be viewed in the  
light of reading 101 Appendix 3.6.2 which indicates that the  
temperature could have risen to more than 41°C in comparable

conditions if there was no cooling. In the light of reading number 115 Appendix 3.6.6 indicated that with a 60 Watt load the indoor temperature did not exceed 38°C, although the ambient temperature had risen as high as 24°C. These tests helped to create an understanding of the limitation of the system when it was operated on site.

### 3.8.2 CLIMATIC CHAMBER READINGS

Seventeen sets of readings were taken in the climatic chamber. All of these readings have been included in Appendices below

APPENDIX	FILE	TEMP. PROG.	HEAT LOAD	SYSTEM
3.7.1	28	Sol-air	100W	2,25 A
3.7.2	30	Stepped	100W	2,25 A
3.7.3	31	Sol-air	100W	2,25 A
3.7.4	32	Sol-air	60W	2,25 A
3.7.5	33	Stepped	60W	System off
3.7.6	34	Stepped	60W	2,25 A
3.7.7	35	Sol-air	100W	System off
3.7.8	36	Stepped	100W	2,5 A
3.7.9	37	Stepped	60W	2,5 A
3.7.10	38	Sol-air	60W	2,5 A
3.7.11	39	Sol-air	100W	2,5 A
3.7.12	40	Sol-Air	No load	System off
3.7.13	41	Stepped	No load	System off
3.7.14	42	Sol-Air	60W	System off
3.7.15	43	Stepped	100W	System off
3.7.16	44	Stepped	100W	3,0 A
3.7.17	45	Stepped	60W	3,0 A

The overall goal when these readings were taken was to determine the performance of the cooling system under various temperature and loading conditions. After considering a number of different approaches an instantaneous approach was eventually attempted.

It will be beneficial to consider the instantaneous heat flow conditions in the following way:

- i) Heat flowing out from hot sink to ambient environment;
- ii) Heat flowing out of the inside of the container environment to the cold sink;
- iii) Heat flow from the heat load (globe) to the environment inside the container;
- iv) Heat absorbed by the air in the container ( $q_a$ );
- v) The heat conducted through the wall of the container ( $q_w$ ).

The instantaneous method considered that all of these heat transfer factors had to be considered simultaneously to obtain a correct picture of the heat flow. The heat flow conditions were taken care of in the following way.

i & ii) The rejection of heat from the outside heat sink has only a remote effect on the inside of the container in that it makes the cooling system more effective or less effective. The absorption of heat by the inside heat sink has a direct effect on the inside temperature. These two effects are taken up by one effect the cooling effect ( $q_c$ ) of the system as a whole.

iii) The globe which provides the heat load is assumed to impart all its heat ( $q_1$ ) to the internal environment.

iv) The equation used here to determine the heat absorbed by the container is shown bellow.

$$q_a = m C_p T_d \dots\dots\dots 3.6$$

Where  $m$  = mass of air. Taken from a psychometric chart at 24°C dry bulb, 50% R.H. and 1100m above sea level for Roodeplaat ( $0,979 \text{ m}^3/\text{Kg}$  or  $1,021 \text{ kg/m}^3$ ).

$C_p$  = specific heat capacity at constant pressure  
Assumed to be  $1,0045 \text{ kJ/kgK}$

$T_d$  = temperature difference between the last reading and current reading

$$q_a = 1,021 \times 1,0045 \times T_d = 1,026 \text{ kW}$$

v) The equation for heat conducted through the wall is as shown below.

$$q_w = \frac{T_a}{X_1/k_1A + X_2/k_2A} \dots\dots\dots 3.7$$

Skin effects have been ignored as the surface temperatures of the container will be used.

$$T_a = T_i - T_o$$

$k_1$  = the thermal conductivity for fibreglass at 24°C  
 ambient temperature is 0,0378 kW/m °C (Fibreglass  
 South Africa, July 1984, Specifile 154 )

$k_2$  = the thermal conductivity for steel 51,9 kW/m °C  
 (Simonson, 1983, p223)

A = area of the container exposed to ambient temperature.  
 The area housing the cooling system has been  
 deducted (4,712 m<sup>2</sup>).

$$q_w = \frac{T_a}{0,050/0,0378 \times 4,712 + 0,016/51,9 \times 4,712} = 3,561 T_a \text{ kW}$$

The heat balance will then be

$$q_c = q_i + q_a + q_w$$

3.8.2.1 Analysis of Climatic Chamber Readings.

Readings were compared over as short a time as possible, ten minutes in this case. Data file 30 (Appendix 3.7.2) was selected as a basis for the above calculations. File 30 was used as it showed the performance of the system as a whole. During these readings the container was placed in a climatic chamber controlled by a stepped temperature program which simulated a number of temperatures which could be encountered in site conditions. It must be borne in mind when comparing temperatures encountered in the climatic chamber that there is no solar radiation in the chamber. For further discussion of these factors, see section 2.10.4 on sol-air temperatures. The 100 Watt heat load and the cooling system were switched on during these tests. It can be seen from the graphs that the cooling system held control of the heat load up to 32.9°C where it commenced to lose control (See Appendix 3.7.2,

Reading 125). The graphs in Appendix 3.7.2 also clearly shows the heat pump being switched in at  $\pm 40^{\circ}\text{C}$  and out at  $\pm 38^{\circ}\text{C}$ . These temperatures were  $\pm 2^{\circ}\text{C}$  higher than what was desired. They do however give an overall picture of the operation of the cooler.

### 3.8.2.2 Inadequacies in Conventional Approach

Spread sheets based on the above calculations exposed certain inadequacies in the approach. In Appendix 3.18 for instance it can be seen that there appeared to be cooling although the system was switched off. In Appendix 3.19 using readings sourced from file 43 it can be seen that there appears to once again be heat which is unaccounted for. Another spread sheet found in Appendix 20 based on file 38 Appendix 3.7.10 revealed that heat that should have been conducted through the container wall was not absorbed by the air inside the container. These anomalies led to an investigation of a method of analysis based on mathematics.

### 3.8.2.3 Mathematical Analysis of Climatic Chamber Readings

In this approach the container was perceived to have a constant resistance to the penetration of heat and all the thermal factors were then considered globally. The formulas were developed thus

Thermal resistance of the container walls

$$W_{TR} = P/A \times T_{d1} \dots (\text{Watts}/\text{m}^2/^{\circ}\text{C}) \dots \dots \dots 3.8$$

A = surface area of the container ( $\text{m}^2$ )

P = power in (100 Watts in this case)

$T_{d1}$  = pemperature difference with heat pump off  
(Usually constant at  $\pm 15^{\circ}\text{C}$ )

Heat lost via thermal resistance

$$HL_{TR} = P \times T_{d2}/T_{d1} \dots \dots \dots 3.9$$

$T_{d2}$  = Temperature difference with the heat pump on

Heat pumped by thermoelectric cooler

$$H_p = P(1 - T_{d2}/T_{d1}) \dots \dots \dots 3.10$$

Thermal resistance of heat pump

$$HP_{TR} = \frac{P(1-T_{d2}/T_{d1})}{A \times T_{d2}} \dots\dots\dots 3.11$$

A typical example of a calculation is as follows:  
Refer to Appendix 3.7.15 file 43 where climatic chamber readings were taken with the 100 Watt heat load on and the cooler switched off. From an examination of the stepped graph at the back of the file it can be clearly seen that after a temperature step was taken conditions stabilised giving a constant indoor to outdoor temperature differential. Stability was considered to be reached after the outdoor temperature was held constant for ±3 hours. The calculations documented below illustrate this point.

Examine file 43 reading 18  $T_{d1} = 36,65 - 21,7 = 14,95 \text{ K}$

file 43 reading 90  $T_{d1} = 45,00 - 29,65 = 15,35 \text{ K}$

file 43 reading 126  $T_{d1} = 48,4 - 33,25 = 15,15 \text{ K}$

The figure of ± 15°C was typical right across the temperature range used in the climatic chamber.

The surface area of the container was calculated at  $A = 4,712 \text{ m}^2$ .

The power in was constant at  $P = 100 \text{ Watts}$ .

The thermal resistance of the container wall was found applying formula 3.8:

$$W_{TR} = 100 / 4,712 \times 15,15 = 1,401 \text{ W/m}^2/\text{°C}$$

A wall thermal resistance of ± 1,4 W/m<sup>2</sup>/°C was typical across the temperature range.

Appendix 3.7.2 file 30 was used to determine the outside to inside temperature difference with the thermoelectric cooling system operating on 2,25 A. Although this temperature differential varied constantly across the temperature range

it seemed to remain between 6°C and 7°C where temperatures exceeded 38°C inside the container. This method could not be reasonably applied to temperatures below 38°C inside the container because the sensor control switch shut the cooling system off below that temperature. There was therefore no equalisation of temperatures below that temperature and no knowing what temperature the container might have stabilised on.

Examine file 30 reading 125  $T_{d2} = 40,1 - 32,9 = 7,2$  K

file 30 reading 143  $T_{d2} = 41,4 - 34,8 = 6,6$  K

file 30 reading 156  $t_{D2} = 43,1 - 36,75 = 6,35$  K

These readings were all final readings before the 3 hour temperature step was taken.

Applying formula 3.9 to determine the heat lost via the thermal resistance:

$$HL_{TR} = 100 \times 7,2 / 15,15 = 47,52 \text{ Watts}$$

Formula 3.10 could now be applied to the heat pumped by the thermoelectric cooler

$$H_P = 100(1 - 7,2/15,15) = 52,48 \text{ Watts}$$

The application of formula 3.11 which is the same as

$$HP_{TR} = H_P/A \times T_{d2} = 523,48 / 4,712 \times 7,2 = 1,547 \text{ W/m}^2/\text{°C}$$

Sets of the above calculations can be found on a spread sheet in Appendix 3.21.

### 3.8.3 Conclusion

Based on these calculations the cooling effect that had initially been anticipated does not appear to have been realised. The calculations do however indicate that there definitely was cooling even when high outdoor temperatures were encountered. The cooling effects of between 50 Watts and 60 Watts were not entirely disappointing. This type of

cooling power must be judged against the size of the little cooling systems rather than against the cooling ability of large conventional systems.

CHAPTER 4

RESULTS

## 4 . 1 GENERAL

The approach taken in this chapter will be the same as in the other chapters. Discussion on each area of the dissertation eg "Heat Loads" will be kept together under one section within the chapter. The sections however will as far as possible be divided into the following sections:

- i) Results
- ii) Proposals
- iii) Conclusions

The financial aspects of the project will be discussed in general terms at the end of this chapter.

## 4 . 2 HEAT LOAD

### 4.2.1 HEAT LOAD - RESULTS

The decision to adopt the Sol-Air method used in the project appeared to be vindicated by the climatic chamber results (See paragraph 3.2.4.1). The results of the temperatures reached inside the container when it was tested inside the climatic chamber were very close to those temperatures attained inside the container when it was tested on site. The small discrepancies in temperature could have been owing to wind, cloud cover or humidity which the instruments were not capable of recording. The Sol-Air method has been well researched by experts in air-conditioning and the accuracy of the results was not unexpected. This route used to solve heat load calculations where high indoor temperatures encountered in containers appear to be suitable for application in all the climatic centres in South Africa. The slightly pessimistic heat loads obtained with this modified Sol-Air method were satisfactory.

Temperatures calculated for generating heat loads when using the Sol-Air method were very useful for placing the climatic chamber readings in context.

#### 4.2.2 HEAT LOAD - PROPOSAL

There are no specific proposals in this section.

#### 4.2.3 HEAT LOAD - CONCLUSION

Based on the experiments conducted on the container it seems evident that the methods and calculations were suitable for analysing heat loads on Telkom's containers sited in other parts of the country. The only variables within the equations are climatic data parameters which are readily available for all of the main centres in South Africa.

### 4.3 Heat Pumps

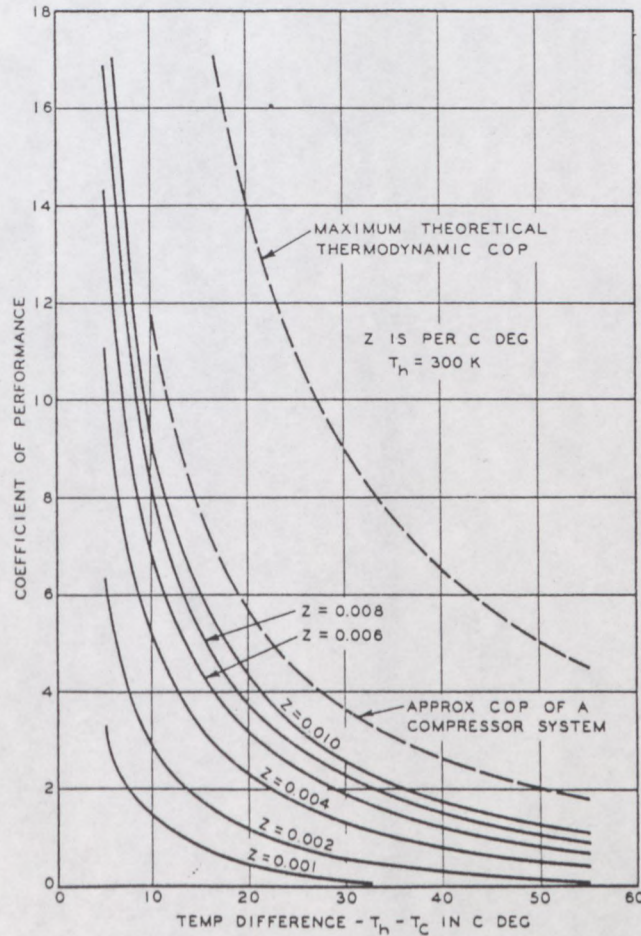
#### 4.3.1 HEAT PUMPS - RESULTS

The work that was carried out in the project showed that thermoelectric cooling has a useful contribution to make in terms of cooling for components and electronic systems in South Africa. Telkom will be able to apply these compact cooling systems in many areas where electronic cooling can be beneficial.

##### 4.3.1.1 Purpose Made Heat Pumps - Theoretical Results

Every indication was that given the opportunity to design and specify their own heat pumps Telkom's engineers would be able to design efficient and powerful cooling systems. Theoretical calculations using real material parameters proved that coefficients of performance of more than 1 were possible in practice (Section 3.3.1.1 COP=1,175). This type of COP is obviously not at this stage competitive with modern mechanical systems that will at times exceed a COP of 6. ASHRAE (1981, p1.30) produced an interesting graph which showed the possible COP of TECs in relation to the figure of merit (Z) (See Fig.4.1 for ASHRAE's Graph). The COP is also related to temperature difference. It is interesting to compare the performance curve of a TEC with the curve of a conventional compressor system also plotted on the graph. By using these performance curves Peltier coolers can be related readily to conventional cooling systems. Although materials

with figures of merit as high as  $4 \times 10^{-3}$  were produced by Horst and Williams (1980, p1871) a  $Z$  of approximately  $3 \times 10^{-3}$  was what would be expected from a normal production heat pump.



Maximum Coefficient of Performance of a Thermoelectric Couple as a Function of Temperature Difference and Figure of Merit

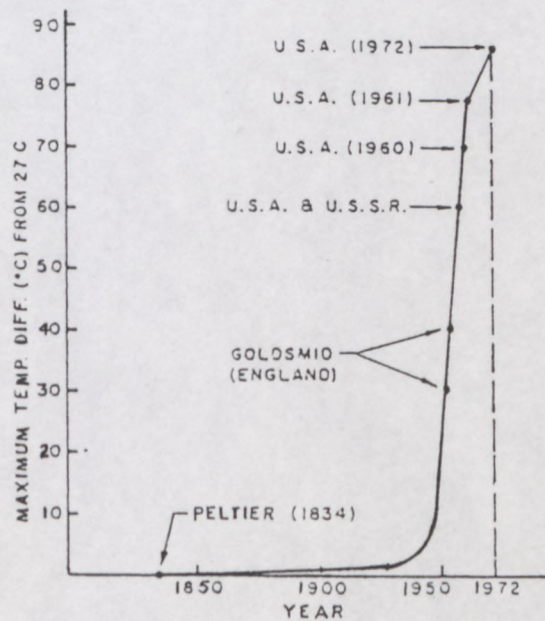
Figure 4.1

Source: ASHRAE (1981, p1.30)

It can be seen from the graph that a  $Z$  equal to 3 is unlikely to give a COP much greater than 1. This is owing to the fact that the temperature difference hot to cold junction will almost always approach or exceed 20K because the cooling medium is ambient air on heat sinks.

There is also very unlikely that there will be any great improvement in suitable thermoelectric materials. ASHRAE

(1981, pl.31) showed a graph in which the maximum temperature difference achieved with thermoelectric couples over the years was plotted up to the year 1972. A distinct drop off in progress can be seen from 1961 to 1972 and the results obtained by Horst and Williams (1980, p1871) appear to indicate little if any progress to 1980 (See Figure 4.2). Telkom's engineers will have to accept that thermoelectric cooling systems have a limited COP.



Maximum Temperature Difference Achieved with a Thermoelectric Couple over the Years

Figure 4.2

Source: ASHRAE (1981,pl.31)

#### 4.3.1.2 Purpose Made Heat Pumps - Practical Limitations

The reality is however that specification of a tailored system would lead to increased expenditure on an already expensive system. The specified heat pump would have to be development by overseas specialist manufacturers which would mean that Telkom would have to deal with overseas exchange rates. Ideally a South African specialist company would have to be developed to make the idea viable. This type of development is not expected to take place in the near future

in South Africa as the demand for equipment in this super specialised area is not sufficiently large to warrant the creation of a company. The specialist route does not seem to be the answer and standard imported equipment would have to be used.

#### 4.3.1.3 Practical Heat Pumps - Results.

Exhaustive tests that were conducted on site and in the climatic chamber indicated that the cooling system was definitely operating. Given that the mathematical analysis was reasonably accurate cooling of the order of 50W to 60W was being obtained with a COP of 0,3 to 0,4. This was disappointing in that a COP of at least 1 had been aimed at. The fact that the heat pumps were definitely giving cooling was however, encouraging.

Performance of the pump deteriorated as the outdoor ambient temperature rose. Greater sensitivity to the higher temperatures was detected when tests were conducted on site than when tests were conducted in the climatic chamber. This was thought to be because of the effects of solar radiation on the heat sinks. This seemed to be the only explanation as tests had proven that the sol-air temperatures were relatively accurate.

#### 4.3.2 HEAT PUMP - CONCLUSION

The Peltier cooling system was capable of delivering cooling although it was difficult to predict how much cooling power a designed cooling system would deliver. Developing a prototype and testing it seemed to be the only sure way of overcoming the imponderables involved in TEC design. The difficulty of predicting the cooling output was probably due to the problem of forecasting the hot junction temperature. In hind site what is now realised and was not discerned during the design stage was that an efficient system could have been developed simply by overselecting the heat pump. To explain what is meant by overdesigning, Melcor listed heat pumps on technical data sheets showing maximum possible outputs. What was not at first grasped was that these

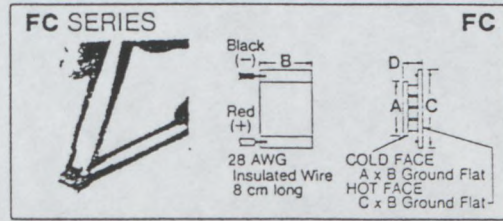
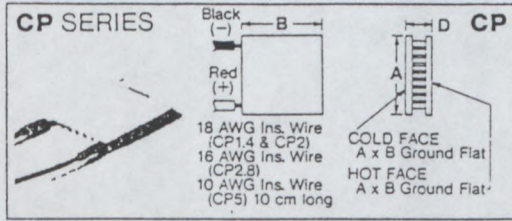
selections did not lead to good. Without realising this fact a heat pump was selected that required power to match the output capabilities of the envisaged solar panels. The solar panels were capable of delivering 2 to 3 amps and with this in mind a TEC was selected that would operate on 3 amps. In the case of the CP1.0-127-06 a 3 amp current produced near to maximum output in the small thermoelectric chip. Almost at the outermost reaches of performance the TEC became sensitive to hot junction temperature and the performance was adversely influenced by joule heating effect. There seemed to be a run on effect which occurred in the couple. The relatively high current through the small elements caused a joule heating effect which in turn caused higher temperature which increased the resistance. This cycle decreased efficiency. Cowling (et al) (1969, p107) emphasised that more than 50% of Peltier cooling is used merely to remove Joule heating and heat transferred and heat transmitted by conduction from the hot junction. At a very late stage in the development of the system the question arose as to why when in theoretical calculations such encouraging coefficients of performance were predicted could they not be duplicated in practice. There was reasonable certainty that the problem did not lie with the material which was almost definitely equal or better than the materials that had been assumed in the theoretical calculations. It was suddenly realised that Telkom could produce a highly efficient system equal to the theoretical design and still use patent heat pumps. To explain how this would be done refer to calculations in section 3.3.1.1.. The high COP of 1,175 was made possible by using couples of 5mm cube bismuth based alloys. Selecting a CP5 - 31 - 10L from the Melcor catalogue (See Figure 4.4, which shows a reproduction of p17 of the Melcor catalogue).

# SOLID STATE COOLING WITH THERMOELECTRICS

## Thermoelectric (Peltier) Heat Pump Module Specifications

Thermocouples constructed of N & P elements of highest grade bismuth telluride in form of oriented polycrystalline ingots. Ingot ends soldered to copper bus bars interfaced with ceramic plates, affording good mechanical integrity, high dielectric strength and

thermal conduction. Temperature range, -150°C to +110°C. Solid state construction. Both hot and cold faces lapped flat, TYPE L. Both faces metallized and tinned, TYPE TT. Hybrid, hot face tinned, cold face lapped, TYPE TL.



CATALOG NUMBER	I MAX AMPS	HOT FACE Th = 25°C			UNIVERSAL MULTIPLIERS			DIMENSIONS, MM				WEIGHT GRAMS
		Q MAX WATTS	V MAX VOLTS	Δ T MAX °C	N NO. OF COUPLES	G GEOMETRY FACTOR	G x N	A	B	C	D*	
CP 1.0- 7-06L	3.0	1.4	0.85	67	7	0.060	0.42	7.5	7.5		3.6	1.5
CP 1.0- 14-08L	3.0	2.9	1.69	67	14	0.060	0.84	11	9		3.6	2.1
CP 1.0- 31-08L	3.0	6.4	3.75	67	31	0.060	1.86	15	15		3.6	3.6
CP 1.0- 63-08L	3.0	12.9	7.52	67	63	0.060	3.78	15	30		3.6	6.4
CP 1.0-127-06L	3.0	26.0	15.4	67	127	0.060	7.62	30	30		3.6	12.0
CP 1.0-127-05L	3.9	33.4	15.4	67	127	0.078	9.91	30	30		3.2	10.5
CP 1.4- 3-10L	3.9	0.77	0.36	70	3	0.078	0.23	5	10		4.7	0.6
CP 1.4- 7-10L	3.9	1.85	0.85	70	7	0.078	0.55	10	10		4.7	1.4
CP 1.4- 11-10L	3.9	2.90	1.33	70	11	0.078	0.86	10	15		4.7	2.2
CP 1.4- 17-10L	3.9	4.48	2.06	70	17	0.078	1.33	15	15		4.7	3.4
CP 1.4- 31-10L	3.9	8.15	3.75	70	31	0.078	2.4	20	20		4.7	6.4
CP 1.4- 35-10L	3.9	9.2	4.24	70	35	0.078	2.73	15	30		4.7	7.0
CP 1.4- 71-10L	3.9	18.7	8.60	70	71	0.078	5.54	30	30		4.7	14.2
CP 1.4-127-10L	3.9	33.4	15.4	70	127	0.078	9.91	40	40		4.7	25.4
CP 1.4- 3-06L	6.0	1.2	0.36	67	3	0.12	0.36	5	10		3.8	0.5
CP 1.4- 7-06L	6.0	2.8	0.85	67	7	0.12	0.84	10	10		3.8	1.2
CP 1.4- 11-06L	6.0	4.4	1.33	67	11	0.12	1.32	10	15		3.8	1.8
CP 1.4- 17-06L	6.0	6.9	2.06	67	17	0.12	2.04	15	15		3.8	2.9
CP 1.4- 31-06L	6.0	12.5	3.75	67	31	0.12	3.72	20	20		3.8	5.5
CP 1.4- 35-06L	6.0	14.2	4.24	70	35	0.12	4.20	15	30		3.8	6.0
CP 1.4- 71-06L	6.0	28.7	8.60	67	71	0.12	8.52	30	30		3.8	12.2
CP 1.4-127-06L	6.0	51.4	15.4	67	127	0.12	15.24	40	40		3.8	21.8
CP 1.4-127-045L	8.5	68.8	15.4	65	127	0.17	21.60	40	40		3.3	20.0
CP 2 - 3-10L	9.0	1.8	0.36	70	3	0.18	0.54	8	15		5.6	1.3
CP 2 - 7-10L	9.0	4.2	0.85	70	7	0.18	1.26	15	15		5.6	4.3
CP 2 - 15-10L	9.0	9.1	1.81	70	15	0.18	2.70	15	30		5.6	8.9
CP 2 - 17-10L	9.0	10.3	2.06	70	17	0.18	3.06	22	22		5.6	10.1
CP 2 - 31-10L	9.0	18.8	3.75	70	31	0.18	5.58	30	30		5.6	18.5
CP 2 - 71-10L	9.0	43.1	8.60	70	71	0.18	12.78	44	44		5.6	42.0
CP 2 - 3-06L	14.0	2.8	0.36	67	3	0.28	0.84	8	15		4.6	1.5
CP 2 - 7-06L	14.0	6.5	0.85	67	7	0.28	1.96	15	15		4.6	3.6
CP 2 - 15-06L	14.0	14.1	1.81	67	15	0.28	4.20	15	30		4.6	7.5
CP 2 - 17-06L	14.0	16.0	2.06	67	17	0.28	4.76	22	22		4.6	8.5
CP 2 - 31-06L	14.0	29.2	3.75	67	31	0.28	8.68	30.0	30.0		4.6	15.7
CP 2 - 71-06L	14.0	67.0	8.60	67	71	0.28	19.88	44.0	44.0		4.6	35.5
CP 2.8- 32-06L	24.0	51.8	3.87	67	32	0.48	15.36	40.0	40.0		5.0	34.0
CP 5 - 31-10L	39.0	81.5	3.75	67	31	0.78	24.18	55.0	55.0		5.8	73.0
CP 5 - 31-06L	60.0	125.4	3.75	67	31	1.20	37.20	55.0	55.0		4.9	64.5
FC 0.45- 4-05L	0.8	0.22	0.48	67	4	0.016	0.064	1.8	3.4	3.4	2.4	2.4
FC 0.45- 8-05L	0.8	0.43	0.97	67	8	0.016	0.13	3.4	3.4	5.0	2.4	2.4
FC 0.45- 12-05L	0.8	0.65	1.45	67	12	0.016	0.19	3.4	5.0	5.0	2.4	2.4
FC 0.45- 18-05L	0.8	0.97	2.18	67	18	0.016	0.29	5.0	5.0	6.6	2.4	2.4
FC 0.45- 32-05L	0.8	1.72	3.87	67	32	0.016	0.51	6.6	6.6	8.3	2.4	2.4
FC 0.45- 66-05L	0.8	3.56	7.98	67	66	0.016	1.06	9.9	9.1	11.5	2.4	2.4
FC 0.6- 4-06L	1.2	0.32	0.48	67	4	0.024	0.096	2.2	4.2	4.2	2.7	2.7
FC 0.6- 8-06L	1.2	0.65	0.97	67	8	0.024	0.19	4.2	4.2	6.2	2.7	2.7
FC 0.6- 12-06L	1.2	0.97	1.45	67	12	0.024	0.29	4.2	6.2	6.2	2.7	2.7
FC 0.6- 18-06L	1.2	1.46	2.18	67	18	0.024	0.43	6.2	6.2	8.3	2.7	2.7
FC 0.6- 32-06L	1.2	2.59	3.87	67	32	0.024	0.77	8.3	8.3	10.3	2.7	2.7
FC 0.6- 66-06L	1.2	5.34	7.98	67	66	0.024	1.58	12.3	11.3	14.4	2.7	2.7
FC 0.6- 4-05L	1.5	0.40	0.48	67	4	0.030	0.12	2.2	4.2	4.2	2.4	2.4
FC 0.6- 8-05L	1.5	0.81	0.97	67	8	0.030	0.24	4.2	4.2	6.2	2.4	2.4
FC 0.6- 12-05L	1.5	1.21	1.45	67	12	0.030	0.36	4.2	6.2	6.2	2.4	2.4
FC 0.6- 18-05L	1.5	1.82	2.18	67	18	0.030	0.54	6.2	6.2	8.3	2.4	2.4
FC 0.6- 32-05L	1.5	3.23	3.87	67	32	0.030	0.96	8.3	8.3	10.3	2.4	2.4
FC 0.6- 66-05L	1.5	6.67	7.98	67	66	0.030	1.98	12.3	11.3	14.4	2.4	2.4
FC 0.7- 4-05L	2.0	0.54	0.48	67	4	0.040	0.16	2.4	4.7	4.7	2.4	2.4
FC 0.7- 8-05L	2.0	1.08	0.97	67	8	0.040	0.32	4.7	4.7	7.0	2.4	2.4
FC 0.7- 12-05L	2.0	1.62	1.45	67	12	0.040	0.48	4.7	7.0	7.0	2.4	2.4
FC 0.7- 18-05L	2.0	2.43	2.18	67	18	0.040	0.72	7.0	7.0	9.3	2.4	2.4
FC 0.7- 32-05L	2.0	4.31	3.87	67	32	0.040	1.28	9.3	9.3	11.6	2.4	2.4

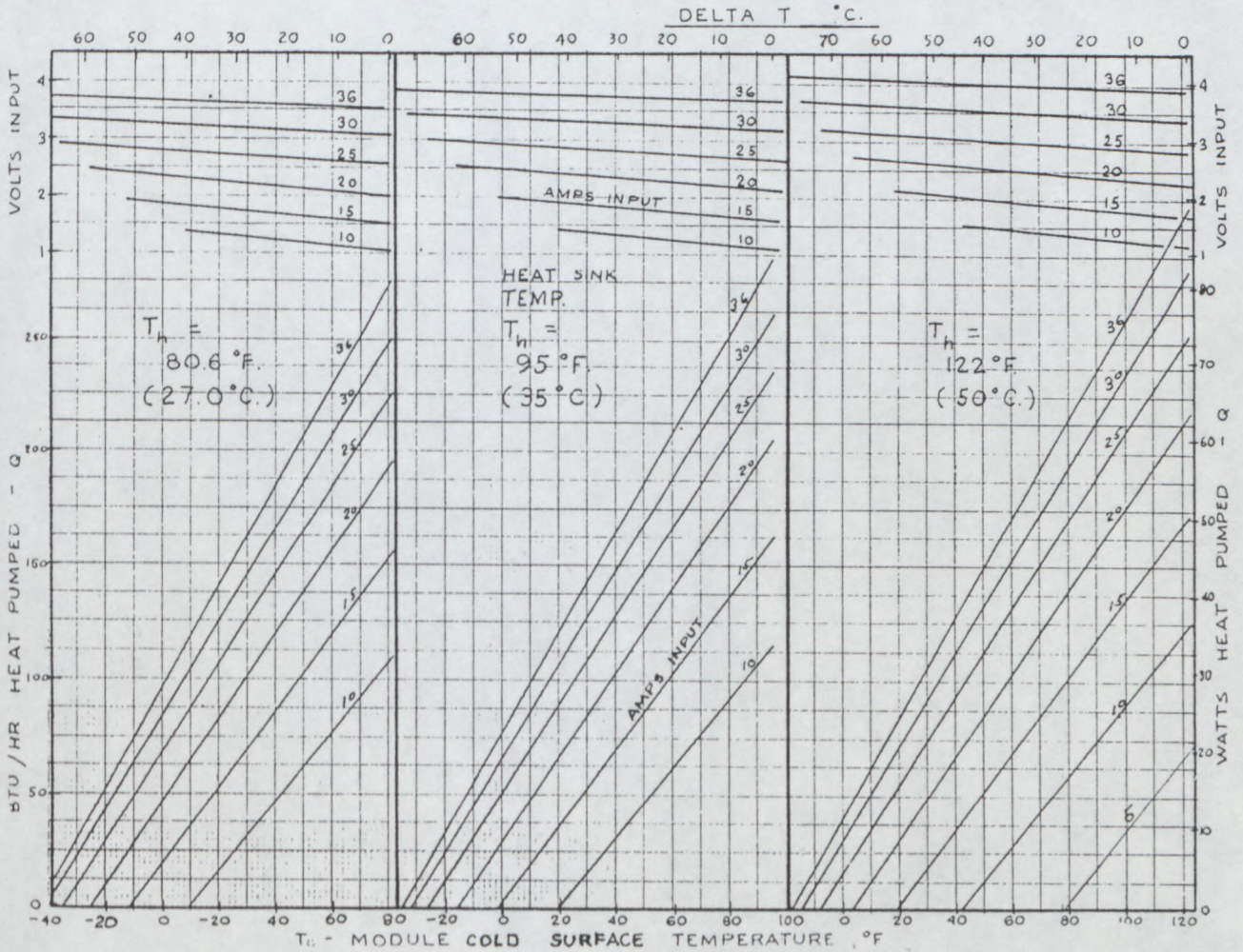
\*Thickness (D, mm) for TYPE L only

List of Devices Available From Melcor  
 with their Predicted Performances

Figure 4.3

Source: Melcor Catalogue p17

There are 31, 5mmx5mmx2.5mm couples in the TEC. An estimate of the device performance can now be made (See Figure 4.4 sourced from p42 from the Melcor catalogue).



Performance Graphs for Melcor's CP5-31-10L Heat Pump

Figure 4.4

Source: Melcor Catalogue p42

The performance graphs indicate that with a hot junction temperature (T<sub>H</sub>) of 50°C and a current of 10 amps, the Peltier cooling chip would yield 20 Watts of cooling with a temperature difference (T<sub>Δ</sub>) of 20K. This type of cooling could be accomplished using only 1,2 volts. The COP is calculated to be 1,6. The Joule effect would be minimised due to relatively lower current and the deleterious effect of Joule heating would be avoided. This would make the system

absolutely feasible, notwithstanding apparent pessimistic results obtained while testing the prototype. Telkom can move forward confident in the knowledge that a TEC system could be developed which would operate with a COP of better than 1. Scofield in his research document on manufacturing costs of thermoelectric coolers felt that this course could yield enhanced COP with minimal increase in cost (1960, p72). For more comprehensive discussion on costs see paragraph 4.7.1.

#### 4.4 HEAT SINKS

##### 4.4.1 HEAT SINKS - RESULTS

As mentioned in paragraph 3.4.4. critical analysis of heat sinks made it clear that the best way to predict temperature rise was by measuring an operating system. Both the temperature of the hot junction and the cold junction were critical to the operation of the cooling system. Increased dissipation of heat from the hot junction would lead to an immediate return in improved COP and therefore in cooling benefit. Each heat sink appeared to be disposing of as much as 60 Watts of heat. This can be proven by comparing the temperatures that the heat sink rose to when a resistor was used to superimposed a load on one of them with the temperatures that were reached in the climatic chamber tests (Compare Appendix 3.15.5 with reading 180 Appendix 3.7.2).

##### 4.4.2 HEAT SINKS - PROPOSALS

The anodised aluminium heat sinks were the most efficient available to Telkom. Gold excluded, there is only one other metal that exceeds aluminium's conductivity and that is copper. At 300K aluminium has a thermal conductivity of 237 W/(m.K) as opposed to copper which has a figure of 401 W/(m.K) (Rohsenow (et al), 1985, p3-113). Most manufacturers of heat sinks only manufacture heat sinks in aluminium alloy because aluminium is relatively cheap, has a high conductivity, is readily available and lends itself to various manufacturing processes. Anodising of aluminium heat

sinks can improve conductivity between 10% and 20% according to the manufacturers. Telkom was virtually forced to use anodised aluminium rather than copper for reasons of availability and economics. Any improvement in the interests of dropping the temperature of the heat sinks would have to involve other methods of heat dissipation which will be discussed in the next section under recommendations.

#### 4.4.3 HEAT SINKS - CONCLUSION

Within the restraints that were originally placed on the project heat sinks were probably the best if not the only solution to Telkom's heat transfer problems. Telkom had initially specified a non-mechanical system, in which case no fans pumps etc. were acceptable.

### 4.5 PHOTOVOLTAIC PANELS

#### 4.5.1 PV PANELS - RESULTS

The PV panels were investigated to determine how they would react in the conditions under which they would be expected to operate. The manufacturers have researched and investigated the solar panels which they market more than adequately and the information which they distribute to their clients is sufficient to cover most of the technical aspects of this field. Researchers like Eberhoud (1990) have made it easy to estimate the amount of power that specific panels could be expected to deliver during a solar day. The research carried out in this project only served to corroborate that their figures were applicable under the conditions that Telkom would use them. One interesting factor did however emerge during the testing of the PV panels. Contrary to what the suppliers had found in their research there appeared to be only a minimal reduction in panel output when the cells heated up towards midday. This phenomenon might have been because of the increase in solar radiation during the hotter times of the day. Telkom's interest was focused on probable cell output per solar day rather than in investigating the effects of heat on the panels. It is probable that if the

radiation stayed constant and the temperature of the cells was varied the results would substantiate the manufacturer's curves. It was remarkable that temperatures as high as 62°C were measured on the PV panels (Appendix 3.16.2). These temperatures suggested that there is definite justification for using the 47°C IV curve for determining PV panel output.

The foremost goal in this part of the work was to determine suitable sizing procedures and the most effective way to set up the power supply. The objective was to ensure minimum capital outlay, maximum battery life and sufficient power to allow efficient operation of the Peltier cooling system. These goals could only be accomplished if suitable sizing methods were determined. The rule of thumb method that was applied in the project was verified by Siemens computer methods.

Both of the above procedures seemed to yield optimistic results when equated with the readings which were taken on the loaded panels. The argument for the decreased Wattage per day was the suspicion that the panels would deliver negligible voltages when the solar radiation dropped below 1000W/m<sup>2</sup>. With a 2 A load the panels consistently switched on at 08:30 and off at 15:30 even on a cloudless day in the middle of summer (See appendix 3.16.2). The length of charge frequently cut off as early as 14:00 with the development of cloud cover. Test loads of 2,5 As further shortened the day (See section 3.5.2). In spite of this negative scenario it must be borne in mind that 3 days autonomy has been built into the system to prevent failure in overcast conditions.

#### 4.5.2 PV PANELS - PROPOSALS

Notwithstanding all of the above factors Arco Solar's calculations were considered to be accurate in view of the fact that specialists had tested their theory over a considerable time. The rule of thumb method has also been tested in practice and has certainly gained acceptance with technicians that specialise in photovoltaic power. The

accuracy of this method was substantiated by the Arco computer program. As Telkom has access to the Arco program, they ought to make use of it to size PV installations.

#### 4.5.3 PV PANELS - CONCLUSIONS

Based on the information researched, the number of PV panels for any climatic conditions could be accurately decided. Roodeplaat Pretoria was used as an example because it was close to the test site which had a climate similar to the actual sites where the system would be used in practice. The intention was to perfect a method which would be applicable in any part of South Africa. The method that was investigated fulfilled that requirement adequately.

### 4.6 BATTERY

#### 4.6.1 BATTERY - RESULTS

The batteries which provided storage or autonomy were an essential part of the power supply. Telkom has used tubular lead acid batteries effectively since the inception of the practical use of PV power. These batteries with their resistance to deep discharge and cycle ability remain the most economical answer in terms of capital cost, long life, and maintenance costs. The Arco computer analysis confirmed that the manual battery selection process using tables and graphs supplied by battery distributors was moderately accurate.

##### 4.6.1.1 Battery Protection

A crucial part of the power system is the voltage regulator. A pulse type temperature sensing regulator similar to the type which is represented in Figure 2.37 provides good protection for the batteries. Careful attention will need to be paid to charging rates both to prevent battery damage during times of high solar insolation and also to prevent stratification. The charging rates have been comprehensively documented in Section 2.13.3.

#### 4.6.2 BATTERY - PROPOSALS

Telkom is advised to continue to use tubular storage batteries with pulse type voltage regulators which are temperature compensating. Once again it is recommend that Telkom make use of the Arco program to check any battery selections which it makes in conjunction with PV panels.

#### 4.6.3 BATTERY - CONCLUSIONS

An attempt should be made to keep the battery system below 12V which will save capital cost on both the battery cells and solar panels. The higher efficiency heat pump choice which was made in paragraph 4.3.2 would make it possible to operate the system from a much lower voltage. Although the drop in voltage will have to be compensated for by using higher amperage the higher COP will reduce the power consumption.

### 4 . 7 F I N A N C I A L .

There are numerous ways of examining the cost of the cooling system. First there is the actual cooling device and then in this case there is the system as a whole which incorporates the PV panel power supply. To be fair to the Peltier cooling system it will be necessary to investigate its cost in isolation before including the price of the energy source.

#### 4.7.1 COMPARISON OF TEC SYSTEMS WITH OTHER SYSTEMS.

In 1960 Scofield (et al) (p37) made an interesting comparative study of thermoelectric and mechanical refrigerating systems. Many of his observations are still pertinent today. He foresaw that thermoelectricity would have applications for devices up to 200 Btu/hr (58,6 W). Little did he foresee that installations of 24 kW would be used as early as 1978 by companies like TNEE of France who designed a TEC designated PR2 for use in a French Railway coach (Wacks, 1960, p33). Incidentally TNEE in conjunction with Vickers Marine also refined another system suitable for

marine utilisation which rejected 1500W of heat to water at a COP of 1.

Scofield's approach was interesting in that he developed a relationship between cost and heat pump capacity for thermoelectric systems. Building a 58,6W system quickly revealed to him that the design parameters could have a profound effect on the total manufacturing cost of the system. Scofield (et al) generated a very useful graph which has been reproduced in figure 4.5 (1960, p38). The dollar prices are out of date but the graph is still pertinent. The figure of merit is in fact almost identical to that which was used in the project and the temperature difference ( $T_a$ ) is also appropriate. Although Scofield's test system seems similar to Telkom's, caution must be practised when reviewing his results, as he incorporated into his design a small motor with a double ended shaft and two small diameter fans. He perceived that a minimum manufacturing cost could be achieved by designing the system to operate at some appropriate condition between that of maximum COP and maximum heat pumping capacity.

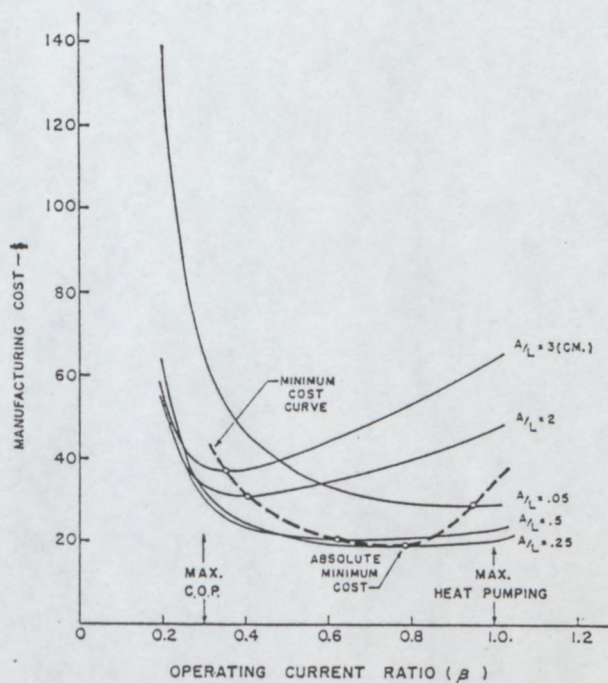
$\beta$  in the graphs is as follows:

$$\beta = RI/T_a\alpha$$

R = resistance

I = Current

$T_a$  = temperature



Effect of Design Parameters on Manufacturing Cost

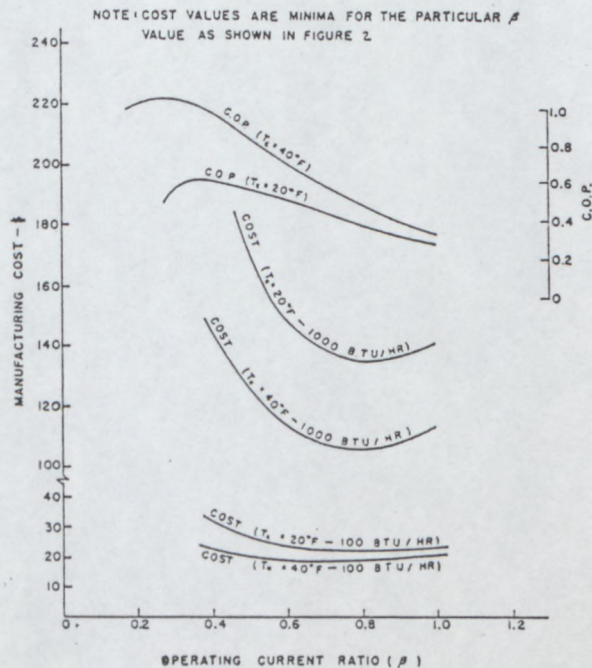
100 Btu/hr (29.3 W) TE System

$T_h = 32,2^\circ\text{C}$      $T_c = 4,4^\circ\text{C}$      $Z = 3 \times 10^{-3}\text{C}_{-1}$

Figure 4.5

Source: Scofield (1960, p38)

In the case of Telkom's cooling system COP was a very important factor. Scofield (et al) (1960, p39) was able to produce another graph from his analysis which highlights the effect on cost of COP and  $T_c$  or cold junction temperature.



Effect of the Operating Current Ratio ( $\beta$ ) on Manufacturing Cost and COP for 100 Btu/hr ( $\pm 30$  W) and 1000 Btu/hr ( $\pm 300$  W) TE Systems.

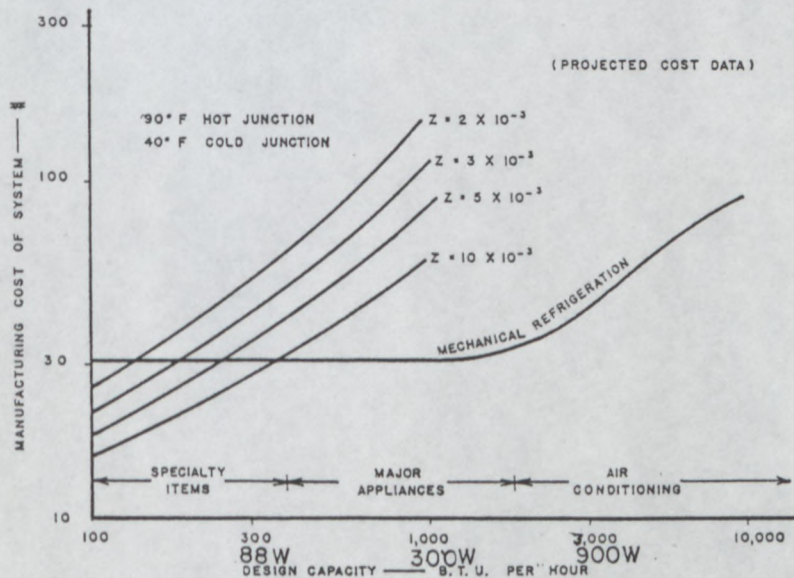
$$T_h = 32,2^\circ C \quad T_c = 4,4^\circ C$$

Figure 4.6

Source: Scofield (1990, p39)

The above graph clearly shows how a higher COP and a greater temperature differential increases the cost of TEC systems. Scofield (et al) also observed that for large values of  $\beta$  the cost changed more slowly. He also recognised that design to achieve minimum costs became more critical at higher capacity. Perhaps Scofield's most interesting statement was that, "Considerably enhanced COP can be achieved with little increase in cost by operating couples at somewhat less than their maximum heat pumping capacity" (Scofield, (et al) 1960, p72). This declaration is highly pertinent to this research document particularly in the light of observations which were made in paragraph 4.3.2. He also stumbled onto the fact that a A/L ratio = 0,5 Cm was close to the optimum design ratio.

In a final comparative cost graph Scofield (et al) (1990, p39) once again compared thermoelectric cooling with mechanical cooling but in this graph he emphasises the application of the system (See Figure 4.7). He also shows how TEC price would change with various figures of merit. It can be seen that small specialised Peltier devices have an advantage over mechanical systems where less than 88 Watts of cooling is required. From the curves it should be noted that the cost of mechanical systems ceases to drop when the system falls below the 300 Watt mark. This situation might have changed somewhat since the research document was prepared.



Comparative Manufacturing Costs of Thermoelectric vs Mechanical Refrigeration Systems

Figure 4.7

Scofield (et al)(1960,p39)

At the conclusion of their study Scofield (et al) felt that although the figure of merit (Z) is important in determining performance it does not necessarily determine the total cost of the thermoelectric material used. This was evidently owing to the fact that the amount of materials used was influenced more by the parameters making up the figure of

merit than the figure of merit itself. In that case a moderate figure of merit might be more plausible than a high figure of merit if a better combination of parameters resulted.

Although the prototype was only designed to approach 100 Watts the final system would have to handle at least 500 Watts. The fact had to be faced that the thermoelectric cooling system was going to fall well outside the competitive Watt range according to Scofield's curves. The competitive Watt range occurs when cooling capacities of less than 87,9W are demanded.

#### 4.7.1.1 Actual Costs Of the Thermoelectric Cooler

The actual cost of the cooling system was counted as follows.

DESCRIPTION	COST	%TOTAL
Aluminium heat sinks PDH 13 160 Wide 300 Lg. Black anodised. Supplied with a 50mm x 50mm x 55mm Lg. aluminium block single epoxy bonded into place. 10-off.	R2514-25	63,215
E.P.X. 33 White 900mm x 320mm x 50mm	R 65-89	1,657
Heat Pumps Melcor CP 1.0 - 127 - 06L 5-off	R 610-00	15,337
Rod Stainless Steel 16mm diam. 1m long for spacers	R 25-92	0,652
Screws Cheese Hd. Stainless Steel 30-1g. 24-off	R 16-00	0,402
Screws Cheese Hd. Stainless Steel 40-1g. 24-off	R 23-44	0,589
Sondorband 5x 30 8m-1g.	R 15-84	0,398
Springs S/S (302) dm=1,6mm D=8 c/c 4-coils 24-off	R 71-87	1,807

DESCRIPTION	COST	%TOTAL
Total material cost including G.S.T (1990-1991)	R3343-21	
To the above price the following must be added. Labour skilled approx. 20 hrs. @ R20 an hr.	R400-00	10,057
The temperature controller which Telkom is able to manufacture at R80-00 for components and 4 hrs labour at approximately at R30-00 per hr.	R200-00	5,029
Total cost	R3977-28	
Per Watt cost approximately	R 65-72	

These statistics reveal a major problem in the system; the cost was prohibitive. The frustrating part was that approximately 63% of the total cost of the prototype was the cost of the heat sinks. The heat sink cost appeared to be absolutely out of proportion when compared to the total price. It was considered that this was due to the restrictions of no mechanical devices on the prototype. This unusual stipulation which prohibited the use of pumps, fans or other mechanical equipment was overcome with a loss in efficiency and a high cost in capital expenditure. Of all the negative factors involved in the manufacture of the Peltier cooler, the price would likely prove to be the biggest deterrent to future development of the system. It must be remembered that prototypes are usually considerably more expensive than production models. To place the cost in perspective Telkom's experience has proven that even a sophisticated variable volume system does not generally exceed R2400 per kW, which works out to R2-40 per Watt.

#### 4.7.1.2 The Power Supply

To the cost of the thermoelectric cooling system must be added the cost of the power source.

Raylite RST600 batteries cost R538-00 per cell and Raylite RST700 batteries cost R622-00 per cell (1992). If a 24 Volt RST700 battery is assumed then the cost of the battery will be R7464. Using a 12V RST700 battery will halve the price to R3742-00. The importance of working from a 12V system can clearly be seen from comparing the two prices.

The cost of a Siemens M 55 PV panel is approximately R1060-00 per panel (1992). This price has remained remarkably stable over the last two years. The sr-9 voltage regulator for the batteries cost R400 each and will feed 8 - M55 modules in 24V form and 6 - M55 modules in 12V form (1992).

Electricity supply cost summary:

DESCRIPTION	COST
Siemens M55 panels at R1060 each. 22-off	R23320-00
Battery 24V Raylite RST700	R 7464-00
Regulator 24V Siemens sr-9 at R400 each 3-off	R 1200-00
Total cost of 24V power	R31984-00

The cost of photovoltaic power was enormous. Almost 9 times the cost of the system it was feeding. This was clearly a target area for cost reduction.

Total cost of a 60 Watt mechanism and the electricity supply assuming 24V:

DESCRIPTION	COST
Cooling system	R 3877-28
Power supply 24V	R31984-00
Total Cost of system run from 24V.	R35861-28

If the cost of discount due to bulk ordering is ignored the price of a 500 Watt system would amount to R298844-00.

For Telkom, Peltier cooling would be competing against passive cooling as a means of providing cooling for remote

electronic installations. The last date in which Passive cooling was supplied to Telkom was in 1988 at a price of R44000-00 for a 500 Watt installation. It has to be understood that passive cooling installations require no power so the above price was the total price. Even at an inflation rate of  $\pm 25\%$  the current price would not exceed R107421-87 which would mean that the Peltier cooling system is uncompetitive in terms of cost in its present form.

4.7.1.3 Cost Conclusion

The above cost comparison is the worst possible scenario. It is apparent that a slight improvement in efficiency will allow the system to accept a 12V supply and an RST 600 battery. This would almost halve the capital cost of the power system.

DESCRIPTION	COST
Siemens M55 panels at R1060 each. 11-off	R 1160-00
Battery 12V Raylite RST600	R 3228-00
Regulator 12V Siemens sr-9 at R400 each 2-off	R 800-00
Total cost of 12V power.	R15688-00

The total cost of 60 watts of cooling would immediately drop if a 12V system was assumed:

DESCRIPTION	COST
Cooling system	R 3877-28
Power supply 12V	R15688-00
Total cost of system run on 12V	R19565-00

If the discount due to bulk ordering is again ignored the price of a 500 Watt system would amount to = R163044-00

It can therefore be seen that thermoelectric cooling system with its low COP in an early stage of development cannot compete favourably with the passive system, but further development would almost definitely lift the COP and drop the

capital cost further to a degree where it could conceivably compete successfully with passive cooling.

CHAPTER 5

SYNTHESIS

## 5 . 1 GENERAL

In this chapter particular areas of research eg "Heat Pumps" will be discussed under the following headings.

i. Solution to practical problems

The problems formulated in the introduction will be briefly addressed here.

ii. Recommendations

Possible applications of results in industry will be outlined in this section.

Recommendations to users in industry will also be reviewed in this section.

iii. Further research.

An indication of where further research needs to be undertaken will be previewed here.

### 5.1.1 GENERAL OBJECTIVES

The aims and objects mentioned in Section 1.4 of the introduction have been adequately achieved. Peltier devices had the potential to adapt well to photovoltaic power.

The cooling device was compatible with photovoltaic power because the Peltier device operated adequately at the design current of 2,25 A. A brief examination of the possibilities of tubular storage batteries indicated that they would afford the cooling system autonomy and flexibility. The advantages of using storage batteries were not anticipated at the commencement of the project and these advantages were only identified after the prototype was developed.

Although technologically involved the thermoelectric cooling system was simple to operate and assemble once the design and development stage was complete. The thermoelectric cooling chips at first appeared to be fragile but the devices proved themselves rugged once they were properly installed. This fact was borne out when the prototype container was dropped on its side while it was being transported to the climatic

chamber. The impact had no adverse effect on the operation of the Melcor heat pumps. The solid state mechanism fulfilled Telkom's stipulation that no moving parts were desirable. Even a novice with no electrical or mechanical knowledge could effect repairs on the device. These repairs would probably not amount to more than exchanging a damaged thermoelectric cooling module. In spite of the extremely hot summer conditions experienced on the test site in the Northern Transvaal, the TEC unceasingly functioned reliably. In fact not one breakdown was experienced during the test period. No deleterious effects were detected at the conclusion of continuous testing at high ambient temperature. Once the device was properly mounted no further adjustment was necessary. The reliability which had been demanded at the outset of research proved to be an inherent characteristic of the system.

Severe thunderstorms did not effect the system and there was reason to believe that the non-corrosive anodised aluminium heat exchangers would be able to resist the destructive forces of the elements. There could be no chemical corrosion from within because no chemicals were used to absorb heat as is the case with conventional cooling systems.

The TEC was a constant current device with none of the usual dynamic systems such as motors which cause disturbances to radio waves

Although the prototype was designed to induce only 100 Watts of cooling the modular configuration would lend itself to unlimited expansion. A capacity of only 60 Watts was realised in the preliminary stages of development attained in the experimental model. Knowledge accumulated during research, indicated that the system could be readily refined to produce greater cooling power at higher efficiency.

Knowledge of the science of thermoelectric cooling was gathered during the development and testing of the TEC. Information thus gained will be invaluable to Telkom in the development of future projects of this nature. A spin-off

from the research was that Telkom also expanded its general understanding of direct energy conversion which can be applied in other areas of engineering, such as power generation.

## 5.2 Heat Loads

### 5.2.1 HEAT LOADS SOLUTION TO PRACTICAL PROBLEMS

The heat load was split into a superimposed equipment load and a constantly varying climatic load. The equipment load had a known value of 100 Watts but the variable load had to be evaluated by calculations and experimentation. Tests in a climatic chamber proved that the prescribed sol-air method of analysis was adequate for Telkom's purposes. This method solved the problem of determining heat loads in a small container where high indoor temperatures were permitted. The calculations were suitable for application on any site for which climatic tables were available. Climatic chamber readings were used to corroborate the validity of the calculations.

Sol-air temperatures were fed into the climatic chamber computer so that site conditions could be simulated. Sol-air temperatures were validated by comparing climatic chamber temperature readings and normal site temperature. Sol-air temperatures were useful for building spreadsheet calculations used for determining cooling demand.

### 5.2.2 HEAT LOADS RECOMMENDATIONS

This method of calculation will be a useful tool for companies that have to house electronic equipment in small huts or containers. Electronic equipment can often resist high ambient temperatures and a knowledge of temperatures that will be experienced in the container may even in some cases obviate the use of cooling systems.

Caution should be exercised when using these calculations on larger buildings as they may yield heat loads that are too high.

### 5.2.3 HEAT LOADS FURTHER RESEARCH

The research in this area appears to be complete. The compilation of a suitable computer program based on the calculations used in Appendix 3.5 is the only possible area of future development.

## 5.3 HEAT PUMPS

### 5.3.1 HEAT PUMPS - SOLUTION TO PRACTICAL PROBLEMS

A top priority in the early part of the research was to determine the cooling power of the proposed thermoelectric cooler. An insight into the materials had first to be established so that material parameters could be determined. Alloys of bismuth telluride in particular were focused on. Section 2.1.3 placed the materials in perspective and section 3.3.1 targeted the practical use of materials that were used in modern devices. Peltier heat pumps were evaluated using thermoelectric parameters based on the Horst and Williams (1980) research document. These parameters were substituted in calculations based on research carried out by Goldsmid (1964), Angrist (1977) and ASHRAE (1981). The calculations yielded capacities, coefficients of performances, optimum operating currents, voltages and other vital information required for the development of Peltier coolers. Both theoretical and practical design problems were solved because of literature research which was carried out in this area. Spreadsheets were developed and used to estimate cooling power at various times of the day. These calculations were used together with spreadsheet calculations giving cooling demand. The above information was used to solve the design problems which were encountered during the design stage of the project.

Stainless steel springs were designed and purpose made to specification so that expansion and contraction of the thermoelectric heat pumps which occurred during temperature fluctuation could be compensated for. This precaution was necessary as a constant pressure had to be maintained on the

devices to allow for heat transfer to take place. Silicon grease was also smeared between the heat pump and the heat sink to improve conduction. The Peltier devices did not sustain any damage during testing and the measures were therefore assumed to be successful. Moisture and dust was sealed out of the device with a purpose made Sondorbond strip which was also slightly compressed so that it could expand and contract in continuity with the cooling chip.

### 5.3.2 HEAT PUMPS - RECOMMENDATIONS

#### 5.3.2.1 Heat Pumps Applications in Industry

There are numerous special applications for thermoelectric cooling. A few conventional applications which have been successful are mentioned below.

i. Purcupile (et al)(1968) designed a 7kW thermoelectric unit cooling for cooling a military shelter and van enclosure containing electronic equipment. The electronic system demanded a clean temperature controlled air heat sink in addition to a tolerable environment for operating personnel. It was claimed that the TECU had a superior performance and that it was cost effective.

ii. The medical profession has benefited substantially from the advent of thermoelectric cooling. Medical-biological thermostats were used in experiments on space crafts. The Peltier coolers were particularly suitable for this application because of the following three factors:-

a) Their ability to give heating when the DC current is reversed.

b) Their capability of maintaining extremely close control on the temperature.

c) The lack of pressure sensitive chemical fluids for heat transfer.

The Bioterm series thermostat was able to maintain a  $\pm 0,5^{\circ}\text{C}$  inside temperature in its  $600\text{cm}^3$  chamber. These containers are invaluable for transportation of human organs that need

close temperature control to preserve the condition (Iordanishvili, 1980, p18).

Ophthalmic surgery and neurosurgery has advanced because of the perfecting of thermoelectric cryoprobes. Cryogenic surgery is a method of removing tissue by local freezing (Iordanishvili, 1980, p19). An inherent advantage of Peltier cooling in this application is that intense cooling can be applied to the tip of a fine pointed instrument.

iii. One advantage of Cascade thermoelectric heat pumps is that they are able to reach much lower temperatures than conventional refrigerators. They have this ability because they are solid state and are not limited to the freezing temperature of the refrigerant. A lead sulphide infra-red detector has been successfully cooled to  $-100^{\circ}\text{C}$  using a three stage thermoelectric cascade (Goldsmid, 1964, p215. Cites De La Rue).

iv. Goldsmid (1964, p214) has stated that it was noted early in the development of practical thermoelectric coolers that they would be ideal for the refrigeration of electric components and especially to applications in the field of instrumentation. Peltier coolers have been successfully applied to the cooling of sample tables for microscopy (Goldsmid, 1964, p214, cited Ioffe) and spectrometry (Goldsmid, 1964, p215, cited De La Rue).

v. An excellent example of the practical application of thermoelectric cooling is that of the cooling of the Navigation System Inertial Measuring Unit for the C-5A aircraft. In order to meet the navigation system accuracies, inertial components, such as gyroscopes and accelerometer had to be stabilised at their optimum operating temperature. The thermoelectric system was chosen because of its proficiency under conditions that would be hostile to conventional systems. For example, sudden and extreme variations in temperature and altitude. A good capacity to weight ratio made the TEC solution even more appealing to aviation engineers (mass = 1,3608 kg; 205 Watts/kg.). This compact

cooling system had a capacity of 280 watts at a COP of 0,65 (Boesen and Fox, 1968, p70).

vi. For military applications, the effort to develop Peltier cooling has proved worthwhile because of its silent operation, near indestructible nature, lack of moving parts and absence of refrigerant. Taking advantage of a ready cooling source (the sea) for the hot junction the US Navy developed a 31,7 kW air conditioner for a small submarine (ASHRAE Fundamentals, 1981, pl.31).

vii. There are innumerable other commercial applications of thermoelectric cooling. To mention but a few

- a) a drinking water cooler for a diesel locomotive (ASHRAE Fundamentals, 1981, pl.31, cited Turbush and Meess);
- b) bottle type water coolers for offices (ASHRAE, Fundamentals, 1981, pl.31);
- c) small ice maker for hotel rooms (ASHRAE, Fundamentals, 1981, pl.31);
- d) small portable refrigerators which can also be used as warmers when the current is reversed (ASHRAE Fundamentals, 1981, pl.31) (Typical size = 0,0566 m<sup>3</sup> and Temperatures are 2°C on cooling and 71°C on warming).

#### 5.3.2.2 Heat Pumps - Recommendations to Users in Industry

It is important to operate thermoelectric coolers at their optimum current ( $I_{\phi_{max}}$ ) as calculated in equation 2.39. In this way maximum COP will be realised. It is normally more desirable to maximise the efficiency of a system than it is to maximise output and so sacrifice efficiency. Optimising efficiency will result in an increase in capital cost which should be outweighed by the advantage of a higher COP.

All heat sink surfaces that abut heat pump surfaces should be fine ground to ensure minimum temperature rise across the junctions. These adjoining areas should also be smeared with thermal grease to further improve heat transfer. Grinding

will also help to obviate damage which could arise from inaccurate seating of heat pumps.

The springs on the heat sinks ought to be designed to exert maximum safe pressure as this will guarantee maximum COP. The exertion of pressure on heat pumps tends to improve efficiency. The improvement in efficiency is probably owing to an improvement in heat transfer and a drop in electrical resistance within the heat pump.

#### 5.3.2.3 Heat Pumps - Recommendations to Users , When to Consider a TEC

In summary industry is advised to consider using thermoelectric cooling when one or more of the following factors arise in a cooling application:

- i. the desired capacity is under 100 watts of sensible cooling
- ii. compactness would be beneficial
- iii. low mass to capacity ratio is advantageous
- iv. lightness is a critical factor
- v. extremely close temperature control is desirable
- vi. the absence of liquid refrigerant is an advantage in many applications an example being when the system is operated in varying altitudes resulting in a variation of pressure.
- vii) low noise level is extremely important.

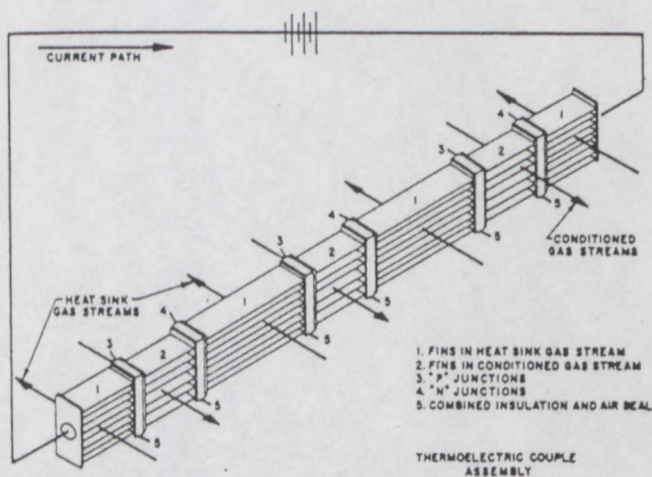
#### 5.3.3 HEAT PUMPS - FURTHER RESEARCH

At this stage it is doubtful that further research will result in any ready improvement in the function of thermoelectric materials as the curve of maximum temperature difference achieved in thermoelectric couples has tended to flatten out from 1980 (see Figure 4.2 and paragraph 4.3.1.1). This means that the research of materials will not yield rapid progress. Investigation in the area of materials will also not be cost efficient as this type of research is complex and will need to be addressed at a high level of research.

### 5.3.3.1 Direct Transfer Principle

The most ready return is likely to come from improving the configuration of heat pumps and intensifying dissipation of heat from the heat sinks. The recommendations in this section overlap with the discussion in 5.4.3 which comments on alternative methods of heat rejection.

The direct transfer principle is typical of an improvement of configuration which has resulted in superior COP. In this method the electrical insulation is removed from the heat flow path. This is accomplished by using the heat sink fins as electrical conductors. That means that the individual heat exchangers serve as couples between the thermocouples. This arrangement eliminates the insulation between the heat sinks and the junctions which results in immediate withdrawal of heat from the bismuth telluride elements which in turn gives rise to an improvement in efficiency. A reproduction from the ASHRAE Fundamentals Handbook (1981, pl.33) showing a possible air to air heat exchanger using this approach, can be seen in Figure 5.1.

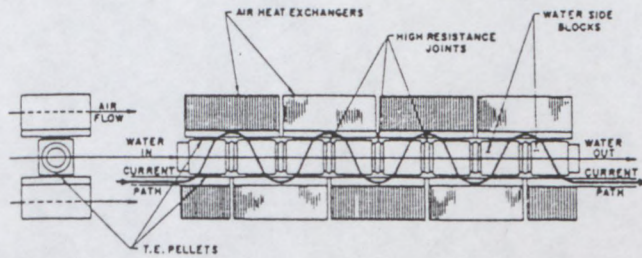


Modified Couple for Gas-to-Gas Heat Transfer

Figure 5.1

Source: ASHRAE (1981, pl.33)

Another technique researched by Mole and Meenan cited in the ASHRAE Fundamentals Handbook (1981, pl.33) uses a water to air principle (see Figure 5.2).



General Arrangement of Components  
for Water-Air Thermoelectric Module

Figure 5.2

Source: ASHRAE (1981,p1.33)

These innovative ideas show possible directions that future research should take to further develop thermoelectric cooling.

## 5.4 HEAT SINKS

### 5.4.1 HEAT SINKS - SOLUTION TO PRACTICAL PROBLEMS

The heat sink used on the prototype was a standard item which provided the Peltier device with a simple heat exchanger that complied with the limitations specified by Telkom. A 50mm x 50mm x 55mm aluminium block single epoxy bonded in place allowed the heat to be transferred through the side of the container. A 50mm white EPX sheet manufactured by Sondor was used to insulate the hot sink from the cold sink. This material had good heat resisting capabilities and was heat and moisture resistant. Spacers manufactured from Ertalite had the advantage of being nonthermal conducting and heat resistant. Another benefit arising from using this material was that it would accept tensile loads so that the springs could be tensioned against the spacers without risk of failure.

A number of points on the heat sinks of the prototype were monitored for temperature during test runs. The readings that were taken later permitted the prediction of possible temperature rises that could occur under actual operating conditions. Although the temperature rise did stay within permissible levels a more sophisticated heat rejection system would have vastly improved the efficiency of the system.

#### 5.4.2 HEAT SINKS - RECOMMENDATIONS

##### 5.4.2.1 Heat Sinks - Possible Application in Industry

The section on temperature rises through the heat sinks will probably be of value to industry. Recorded temperatures should provide future TEC designers with a guide to temperature differences on Peltier devices.

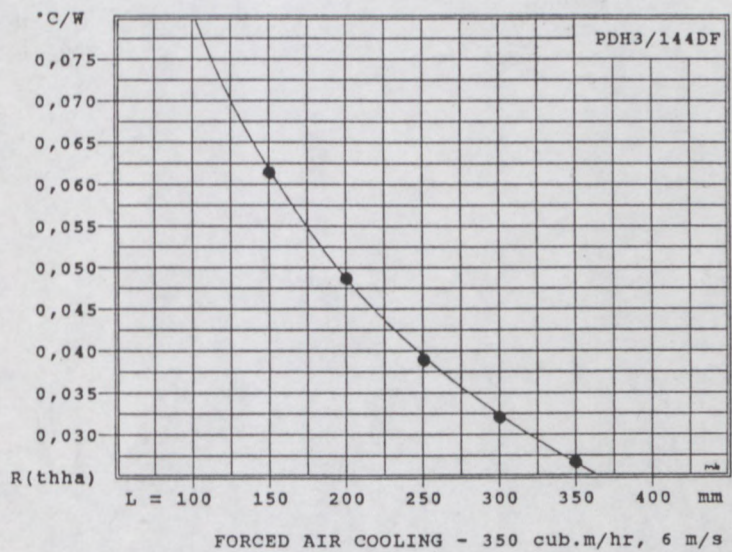
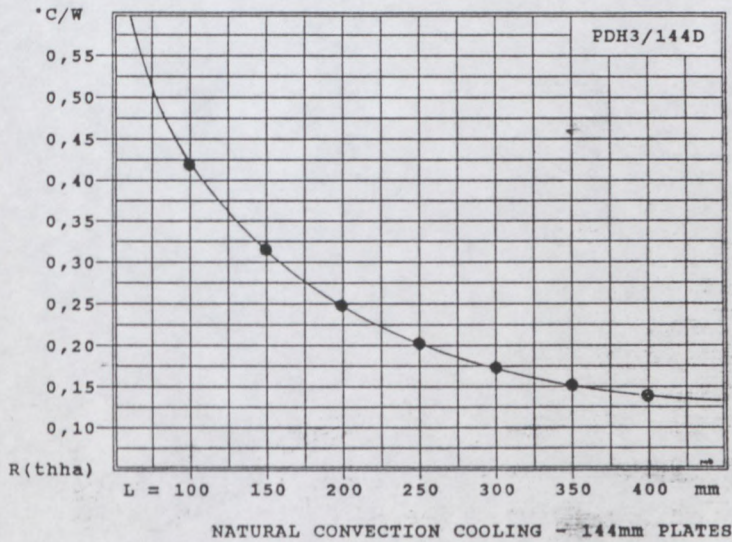
##### 5.4.2.2 Heat Sinks - Recommendations to Users in Industry

Precautions which should be taken when assembling the system, for example the use of silicon heat transfer grease, will not be discussed here as these points have already been covered in Section 5.3.1.

Heat sinks are vitally important to the operation of the cooler. The temperature of the hot sink directly affects the efficiency of the mechanism. A natural off spin of a reduction in hot junction temperature is that the temperature differential automatically decreases, immediately resulting in higher efficiency. This stresses the importance of efficient heat transfer.

There are a number of other feasible and elementary ways to improve heat transfer which were not considered in this project. Simply blowing air over the heat sinks would cause a substantial drop in temperature. To give an example of how substantial the effects of forced convection on a heat sink can be, two graphs of a highly effective heat sink produced by Power Devices have been reproduced in Figure 5.3. The Power Devices PDH3/144D heat sink is probably designed most efficient heat sinks on the market today. This heat sink is similar to a fine comb heat sink but with both sides of the

comb closed to form little ducts. The top graph is for natural convection and the bottom graph is for forced convection. By comparing these two graphs it can be observed that a 300mm long PDH3/144D heat sink with natural convection rises by a temperature of 0,175°C/W. The same heat sink with forced convection at 6 m/s rises by a temperature of 0,0325°C/W. A reduction in temperature rise of 81,4% takes place when forced convection is employed.



Heat Sink Performance Curves

Figure 5.3

Source: Power Devices Catalogue

Another approach would be to use water instead of air to transfer the heat away from the thermichip. The case for a

heat transfer system that is more sophisticated than a standard heat sink is obvious and must be recommended.

#### 5.4.3 HEAT SINKS - FURTHER RESEARCH

##### 5.4.3.1 Forced Convection

For Telkom the above section should provide food for thought. Its stringent standard of no fans or pumps should perhaps be revised in the interests of efficiency. To illustrate this point, assume that a forced air cooling system replaced the natural convection heat sink and the temperature rise was decreased from the present worst temperature rise of 32K by 82% to only 6K (see Section 3.4.1). Now consider a typical Pretoria worst ambient temperature of 33°C in a system requiring a cold junction temperature of 20°C. Using a Melcor CP1.0.127-06 cooling chip the following scenario would be revealed.

##### NATURAL CONVECTION

cold junction temperature	= 20°C (assumed)
hot junction temperature	= 65°C
necessary temp diff	= 45°C
cooling capacity	= 10 W (Melcor Curves)
amperage	= 2 A
voltage	= 12 V
power input	= 24 W
COP	= 0,42

##### FORCED CONVECTION

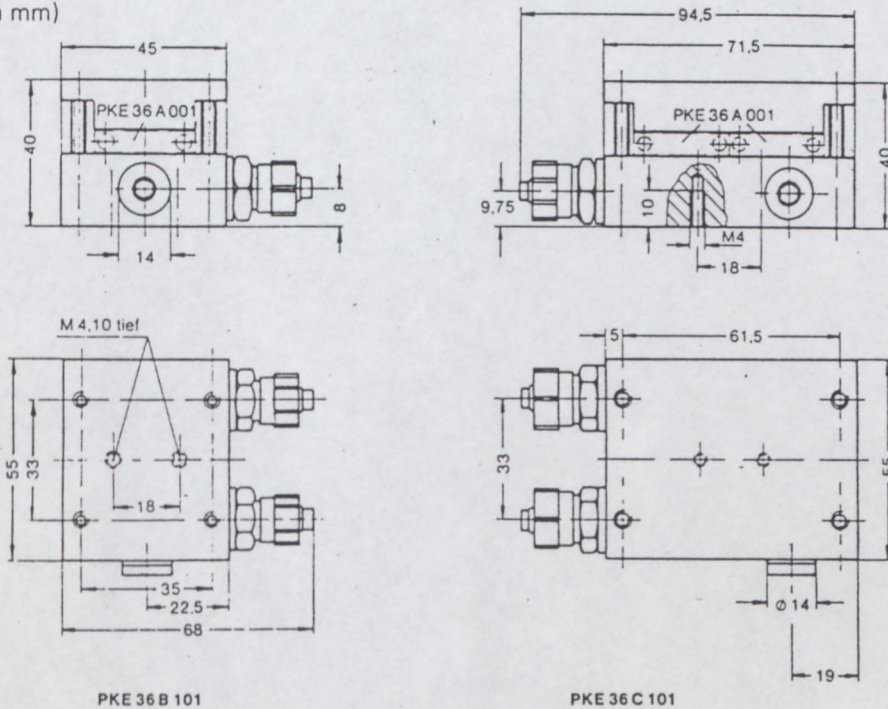
cold junction temperature	= 20°C (assumed)
hot junction temperature	= 37°C
necessary temp diff	= 17°C
cooling capacity	= 18 W (Melcor Curves)
amperage	= 2 amps
Voltage	= 10 V
Power input	= 20 W
Power input for the fan	= 10 W
(The fan is assumed to be a Ziehl-ebm type G2G 085-AB 04-01 for the estimation of power)	
COP	= 0,6

The above assessment of COP is only the roughest approximation to indicate that it may be possible to upgrade the COP by improving the heat transfer arrangement.

#### 5.4.3.2 Liquid Heat Exchanger

The other technique which can be exploited is the use of liquid as a cooling medium. Peltron GmbH a German firm that produces what they call Peltier Cooling Blocks have identified the advantage of a water heat exchanger and are marketing a water manifold which interfaces with their Peltier cooling devices. The complete heat exchanger comprises liquid cooler with connecting points for 6mm hoses, counter support plates, screws with heat insulation bushes and two mica plates. The two mica plate are used to insulate the connecting strips on Peltron's Peltier device. Drawings of this device sourced from their catalogue can be seen in Figure 5.4 below.

Abmessungen (in mm)  
 Dimensions (in mm)  
 Dimensions (en mm)



Water Manifolds by Peltron GmbH

Figure 5.4

Source: Peltron GmbH Catalogue

Peltron's manifold design does convey some idea of a new direction of research for Telkom. There seem to be some definite advantages of using water or some other convenient fluid to assist heat transfer. The greatest advantage of using liquid is that the heat will be drawn straight out of the manifold, as opposed to a heat sink arrangement where the heat from the hot sink tends to be reflected back onto the cold sink. The disadvantage of employing liquid is the same as that of using forced air in that power would have to be used to drive a fan or pump motor to move the liquid or the air. The penalty in terms of energy use to convey coolant through a circuit could outweigh the advantages of using a liquid type heat exchanger. In the case of a fluid, though, this problem may be overcome by using the natural convection

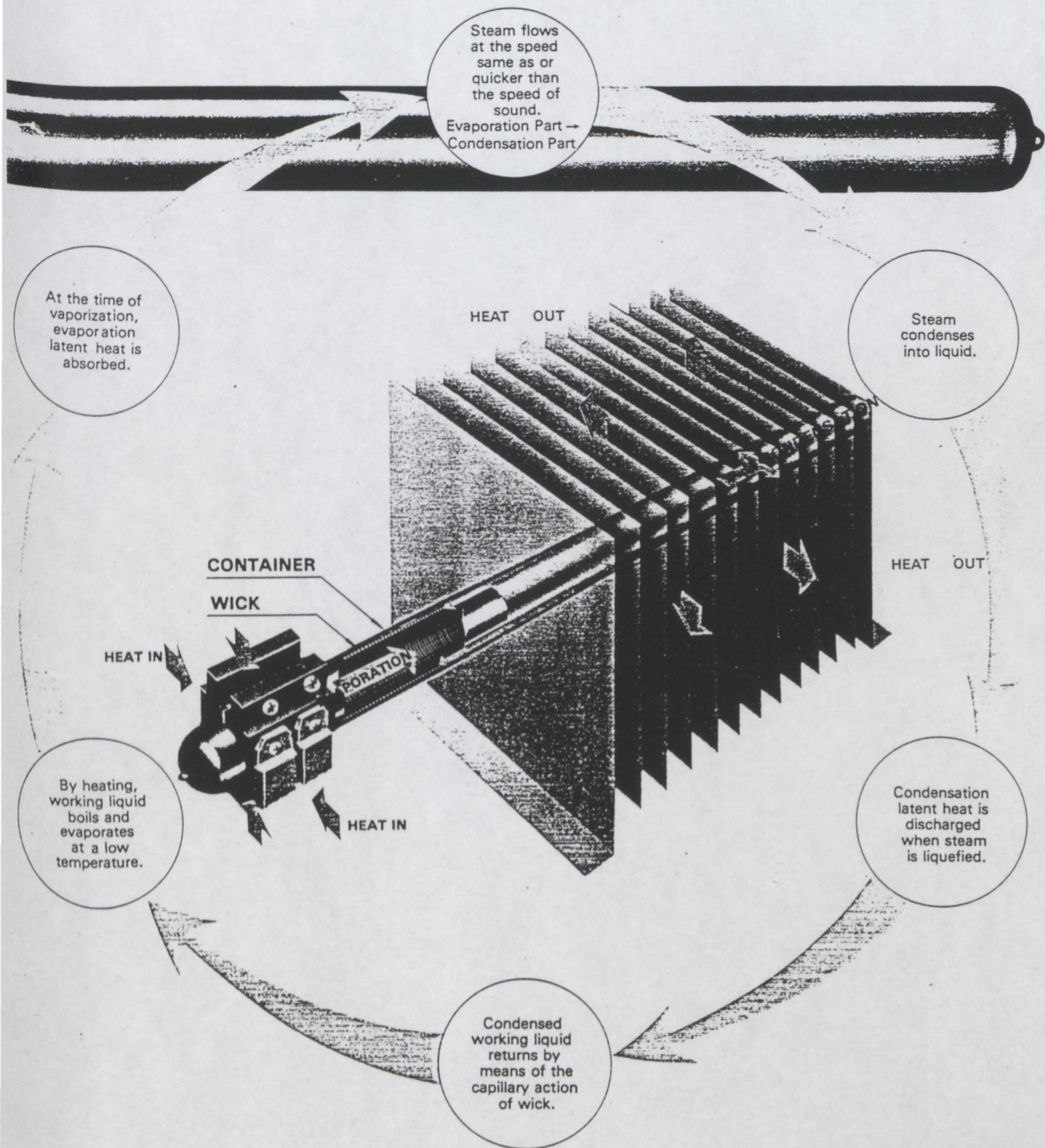
of the liquid. This area has enormous potential for further research.

Another drawback with using liquid as a cooling medium is the threat that a leak would pose to the electronic systems. This problem could be overcome by sealing the liquid heat exchanger off from the electronics by, for example, locating the entire liquid cooling system outside the container.

#### 5.4.3.3 Heat Pipes

Heat pipes were weighed up during the preliminary design stage as a possible more effective alternative to heat sinks. Unfortunately it was necessary to discard that line of thought at an early stage in the project so as to be able to concentrate on other aspects of the cooling system that had a higher priority. It is very possible that this line of thought may have yielded a substantially more effective heat dissipation system without any penalty of increased power. Power Devices were extremely helpful when initial research was carried out in this area and Mike Burger, their managing director, indicated that he had established contact with companies that would be prepared to export to South Africa. Figure 5.5 shows a diagram from the Heatkicker brochure explaining the principle of a heat pipe.

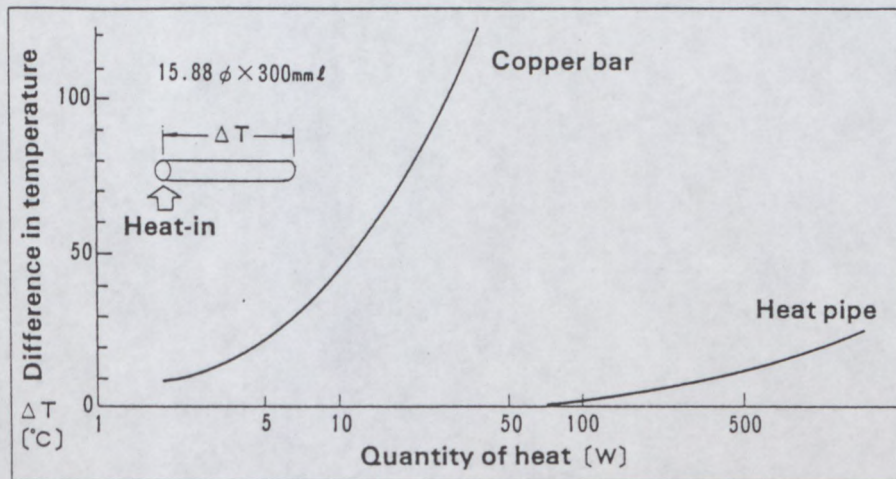
Heatkicker manufactured by Furukawa of Tokyo Japan, who stocks a full range of heat pipes, has developed a graph which illustrates one of the advantages of using heat pipes (See Figure 5.6).



The Operating Principle of Heat Pipes

Figure 5.5

Source: Furukawa Brochure



Conduction of Copper Pipe Compared to Heat Pipe

Figure 5.6

Source: Furukawa Brochure

It can be seen from the graph, which compares the heat pipe with a copper rod, that an almost negligible temperature differential is detected on a 300mm long pipe when 100W of heat is applied to its end. If this advantage of heat pipes is combined with heat dissipation plates, a substantial reduction in hot junction temperature would result in a reciprocal improvement in COP.

This is a prime target for further research. This line of investigation could prove to be beneficial to Telkom.

## 5.5 PV PANELS AND BATTERIES

### 5.5.1 PV PANELS AND BATTERIES - SOLUTION TO PRACTICAL PROBLEMS

The need for a self-sufficient system was fulfilled by using photovoltaic power combined with storage batteries. Tubular storage batteries were chosen because of their ability to perform well under photovoltaic charge conditions. Suitable charging methods and rates were recommended to prevent both stratification and excess gassing (see Section 2.4.2.2).

Proficient temperature compensating techniques and voltage shut-off points for specific temperatures were also suggested. A solution was found to the problem of determining the capacities of batteries, the number of panels and the sizes of panels by applying the rule of thumb approach and then verifying the procedure with the Arco Solar computer program. A knowledge of the anticipated output from panels under load conditions was also researched and documented. Suitable tubular batteries and solar panels were finally selected to provide for on-site power needs.

### 5.5.2 PHOTOVOLTAIC PANELS AND BATTERIES RECOMMENDATIONS.

#### 5.5.2.1 Photovoltaic Panels and Batteries - Possible Applications of Results in Industry

Industry or certain branches of industry has exploited PV power to its fullest extent and the use of PV panels will undoubtedly continue to grow. The use of PV power for refrigeration purposes has also already gained acceptance for use in remote areas and Siemens markets PV panel systems that are matched to a variety of home appliances including refrigerators which are marketed under the trade name of Sunsave. It can be foreseen that the application of the Peltier cooling systems combined with PV power could also be adapted to a variety of telecommunications applications.

#### 5.5.2.2 Photovoltaic Panels and Batteries - Recommendations to Users in Industry

Once correct selection of batteries and photovoltaic panels has been made, the most important aspect is the setting up of correct charging rates. The selected rates should be carefully temperature compensated especially in the typically hot South African climatic conditions. The optimal recommended charging rates were comprehensively discussed in section 2.4.2.2.

In summary:-

- i. Voltage is allowed to rise to 2.4 Vpc and then held constant.
- ii. When the battery reaches a temperature of 30°C

the charge rate is decreased to between 2,25 Vpc and 2,3 Vpc.

- iii. As the temperature increases from 30°C to 35°C the charge is again reduced to 2,2 Vpc.
- iv. If the temperature of the battery eventually reaches 40°C then the regulator is to shut the charge down completely.

If this charging pattern is observed neither stratification nor over-gassing will limit the life of the battery.

### 5.5.3 PHOTOVOLTAIC PANELS AND BATTERIES - FURTHER RESEARCH

No further research is recommended in this area. This part of the project only played a support role and the investigation in this area was simply undertaken to establish the requirements of the cooling system and the feasibility of using PV power. An understanding of the best way to utilise the storage batteries in conjunction with PV energy was also essential. All these goals were adequately met and no further work is recommended in this area.

## 5.6 ELECTRICAL SYSTEM

### 5.6.1 ELECTRICAL SYSTEM - SOLUTION TO PRACTICAL PROBLEMS

A purpose made constant current source was designed and built to test the prototype. This system was used to smooth the ripples in the supply current during testing. The five Peltier coolers were controlled by a temperature sensor that triggered a 24V double pole relay which in turn switched the power to five constant current controls. The transformer which originally fed the cooler was eventually discarded and replaced with a Hewlett Packard power source which delivered a greater range of power with accurate voltage and current settings. This modification facilitated convenient testing over a wide variety of current settings. The electrical system operated without failure during the testing period. The electronic thermostat which exercised control over the

Peltier system operated without failure throughout the test period.

## 5.6.2 ELECTRICAL SYSTEM - RECOMMENDATIONS

### 5.6.2.1 Electrical System -

#### Possible Applications of Results in industry

Telkom has already pressed the electronic thermostat into operation to regulate rectifier cooling fans. This device could be used to switch virtually any circuit in or out on the basis of temperature demand. The cost of the control unit was inexpensive in comparison with alternative mechanical thermostats. At a price of R200 (1992) industry should find innumerable uses for the electronic thermostat.

### 5.6.2.2 Electric System -

#### Recommendations to Users in Industry

The thermostat should preferably be adjusted in a climatic oven before it is coupled to the equipment that it is to control. Final adjustments should then be made after temperature readings have been related to actual triggering temperatures.

## 5.6.3 ELECTRICAL - FURTHER RESEARCH

No further research is anticipated in this part of the project. The electrical system served its purpose adequately during all of the tests that were made. This area of the work played a support role because the main thrust of the research did not lie here.

## 5.7 GENERAL CONCLUSION

The use of PV Panels to provide power for the thermoelectric cooling system was a viable but extremely expensive option which tended to detract from the feasibility of thermoelectric cooling.

The research work carried out in this project has proved that it is possible to use thermoelectric cooling operating on the principle of Peltier effect for electronic cooling.

Notwithstanding the fact that drawbacks to the practical implementation of Peltier cooling still remain, this investigation of Peltier cooling promises to provide the springboard for the development of a far more efficient, practical and economical system in the near future.

APPENDIXES

3.1 to 3.21

## APPENDIX 3.1

### U FACTOR

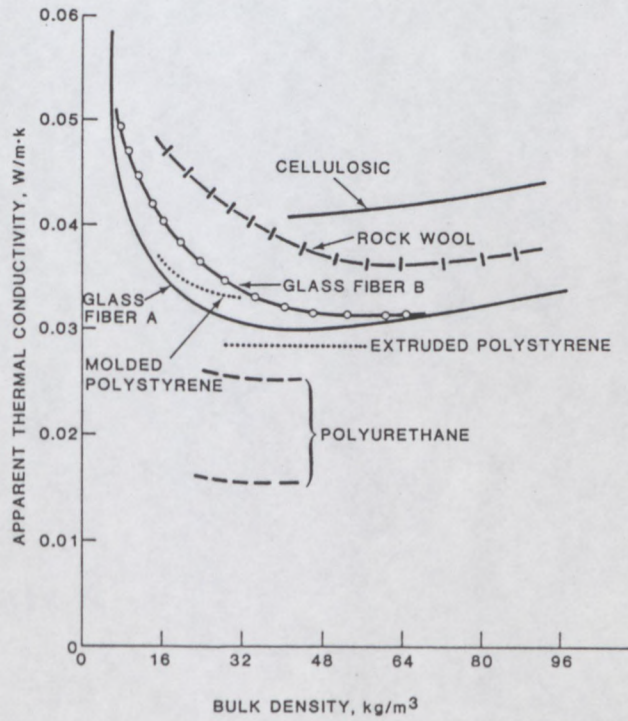


Figure A.3.1

Apparent Thermal Conductivity Versus Density of Several Thermal Insulations Used as Building Insulations  
Source: ASHRAE Fundamentals Handbook (1989, p.20.4)

$k$  from chart = 0,032

$$R = 1/h_o + x/k + 1/h_i$$

$$h_i = 8,1 \text{ (HIVE, 1970, table 10.1)}$$

$$h_o = 18 \text{ (HIVE, 1970, table 10.1)}$$

$$R = 1/8,1 + 0.05/0,032 + 1/18$$

Therefore :-

$$U = 0,5742 \text{ W/m}^2\text{°C}$$

## APPENDIX 3.2

### CLTD TEST CALCULATIONS

Using 50mm IM 24 Resin impregnated fibreglass insulation.

$$\begin{aligned}
 k &= 0,0378 \text{ W/}^\circ\text{Cm @ } 24^\circ\text{C (Fibreglass S.A. Insulation -} \\
 &\quad \text{materials, Fibreglass Structural - Industrial} \\
 &\quad \text{Insulation Specifile Section No 154, July 1984.)} \\
 h_i &= 8,1 \text{ W/m (IHVE, 1970, Table 10.1)} \\
 h_o &= 18 \text{ W/m (IHVE, 1970, Table 10.1)} \\
 R &= 1/h_i + t/k + 1/h_o \\
 R &= 1/8,1 + 0,05/0,0378 + 1/18 \\
 R &= 1,512 \\
 U &= 1/R \\
 U &= 0,661 \text{ W/m}^2\text{ }^\circ\text{C}
 \end{aligned}$$

Assuming maximum heat load occurs at 14:00 on the 22 December.

#### TRANSMISSION AND SENSIBLE HEAT GAIN

ITEM	AREA m <sup>2</sup>	TEMP DIFF.	U FACTOR	Q=AUT <sub>d</sub>
Exterior Wall N	1,0	11,1 °C	0,661	7,33 W
Exterior Wall S	1,1	6,7 °C	0,661	4,87 W
Exterior Wall W	1,050	7,8 °C	0,661	5,41 W
Exterior Wall E	1,050	7,8 °C	0,661	5,41 W
Roof	1,005	38,3 °C	0,661	25,44W
Total Trans and Solar				48,46W

The temperature differences were taken from the Trane Air-conditioning Manual, (1979, p.386 & P.390) T<sub>d</sub> for 1" Wood + 2" insulation which was the closest material to steel sheet with 50mm fibreglass insulation. It must be remembered that an indoor temperature of 23°C is assumed in Trane's tables which is a lot lower than the required indoor temperature of 38°C specified by Telkom.

NOTE: One of the basic problems is emphasised in the above calculations where it can be seen that it was necessary to select walls and roof structures which are similar in U-factor but not the same in construction to the ones used in the container.

### APPENDIX 3.3

## HEAT LOAD CALCULATIONS

### SINGLE HOUR LOAD CALCULATION OUTPUT

JAN 17:00 : RICHARD

Job name : Container      Date Prepared : 1990-09-20  
Site name : Pretoria, So Africa      60501852.1  
Outdoor DB/WB: 31.1/21.1°C Indoor DB: 23°C RH:49%

---

#### ELEMENT BY ELEMENT LOADS FOR CONTAINER

ELEMENT	DESCRIPTION
E. WALL	Sens:                    5 W Area:                    1,1 m <sup>2</sup> U-Val : 0,574 W/m <sup>2</sup> /K Eqv.T <sub>a</sub> :                    7,8 K
S. WALL	Sens:                    5 W Area:                    1,1 m <sup>2</sup> U-Val : 0,574 W/m <sup>2</sup> /K Eqv.T <sub>a</sub> :                    7,3 K
W. WALL	Sens:                    11 W Area:                    1,1 m <sup>2</sup> U-Val : 0,574 W/m <sup>2</sup> /K Eqv.T <sub>a</sub> :                    18,4 K
N. WALL	Sens:                    5 W Area:                    1,1 m <sup>2</sup> U-Val : 0,574 W/m <sup>2</sup> /K Eqv.T <sub>a</sub> :                    8,4 K
ROOF	Sens:                    11 W Area:                    1,1 m <sup>2</sup> U-Val : 0,574 W/m <sup>2</sup> /K 0% of load                100% of load to plenum                    to space
	TOTAL LOAD                37 W

## APPENDIX 3.4

### HEAT LOAD CALCULATIONS

#### SINGLE HOUR LOAD CALCULATION OUTPUT

JAN 17:00 : RICHARD

Job name : Container      Date Prepared : 1990-09-20  
Site name : Pretoria, So Africa      60501852.1  
Outdoor DB/WB: 31.1/21.1°C Indoor DB: 30°C RH:19%

---

#### ELEMENT BY ELEMENT LOADS FOR CONTAINER

ELEMENT	DESCRIPTION
E. WALL	Sens:                    1 W Area:                    1,1 m <sup>2</sup> U-Val : 0,574 W/m <sup>2</sup> /K Eqv.T <sub>a</sub> :                    0,8 K
S. WALL	Sens:                    0 W Area:                    1,1 m <sup>2</sup> U-Val : 0,574 W/m <sup>2</sup> /K Eqv.T <sub>a</sub> :                    0,3 K
W. WALL	Sens:                    7 W Area:                    1,1 m <sup>2</sup> U-Val : 0,574 W/m <sup>2</sup> /K Eqv.T <sub>a</sub> :                    11,4 K
N. WALL	Sens:                    1 W Area:                    1,1 m <sup>2</sup> U-Val : 0,574 W/m <sup>2</sup> /K Eqv.T <sub>a</sub> :                    1,4 K
ROOF	Sens:                    7 W Area:                    1,1 m <sup>2</sup> U-Val : 0,574 W/m <sup>2</sup> /K Eqv.T <sub>a</sub> :                    11,4 K Exposed to Sun 0% of load                100% of load to plenum                    to space
TOTAL LOAD	16 W

## Appendix 3.5

### Sol - Air Heat Loads

All walls  
assumed to  
be 1 m<sup>2</sup> to  
simplify  
calculations

Time	Orient	Ambient Temp T <sub>o</sub>	$\frac{\alpha}{h_o} \times I_t - \epsilon \frac{\alpha R}{h_o} =$	T <sub>e</sub>	A U (Δt)	La	Total La	Le + La 100 + La #
01:00	N.S.W.E.R	18,3 °C	No solar radiation load	-	5 x [0,661(18,3-38)]	-	-65,11	34,89 W
02:00	"	17,6 °C	"	-	5 x [0,661(17,6-38)]	-	-67,42	32,58 W
03:00	"	17,2 °C	"	-	5 x [0,661(17,2-38)]	-	-68,74	31,26 W
04:00	"	16,6 °C	"	-	5 x [0,661(16,6-38)]	-	-70,73	29,27 W
05:00	"	16,2 °C	"	-	5 x [0,661(16,2-38)]	-	-72,05	27,95 W
06:00	N.S.W.E	16,3 °C	"	-	4 x [0,661(16,3-38)]	-57,37	-	-
	R	16,3 °C	0,026 x 30 -3,9	NEG	1x[0,661(16,3-38)]	-14,34	-71,71	28,29 W
07:00	R	19,1 °C	0,026 x 192 -3,9	20,19	0,661(20,19-38)	-11,77	-	-
	N	"	0,026 x 43 -0	20,22	0,661(20,22-38)	-11,75	-	-
	E	"	0,026 x 574 -0	34,02	0,661(34,02-38)	-2,63	-	-
	S	"	0,026 x 186 -0	23,94	0,661(23,94-38)	-9,30	-	-
	W	"	0,026 x 45 -0	20,27	0,661(20,27-38)	-11,72	-47,17	52,83 W
08:00	R	21,8	0,026 x 413 -3,9	28,64	0,661(28,64-38)	-6,19	-	-
	N	"	0,026 x 90 -0	24,14	0,661(24,14-38)	-9,16	-	-
	E	"	0,026 x 692 -0	39,79	0,661(39,79-38)	1,18	-	-
	S	"	0,026 x 197 -0	26,92	0,661(26,92-38)	-7,32	-	-
	W	"	0,026 x 90 -0	24,14	0,661(24,14-38)	-9,161	-30,65	69,35 W
09:00	R	24,1	0,026 x 611 -3,9	36,09	0,661(36,09-38)	-1,27	-	-
	N	"	0,026 x 144 -0	27,84	0,661(27,84-38)	-6,71	-	-
	E	"	0,026 x 690 -0	42,04	0,661(42,04-38)	+2,67	-	-
	S	"	0,026 x 173 -0	28,60	0,661(28,60-38)	-6,21	-	-
	W	"	0,026 x 132 -0	27,53	0,661(27,53-38)	-6,92	-18,44	81,56 W
10:00	R	25,6	0,026 x 800 -3,9	42,5	0,661(42,5-38)	2,97	-	-
	N	"	0,026 x 210 -0	31,06	0,661(31,06-38)	-4,59	-	-
	E	"	0,026 x 627 -0	41,90	0,661(41,90-38)	+2,58	-	-
	S	"	0,026 x 174 -0	30,12	0,661(30,12-38)	-5,21	-	-
	W	"	0,026 x 163 -0	29,84	0,661(29,84-38)	-5,39	-9,63	90,37 W

Time	Orient	Ambient Temp	$\frac{\alpha}{h_o} \times I_t - \epsilon \frac{\alpha R}{h_o} =$	Te	All walls assumed to be 1 m <sup>2</sup> to simplify calculations A U (Δt)	La	Total La	Le + La	
								100 + La	#
11:00	R	27,1	0,026 x 929 -3,9	47,35	0,661(47,35-38)	6,183			
	N	"	0,026 x 256 -0	33,76	0,661(33,76-38)	-2,805			
	E	"	0,026 x 483 -0	39,66	0,661(39,66-38)	1,096			
	S	"	0,026 x 182 -0	31,83	0,661(31,83-38)	-4,08			
	W	"	0,026 x 182 -0	31,83	0,661(31,83-38)	-4,08	-3,680	96,3	
12:00	R	28,3	+0,026 x 1 014 -3,9	50,76	0,661(50,76-38)	8,43			
	N	"	0,026 x 316 -0	36,52	0,661(36,52-38)	-0,99			
	E	"	0,026 x 303 -0	36,18	0,661(36,21,-38)	-1,19			
	S	"	0,026 x 195 -0	33,37	0,661(33,37-38)	-3,06			
	W	"	0,026 x 195 -0	33,37	0,661(33,37-38)	-3,06	0,13	100,13	
13:00	R	29,4	0,026 x 972 -3,9	50,77	0,661(50,77-38)	8,44			
	N	"	0,026 x 301 -0	37,23	0,661(37,23-38)	-0,51			
	E	"	0,026 x 192 -0	34,39	0,661(34,39-38)	-2,38			
	S	"	0,026 x 192 -0	34,39	0,661(34,39-38)	-2,39			
	W	"	0,026 x 294 -0	37,04	0,661(37,04-38)	-0,63	2,53	102,5	
14:00	R	30,1	0,026 x 891 -3,9	49,37	0,661(49,37-38)	7,51			
	N	"	0,026 x 288 -0	37,59	0,661(37,59-38)	-0,27			
	E	"	0,026 x 187 -0	34,96	0,661(34,96-38)	-2,01			
	S	"	0,026 x 187 -0	34,96	0,661(34,96-38)	-2,01			
	W	"	0,026 x 472 -0	42,37	0,661(42,37-38)	2,89	6,11	106,1	
15:00	R	30,4	0,026 x 694 -3,9	44,54	0,661(44,54-38)	4,33			
	N	"	0,026 x 201 -0	35,63	0,661(35,63-38)	-1,57			
	E	"	0,026 x 159 -0	34,53	0,661(34,53,-38)	-3,47			
	S	"	0,026 x 163 -0	34,64	0,661(34,64-38)	-2,22			
	W	"	0,026 x 538 -0	44,39	0,661(44,39-38)	4,22	1,290	101,3	
16:00	R	30,1	0,026 x 508 -3,9	39,41	0,661(39,41-38)	0,93			
	N	"	0,026 x 142 -0	33,79	0,661(33,79-38)	-2,78			
	E	"	0,026 x 128 -0	33,43	0,661(33,43-38)	-3,02			
	S	"	0,026 x 149 -0	33,97	0,661(33,97-38)	-2,66			
	W	"	0,026 x 553 -0	44,48	0,661(44,48-38)	4,28	-3,25	96,75	

All walls  
assumed to  
be 1 m<sup>2</sup> to  
simplify  
calculations

Time	Orient	Ambient Temp T <sub>o</sub>	$\frac{\alpha}{h_o} \times I_t - \epsilon \frac{\alpha R}{h_o} =$	Te	A U (Δt)	La	Total La	Le + La 100 + La #
17:00	R	29,3	0,026 x 323 -3,9	33,8	0,661(33,8-38)	-2,78		
	N	"	0,026 x 90 -0	31,64	0,661(31,64-38)	-4,20		
	E	"	0,026 x 86 -0	31,54	0,661(31,54-38)	-4,27		
	S	"	0,026 x 143 -0	33,02	0,661(33,02-38)	-3,29		
	W	"	0,026 x 520 -0	42,82	0,661(42,82-38)	3,19	-11,36	88,64
18:00	R	27,7	0,026 x 139 -3,9	NEG	0,661(27,7-38)	-6,8		
	N	"	0,026 x 47 -0	28,92	0,661(28,92-38)	-6,0		
	E	"	0,026 x 47 -0	28,92	0,661(28,92,-38)	-6,0		
	S	"	0,026 x 109 -0	30,53	0,661(30,53-38)	-4,94		
	W	"	0,026 x 359 -0	37,03	0,661(37,03-38)	-0,64	-24,38	75,62
19:00	R	25,4	0,026 x 34 -3,9	NEG	0,661(25,4-38)	-8,33		
	N.E.S.W	"			4 x [0,661(25,4-38)]	-33,31	-41,61	58,36
20:00	R.N.E.S.W	23,2			5x[0,661(23,2-38)]		-48,91	51,09
21:00	R.N.E.S.W	22,0			5 x [0,661(22,0-38)]		-52,88	47,12
22:00	R.N.E.S.W	20,9			5 x [0,661(20,9-38)]		-56,52	43,48
23:00	R.N.E.S.W	20,1			5 x [0,661(20,1-38)]		-59,16	40,84
24:00	R.N.E.S.W	19,4			5 x [0,661(19,4-38)]		-61,47	38,53

# The Le = 100 W load that is added is an assumed load which represents a constant equipment load.

## APPENDIX 3.6.1

### ON SITE CONTAINER TEMPERATURE READINGS

File 7

No heat load

No cooling

Container on site

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east

Ch 2 Outside heat sink

Ch 3 Inside heat sink

Ch 4 Inside floor level

Ch 5 Inside globe level

Ch 6 Outside globe level

# Channel Readings

Data file - FILE7

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 22-Feb-91 16:30:00.  
    Finish : 25-Feb-91 07:30:01.  
Readings per channel: 379

All readings

Rdg no	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC
0	22-Feb-91 16:30:00.	32.100	33.850	37.050	36.800	36.850	31.350
1	22-Feb-91 16:40:00.	31.950	33.750	36.800	36.550	36.500	31.150
2	22-Feb-91 16:50:00.	31.650	33.450	36.500	36.300	36.200	31.050
3	22-Feb-91 17:00:00.	31.350	33.250	36.200	36.000	35.900	30.800
4	22-Feb-91 17:10:00.	31.300	33.000	35.900	35.700	35.550	30.650
5	22-Feb-91 17:20:00.	30.950	32.750	35.650	35.450	35.300	30.500
6	22-Feb-91 17:30:00.	30.700	32.500	35.400	35.150	34.950	30.350
7	22-Feb-91 17:40:00.	30.400	32.350	35.100	34.850	34.550	30.150
8	22-Feb-91 17:50:00.	29.950	32.000	34.750	34.500	34.050	29.750
9	22-Feb-91 18:00:00.	29.400	31.700	34.450	34.150	33.650	29.350
10	22-Feb-91 18:10:00.	28.650	31.300	34.050	33.700	33.150	28.900
11	22-Feb-91 18:20:00.	27.450	30.700	33.700	33.350	32.600	28.350
12	22-Feb-91 18:30:00.	26.200	30.000	33.250	32.800	31.800	27.450
13	22-Feb-91 18:40:00.	25.350	28.950	32.750	32.200	30.950	26.850
14	22-Feb-91 18:50:00.	24.850	28.250	32.200	31.550	30.150	26.300
15	22-Feb-91 19:00:00.	24.500	27.550	31.600	30.900	29.500	25.900
16	22-Feb-91 19:10:00.	24.300	27.050	31.050	30.300	28.900	25.700
17	22-Feb-91 19:20:00.	24.350	26.550	30.500	29.700	28.300	25.400
18	22-Feb-91 19:30:00.	24.000	26.000	29.900	29.100	27.800	25.150
19	22-Feb-91 19:40:00.	23.950	25.550	29.350	28.550	27.350	24.950
20	22-Feb-91 19:50:00.	24.000	25.150	28.800	28.100	26.900	24.800
21	22-Feb-91 20:00:00.	23.900	24.850	28.300	27.650	26.500	24.750
22	22-Feb-91 20:10:00.	23.900	24.550	27.850	27.200	26.150	24.750
23	22-Feb-91 20:20:00.	23.850	24.300	27.400	26.800	25.750	24.450
24	22-Feb-91 20:30:00.	23.700	24.050	26.950	26.400	25.450	24.300
25	22-Feb-91 20:40:00.	23.700	23.850	26.600	26.050	25.150	24.150
26	22-Feb-91 20:50:00.	23.450	23.650	26.200	25.700	24.900	23.950
27	22-Feb-91 21:00:00.	23.100	23.350	25.850	25.400	24.650	23.500
28	22-Feb-91 21:10:00.	22.750	23.100	25.550	25.150	24.400	23.250
29	22-Feb-91 21:20:00.	22.300	22.750	25.200	24.900	24.150	22.700
30	22-Feb-91 21:30:00.	22.300	22.450	24.950	24.600	23.850	22.650
31	22-Feb-91 21:40:00.	21.950	22.200	24.600	24.350	23.550	22.350
32	22-Feb-91 21:50:00.	21.750	21.950	24.300	24.050	23.300	22.200
33	22-Feb-91 22:00:00.	21.250	21.650	24.050	23.800	23.000	21.800
34	22-Feb-91 22:10:00.	21.100	21.400	23.700	23.500	22.700	21.500
35	22-Feb-91 22:20:00.	21.350	21.200	23.450	23.200	22.350	21.600
36	22-Feb-91 22:30:00.	21.000	21.050	23.150	22.900	22.100	21.500
37	22-Feb-91 22:40:00.	21.350	21.050	22.900	22.700	21.950	21.650
38	22-Feb-91 22:50:00.	21.050	20.950	22.650	22.450	21.800	21.600
39	22-Feb-91 23:00:00.	21.100	20.850	22.400	22.250	21.600	21.500
40	22-Feb-91 23:10:00.	20.850	20.700	22.200	22.050	21.450	21.250
41	22-Feb-91 23:20:00.	20.900	20.550	22.000	21.850	21.200	21.350

42	22-Feb-91 23:30:00.	20.650	20.400	21.800	21.600	21.000	21.100
43	22-Feb-91 23:40:00.	20.550	20.250	21.600	21.450	20.750	21.050
44	22-Feb-91 23:50:00.	20.850	20.300	21.450	21.250	20.600	21.100
45	22-Feb-91 24:00:00.	20.050	20.100	21.250	21.100	20.500	20.500
46	23-Feb-91 00:10:00.	19.450	19.700	21.050	20.900	20.300	20.150
47	23-Feb-91 00:20:00.	18.500	19.350	20.850	20.650	20.000	19.750
48	23-Feb-91 00:30:00.	18.250	19.000	20.600	20.400	19.600	19.150
49	23-Feb-91 00:40:00.	18.600	18.800	20.350	20.150	19.300	19.100
50	23-Feb-91 00:50:00.	18.050	18.500	20.150	19.900	19.100	18.900
51	23-Feb-91 01:00:00.	17.950	18.300	19.900	19.650	18.850	18.700
52	23-Feb-91 01:10:00.	18.300	18.150	19.650	19.450	18.650	18.750
53	23-Feb-91 01:20:00.	17.850	17.950	19.450	19.250	18.500	18.550
54	23-Feb-91 01:30:00.	17.800	17.850	19.250	19.050	18.350	18.450
55	23-Feb-91 01:40:00.	18.200	17.800	19.050	18.900	18.150	18.600
56	23-Feb-91 01:50:00.	18.100	17.750	18.850	18.750	18.100	18.650
57	23-Feb-91 02:00:00.	18.250	17.700	18.700	18.600	18.000	18.700
58	23-Feb-91 02:10:00.	18.250	17.650	18.550	18.500	17.900	18.700
59	23-Feb-91 02:20:00.	17.550	17.550	18.400	18.350	17.750	18.400
60	23-Feb-91 02:30:00.	15.500	17.150	18.250	18.200	17.550	17.950
61	23-Feb-91 02:40:00.	17.450	17.000	18.050	18.000	17.250	18.350
62	23-Feb-91 02:50:00.	16.650	16.750	17.900	17.800	17.000	17.700
63	23-Feb-91 03:00:00.	17.900	16.850	17.700	17.650	16.850	18.650
64	23-Feb-91 03:10:00.	18.650	17.500	17.550	17.550	16.850	19.400
65	23-Feb-91 03:20:00.	18.150	17.250	17.500	17.500	16.950	19.000
66	23-Feb-91 03:30:00.	18.800	17.400	17.400	17.500	16.900	19.300
67	23-Feb-91 03:40:00.	18.850	17.500	17.350	17.400	16.900	19.200
68	23-Feb-91 03:50:00.	18.800	17.600	17.300	17.400	16.900	19.150
69	23-Feb-91 04:00:00.	17.250	17.300	17.250	17.350	16.850	18.050
70	23-Feb-91 04:10:00.	16.800	16.950	17.200	17.300	16.700	17.500
71	23-Feb-91 04:20:00.	17.150	16.800	17.150	17.200	16.550	17.500
72	23-Feb-91 04:30:00.	16.450	16.600	17.000	17.100	16.450	17.100
73	23-Feb-91 04:40:00.	16.900	16.600	16.950	17.000	16.400	17.450
74	23-Feb-91 04:50:00.	17.200	16.650	16.850	16.950	16.350	17.550
75	23-Feb-91 05:00:00.	18.250	16.900	16.800	16.900	16.300	18.500
76	23-Feb-91 05:10:00.	17.600	16.850	16.750	16.850	16.300	18.000
77	23-Feb-91 05:20:00.	17.150	16.650	16.650	16.850	16.250	17.700
78	23-Feb-91 05:30:00.	16.700	16.400	16.600	16.750	16.150	17.350
79	23-Feb-91 05:40:00.	16.800	16.300	16.550	16.650	16.000	17.500
80	23-Feb-91 05:50:00.	17.300	16.200	16.450	16.500	15.850	17.750
81	23-Feb-91 06:00:00.	17.350	16.250	16.350	16.400	15.800	17.700
82	23-Feb-91 06:10:00.	17.050	16.200	16.300	16.300	15.700	17.700
83	23-Feb-91 06:20:00.	17.100	16.350	16.200	16.250	15.650	17.850
84	23-Feb-91 06:30:00.	17.850	16.550	16.150	16.200	15.650	18.150
85	23-Feb-91 06:40:00.	24.850	16.650	16.100	16.150	15.700	18.400
86	23-Feb-91 06:50:00.	26.450	17.250	16.100	16.200	15.850	19.100
87	23-Feb-91 07:00:00.	28.700	17.700	16.200	16.350	16.250	19.400
88	23-Feb-91 07:10:00.	29.550	18.350	16.350	16.550	16.700	19.950
89	23-Feb-91 07:20:00.	29.450	18.950	16.550	16.800	17.200	20.550
90	23-Feb-91 07:30:00.	27.800	19.550	16.850	17.100	17.650	21.000
91	23-Feb-91 07:40:00.	28.750	20.500	17.200	17.400	18.200	21.300
92	23-Feb-91 07:50:00.	31.850	21.350	17.600	17.750	18.750	22.150
93	23-Feb-91 08:00:00.	28.600	22.100	18.050	18.150	19.300	22.800
94	23-Feb-91 08:10:00.	32.300	22.700	18.550	18.600	19.850	23.250
95	23-Feb-91 08:20:00.	36.500	23.350	19.050	19.000	20.400	23.450
96	23-Feb-91 08:30:00.	35.450	23.950	19.600	19.450	20.950	24.400
97	23-Feb-91 08:40:00.	35.450	24.550	20.150	19.900	21.550	24.700
98	23-Feb-91 08:50:00.	38.150	25.200	20.700	20.350	22.100	25.300
99	23-Feb-91 09:00:00.	35.600	25.800	21.300	20.850	22.700	25.350
100	23-Feb-91 09:10:00.	33.400	26.450	21.850	21.350	23.300	26.000
101	23-Feb-91 09:20:00.	32.800	26.850	22.400	21.800	23.800	26.100
102	23-Feb-91 09:30:00.	33.950	27.500	22.950	22.250	24.250	26.650
103	23-Feb-91 09:40:00.	35.650	28.200	23.500	22.750	24.750	27.250
104	23-Feb-91 09:50:00.	35.150	28.800	24.100	23.250	25.300	27.450
105	23-Feb-91 10:00:00.	40.050	29.500	24.650	23.750	25.900	28.000
106	23-Feb-91 10:10:00.	37.800	30.150	25.200	24.250	26.500	28.750

107	23-Feb-91 10:20:00.	33.650	30.550	25.850	24.800	27.150	29.000
108	23-Feb-91 10:30:00.	33.550	30.900	26.400	25.200	27.550	28.950
109	23-Feb-91 10:40:00.	36.150	31.750	26.950	25.650	28.000	29.550
110	23-Feb-91 10:50:00.	35.650	32.050	27.500	26.150	28.450	29.950
111	23-Feb-91 11:00:00.	33.950	32.450	28.000	26.600	28.900	29.650
112	23-Feb-91 11:10:00.	34.150	32.800	28.500	27.000	29.300	29.650
113	23-Feb-91 11:20:00.	39.500	33.250	28.950	27.400	29.700	29.750
114	23-Feb-91 11:30:00.	37.250	33.850	29.450	27.800	30.100	30.450
115	23-Feb-91 11:40:00.	33.200	33.500	29.850	28.200	30.500	30.200
116	23-Feb-91 11:50:00.	34.750	34.150	30.350	28.550	30.750	31.000
117	23-Feb-91 12:00:00.	32.900	34.000	30.650	28.850	31.000	30.450
118	23-Feb-91 12:10:00.	34.400	34.300	31.000	29.200	31.250	30.400
119	23-Feb-91 12:20:00.	36.400	34.200	31.350	29.500	31.500	30.300
120	23-Feb-91 12:30:00.	34.500	34.850	31.600	29.750	31.750	31.000
121	23-Feb-91 12:40:00.	32.850	34.950	31.900	30.100	32.050	31.200
122	23-Feb-91 12:50:00.	33.200	35.050	32.200	30.400	32.350	31.500
123	23-Feb-91 13:00:00.	32.050	34.300	32.450	30.650	32.550	31.000
124	23-Feb-91 13:10:00.	32.150	34.000	32.700	30.850	32.650	31.300
125	23-Feb-91 13:20:00.	32.000	33.450	32.850	31.000	32.650	31.050
126	23-Feb-91 13:30:00.	32.500	34.050	32.950	31.200	32.750	31.300
127	23-Feb-91 13:40:00.	32.700	34.000	33.100	31.350	32.900	31.450
128	23-Feb-91 13:50:00.	32.850	34.250	33.200	31.500	33.050	31.650
129	23-Feb-91 14:00:00.	33.000	34.400	33.250	31.650	33.200	31.650
130	23-Feb-91 14:10:00.	32.250	33.900	33.400	31.800	33.400	31.200
131	23-Feb-91 14:20:00.	34.000	34.000	33.450	31.950	33.450	31.300
132	23-Feb-91 14:30:00.	32.600	33.950	33.550	32.100	33.550	31.650
133	23-Feb-91 14:40:00.	32.700	34.250	33.600	32.200	33.600	31.550
134	23-Feb-91 14:50:00.	32.800	34.100	33.650	32.350	33.750	32.000
135	23-Feb-91 15:00:00.	32.400	33.950	33.700	32.450	33.800	31.550
136	23-Feb-91 15:10:00.	32.750	33.950	33.750	32.500	33.800	31.800
137	23-Feb-91 15:20:00.	33.150	34.250	33.800	32.650	33.850	32.050
138	23-Feb-91 15:30:00.	32.500	34.150	33.800	32.700	33.900	31.500
139	23-Feb-91 15:40:00.	32.300	33.950	33.850	32.750	34.000	31.550
140	23-Feb-91 15:50:00.	32.550	33.900	33.850	32.850	34.000	31.600
141	23-Feb-91 16:00:00.	32.200	34.000	33.900	32.950	34.050	31.500
142	23-Feb-91 16:10:00.	32.350	34.000	33.900	32.950	34.050	31.550
143	23-Feb-91 16:20:00.	31.600	33.600	33.950	33.000	34.050	31.350
144	23-Feb-91 16:30:00.	32.050	33.350	33.850	32.950	33.600	31.350
145	23-Feb-91 16:40:00.	32.000	33.350	33.800	32.850	33.400	31.400
146	23-Feb-91 16:50:00.	30.650	32.750	33.700	32.850	33.550	30.600
147	23-Feb-91 17:00:00.	30.900	32.450	33.600	32.700	33.100	30.500
148	23-Feb-91 17:10:00.	30.450	32.100	33.400	32.550	32.650	30.200
149	23-Feb-91 17:20:00.	30.650	31.650	33.150	32.300	32.250	30.400
150	23-Feb-91 17:30:00.	30.750	31.750	32.950	32.100	32.050	30.450
151	23-Feb-91 17:40:00.	30.350	31.500	32.750	31.950	32.050	30.300
152	23-Feb-91 17:50:00.	30.200	31.500	32.550	31.800	31.900	30.100
153	23-Feb-91 18:00:00.	29.650	31.200	32.350	31.650	31.650	29.800
154	23-Feb-91 18:10:00.	29.200	30.950	32.200	31.450	31.400	29.400
155	23-Feb-91 18:20:00.	28.650	30.200	31.900	31.250	30.950	28.950
156	23-Feb-91 18:30:00.	27.950	29.750	31.600	30.900	30.300	28.450
157	23-Feb-91 18:40:00.	26.900	29.050	31.300	30.500	29.700	27.800
158	23-Feb-91 18:50:00.	26.150	28.400	30.900	30.050	29.050	27.450
159	23-Feb-91 19:00:00.	24.550	27.800	30.450	29.500	28.450	26.900
160	23-Feb-91 19:10:00.	24.900	27.100	29.950	28.950	27.900	26.100
161	23-Feb-91 19:20:00.	24.600	26.500	29.500	28.500	27.450	25.800
162	23-Feb-91 19:30:00.	24.550	26.150	29.000	28.100	27.100	25.500
163	23-Feb-91 19:40:00.	24.200	25.600	28.550	27.600	26.600	25.150
164	23-Feb-91 19:50:00.	23.750	25.250	28.100	27.200	26.200	24.900
165	23-Feb-91 20:00:00.	23.650	24.850	27.650	26.800	25.800	24.600
166	23-Feb-91 20:10:00.	23.400	24.450	27.200	26.400	25.450	24.350
167	23-Feb-91 20:20:00.	23.350	24.200	26.800	26.050	25.150	24.200
168	23-Feb-91 20:30:00.	23.500	23.900	26.400	25.700	24.850	24.000

169	23-Feb-91 20:40:00.	23.550	23.750	26.050	25.350	24.550	24.200
170	23-Feb-91 20:50:00.	23.450	23.650	25.700	25.100	24.350	24.250
171	23-Feb-91 21:00:00.	23.500	23.550	25.400	24.900	24.200	24.250
172	23-Feb-91 21:10:00.	23.000	23.300	25.150	24.650	24.000	23.850
173	23-Feb-91 21:20:00.	23.050	23.200	24.900	24.400	23.800	23.700
174	23-Feb-91 21:30:00.	23.350	23.200	24.600	24.200	23.600	23.800
175	23-Feb-91 21:40:00.	23.150	23.150	24.400	24.050	23.500	23.950
176	23-Feb-91 21:50:00.	23.600	23.350	24.200	23.900	23.400	24.200
177	23-Feb-91 22:00:00.	23.250	23.150	24.050	23.750	23.350	23.850
178	23-Feb-91 22:10:00.	22.900	22.950	23.900	23.600	23.200	23.600
179	23-Feb-91 22:20:00.	22.750	22.800	23.700	23.450	23.000	23.350
180	23-Feb-91 22:30:00.	22.550	22.550	23.550	23.350	22.850	23.000
181	23-Feb-91 22:40:00.	21.850	22.250	23.400	23.150	22.650	22.700
182	23-Feb-91 22:50:00.	21.950	22.150	23.250	22.950	22.450	22.550
183	23-Feb-91 23:00:00.	22.200	22.100	23.050	22.850	22.300	22.450
184	23-Feb-91 23:10:00.	22.200	22.100	22.900	22.750	22.300	22.400
185	23-Feb-91 23:20:00.	21.800	21.900	22.800	22.700	22.250	22.250
186	23-Feb-91 23:30:00.	21.750	21.750	22.700	22.550	22.100	22.100
187	23-Feb-91 23:40:00.	21.100	21.400	22.550	22.400	21.900	21.350
188	23-Feb-91 23:50:00.	20.700	21.100	22.350	22.250	21.700	21.100
189	24-Feb-91 00:00:00.	20.700	20.800	22.150	22.050	21.500	21.000
190	24-Feb-91 00:10:00.	20.550	20.650	22.000	21.900	21.300	20.850
191	24-Feb-91 00:20:00.	20.350	20.450	21.800	21.750	21.150	20.650
192	24-Feb-91 00:30:00.	20.150	20.300	21.650	21.600	20.950	20.500
193	24-Feb-91 00:40:00.	20.100	20.100	21.500	21.450	20.800	20.400
194	24-Feb-91 00:50:00.	20.050	20.000	21.300	21.250	20.600	20.400
195	24-Feb-91 01:00:00.	20.450	19.950	21.150	21.100	20.450	20.850
196	24-Feb-91 01:10:00.	21.050	20.150	20.950	20.900	20.300	21.400
197	24-Feb-91 01:20:00.	20.050	19.950	20.800	20.800	20.200	20.600
198	24-Feb-91 01:30:00.	20.000	19.800	20.700	20.650	20.050	20.500
199	24-Feb-91 01:40:00.	19.900	19.700	20.500	20.500	19.900	20.400
200	24-Feb-91 01:50:00.	20.200	19.700	20.400	20.350	19.800	20.500
201	24-Feb-91 02:00:00.	19.650	19.600	20.300	20.250	19.700	20.000
202	24-Feb-91 02:10:00.	19.500	19.450	20.150	20.150	19.650	19.750
203	24-Feb-91 02:20:00.	19.600	19.350	20.050	20.050	19.500	19.800
204	24-Feb-91 02:30:00.	19.300	19.200	19.950	19.950	19.400	19.650
205	24-Feb-91 02:40:00.	19.300	19.100	19.800	19.800	19.250	19.650
206	24-Feb-91 02:50:00.	19.500	19.050	19.700	19.700	19.150	19.600
207	24-Feb-91 03:00:00.	20.350	19.300	19.600	19.600	19.050	20.500
208	24-Feb-91 03:10:00.	19.300	19.100	19.500	19.550	19.050	19.750
209	4-Feb-91 03:20:00.	18.250	18.650	19.450	19.450	18.900	18.750
210	24-Feb-91 03:30:00.	18.750	18.550	19.300	19.300	18.700	19.100
211	24-Feb-91 03:40:00.	16.700	18.200	19.150	19.100	18.500	17.950
212	24-Feb-91 03:50:00.	15.850	17.850	19.000	18.950	18.250	17.850
213	24-Feb-91 04:00:00.	16.200	17.500	18.800	18.750	17.950	17.450
214	24-Feb-91 04:10:00.	16.250	17.300	18.600	18.500	17.700	17.550
215	24-Feb-91 04:20:00.	16.750	17.100	18.400	18.300	17.500	17.450
216	24-Feb-91 04:30:00.	17.750	17.150	18.250	18.100	17.350	18.000
217	24-Feb-91 04:40:00.	18.150	17.350	18.050	18.000	17.300	18.350
218	24-Feb-91 04:50:00.	18.000	17.400	17.900	17.950	17.300	18.250
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225	24-Feb-91 06:00:00.	17.800	17.400	17.400	17.700	17.200	17.950
226	24-Feb-91 06:10:00.	17.550	17.350	17.350	17.700	17.200	17.750
227	24-Feb-91 06:20:00.	17.650	17.400	17.350	17.700	17.200	17.750
228	24-Feb-91 06:30:00.	17.750	17.450	17.350	17.650	17.150	17.850
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232	24-Feb-91 07:10:00.	21.850	18.800	17.550	18.000	17.950	18.950
233	24-Feb-91 07:20:00.	22.900	19.200	17.700	18.150	18.250	19.300
234	24-Feb-91 07:30:00.	23.550	19.600	17.900	18.350	18.650	19.600
235	24-Feb-91 07:40:00.	24.000	20.050	18.150	18.600	18.950	19.850
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248	24-Feb-91 09:50:00.	30.150	26.900	23.100	22.750	24.400	25.550
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254	24-Feb-91 10:50:00.	32.550	30.300	26.300	25.350	27.500	27.550
255	24-Feb-91 11:00:00.	35.750	31.200	26.800	25.800	27.950	27.550
256	24-Feb-91 11:10:00.	38.250	31.400	27.350	26.200	28.400	27.800
257	24-Feb-91 11:20:00.	35.450	31.950	27.850	26.650	28.800	28.000
258	24-Feb-91 11:30:00.	37.650	32.650	28.300	27.050	29.200	28.350
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264	24-Feb-91 12:30:00.	33.900	35.100	30.900	29.100	31.050	29.300
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272	24-Feb-91 13:50:00.	34.300	36.900	33.400	31.450	33.150	30.500
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274	24-Feb-91 14:10:00.	33.800	37.400	33.900	32.050	33.700	30.450
275	24-Feb-91 14:20:00.	33.450	37.650	34.150	32.300	33.900	31.250
276	24-Feb-91 14:30:00.	34.400	38.200	34.400	32.550	34.300	30.800
277	24-Feb-91 14:40:00.	35.950	38.550	34.650	32.850	34.600	31.250
278	24-Feb-91 14:50:00.	36.300	38.150	34.950	33.150	34.850	31.400
279	24-Feb-91 15:00:00.	35.450	37.650	35.200	33.450	35.150	31.200
280	24-Feb-91 15:10:00.	34.300	37.800	35.350	33.700	35.100	31.100
281	24-Feb-91 15:20:00.	35.450	37.700	35.500	33.850	34.950	31.650
282	24-Feb-91 15:30:00.	34.950	38.150	35.600	34.000	35.150	31.300
283	24-Feb-91 15:40:00.	33.200	36.950	35.700	34.150	35.200	31.100
284	24-Feb-91 15:50:00.	31.900	35.850	35.650	34.150	34.750	30.800
285	24-Feb-91 16:00:00.	31.450	35.000	35.500	34.050	34.350	30.500
286	24-Feb-91 16:10:00.	31.300	34.500	35.300	33.850	33.850	30.450
287	24-Feb-91 16:20:00.	33.100	35.150	35.050	33.650	33.650	31.350
288	24-Feb-91 16:30:00.	33.450	35.700	34.950	33.650	34.150	31.450
289	24-Feb-91 16:40:00.	33.850	36.350	34.950	33.700	34.500	31.000
290	24-Feb-91 16:50:00.	33.850	36.350	34.950	33.800	34.600	31.300
291	24-Feb-91 17:00:00.	31.950	35.750	34.950	33.850	34.500	30.950
292	24-Feb-91 17:10:00.	32.250	35.350	34.900	33.750	34.000	30.550
293	24-Feb-91 17:20:00.	31.450	34.750	34.750	33.550	33.450	30.600

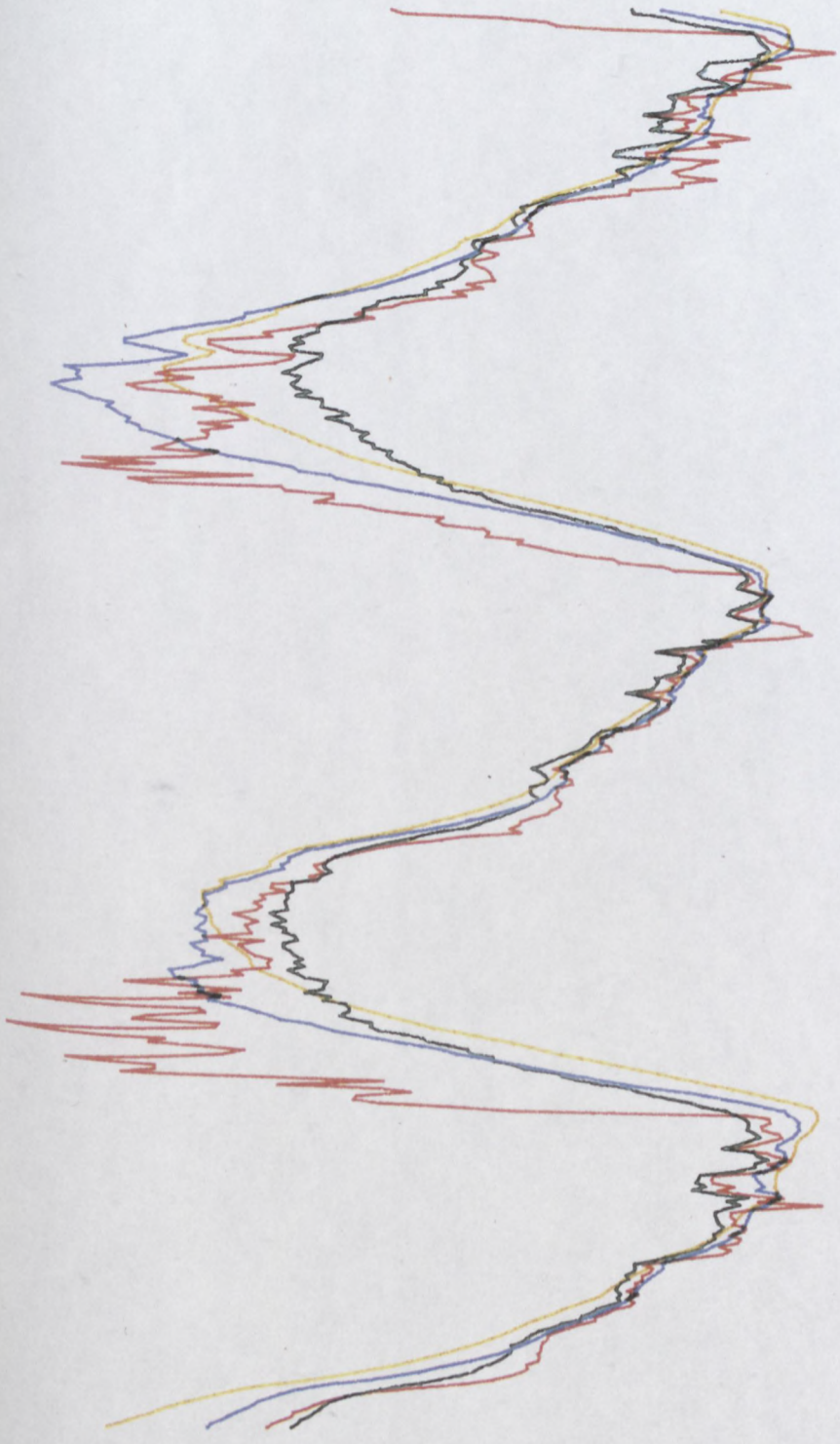
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296	24-Feb-91 17:50:00.	28.900	32.800	33.950	32.700	32.200	29.200
297	24-Feb-91 18:00:00.	29.500	32.750	33.650	32.450	31.850	29.200
298	24-Feb-91 18:10:00.	29.150	32.050	33.350	32.200	31.850	29.200
299	24-Feb-91 18:20:00.	28.350	31.650	33.100	31.900	31.500	28.800
300	24-Feb-91 18:30:00.	28.050	31.150	32.750	31.650	31.150	28.750
301	24-Feb-91 18:40:00.	27.300	30.600	32.400	31.350	30.700	28.250
302	24-Feb-91 18:50:00.	26.150	29.900	32.050	31.000	30.300	27.300
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304	24-Feb-91 19:10:00.	25.650	28.850	31.300	30.300	29.500	26.800
305	24-Feb-91 19:20:00.	26.150	28.500	30.900	29.900	29.100	27.000
306	24-Feb-91 19:30:00.	25.300	28.100	30.500	29.550	28.700	26.500
307	24-Feb-91 19:40:00.	25.400	27.750	30.100	29.200	28.350	26.350
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309	24-Feb-91 20:00:00.	25.600	27.100	29.350	28.550	27.850	26.100
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312	24-Feb-91 20:30:00.	25.400	26.200	28.350	27.700	27.100	25.950
313	24-Feb-91 20:40:00.	25.200	25.950	28.100	27.500	26.850	25.700
314	24-Feb-91 20:50:00.	25.750	25.750	27.750	27.200	26.600	25.850
315	24-Feb-91 21:00:00.	25.650	25.700	27.500	27.000	26.400	25.950
316	24-Feb-91 21:10:00.	25.600	25.550	27.300	26.850	26.350	25.900
317	24-Feb-91 21:20:00.	24.850	25.250	27.050	26.650	26.150	25.350
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322	24-Feb-91 22:10:00.	24.450	24.300	25.800	25.500	24.950	24.750
323	24-Feb-91 22:20:00.	24.250	24.200	25.600	25.300	24.800	24.650
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325	24-Feb-91 22:40:00.	24.050	23.950	25.200	24.950	24.450	24.500
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329	24-Feb-91 23:20:00.	21.250	22.850	24.400	24.150	23.500	22.800
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332	24-Feb-91 23:50:00.	19.700	21.700	23.650	23.300	22.400	21.750
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334	25-Feb-91 00:10:00.	19.800	21.150	23.000	22.650	21.700	21.400
335	25-Feb-91 00:20:00.	20.000	20.900	22.700	22.350	21.500	21.650
336	25-Feb-91 00:30:00.	19.450	20.700	22.450	22.100	21.250	21.250
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339	25-Feb-91 01:00:00.	20.800	20.300	21.600	21.350	20.500	21.750
340	25-Feb-91 01:10:00.	20.800	20.150	21.400	21.200	20.450	21.650
341	25-Feb-91 01:20:00.	19.800	19.950	21.250	21.000	20.350	21.200
342	25-Feb-91 01:30:00.	18.600	19.650	21.000	20.800	20.100	20.450
343	25-Feb-91 01:40:00.	18.950	19.450	20.800	20.600	19.850	19.850
344	25-Feb-91 01:50:00.	17.700	19.150	20.600	20.400	19.650	19.550
345	25-Feb-91 02:00:00.	18.500	18.950	20.350	20.200	19.450	19.450
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347	25-Feb-91 02:20:00.	19.550	18.900	20.000	19.900	19.200	20.300
348	25-Feb-91 02:30:00.	19.650	18.850	19.800	19.750	19.100	20.400
349	25-Feb-91 02:40:00.	19.350	18.800	19.650	19.650	18.950	20.000
350	25-Feb-91 02:50:00.	20.700	19.250	19.550	19.500	18.850	20.850
351	25-Feb-91 03:00:00.	19.650	19.050	19.450	19.450	18.900	20.050
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354	25-Feb-91 03:30:00.	19.550	19.000	19.200	19.300	18.750	19.900
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356	25-Feb-91 03:50:00.	18.100	18.650	19.050	19.100	18.550	19.550

357	25-Feb-91 04:00:00.	18.250	18.350	18.950	19.000	18.350	19.250
358	25-Feb-91 04:10:00.	16.450	18.000	18.850	18.800	18.150	18.300
359	25-Feb-91 04:20:00.	17.300	17.850	18.700	18.650	17.900	18.600
360	25-Feb-91 04:30:00.	18.550	17.850	18.550	18.500	17.700	19.100
361	25-Feb-91 04:40:00.	18.350	17.800	18.400	18.350	17.650	19.250
362	25-Feb-91 04:50:00.	17.900	17.800	18.250	18.250	17.600	19.050
363	25-Feb-91 05:00:00.	16.750	17.550	18.150	18.150	17.550	19.000
364	25-Feb-91 05:10:00.	17.650	17.300	18.050	18.000	17.350	18.900
365	25-Feb-91 05:20:00.	16.800	17.000	17.900	17.900	17.300	17.400
366	25-Feb-91 05:30:00.	16.250	16.850	17.750	17.800	17.150	17.400
367	25-Feb-91 05:40:00.	15.150	16.550	17.650	17.650	16.950	17.050
368	25-Feb-91 05:50:00.	16.500	16.400	17.450	17.500	16.750	17.150
369	25-Feb-91 06:00:00.	16.900	16.400	17.300	17.350	16.600	17.300
370	25-Feb-91 06:10:00.	17.150	16.450	17.200	17.250	16.500	17.400
371	25-Feb-91 06:20:00.	17.250	16.500	17.050	17.200	16.500	17.450
372	25-Feb-91 06:30:00.	17.600	16.750	16.950	17.150	16.500	17.600
373	25-Feb-91 06:40:00.	21.900	17.050	16.900	17.100	16.500	18.600
374	25-Feb-91 06:50:00.	23.500	17.650	16.900	17.100	16.650	19.300
375	25-Feb-91 07:00:00.	23.850	18.350	17.000	17.250	17.050	19.900
376	25-Feb-91 07:10:00.	25.150	19.050	17.100	17.450	17.550	20.250
377	25-Feb-91 07:20:00.	28.100	19.700	17.350	17.700	18.050	21.150
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Ch 1 Ch Ch 5 Ch 6

degC

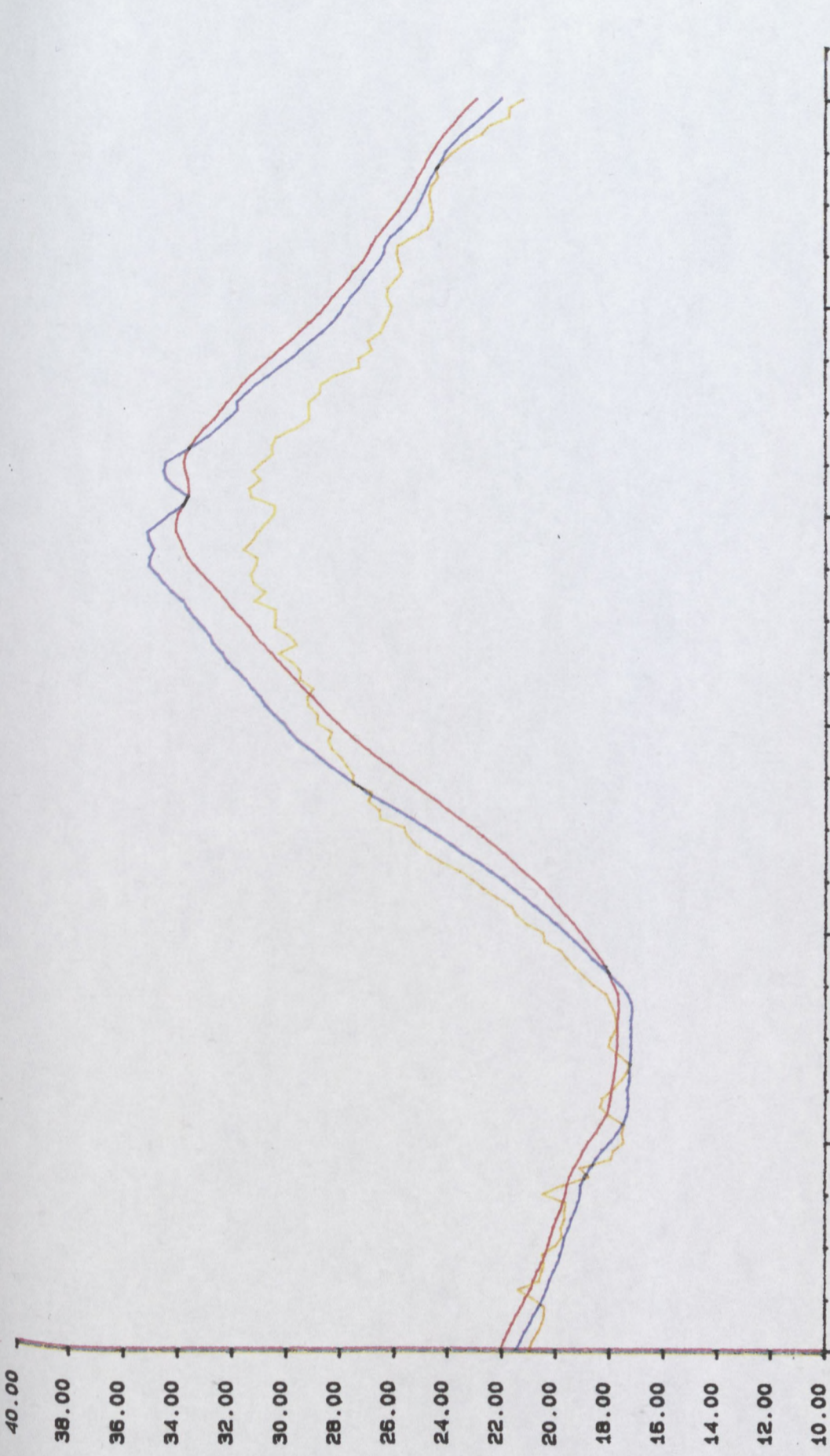
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12: 00: 00. 22-Feb-91  
24: 00: 00.  
12: 00: 00.  
00: 00: 00. 24-Feb-91  
12: 00: 00.  
00: 00: 00.  
12: 00: 00.  
12: 00: 00. 25-Feb-91

degC

Ch 4 Ch 5 Ch 6



00: 00: 00. 04: 00: 00. 08: 00: 00. 12: 00: 00. 16: 00: 00. 20: 00: 00. 24: 00: 00.  
24-Feb-91

## APPENDIX 3.6.2

### ON SITE CONTAINER TEMPERATURE READINGS

File 14  
100 Watt Heat Load  
No Cooling  
Container on site

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level

## Channel Readings

Data file - FILE14

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

Run number : 1  
Channels used : 6  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 01-Mar-91 16:00:00.  
    Finish : 04-Mar-91 07:30:01.

Readings per channel: 382

All readings

Rdg no:	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC
0	01-Mar-91 16:00:00.	25.200	25.950	30.650	33.850	34.750	25.700
1	01-Mar-91 16:10:00.	25.350	26.100	31.550	34.500	36.300	25.550
2	01-Mar-91 16:20:00.	25.700	26.250	32.450	35.100	37.200	25.750
3	01-Mar-91 16:30:00.	26.350	26.500	33.200	35.750	37.900	26.200
4	01-Mar-91 16:40:00.	26.850	26.900	33.900	36.300	38.500	26.600
5	01-Mar-91 16:50:00.	26.700	26.950	34.600	36.800	38.950	26.250
6	01-Mar-91 17:00:00.	27.250	27.400	35.250	37.400	39.500	27.000
7	01-Mar-91 17:10:00.	27.200	27.600	35.800	37.900	40.000	26.800
8	01-Mar-91 17:20:00.	27.850	28.100	36.300	38.300	40.500	27.350
9	01-Mar-91 17:30:00.	27.850	28.400	36.850	38.850	41.200	27.350
10	01-Mar-91 17:40:00.	27.900	28.650	37.400	39.400	41.700	27.500
11	01-Mar-91 17:50:00.	27.200	28.600	37.900	39.850	42.150	27.200
12	01-Mar-91 18:00:00.	27.050	28.500	38.250	40.150	42.300	27.150
13	01-Mar-91 18:10:00.	26.850	28.450	38.550	40.450	42.450	27.050
14	01-Mar-91 18:20:00.	26.500	28.350	38.800	40.650	42.550	26.800
15	01-Mar-91 18:30:00.	26.050	28.150	39.000	40.850	42.600	26.500
16	01-Mar-91 18:40:00.	25.800	28.000	39.200	40.950	42.550	26.500
17	01-Mar-91 18:50:00.	25.950	27.950	39.300	41.000	42.550	26.750
18	01-Mar-91 19:00:00.	25.750	27.600	39.400	41.100	42.550	26.400
19	01-Mar-91 19:10:00.	25.200	27.350	39.450	41.150	42.700	26.050
20	01-Mar-91 19:20:00.	24.400	27.300	39.500	41.200	42.750	25.150
21	01-Mar-91 19:30:00.	24.550	27.100	39.500	41.200	42.650	24.900
22	01-Mar-91 19:40:00.	23.700	27.050	39.500	41.150	42.600	24.200
23	01-Mar-91 19:50:00.	23.000	26.900	39.500	41.100	42.450	24.200
24	01-Mar-91 20:00:00.	22.650	26.450	39.400	41.000	42.200	24.050
25	01-Mar-91 20:10:00.	22.300	26.200	39.300	40.900	42.050	23.550
26	01-Mar-91 20:20:00.	21.600	25.900	39.200	40.800	41.900	23.250
27	01-Mar-91 20:30:00.	20.550	25.450	39.000	40.650	41.700	22.650
28	01-Mar-91 20:40:00.	20.150	25.200	38.800	40.500	41.450	21.850
29	01-Mar-91 20:50:00.	20.600	24.900	38.650	40.350	41.250	22.050
30	01-Mar-91 21:00:00.	19.800	24.650	38.450	40.150	41.100	21.150
31	01-Mar-91 21:10:00.	20.300	24.050	38.300	40.000	40.950	21.550
32	01-Mar-91 21:20:00.	19.500	23.850	38.100	39.850	40.800	20.350
33	01-Mar-91 21:30:00.	19.600	23.700	37.900	39.700	40.600	21.100
34	01-Mar-91 21:40:00.	19.300	23.650	37.700	39.500	40.400	20.750

35	01-Mar-91 21:50:00.	19.950	23.650	37.550	39.400	40.250	21.050
36	01-Mar-91 22:00:00.	20.500	23.650	37.400	39.350	40.250	21.200
37	01-Mar-91 22:10:00.	20.800	23.500	37.300	39.300	40.300	21.050
38	01-Mar-91 22:20:00.	21.450	23.550	37.200	39.300	40.350	21.700
39	01-Mar-91 22:30:00.	21.450	23.550	37.200	39.350	40.400	21.800
40	01-Mar-91 22:40:00.	21.300	23.600	37.150	39.350	40.500	22.050
41	01-Mar-91 22:50:00.	21.550	23.650	37.150	39.400	40.500	22.300
42	01-Mar-91 23:00:00.	20.850	23.650	37.150	39.400	40.500	21.750
43	01-Mar-91 23:10:00.	20.900	23.350	37.100	39.350	40.400	21.500
44	01-Mar-91 23:20:00.	20.900	23.200	37.050	39.300	40.350	21.850
45	01-Mar-91 23:30:00.	20.250	23.100	37.000	39.250	40.300	21.350
46	01-Mar-91 23:40:00.	19.400	23.000	36.900	39.100	40.100	20.750
47	01-Mar-91 23:50:00.	18.950	22.800	36.800	38.950	39.850	20.150
48	01-Mar-91 24:00:00.	19.900	22.400	36.650	38.850	39.700	20.600
49	02-Mar-91 00:10:00.	20.200	22.350	36.500	38.750	39.650	20.900
50	02-Mar-91 00:20:00.	20.800	22.200	36.400	38.700	39.600	21.200
51	02-Mar-91 00:30:00.	20.700	22.150	36.300	38.700	39.700	20.750
52	02-Mar-91 00:40:00.	21.100	22.350	36.250	38.700	39.650	21.250
53	02-Mar-91 00:50:00.	20.600	22.200	36.200	38.700	39.700	20.600
54	02-Mar-91 01:00:00.	20.500	22.100	36.200	38.700	39.700	20.550
55	02-Mar-91 01:10:00.	20.350	21.850	36.150	38.700	39.650	20.350
56	02-Mar-91 01:20:00.	20.150	21.600	36.050	38.650	39.550	20.150
57	02-Mar-91 01:30:00.	19.900	21.450	36.000	38.650	39.550	19.900
58	02-Mar-91 01:40:00.	19.800	21.300	35.900	38.550	39.450	19.850
59	02-Mar-91 01:50:00.	19.700	21.150	35.800	38.500	39.300	19.750
60	02-Mar-91 02:00:00.	19.600	21.050	35.700	38.400	39.200	19.800
61	02-Mar-91 02:10:00.	19.450	20.900	35.600	38.300	39.100	19.600
62	02-Mar-91 02:20:00.	19.150	20.750	35.500	38.250	39.000	19.400
63	02-Mar-91 02:30:00.	18.900	20.650	35.450	38.150	38.900	19.300
64	02-Mar-91 02:40:00.	19.050	20.550	35.300	38.050	38.700	19.400
65	02-Mar-91 02:50:00.	18.900	20.450	35.200	37.950	38.650	19.200
66	02-Mar-91 03:00:00.	18.700	20.400	35.100	37.850	38.600	19.150
67	02-Mar-91 03:10:00.	18.600	20.300	35.000	37.800	38.550	19.100
68	02-Mar-91 03:20:00.	18.350	20.150	34.900	37.650	38.400	18.850
69	02-Mar-91 03:30:00.	18.150	20.000	34.800	37.550	38.300	18.600
70	02-Mar-91 03:40:00.	17.950	19.900	34.700	37.450	38.150	18.450
71	02-Mar-91 03:50:00.	17.800	19.650	34.600	37.350	38.000	18.250
72	02-Mar-91 04:00:00.	17.750	19.550	34.500	37.250	37.950	18.250
73	02-Mar-91 04:10:00.	17.650	19.500	34.350	37.150	37.900	18.150
74	02-Mar-91 04:20:00.	17.650	19.300	34.200	37.050	37.700	18.000
75	02-Mar-91 04:30:00.	17.550	19.250	34.100	36.950	37.650	18.000
76	02-Mar-91 04:40:00.	17.450	19.250	34.000	36.850	37.550	17.950
77	02-Mar-91 04:50:00.	17.600	19.300	33.900	36.800	37.450	18.000
78	02-Mar-91 05:00:00.	17.650	19.350	33.850	36.750	37.450	18.050
79	02-Mar-91 05:10:00.	17.650	19.300	33.800	36.700	37.450	18.000
80	02-Mar-91 05:20:00.	17.450	19.250	33.700	36.650	37.400	17.900
81	02-Mar-91 05:30:00.	17.200	19.250	33.650	36.550	37.300	17.700
82	02-Mar-91 05:40:00.	17.300	19.200	33.600	36.450	37.200	17.800
83	02-Mar-91 05:50:00.	17.300	19.300	33.550	36.400	37.100	18.000
84	02-Mar-91 06:00:00.	17.250	19.450	33.500	36.300	37.050	18.050
85	02-Mar-91 06:10:00.	17.450	19.650	33.450	36.250	37.050	18.100
86	02-Mar-91 06:20:00.	17.600	20.000	33.450	36.200	37.000	18.200
87	02-Mar-91 06:30:00.	18.300	20.350	33.450	36.200	37.000	18.400
88	02-Mar-91 06:40:00.	20.050	20.750	33.500	36.250	37.100	18.750
89	02-Mar-91 06:50:00.	20.600	21.150	33.600	36.350	37.250	19.000
90	02-Mar-91 07:00:00.	19.900	21.450	33.700	36.450	37.400	19.050
91	02-Mar-91 07:10:00.	20.200	21.650	33.800	36.500	37.450	19.050
92	02-Mar-91 07:20:00.	20.400	21.950	34.000	36.650	37.600	19.200
93	02-Mar-91 07:30:00.	21.150	22.200	34.100	36.700	37.700	19.400
94	02-Mar-91 07:40:00.	27.150	22.800	34.250	36.800	37.800	19.900
95	02-Mar-91 07:50:00.	32.350	23.450	34.500	36.950	38.150	20.550

96	02-Mar-91 08:00:00.	34.250	24.000	34.750	37.300	38.700	20.250
97	02-Mar-91 08:10:00.	34.750	24.550	35.100	37.600	39.150	20.850
98	02-Mar-91 08:20:00.	34.900	25.150	35.500	37.900	39.600	21.450
99	02-Mar-91 08:30:00.	34.500	25.650	35.850	38.250	40.100	21.850
100	02-Mar-91 08:40:00.	36.000	26.500	36.300	38.650	40.650	22.050
101	02-Mar-91 08:50:00.	35.450	27.200	36.800	39.000	41.050	22.050
102	02-Mar-91 09:00:00.	36.550	27.750	37.250	39.450	41.600	22.700
103	02-Mar-91 09:10:00.	38.150	28.450	37.800	39.850	42.100	23.700
104	02-Mar-91 09:20:00.	40.850	29.050	38.300	40.300	42.750	23.050
105	02-Mar-91 09:30:00.	39.100	29.850	38.850	40.800	43.300	23.450
106	02-Mar-91 09:40:00.	37.300	30.400	39.400	41.250	43.750	23.800
107	02-Mar-91 09:50:00.	38.050	31.100	39.900	41.600	44.150	24.450
108	02-Mar-91 10:00:00.	39.500	31.550	40.450	42.050	44.650	24.800
109	02-Mar-91 10:10:00.	39.100	32.100	40.950	42.450	45.050	24.950
110	02-Mar-91 10:20:00.	40.050	32.300	41.400	42.850	45.450	25.400
111	02-Mar-91 10:30:00.	41.500	32.450	41.850	43.200	45.800	25.150
112	02-Mar-91 10:40:00.	39.900	32.800	42.300	43.550	46.200	25.800
113	02-Mar-91 10:50:00.	36.750	33.200	42.750	43.900	46.650	25.400
114	02-Mar-91 11:00:00.	39.900	33.350	43.200	44.300	47.000	26.850
115	02-Mar-91 11:10:00.	37.150	33.550	43.500	44.600	47.150	26.850
116	02-Mar-91 11:20:00.	36.550	34.000	43.800	44.800	47.300	26.600
117	02-Mar-91 11:30:00.	36.500	34.350	44.100	45.150	47.700	27.400
118	02-Mar-91 11:40:00.	38.300	35.000	44.500	45.500	48.200	27.750
119	02-Mar-91 11:50:00.	38.150	35.350	44.900	45.850	48.550	28.050
120	02-Mar-91 12:00:00.	36.650	35.900	45.250	46.200	48.800	27.750
121	02-Mar-91 12:10:00.	36.950	35.150	45.600	46.500	49.150	28.750
122	02-Mar-91 12:20:00.	36.050	34.550	45.900	46.750	49.300	28.450
123	02-Mar-91 12:30:00.	34.750	35.350	46.050	46.900	49.200	29.000
124	02-Mar-91 12:40:00.	34.750	35.000	46.250	47.100	49.450	28.950
125	02-Mar-91 12:50:00.	34.950	34.950	46.450	47.300	49.550	29.200
126	02-Mar-91 13:00:00.	34.600	35.200	46.500	47.450	49.550	29.600
127	02-Mar-91 13:10:00.	35.200	34.800	46.650	47.650	49.800	29.550
128	02-Mar-91 13:20:00.	35.000	34.950	46.750	47.800	49.900	29.850
129	02-Mar-91 13:30:00.	34.650	35.350	46.900	47.950	50.000	29.500
130	02-Mar-91 13:40:00.	35.200	35.000	47.000	48.200	50.250	29.600
131	02-Mar-91 13:50:00.	34.750	35.200	47.100	48.300	50.250	29.350
132	02-Mar-91 14:00:00.	34.500	35.600	47.200	48.400	50.300	29.750
133	02-Mar-91 14:10:00.	34.150	35.800	47.300	48.450	50.300	29.800
134	02-Mar-91 14:20:00.	34.400	35.900	47.400	48.650	50.550	29.950
135	02-Mar-91 14:30:00.	34.300	34.800	47.550	48.800	50.650	29.850
136	02-Mar-91 14:40:00.	34.150	35.550	47.550	48.900	50.750	29.700
137	02-Mar-91 14:50:00.	34.450	35.550	47.650	49.150	50.950	29.850
138	02-Mar-91 15:00:00.	34.150	36.050	47.750	49.150	50.950	30.100
139	02-Mar-91 15:10:00.	33.850	36.000	47.800	49.300	51.000	29.900
140	02-Mar-91 15:20:00.	33.950	35.450	47.900	49.450	51.050	30.100
141	02-Mar-91 15:30:00.	33.700	35.650	47.950	49.500	51.150	30.500
142	02-Mar-91 15:40:00.	33.150	35.800	47.950	49.500	50.950	30.200
143	02-Mar-91 15:50:00.	33.100	35.150	47.950	49.550	50.950	30.050
144	02-Mar-91 16:00:00.	33.300	35.100	48.000	49.650	51.150	30.200
145	02-Mar-91 16:10:00.	32.550	35.500	48.000	49.650	51.050	29.550
146	02-Mar-91 16:20:00.	32.550	34.950	48.000	49.700	51.100	29.900
147	02-Mar-91 16:30:00.	32.200	35.350	47.950	49.650	51.000	29.900
148	02-Mar-91 16:40:00.	32.050	35.250	47.950	49.650	51.000	29.850
149	02-Mar-91 16:50:00.	31.900	35.200	47.950	49.650	51.000	29.550
150	02-Mar-91 17:00:00.	31.400	35.150	47.900	49.600	50.950	29.350
151	02-Mar-91 17:10:00.	31.050	35.000	47.850	49.500	50.750	29.250
152	02-Mar-91 17:20:00.	30.700	34.750	47.750	49.350	50.600	29.150
153	02-Mar-91 17:30:00.	30.400	34.650	47.650	49.250	50.400	29.000
154	02-Mar-91 17:40:00.	29.900	34.550	47.550	49.100	50.250	28.750
155	02-Mar-91 17:50:00.	29.250	34.300	47.400	48.950	50.050	28.350

156	02-Mar-91 18:00:00.	27.450	33.150	47.200	48.550	49.450	26.150
157	02-Mar-91 18:10:00.	25.950	31.600	46.900	48.200	48.850	25.050
158	02-Mar-91 18:20:00.	25.050	30.800	46.500	47.850	48.350	24.450
159	02-Mar-91 18:30:00.	24.150	30.100	46.050	47.550	48.000	23.850
160	02-Mar-91 18:40:00.	23.350	29.450	45.600	47.150	47.550	23.550
161	02-Mar-91 18:50:00.	22.900	28.900	45.150	46.750	47.050	23.500
162	02-Mar-91 19:00:00.	22.450	28.650	44.650	46.350	46.600	23.450
163	02-Mar-91 19:10:00.	22.150	28.300	44.200	45.950	46.100	23.050
164	02-Mar-91 19:20:00.	21.950	28.050	43.750	45.500	45.700	23.250
165	02-Mar-91 19:30:00.	21.900	27.900	43.350	45.150	45.400	23.250
166	02-Mar-91 19:40:00.	21.850	27.700	42.950	44.850	45.100	23.150
167	02-Mar-91 19:50:00.	21.800	27.300	42.550	44.550	44.800	22.800
168	02-Mar-91 20:00:00.	21.600	27.000	42.200	44.200	44.500	22.450
169	02-Mar-91 20:10:00.	21.350	26.750	41.850	43.900	44.200	22.300
170	02-Mar-91 20:20:00.	21.200	26.600	41.500	43.650	43.900	22.050
171	02-Mar-91 20:30:00.	21.350	25.950	41.200	43.350	43.650	21.900
172	02-Mar-91 20:40:00.	21.700	25.200	40.900	43.050	43.450	22.200
173	02-Mar-91 20:50:00.	21.850	24.950	40.600	42.800	43.350	22.250
174	02-Mar-91 21:00:00.	21.800	24.750	40.300	42.600	43.200	22.250
175	02-Mar-91 21:10:00.	22.000	24.450	40.050	42.350	42.950	22.400
176	02-Mar-91 21:20:00.	21.950	24.400	39.750	42.150	42.900	22.400
177	02-Mar-91 21:30:00.	21.850	24.150	39.600	42.050	42.750	22.200
178	02-Mar-91 21:40:00.	21.600	24.050	39.400	41.900	42.600	22.000
179	02-Mar-91 21:50:00.	21.550	23.850	39.150	41.700	42.350	21.900
180	02-Mar-91 22:00:00.	21.400	23.650	38.900	41.550	42.150	21.800
181	02-Mar-91 22:10:00.	21.400	23.650	38.700	41.350	41.950	21.900
182	02-Mar-91 22:20:00.	21.550	23.600	38.550	41.150	41.750	21.950
183	02-Mar-91 22:30:00.	21.150	23.550	38.400	41.000	41.650	21.650
184	02-Mar-91 22:40:00.	21.000	23.500	38.200	40.850	41.500	21.650
185	02-Mar-91 22:50:00.	20.000	23.300	38.100	40.700	41.350	20.300
186	02-Mar-91 23:00:00.	19.200	23.300	37.950	40.450	41.100	20.000
187	02-Mar-91 23:10:00.	19.850	23.200	37.800	40.250	40.850	20.500
188	02-Mar-91 23:20:00.	19.500	23.250	37.650	40.050	40.750	20.250
189	02-Mar-91 23:30:00.	19.450	23.200	37.450	39.950	40.600	20.300
190	02-Mar-91 23:40:00.	19.900	23.000	37.350	39.800	40.500	20.450
191	02-Mar-91 23:50:00.	20.100	22.900	37.200	39.700	40.400	20.650
192	03-Mar-91 00:00:00.	20.100	22.650	37.100	39.650	40.400	20.550
193	03-Mar-91 00:10:00.	20.350	22.450	36.950	39.600	40.300	20.750
194	03-Mar-91 00:20:00.	20.400	22.400	36.900	39.500	40.300	20.850
195	03-Mar-91 00:30:00.	20.250	22.200	36.800	39.450	40.200	20.550
196	03-Mar-91 00:40:00.	19.900	21.900	36.700	39.350	40.100	20.250
197	03-Mar-91 00:50:00.	19.800	21.650	36.550	39.300	39.950	20.100
198	03-Mar-91 01:00:00.	19.450	21.450	36.450	39.200	39.850	19.800
199	03-Mar-91 01:10:00.	19.150	21.150	36.300	39.100	39.700	19.500
200	03-Mar-91 01:20:00.	19.150	21.200	36.200	38.950	39.600	19.650
201	03-Mar-91 01:30:00.	19.250	21.100	36.050	38.800	39.500	19.700
202	03-Mar-91 01:40:00.	19.100	20.900	35.900	38.700	39.400	19.500
203	03-Mar-91 01:50:00.	18.950	20.800	35.800	38.600	39.300	19.350
204	03-Mar-91 02:00:00.	19.200	20.800	35.700	38.500	39.250	19.600
205	03-Mar-91 02:10:00.	19.150	20.800	35.600	38.400	39.150	19.550
206	03-Mar-91 02:20:00.	18.900	20.700	35.500	38.300	39.000	19.300
207	03-Mar-91 02:30:00.	18.600	20.650	35.450	38.250	38.950	19.050
208	03-Mar-91 02:40:00.	18.600	20.600	35.350	38.150	38.850	19.000
209	03-Mar-91 02:50:00.	18.450	20.500	35.250	38.050	38.800	18.900
210	03-Mar-91 03:00:00.	18.350	20.400	35.150	37.950	38.700	18.700
211	03-Mar-91 03:10:00.	18.200	20.200	35.050	37.900	38.600	18.600
212	03-Mar-91 03:20:00.	18.200	20.100	34.950	37.800	38.500	18.600
213	03-Mar-91 03:30:00.	18.350	20.100	34.850	37.700	38.450	18.750
214	03-Mar-91 03:40:00.	18.350	20.250	34.800	37.650	38.400	18.950
215	03-Mar-91 03:50:00.	18.600	20.350	34.750	37.550	38.350	19.150

216	03-Mar-91 04:00:00.	18.300	20.350	34.650	37.550	38.300	18.750
217	03-Mar-91 04:10:00.	18.150	20.350	34.650	37.450	38.250	18.800
218	03-Mar-91 04:20:00.	18.300	20.450	34.600	37.400	38.200	19.000
219	03-Mar-91 04:30:00.	18.150	20.300	34.550	37.350	38.150	18.600
220	03-Mar-91 04:40:00.	18.100	20.250	34.550	37.300	38.150	18.750
221	03-Mar-91 04:50:00.	18.150	20.350	34.500	37.300	38.100	18.800
222	03-Mar-91 05:00:00.	17.900	20.500	34.450	37.200	38.050	18.750
223	03-Mar-91 05:10:00.	17.850	20.550	34.400	37.150	37.950	18.600
224	03-Mar-91 05:20:00.	18.050	20.500	34.400	37.150	37.950	18.650
225	03-Mar-91 05:30:00.	18.000	20.400	34.400	37.100	37.950	18.500
226	03-Mar-91 05:40:00.	17.750	20.350	34.350	37.050	37.900	18.300
227	03-Mar-91 05:50:00.	17.900	20.350	34.300	37.050	37.850	18.450
228	03-Mar-91 06:00:00.	17.750	20.250	34.250	37.000	37.800	18.200
229	03-Mar-91 06:10:00.	17.700	20.250	34.250	36.950	37.800	18.050
230	03-Mar-91 06:20:00.	17.950	20.250	34.200	36.950	37.800	18.150
231	03-Mar-91 06:30:00.	18.300	20.350	34.150	36.900	37.700	18.250
232	03-Mar-91 06:40:00.	19.650	20.500	34.150	36.900	37.800	18.750
233	03-Mar-91 06:50:00.	24.550	20.900	34.150	36.900	37.700	19.200
234	03-Mar-91 07:00:00.	25.950	21.150	34.250	37.050	37.950	19.300
235	03-Mar-91 07:10:00.	28.650	21.700	34.400	37.200	38.250	20.200
236	03-Mar-91 07:20:00.	30.400	22.400	34.550	37.400	38.600	21.250
237	03-Mar-91 07:30:00.	32.050	23.150	34.800	37.650	38.950	21.850
238	03-Mar-91 07:40:00.	33.200	23.900	35.100	37.900	39.350	22.300
239	03-Mar-91 07:50:00.	35.100	24.600	35.500	38.200	39.800	22.900
240	03-Mar-91 08:00:00.	37.700	25.250	35.900	38.550	40.300	22.700
241	03-Mar-91 08:10:00.	39.850	26.250	36.300	38.900	40.850	24.050
242	03-Mar-91 08:20:00.	41.150	27.200	36.850	39.350	41.400	23.450
243	03-Mar-91 08:30:00.	40.950	28.050	37.400	39.800	42.000	23.700
244	03-Mar-91 08:40:00.	40.150	28.700	37.900	40.150	42.400	23.950
245	03-Mar-91 08:50:00.	42.400	29.500	38.400	40.600	42.900	24.400
246	03-Mar-91 09:00:00.	42.050	30.200	38.950	41.050	43.450	24.550
247	03-Mar-91 09:10:00.	38.900	30.700	39.500	41.500	43.900	24.850
248	03-Mar-91 09:20:00.	43.050	31.500	40.050	41.850	44.300	25.100
249	03-Mar-91 09:30:00.	42.600	32.050	40.600	42.300	44.750	25.650
250	03-Mar-91 09:40:00.	39.600	32.500	41.100	42.750	45.200	26.250
251	03-Mar-91 09:50:00.	38.800	32.900	41.600	43.100	45.600	26.300
252	03-Mar-91 10:00:00.	41.900	33.550	42.050	43.500	46.000	26.650
253	03-Mar-91 10:10:00.	40.550	33.900	42.550	43.850	46.450	26.800
254	03-Mar-91 10:20:00.	39.850	34.300	43.050	44.250	46.850	27.050
255	03-Mar-91 10:30:00.	41.250	34.500	43.450	44.650	47.200	27.400
256	03-Mar-91 10:40:00.	41.150	34.800	43.850	45.050	47.650	27.700
257	03-Mar-91 10:50:00.	40.950	34.750	44.250	45.400	47.950	28.050
258	03-Mar-91 11:00:00.	39.750	34.700	44.650	45.750	48.300	28.250
259	03-Mar-91 11:10:00.	38.200	35.300	45.000	46.050	48.500	28.350
260	03-Mar-91 11:20:00.	37.550	35.500	45.300	46.350	48.700	28.350
261	03-Mar-91 11:30:00.	37.800	35.800	45.600	46.600	48.850	28.750
262	03-Mar-91 11:40:00.	37.200	36.150	45.800	46.750	48.900	29.100
263	03-Mar-91 11:50:00.	37.050	36.350	46.050	46.900	49.000	28.650
264	03-Mar-91 12:00:00.	36.650	36.550	46.250	47.100	49.200	29.450
265	03-Mar-91 12:10:00.	35.700	36.900	46.500	47.300	49.500	29.200
266	03-Mar-91 12:20:00.	36.200	37.000	46.800	47.600	49.900	29.150
267	03-Mar-91 12:30:00.	35.600	36.900	47.050	47.800	50.050	29.500
268	03-Mar-91 12:40:00.	35.300	37.100	47.250	48.100	50.400	29.650
269	03-Mar-91 12:50:00.	34.950	37.250	47.400	48.100	50.100	30.100
270	03-Mar-91 13:00:00.	36.250	37.700	47.550	48.300	50.450	30.850
271	03-Mar-91 13:10:00.	35.650	37.700	47.750	48.450	50.500	30.450
272	03-Mar-91 13:20:00.	35.700	37.900	47.850	48.550	50.500	30.800
273	03-Mar-91 13:30:00.	33.650	36.900	47.950	48.600	50.500	29.600
274	03-Mar-91 13:40:00.	34.600	37.300	48.000	48.750	50.600	29.750
275	03-Mar-91 13:50:00.	34.100	37.200	48.050	48.800	50.600	29.700
276	03-Mar-91 14:00:00.	33.600	36.400	48.050	48.850	50.600	29.650

277	03-Mar-91 14:10:00.	32.500	36.000	48.000	48.800	50.500	29.300
278	03-Mar-91 14:20:00.	34.000	36.300	47.950	48.800	50.450	30.350
279	03-Mar-91 14:30:00.	35.350	37.000	47.950	48.850	50.600	31.050
280	03-Mar-91 14:40:00.	32.700	36.150	47.950	48.800	50.500	29.450
281	03-Mar-91 14:50:00.	35.650	37.150	47.950	49.000	50.700	31.250
282	03-Mar-91 15:00:00.	34.400	37.300	48.100	49.250	51.250	30.800
283	03-Mar-91 15:10:00.	34.800	37.450	48.150	49.250	51.000	31.000
284	03-Mar-91 15:20:00.	34.300	37.200	48.250	49.450	51.350	30.450
285	03-Mar-91 15:30:00.	31.900	36.200	48.300	49.500	51.200	29.600
286	03-Mar-91 15:40:00.	31.450	35.250	48.200	49.400	50.700	29.450
287	03-Mar-91 15:50:00.	30.950	34.300	48.050	49.250	50.450	29.250
288	03-Mar-91 16:00:00.	28.900	31.950	47.750	48.950	49.850	27.550
289	03-Mar-91 16:10:00.	22.800	29.300	47.300	48.100	48.450	22.400
290	03-Mar-91 16:20:00.	23.050	28.200	46.500	47.300	47.100	24.050
291	03-Mar-91 16:30:00.	20.950	27.650	45.800	46.850	46.850	21.250
292	03-Mar-91 16:40:00.	21.050	25.950	45.000	45.850	45.650	20.600
293	03-Mar-91 16:50:00.	20.700	24.400	44.200	45.150	45.050	20.000
294	03-Mar-91 17:00:00.	20.600	23.450	43.400	44.650	44.800	19.750
295	03-Mar-91 17:10:00.	20.300	22.650	42.600	44.150	44.250	19.450
296	03-Mar-91 17:20:00.	19.150	21.950	41.800	43.600	43.700	19.400
297	03-Mar-91 17:30:00.	18.800	20.600	41.100	43.100	43.250	19.600
298	03-Mar-91 17:40:00.	18.250	20.150	40.400	42.600	42.650	19.000
299	03-Mar-91 17:50:00.	17.900	19.650	39.700	42.100	42.050	18.700
300	03-Mar-91 18:00:00.	18.000	19.500	39.000	41.700	41.700	18.600
301	03-Mar-91 18:10:00.	17.750	19.350	38.450	41.250	41.250	18.350
302	03-Mar-91 18:20:00.	17.800	19.450	37.950	40.850	40.950	18.400
303	03-Mar-91 18:30:00.	18.000	19.750	37.500	40.450	40.600	18.450
304	03-Mar-91 18:40:00.	18.100	20.000	37.150	40.150	40.350	18.400
305	03-Mar-91 18:50:00.	18.350	20.400	36.850	39.850	40.150	18.600
306	03-Mar-91 19:00:00.	18.650	20.750	36.600	39.600	39.950	18.550
307	03-Mar-91 19:10:00.	18.050	20.700	36.450	39.500	39.850	18.350
308	03-Mar-91 19:20:00.	17.850	20.400	36.250	39.250	39.700	18.150
309	03-Mar-91 19:30:00.	17.700	20.350	36.100	39.100	39.500	18.050
310	03-Mar-91 19:40:00.	17.900	20.600	35.950	38.950	39.400	18.250
311	03-Mar-91 19:50:00.	17.700	20.350	35.800	38.800	39.300	18.100
312	03-Mar-91 20:00:00.	17.600	20.100	35.700	38.650	39.100	18.000
313	03-Mar-91 20:10:00.	17.550	20.100	35.550	38.550	39.000	18.050
314	03-Mar-91 20:20:00.	17.300	20.050	35.450	38.450	38.900	18.050
315	03-Mar-91 20:30:00.	17.350	20.000	35.250	38.300	38.700	18.250
316	03-Mar-91 20:40:00.	17.550	19.900	35.100	38.150	38.550	18.300
317	03-Mar-91 20:50:00.	17.650	20.000	34.950	38.050	38.550	18.350
318	03-Mar-91 21:00:00.	17.700	20.150	34.850	37.950	38.400	18.400
319	03-Mar-91 21:10:00.	17.700	20.150	34.800	37.900	38.300	18.400
320	03-Mar-91 21:20:00.	17.500	20.300	34.750	37.750	38.300	18.300
321	03-Mar-91 21:30:00.	17.250	20.450	34.650	37.650	38.150	18.050
322	03-Mar-91 21:40:00.	17.000	20.250	34.600	37.550	38.100	17.750
323	03-Mar-91 21:50:00.	16.750	20.150	34.550	37.400	38.000	17.650
324	03-Mar-91 22:00:00.	16.500	20.300	34.500	37.300	37.900	17.650
325	03-Mar-91 22:10:00.	16.500	20.200	34.400	37.150	37.750	17.450
326	03-Mar-91 22:20:00.	16.450	20.350	34.300	37.050	37.700	17.400
327	03-Mar-91 22:30:00.	16.500	20.150	34.250	36.950	37.600	17.250
328	03-Mar-91 22:40:00.	16.400	20.250	34.200	36.900	37.550	17.200
329	03-Mar-91 22:50:00.	16.400	20.250	34.150	36.800	37.450	17.150
330	03-Mar-91 23:00:00.	16.400	20.050	34.050	36.700	37.400	17.150
331	03-Mar-91 23:10:00.	16.500	20.100	34.050	36.700	37.400	17.200
332	03-Mar-91 23:20:00.	16.400	20.150	34.000	36.650	37.400	17.200
333	03-Mar-91 23:30:00.	16.300	20.200	33.950	36.550	37.300	17.000
334	03-Mar-91 23:40:00.	16.250	20.000	33.900	36.550	37.200	17.050
335	03-Mar-91 23:50:00.	16.400	20.000	33.850	36.500	37.300	17.350
336	04-Mar-91 00:00:00.	16.650	20.000	33.800	36.450	37.250	17.800
337	04-Mar-91 00:10:00.	16.500	19.900	33.800	36.450	37.200	17.450
338	04-Mar-91 00:20:00.	16.450	19.900	33.700	36.400	37.100	17.650

339	04-Mar-91 00:30:00.	16.500	19.900	33.650	36.300	37.050	17.700
340	04-Mar-91 00:40:00.	16.700	19.800	33.600	36.250	36.950	17.950
341	04-Mar-91 00:50:00.	16.900	19.600	33.550	36.250	36.950	17.800
342	04-Mar-91 01:00:00.	17.000	19.450	33.500	36.250	36.950	17.800
343	04-Mar-91 01:10:00.	17.050	19.350	33.450	36.200	36.950	17.650
344	04-Mar-91 01:20:00.	16.950	19.400	33.400	36.200	36.900	17.650
345	04-Mar-91 01:30:00.	16.850	19.450	33.350	36.150	36.950	17.500
346	04-Mar-91 01:40:00.	17.650	19.550	33.350	36.150	36.900	18.150
347	04-Mar-91 01:50:00.	17.900	19.700	33.300	36.150	36.900	18.200
348	04-Mar-91 02:00:00.	18.250	19.900	33.350	36.150	36.950	18.500
349	04-Mar-91 02:10:00.	18.200	20.000	33.350	36.200	36.950	18.600
350	04-Mar-91 02:20:00.	17.800	19.950	33.400	36.200	36.950	18.200
351	04-Mar-91 02:30:00.	17.300	20.000	33.400	36.200	36.950	17.850
352	04-Mar-91 02:40:00.	17.300	20.050	33.400	36.150	36.900	18.000
353	04-Mar-91 02:50:00.	17.550	20.050	33.400	36.150	36.900	18.050
354	04-Mar-91 03:00:00.	17.800	20.150	33.400	36.150	36.900	18.200
355	04-Mar-91 03:10:00.	17.900	20.050	33.450	36.150	36.950	18.200
356	04-Mar-91 03:20:00.	17.650	20.050	33.450	36.150	36.950	18.050
357	04-Mar-91 03:30:00.	17.400	20.100	33.500	36.200	37.000	17.900
358	04-Mar-91 03:40:00.	17.550	20.100	33.500	36.200	37.050	18.100
359	04-Mar-91 03:50:00.	17.400	20.000	33.550	36.200	37.050	17.900
360	04-Mar-91 04:00:00.	17.150	19.750	33.550	36.200	37.100	17.450
361	04-Mar-91 04:10:00.	17.000	19.650	33.550	36.200	37.050	17.400
362	04-Mar-91 04:20:00.	16.900	19.450	33.500	36.200	37.050	17.250
363	04-Mar-91 04:30:00.	16.800	19.300	33.450	36.200	37.050	17.100
364	04-Mar-91 04:40:00.	16.700	19.050	33.450	36.150	36.950	17.000
365	04-Mar-91 04:50:00.	16.600	19.000	33.400	36.150	36.900	16.850
366	04-Mar-91 05:00:00.	16.500	18.900	33.350	36.100	36.850	16.700
367	04-Mar-91 05:10:00.	16.550	18.750	33.250	36.000	36.750	16.850
368	04-Mar-91 05:20:00.	16.650	18.450	33.200	35.950	36.700	16.900
369	04-Mar-91 05:30:00.	16.650	18.250	33.100	35.900	36.600	16.900
370	04-Mar-91 05:40:00.	16.600	18.050	32.950	35.850	36.450	16.850
371	04-Mar-91 05:50:00.	16.700	17.950	32.800	35.750	36.250	16.950
372	04-Mar-91 06:00:00.	16.650	17.950	32.700	35.650	36.150	16.950
373	04-Mar-91 06:10:00.	16.600	17.900	32.550	35.550	36.050	16.900
374	04-Mar-91 06:20:00.	16.550	18.050	32.450	35.450	36.000	16.950
375	04-Mar-91 06:30:00.	16.700	18.150	32.350	35.350	35.900	17.000
376	04-Mar-91 06:40:00.	16.600	18.050	32.350	35.300	36.000	16.800
377	04-Mar-91 06:50:00.	17.700	18.100	32.300	35.250	35.900	16.700
378	04-Mar-91 07:00:00.	22.900	18.500	32.300	35.250	36.000	17.300
379	04-Mar-91 07:10:00.	24.000	18.800	32.300	35.300	36.100	17.500
380	04-Mar-91 07:20:00.	26.350	19.400	32.400	35.400	36.250	18.300
381	04-Mar-91 07:30:00.	27.450	19.850	32.550	35.550	36.650	18.750

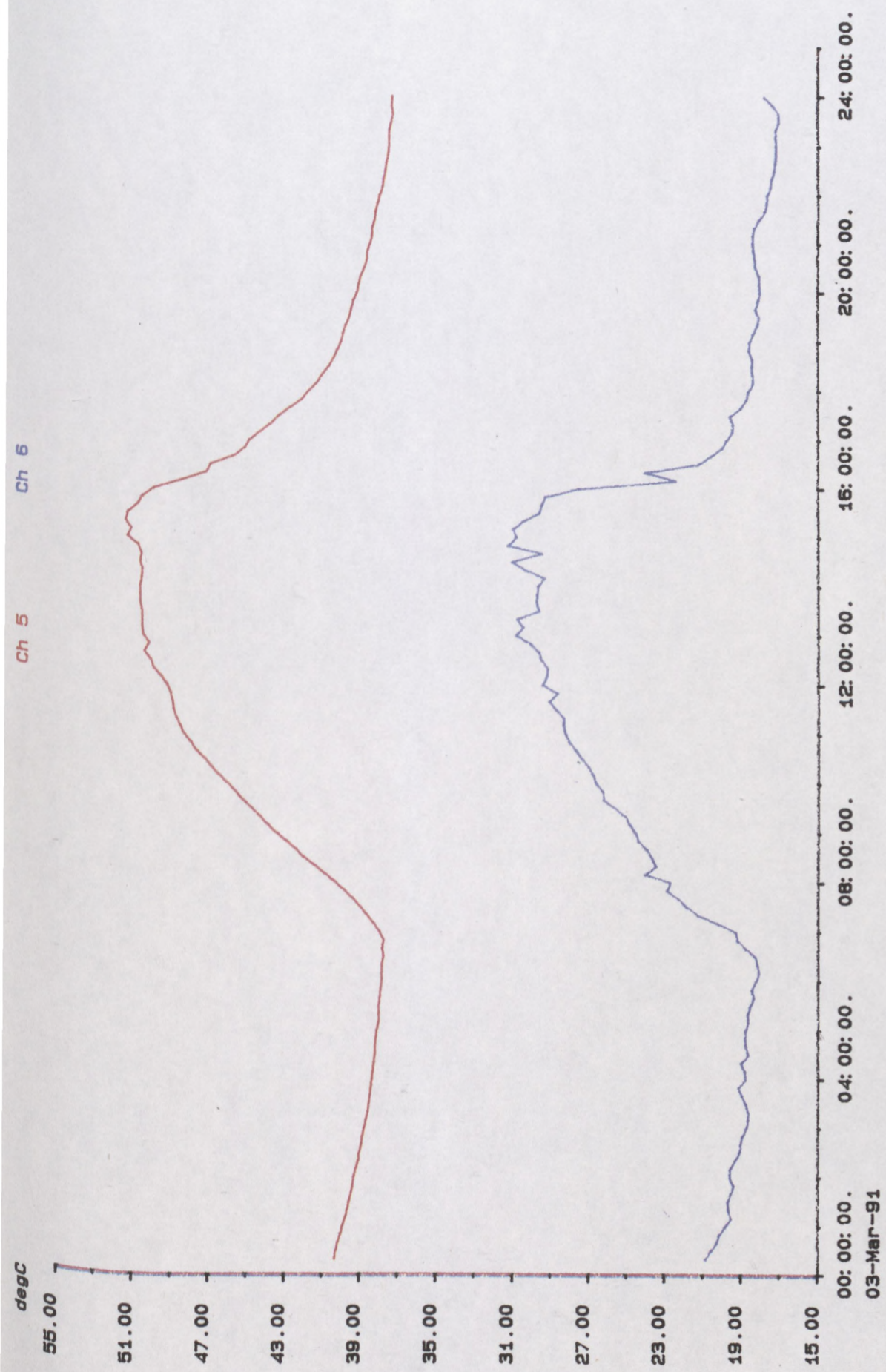
Ch 2 Ch 3 Ch 5 Ch 6

degC

55.00  
51.00  
47.00  
43.00  
39.00  
35.00  
31.00  
27.00  
23.00  
19.00  
15.00

12: 00: 00 . 01-Mar-91  
24: 00: 00 .  
12: 00: 00 .  
00: 00: 00 . 03-Mar-91  
12: 00: 00 .  
00: 00: 00 .  
12: 00: 00 . 04-Mar-91





## APPENDIX 3.6.3

### ON SITE CONTAINER TEMPERATURE READINGS

File 3.6.3

File 18

60 Watt heat load

No cooling

Container on site

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east

Ch 2 Outside heat sink

Ch 3 Inside heat sink

Ch 4 Inside floor level

Ch 5 Inside globe level

Ch 6 Outside globe level

## Channel Readings

Data file - FILE18

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

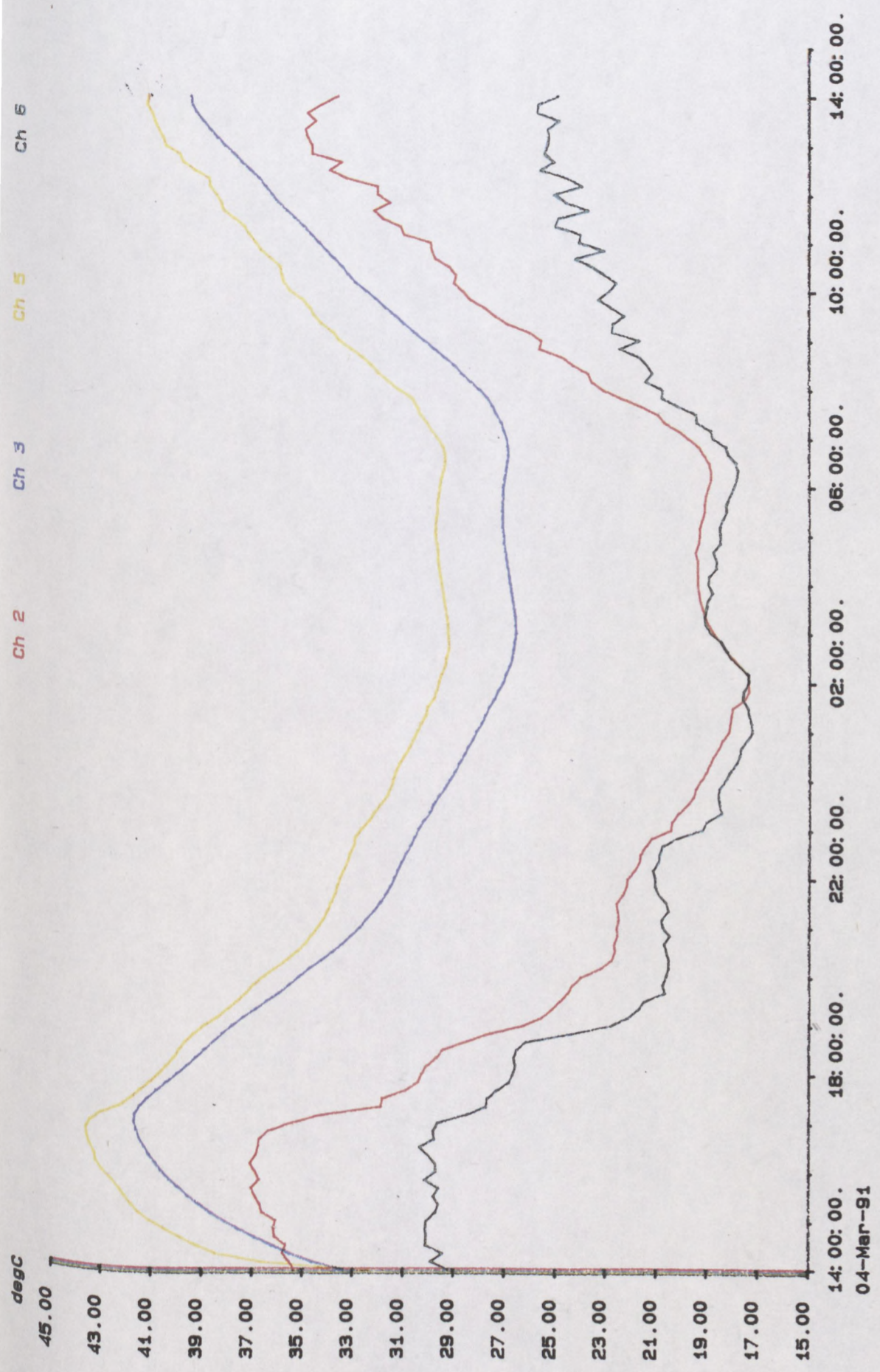
Run number : 1  
Channels used : 6  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 04-Mar-91 14:00:00.  
    Finish : 05-Mar-91 14:00:01.  
Readings per channel: 145

All readings

Rdg no.	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC
0	04-Mar-91 14:00:00.	33.450	35.350	33.350	32.650	32.350	29.200
1	04-Mar-91 14:10:00.	33.400	35.550	34.600	34.000	36.650	29.900
2	04-Mar-91 14:20:00.	33.400	35.800	35.500	35.100	38.450	29.400
3	04-Mar-91 14:30:00.	32.750	35.650	36.200	36.000	39.200	30.100
4	04-Mar-91 14:40:00.	33.150	36.100	36.900	36.850	39.850	30.050
5	04-Mar-91 14:50:00.	33.250	36.150	37.550	37.650	40.450	30.100
6	04-Mar-91 15:00:00.	32.750	36.050	38.150	38.300	41.050	30.050
7	04-Mar-91 15:10:00.	33.200	36.600	38.650	38.900	41.500	29.700
8	04-Mar-91 15:20:00.	32.650	36.700	39.100	39.500	41.800	29.550
9	04-Mar-91 15:30:00.	32.950	36.900	39.550	39.900	42.050	29.800
10	04-Mar-91 15:40:00.	32.900	37.050	39.900	40.350	42.300	29.550
11	04-Mar-91 15:50:00.	32.900	36.700	40.300	40.700	42.600	30.150
12	04-Mar-91 16:00:00.	32.650	36.900	40.600	41.100	42.950	29.700
13	04-Mar-91 16:10:00.	32.750	37.100	40.850	41.450	43.200	29.700
14	04-Mar-91 16:20:00.	32.550	36.850	41.100	41.700	43.250	30.000
15	04-Mar-91 16:30:00.	32.500	36.750	41.300	41.950	43.450	30.350
16	04-Mar-91 16:40:00.	32.300	36.700	41.500	42.150	43.550	29.750
17	04-Mar-91 16:50:00.	31.800	36.350	41.600	42.300	43.600	29.800
18	04-Mar-91 17:00:00.	30.550	35.450	41.700	42.450	43.400	29.600
19	04-Mar-91 17:10:00.	29.250	34.250	41.650	42.300	43.000	28.500
20	04-Mar-91 17:20:00.	28.050	31.850	41.450	42.150	42.250	27.700
21	04-Mar-91 17:30:00.	27.750	31.800	41.150	41.800	41.800	27.650
22	04-Mar-91 17:40:00.	27.200	30.900	40.800	41.500	41.450	27.300
23	04-Mar-91 17:50:00.	26.700	30.400	40.400	41.150	41.050	26.800
24	04-Mar-91 18:00:00.	26.450	30.250	40.000	40.800	40.700	26.650
25	04-Mar-91 18:10:00.	26.300	30.050	39.600	40.450	40.400	26.550
26	04-Mar-91 18:20:00.	26.400	29.650	39.250	40.150	40.100	26.650
27	04-Mar-91 18:30:00.	26.050	29.400	38.900	39.850	39.900	26.500
28	04-Mar-91 18:40:00.	25.900	28.500	38.550	39.600	39.650	26.150
29	04-Mar-91 18:50:00.	24.450	27.600	38.200	39.300	39.300	24.400
30	04-Mar-91 19:00:00.	23.000	26.300	37.800	38.900	38.900	22.800
31	04-Mar-91 19:10:00.	22.250	25.550	37.400	38.550	38.400	22.100
32	04-Mar-91 19:20:00.	21.950	25.150	36.900	38.150	38.000	21.700
33	04-Mar-91 19:30:00.	21.800	24.800	36.450	37.800	37.600	21.450
34	04-Mar-91 19:40:00.	21.300	24.500	35.950	37.450	37.250	20.650
35	04-Mar-91 19:50:00.	21.100	24.300	35.550	37.050	36.950	20.750
36	04-Mar-91 20:00:00.	19.200	23.950	35.150	36.700	36.550	20.600
37	04-Mar-91 20:10:00.	19.150	23.200	34.750	36.300	36.100	20.500

38	04-Mar-91 20:20:00.	19.500	22.750	34.250	35.900	35.650	20.500
39	04-Mar-91 20:30:00.	19.550	22.600	33.800	35.500	35.250	20.600
40	04-Mar-91 20:40:00.	19.700	22.650	33.400	35.150	34.900	20.700
41	04-Mar-91 20:50:00.	19.550	22.500	33.050	34.850	34.650	20.450
42	04-Mar-91 21:00:00.	19.800	22.550	32.700	34.550	34.400	20.750
43	04-Mar-91 21:10:00.	20.100	22.450	32.450	34.250	34.150	20.800
44	04-Mar-91 21:20:00.	19.900	22.500	32.150	34.000	34.000	20.500
45	04-Mar-91 21:30:00.	19.950	22.550	31.900	33.800	33.850	20.600
46	04-Mar-91 21:40:00.	20.400	22.300	31.700	33.600	33.700	20.900
47	04-Mar-91 21:50:00.	20.600	22.150	31.500	33.400	33.600	21.050
48	04-Mar-91 22:00:00.	20.700	22.100	31.350	33.250	33.500	21.050
49	04-Mar-91 22:10:00.	20.800	21.850	31.200	33.150	33.350	21.150
50	04-Mar-91 22:20:00.	20.650	21.650	31.050	33.000	33.200	20.900
51	04-Mar-91 22:30:00.	20.700	21.600	30.900	32.850	33.100	20.850
52	04-Mar-91 22:40:00.	20.700	21.400	30.700	32.700	32.950	20.750
53	04-Mar-91 22:50:00.	19.150	21.150	30.550	32.600	32.900	20.150
54	04-Mar-91 23:00:00.	17.700	20.400	30.400	32.450	32.650	19.150
55	04-Mar-91 23:10:00.	17.700	20.350	30.200	32.250	32.350	19.000
56	04-Mar-91 23:20:00.	17.100	20.100	29.950	32.050	32.150	18.400
57	04-Mar-91 23:30:00.	17.050	19.750	29.800	31.850	31.900	18.500
58	04-Mar-91 23:40:00.	17.200	19.500	29.600	31.650	31.650	18.550
59	04-Mar-91 23:50:00.	17.250	19.400	29.350	31.450	31.500	18.500
60	04-Mar-91 24:00:00.	17.000	19.200	29.150	31.300	31.400	18.250
61	05-Mar-91 00:10:00.	16.700	19.000	28.950	31.150	31.300	18.100
62	05-Mar-91 00:20:00.	16.500	18.850	28.800	31.000	31.150	17.850
63	05-Mar-91 00:30:00.	16.350	18.700	28.600	30.800	30.950	17.700
64	05-Mar-91 00:40:00.	16.300	18.500	28.450	30.650	30.750	17.650
65	05-Mar-91 00:50:00.	16.200	18.350	28.250	30.500	30.600	17.400
66	05-Mar-91 01:00:00.	16.100	18.100	28.100	30.350	30.450	17.200
67	05-Mar-91 01:10:00.	16.000	18.050	27.900	30.200	30.300	17.250
68	05-Mar-91 01:20:00.	15.900	18.000	27.750	30.050	30.100	17.350
69	05-Mar-91 01:30:00.	16.000	17.950	27.600	29.900	30.050	17.400
70	05-Mar-91 01:40:00.	15.850	17.500	27.400	29.750	29.800	17.600
71	05-Mar-91 01:50:00.	16.000	17.300	27.250	29.600	29.700	17.550
72	05-Mar-91 02:00:00.	16.000	17.350	27.050	29.450	29.600	17.350
73	05-Mar-91 02:10:00.	16.000	17.350	26.950	29.350	29.500	17.350
74	05-Mar-91 02:20:00.	16.050	17.650	26.800	29.200	29.350	17.700
75	05-Mar-91 02:30:00.	16.150	17.950	26.700	29.100	29.300	18.050
76	05-Mar-91 02:40:00.	16.300	18.250	26.650	29.000	29.200	18.250
77	05-Mar-91 02:50:00.	16.450	18.450	26.600	28.900	29.200	18.450
78	05-Mar-91 03:00:00.	16.750	18.700	26.550	28.850	29.250	18.850
79	05-Mar-91 03:10:00.	17.000	18.900	26.600	28.800	29.250	19.050
80	05-Mar-91 03:20:00.	17.350	19.050	26.600	28.800	29.300	19.100
81	05-Mar-91 03:30:00.	17.650	19.150	26.650	28.800	29.350	19.000
82	05-Mar-91 03:40:00.	17.850	19.250	26.700	28.800	29.400	18.950
83	05-Mar-91 03:50:00.	18.000	19.300	26.750	28.800	29.450	18.750
84	05-Mar-91 04:00:00.	18.200	19.350	26.800	28.850	29.500	18.950
85	05-Mar-91 04:10:00.	18.250	19.350	26.850	28.900	29.550	18.900
86	05-Mar-91 04:20:00.	18.200	19.350	26.900	28.900	29.600	18.600
87	05-Mar-91 04:30:00.	18.200	19.350	26.950	28.950	29.650	18.600
88	05-Mar-91 04:40:00.	18.350	19.450	27.000	29.000	29.650	18.750
89	05-Mar-91 04:50:00.	18.250	19.300	27.050	29.000	29.700	18.450
90	05-Mar-91 05:00:00.	18.250	19.250	27.050	29.050	29.750	18.450
91	05-Mar-91 05:10:00.	18.300	19.250	27.100	29.050	29.750	18.500
92	05-Mar-91 05:20:00.	18.100	19.150	27.100	29.050	29.700	18.350
93	05-Mar-91 05:30:00.	17.850	19.050	27.100	29.050	29.650	18.200
94	05-Mar-91 05:40:00.	17.800	19.050	27.100	29.000	29.650	18.200
95	05-Mar-91 05:50:00.	17.700	19.000	27.050	29.000	29.600	18.050
96	05-Mar-91 06:00:00.	17.600	18.900	27.050	29.000	29.550	17.900
97	05-Mar-91 06:10:00.	17.550	18.800	27.000	28.950	29.500	17.800
98	05-Mar-91 06:20:00.	17.550	18.800	26.950	28.900	29.400	17.750
99	05-Mar-91 06:30:00.	17.700	18.900	26.900	28.850	29.350	17.850
100	05-Mar-91 06:40:00.	18.250	19.100	26.850	28.800	29.350	18.150

101	05-Mar-91 06:50:00.	20.350	19.300	26.900	28.850	29.450	18.250
102	05-Mar-91 07:00:00.	22.050	19.700	26.950	28.900	29.650	18.750
103	05-Mar-91 07:10:00.	21.350	20.100	27.050	29.050	29.900	18.850
104	05-Mar-91 07:20:00.	22.900	20.650	27.150	29.200	30.100	19.400
105	05-Mar-91 07:30:00.	21.550	20.950	27.350	29.350	30.350	19.450
106	05-Mar-91 07:40:00.	25.650	21.600	27.500	29.500	30.500	20.150
107	05-Mar-91 07:50:00.	30.050	22.400	27.700	29.700	30.700	20.800
108	05-Mar-91 08:00:00.	28.650	23.100	28.000	29.950	31.200	20.750
109	05-Mar-91 08:10:00.	30.750	23.550	28.350	30.300	31.600	21.450
110	05-Mar-91 08:20:00.	26.700	23.700	28.700	30.550	32.000	21.150
111	05-Mar-91 08:30:00.	29.850	24.300	29.000	30.800	32.300	21.400
112	05-Mar-91 08:40:00.	29.450	24.750	29.400	31.150	32.650	21.700
113	05-Mar-91 08:50:00.	31.800	25.650	29.800	31.450	33.100	22.450
114	05-Mar-91 09:00:00.	29.450	25.550	30.200	31.800	33.550	21.650
115	05-Mar-91 09:10:00.	30.600	26.050	30.600	32.150	33.800	22.750
116	05-Mar-91 09:20:00.	29.500	26.900	31.000	32.500	34.250	22.700
117	05-Mar-91 09:30:00.	27.850	27.400	31.350	32.850	34.550	22.250
118	05-Mar-91 09:40:00.	28.450	27.800	31.750	33.150	34.750	22.800
119	05-Mar-91 09:50:00.	31.800	28.350	32.100	33.450	35.050	23.300
120	05-Mar-91 10:00:00.	29.350	28.650	32.500	33.800	35.550	22.850
121	05-Mar-91 10:10:00.	27.350	29.000	32.900	34.150	35.800	22.550
122	05-Mar-91 10:20:00.	26.850	28.900	33.200	34.400	35.900	23.050
123	05-Mar-91 10:30:00.	28.200	29.200	33.450	34.600	35.950	23.550
124	05-Mar-91 10:40:00.	30.500	29.750	33.750	34.800	36.300	24.250
125	05-Mar-91 10:50:00.	27.900	29.900	34.100	35.150	36.700	23.050
126	05-Mar-91 11:00:00.	29.500	29.950	34.400	35.350	36.950	24.100
127	05-Mar-91 11:10:00.	31.800	31.000	34.700	35.650	37.200	24.000
128	05-Mar-91 11:20:00.	31.350	31.150	35.000	35.850	37.400	25.050
129	05-Mar-91 11:30:00.	32.100	31.850	35.350	36.150	37.800	24.900
130	05-Mar-91 11:40:00.	31.350	32.200	35.700	36.450	38.200	23.700
131	05-Mar-91 11:50:00.	29.500	31.550	36.050	36.650	38.300	24.650
132	05-Mar-91 12:00:00.	30.300	32.050	36.300	36.900	38.500	25.100
133	05-Mar-91 12:10:00.	28.700	32.050	36.550	37.200	38.750	23.950
134	05-Mar-91 12:20:00.	32.300	33.250	36.800	37.350	38.800	24.550
135	05-Mar-91 12:30:00.	31.150	33.950	37.150	37.700	39.350	25.650
136	05-Mar-91 12:40:00.	30.450	33.450	37.500	38.050	39.800	25.100
137	05-Mar-91 12:50:00.	32.050	34.650	37.800	38.300	39.950	25.500
138	05-Mar-91 13:00:00.	31.200	34.650	38.150	38.650	40.500	25.350
139	05-Mar-91 13:10:00.	31.650	34.850	38.450	38.900	40.600	25.300
140	05-Mar-91 13:20:00.	31.000	34.950	38.750	39.150	40.800	25.350
141	05-Mar-91 13:30:00.	30.400	34.500	39.000	39.450	40.950	24.850
142	05-Mar-91 13:40:00.	30.500	34.850	39.250	39.600	41.050	25.750
143	05-Mar-91 13:50:00.	29.900	34.250	39.450	39.750	41.250	25.700
144	05-Mar-91 14:00:00.	29.050	33.600	39.500	39.850	41.150	24.950



## APPENDIX 3.6.4

### ON SITE CONTAINER TEMPERATURE READINGS

File 19

60 Watt heat load

2.5 Amp cooling

Container on site

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east

Ch 2 Outside heat sink

Ch 3 Inside heat sink

Ch 4 Inside floor level

Ch 5 Inside globe level

Ch 6 Outside globe level

## Channel Readings

Data file - FILE19

### Recorder details:

Recorder number : 38  
Squirrel type : 1206

### Run details:

Run number : 1  
Channels used : 6  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 05-Mar-91 15:00:00.  
    Finish : 06-Mar-91 15:00:01.

Readings per channel: 145

### All readings

Rdg no	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC
0	05-Mar-91 15:00:00.	30.950	34.750	36.550	35.700	32.050	26.100
1	05-Mar-91 15:10:00.	30.200	34.600	37.400	37.450	38.800	26.750
2	05-Mar-91 15:20:00.	30.800	34.850	37.800	38.050	40.150	26.550
3	05-Mar-91 15:30:00.	30.500	34.950	38.200	38.650	40.850	27.250
4	05-Mar-91 15:40:00.	29.700	34.250	38.600	39.150	41.300	26.950
5	05-Mar-91 15:50:00.	30.100	34.550	38.950	39.600	41.600	26.800
6	05-Mar-91 16:00:00.	30.600	34.800	39.250	39.950	41.900	27.650
7	05-Mar-91 16:10:00.	30.300	34.800	39.550	40.350	42.150	26.950
8	05-Mar-91 16:20:00.	29.900	34.550	39.750	40.600	42.300	27.500
9	05-Mar-91 16:30:00.	29.250	34.300	39.950	40.850	42.400	26.850
10	05-Mar-91 16:40:00.	29.750	34.500	40.100	41.050	42.400	27.050
11	05-Mar-91 16:50:00.	28.800	33.800	40.250	41.150	42.300	27.000
12	05-Mar-91 17:00:00.	28.400	33.450	40.300	41.250	42.350	26.650
13	05-Mar-91 17:10:00.	28.250	33.250	40.300	41.250	42.050	26.500
14	05-Mar-91 17:20:00.	27.300	32.300	40.200	41.150	41.800	26.450
15	05-Mar-91 17:30:00.	26.450	31.650	40.050	40.950	41.400	26.100
16	05-Mar-91 17:40:00.	26.000	31.000	39.800	40.700	40.850	25.650
17	05-Mar-91 17:50:00.	23.150	26.500	39.450	40.200	40.200	22.600
18	05-Mar-91 18:00:00.	21.250	23.400	38.700	39.550	39.200	21.000
19	05-Mar-91 18:10:00.	15.500	15.750	37.650	38.450	37.700	17.550
20	05-Mar-91 18:20:00.	15.400	15.450	36.300	37.450	36.400	17.450
21	05-Mar-91 18:30:00.	15.500	15.500	35.000	36.600	35.450	17.400
22	05-Mar-91 18:40:00.	15.750	15.900	33.900	35.850	34.800	17.150
23	05-Mar-91 18:50:00.	16.300	16.650	33.000	35.200	34.300	16.950
24	05-Mar-91 19:00:00.	16.850	17.550	32.250	34.550	33.900	17.350
25	05-Mar-91 19:10:00.	17.000	17.900	31.600	34.000	33.450	16.750
26	05-Mar-91 19:20:00.	16.850	17.750	31.150	33.500	33.000	16.650
27	05-Mar-91 19:30:00.	16.950	17.900	30.650	33.000	32.650	17.000
28	05-Mar-91 19:40:00.	17.000	18.400	30.300	32.550	32.350	17.150
29	05-Mar-91 19:50:00.	16.850	18.150	29.900	32.200	32.050	17.250
30	05-Mar-91 20:00:00.	16.300	18.050	29.600	31.850	31.850	17.000
31	05-Mar-91 20:10:00.	16.100	17.800	29.300	31.550	31.600	16.750
32	05-Mar-91 20:20:00.	16.500	17.750	29.050	31.300	31.350	16.600
33	05-Mar-91 20:30:00.	16.750	18.250	28.800	31.050	31.200	17.000
34	05-Mar-91 20:40:00.	16.650	18.400	28.600	30.800	31.000	17.300
35	05-Mar-91 20:50:00.	16.900	18.500	28.450	30.650	30.850	16.950
36	05-Mar-91 21:00:00.	16.600	18.400	28.300	30.500	30.650	16.750
37	05-Mar-91 21:10:00.	16.700	18.600	28.150	30.300	30.550	16.600
38	05-Mar-91 21:20:00.	16.550	18.500	28.000	30.150	30.400	16.550

39	05-Mar-91 21:30:00.	16.300	18.400	27.900	30.000	30.300	16.450
40	05-Mar-91 21:40:00.	16.150	18.350	27.800	29.850	30.200	16.550
41	05-Mar-91 21:50:00.	16.200	18.100	27.700	29.750	30.100	16.400
42	05-Mar-91 22:00:00.	16.200	17.900	27.550	29.650	30.000	16.400
43	05-Mar-91 22:10:00.	16.200	17.700	27.450	29.550	29.950	16.450
44	05-Mar-91 22:20:00.	16.300	17.300	27.350	29.450	29.850	16.450
45	05-Mar-91 22:30:00.	16.450	17.850	27.250	29.350	29.800	16.650
46	05-Mar-91 22:40:00.	16.550	17.750	27.200	29.300	29.700	16.950
47	05-Mar-91 22:50:00.	16.600	17.900	27.100	29.250	29.700	16.950
48	05-Mar-91 23:00:00.	16.700	18.250	27.050	29.200	29.650	17.000
49	05-Mar-91 23:10:00.	16.900	18.450	27.050	29.150	29.650	17.050
50	05-Mar-91 23:20:00.	16.800	18.500	27.000	29.100	29.650	16.900
51	05-Mar-91 23:30:00.	16.800	18.400	27.000	29.100	29.600	16.800
52	05-Mar-91 23:40:00.	16.700	18.550	27.000	29.050	29.600	16.900
53	05-Mar-91 23:50:00.	16.600	18.250	27.000	29.000	29.550	16.600
54	05-Mar-91 24:00:00.	16.600	18.450	26.950	28.950	29.500	16.650
55	06-Mar-91 00:10:00.	16.650	18.300	26.950	28.900	29.450	16.600
56	06-Mar-91 00:20:00.	16.550	18.150	26.900	28.850	29.400	16.550
57	06-Mar-91 00:30:00.	16.400	18.100	26.850	28.800	29.400	16.550
58	06-Mar-91 00:40:00.	16.150	17.850	26.800	28.750	29.350	16.550
59	06-Mar-91 00:50:00.	16.150	17.900	26.800	28.700	29.300	16.500
60	06-Mar-91 01:00:00.	16.050	17.750	26.750	28.650	29.250	16.500
61	06-Mar-91 01:10:00.	16.200	17.850	26.700	28.600	29.150	16.500
62	06-Mar-91 01:20:00.	16.200	17.750	26.650	28.550	29.150	16.550
63	06-Mar-91 01:30:00.	16.050	17.650	26.600	28.500	29.100	16.600
64	06-Mar-91 01:40:00.	15.900	17.600	26.550	28.450	29.100	16.600
65	06-Mar-91 01:50:00.	15.900	17.550	26.500	28.400	29.000	16.550
66	06-Mar-91 02:00:00.	16.050	17.850	26.500	28.400	29.000	16.650
67	06-Mar-91 02:10:00.	16.100	17.550	26.450	28.350	29.000	16.650
68	06-Mar-91 02:20:00.	16.150	17.700	26.450	28.350	29.000	16.800
69	06-Mar-91 02:30:00.	16.150	17.650	26.400	28.350	29.000	16.800
70	06-Mar-91 02:40:00.	16.150	17.550	26.400	28.350	28.950	17.000
71	06-Mar-91 02:50:00.	16.100	17.700	26.350	28.300	28.950	17.000
72	06-Mar-91 03:00:00.	16.100	17.900	26.350	28.300	28.950	17.150
73	06-Mar-91 03:10:00.	16.150	17.950	26.350	28.250	28.900	17.050
74	06-Mar-91 03:20:00.	16.200	18.000	26.300	28.250	28.900	17.050
75	06-Mar-91 03:30:00.	16.300	18.150	26.300	28.250	28.900	17.100
76	06-Mar-91 03:40:00.	16.350	18.150	26.350	28.250	28.950	17.200
77	06-Mar-91 03:50:00.	16.350	18.150	26.350	28.300	28.950	17.250
78	06-Mar-91 04:00:00.	16.400	18.250	26.350	28.300	28.950	17.150
79	06-Mar-91 04:10:00.	16.400	18.150	26.350	28.350	28.950	17.300
80	06-Mar-91 04:20:00.	16.400	18.100	26.350	28.350	29.000	17.100
81	06-Mar-91 04:30:00.	16.400	17.950	26.350	28.350	28.950	16.900
82	06-Mar-91 04:40:00.	16.400	17.900	26.350	28.350	29.000	16.950
83	06-Mar-91 04:50:00.	16.450	18.000	26.350	28.350	28.950	17.000
84	06-Mar-91 05:00:00.	16.500	18.100	26.350	28.350	28.950	17.100
85	06-Mar-91 05:10:00.	16.600	18.100	26.300	28.350	28.950	17.250
86	06-Mar-91 05:20:00.	16.600	18.000	26.300	28.350	28.950	17.200
87	06-Mar-91 05:30:00.	16.650	17.900	26.300	28.350	28.900	17.100
88	06-Mar-91 05:40:00.	16.800	17.900	26.250	28.350	28.800	17.300
89	06-Mar-91 05:50:00.	16.750	17.850	26.200	28.300	28.750	17.200
90	06-Mar-91 06:00:00.	16.750	17.700	26.150	28.250	28.750	17.100
91	06-Mar-91 06:10:00.	16.700	17.750	26.100	28.200	28.650	17.050
92	06-Mar-91 06:20:00.	16.750	17.700	26.050	28.150	28.600	17.000
93	06-Mar-91 06:30:00.	16.800	17.750	26.000	28.150	28.650	17.100
94	06-Mar-91 06:40:00.	16.850	17.750	26.000	28.100	28.600	17.100
95	06-Mar-91 06:50:00.	17.050	17.800	25.950	28.050	28.550	17.200
96	06-Mar-91 07:00:00.	17.350	18.050	25.900	28.000	28.550	17.350
97	06-Mar-91 07:10:00.	18.100	18.300	25.950	28.000	28.600	17.550
98	06-Mar-91 07:20:00.	23.000	18.800	26.000	28.050	28.750	18.150
99	06-Mar-91 07:30:00.	24.900	19.300	26.100	28.150	29.050	18.650
100	06-Mar-91 07:40:00.	25.450	19.800	26.250	28.350	29.300	19.050

101	06-Mar-91 07:50:00.	26.500	20.400	26.450	28.500	29.650	19.650
102	06-Mar-91 08:00:00.	27.400	21.000	26.700	28.700	30.000	20.150
103	06-Mar-91 08:10:00.	27.550	21.550	26.950	28.900	30.300	20.500
104	06-Mar-91 08:20:00.	31.350	22.450	27.300	29.200	30.650	21.300
105	06-Mar-91 08:30:00.	34.300	23.300	27.700	29.550	31.200	22.050
106	06-Mar-91 08:40:00.	34.300	24.050	28.100	29.950	31.700	22.350
107	06-Mar-91 08:50:00.	36.300	24.950	28.600	30.400	32.250	23.250
108	06-Mar-91 09:00:00.	35.500	25.550	29.100	30.850	32.800	23.800
109	06-Mar-91 09:10:00.	33.650	25.850	29.650	31.300	33.300	23.700
110	06-Mar-91 09:20:00.	32.700	26.100	30.150	31.650	33.700	23.700
111	06-Mar-91 09:30:00.	33.150	26.450	30.600	32.050	34.050	24.000
112	06-Mar-91 09:40:00.	30.800	26.550	31.050	32.450	34.450	24.100
113	06-Mar-91 09:50:00.	33.350	27.300	31.450	32.800	34.750	24.700
114	06-Mar-91 10:00:00.	33.750	28.100	31.900	33.200	35.200	25.050
115	06-Mar-91 10:10:00.	31.550	28.100	32.350	33.600	35.700	25.200
116	06-Mar-91 10:20:00.	32.100	28.400	32.800	33.950	36.000	25.600
117	06-Mar-91 10:30:00.	32.150	28.650	33.250	34.300	36.400	25.800
118	06-Mar-91 10:40:00.	31.600	28.750	33.600	34.650	36.750	26.150
119	06-Mar-91 10:50:00.	31.450	28.950	33.950	34.950	36.950	26.450
120	06-Mar-91 11:00:00.	32.250	29.300	34.150	35.000	36.900	26.500
121	06-Mar-91 11:10:00.	32.300	30.100	33.850	34.350	34.650	26.850
122	06-Mar-91 11:20:00.	29.700	29.800	34.350	35.200	36.800	26.650
123	06-Mar-91 11:30:00.	29.400	29.750	34.650	35.550	37.400	26.250
124	06-Mar-91 11:40:00.	27.700	29.200	34.950	35.750	37.450	25.600
125	06-Mar-91 11:50:00.	27.550	28.950	35.100	35.900	37.500	25.600
126	06-Mar-91 12:00:00.	29.600	30.150	35.250	36.150	37.700	26.850
127	06-Mar-91 12:10:00.	28.050	29.750	35.500	36.400	38.050	26.200
128	06-Mar-91 12:20:00.	28.850	30.050	35.700	36.650	38.250	26.300
129	06-Mar-91 12:30:00.	27.600	29.350	35.900	36.800	38.300	25.900
130	06-Mar-91 12:40:00.	27.700	29.250	35.550	36.150	36.750	26.050
131	06-Mar-91 12:50:00.	24.950	27.750	35.350	35.950	35.950	24.350
132	06-Mar-91 13:00:00.	19.500	26.000	35.250	36.050	36.600	21.750
133	06-Mar-91 13:10:00.	19.600	25.150	35.000	35.850	36.300	21.600
134	06-Mar-91 13:20:00.	19.300	24.900	34.700	35.600	35.900	20.050
135	06-Mar-91 13:30:00.	19.650	24.850	34.400	35.350	35.450	20.500
136	06-Mar-91 13:40:00.	19.950	24.650	34.050	35.050	35.100	20.550
137	06-Mar-91 13:50:00.	20.500	24.550	33.700	34.800	34.850	20.900
138	06-Mar-91 14:00:00.	20.750	24.800	33.450	34.600	34.750	21.900
139	06-Mar-91 14:10:00.	21.250	24.950	33.250	34.450	34.750	22.300
140	06-Mar-91 14:20:00.	21.950	25.250	33.100	34.300	34.750	22.750
141	06-Mar-91 14:30:00.	22.650	26.250	32.500	34.250	34.700	23.250
142	06-Mar-91 14:40:00.	22.850	26.050	32.550	34.150	34.700	23.150
143	06-Mar-91 14:50:00.	22.600	25.150	32.550	34.100	34.650	22.450
144	06-Mar-91 15:00:00.	21.400	23.850	32.500	34.000	34.400	21.050



## APPENDIX 3.6.5

### ON SITE CONTAINER TEMPERATURE READINGS

File 20

100 Watt heat load

2.25 Amp cooling

Container on site

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east

Ch 2 Outside heat sink

Ch 3 Inside heat sink

Ch 4 Inside floor level

Ch 5 Inside globe level

Ch 6 Outside globe level

Ch 19B 255=Off 254=On

# Channel Readings

Data file - FILE20

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

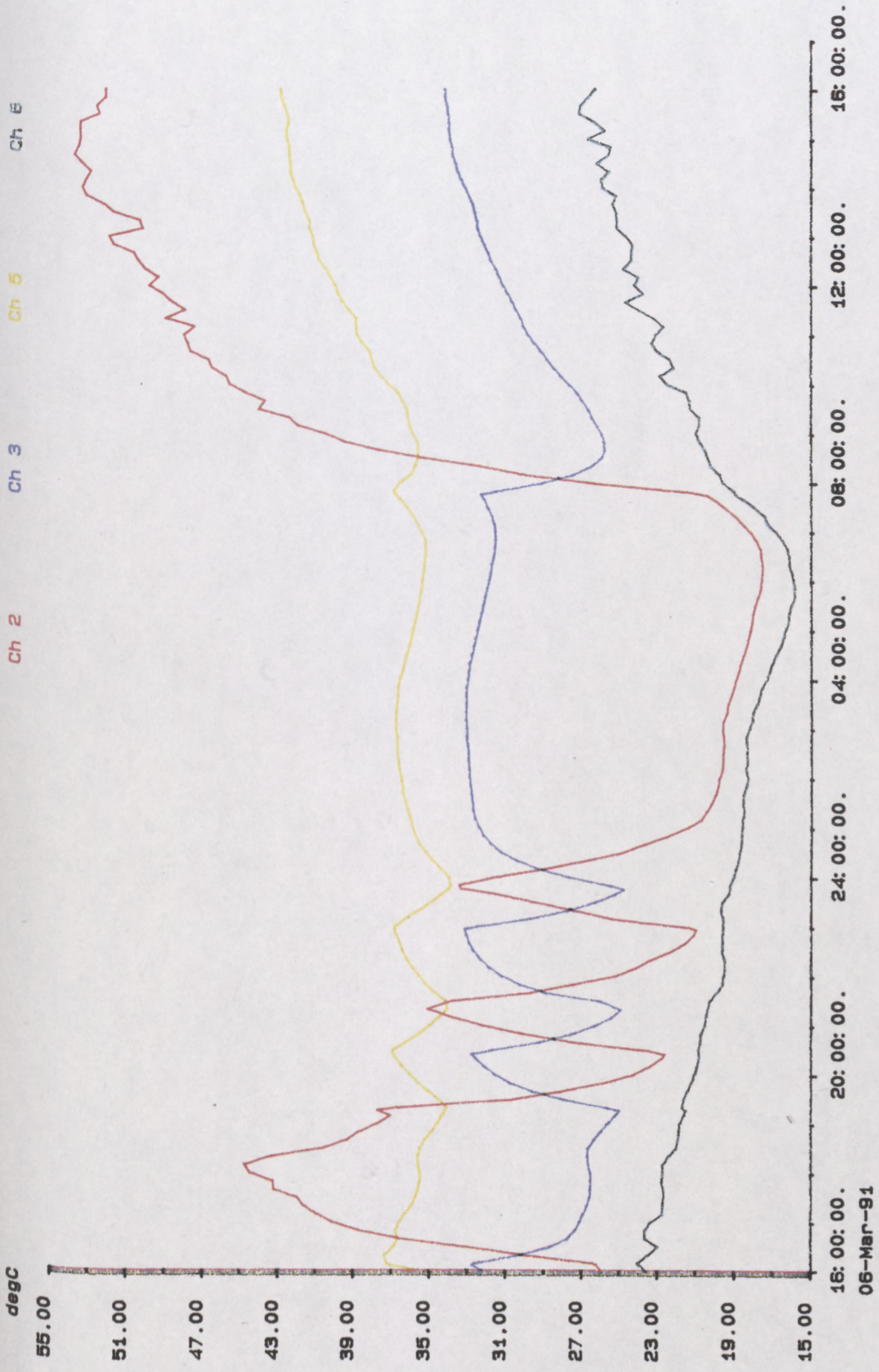
**Run details:**

Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Event/Digital readings  
Recording period :  
    Start : 06-Mar-91 16:00:00.  
    Finish : 07-Mar-91 16:00:01.  
Readings per channel: 153

All readings

Rdg no.	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19 B
0	06-Mar-91 16:00:00.	25.100	25.900	32.200	33.950	35.200	23.550	255
1	06-Mar-91 16:00:00.	25.100	25.900	32.200	33.950	35.200	23.550	255
2	06-Mar-91 16:08:00.	25.350	26.200	32.750	34.750	37.000	23.950	254
3	06-Mar-91 16:10:00.	25.350	26.400	32.600	34.900	37.200	24.050	254
4	06-Mar-91 16:20:00.	24.550	30.050	30.300	35.450	37.350	23.450	254
5	06-Mar-91 16:30:00.	24.100	33.200	28.700	35.550	36.850	22.950	254
6	06-Mar-91 16:40:00.	25.350	36.550	27.750	35.600	36.600	23.650	254
7	06-Mar-91 16:50:00.	25.050	38.700	27.350	35.700	36.750	23.650	254
8	06-Mar-91 17:00:00.	24.150	40.050	27.100	35.750	36.550	23.350	254
9	06-Mar-91 17:10:00.	23.150	40.900	26.900	35.600	36.250	22.700	254
10	06-Mar-91 17:20:00.	22.850	41.600	26.700	35.450	35.900	22.750	254
11	06-Mar-91 17:30:00.	22.800	41.950	26.550	35.250	35.700	22.650	254
12	06-Mar-91 17:40:00.	22.800	43.200	26.500	35.100	35.550	22.650	254
13	06-Mar-91 17:50:00.	23.100	43.250	26.500	34.950	35.450	22.800	254
14	06-Mar-91 18:00:00.	23.200	44.450	26.500	34.950	35.450	22.700	254
15	06-Mar-91 18:10:00.	22.950	44.750	26.650	34.950	35.550	22.700	254
16	06-Mar-91 18:20:00.	22.600	43.350	26.700	34.950	35.600	22.400	254
17	06-Mar-91 18:30:00.	22.000	40.550	26.650	34.900	35.450	22.000	254
18	06-Mar-91 18:40:00.	21.800	39.300	26.350	34.750	35.200	21.900	254
19	06-Mar-91 18:50:00.	21.700	38.650	26.000	34.500	34.850	21.850	254
20	06-Mar-91 19:00:00.	21.600	37.700	25.650	34.250	34.550	21.800	254
21	06-Mar-91 19:10:00.	21.400	37.000	25.250	34.000	34.300	21.600	254
22	06-Mar-91 19:16:40.	21.200	37.700	25.000	33.850	34.150	21.500	255
23	06-Mar-91 19:20:00.	21.250	36.650	25.600	33.800	34.050	21.700	255
24	06-Mar-91 19:30:00.	21.300	30.650	27.950	33.900	34.500	21.600	255
25	06-Mar-91 19:40:00.	21.200	28.100	29.600	34.150	35.050	21.400	255
26	06-Mar-91 19:50:00.	20.850	25.900	30.750	34.500	35.600	21.200	255
27	06-Mar-91 20:00:00.	20.900	24.300	31.550	34.750	36.000	21.050	255
28	06-Mar-91 20:10:00.	20.800	23.450	32.150	35.000	36.400	20.900	255
29	06-Mar-91 20:20:00.	20.800	22.800	32.600	35.300	36.750	20.800	255
30	06-Mar-91 20:25:00.	20.800	22.600	32.800	35.450	36.900	20.800	254
31	06-Mar-91 20:30:00.	20.800	23.550	31.750	35.500	36.900	20.850	254
32	06-Mar-91 20:40:00.	20.700	27.500	29.250	35.350	36.200	20.750	254
33	06-Mar-91 20:50:00.	20.550	30.100	27.550	35.050	35.500	20.700	254
34	06-Mar-91 21:00:00.	20.400	32.200	26.350	34.700	34.950	20.500	254
35	06-Mar-91 21:10:00.	20.350	33.800	25.450	34.350	34.500	20.450	254
36	06-Mar-91 21:20:00.	20.250	35.100	24.950	34.000	34.050	20.350	254
37	06-Mar-91 21:20:10.	20.250	35.100	24.950	33.950	34.050	20.350	255

38	06-Mar-91 21:30:00.	19.900	32.450	27.050	33.900	34.250	20.200	255
39	06-Mar-91 21:40:00.	19.400	29.700	28.900	34.050	34.750	19.900	255
40	06-Mar-91 21:50:00.	19.000	27.450	30.250	34.250	35.200	19.600	255
41	06-Mar-91 22:00:00.	18.950	25.250	31.200	34.500	35.550	19.550	255
42	06-Mar-91 22:10:00.	18.950	24.150	31.850	34.650	35.900	19.450	255
43	06-Mar-91 22:20:00.	19.000	23.350	32.350	34.850	36.200	19.500	255
44	06-Mar-91 22:30:00.	19.300	22.300	32.700	35.050	36.400	19.650	255
45	06-Mar-91 22:40:00.	19.350	21.550	32.950	35.250	36.550	19.600	255
46	06-Mar-91 22:50:00.	19.400	21.100	33.100	35.450	36.750	19.600	255
47	06-Mar-91 22:56:50.	19.350	20.950	33.200	35.500	36.850	19.550	254
48	06-Mar-91 23:00:00.	19.400	21.400	32.550	35.550	36.800	19.550	254
49	06-Mar-91 23:10:00.	19.350	25.400	29.750	35.450	36.200	19.550	254
50	06-Mar-91 23:20:00.	19.550	27.450	27.750	35.100	35.500	19.700	254
51	06-Mar-91 23:30:00.	19.450	29.500	26.300	34.700	34.850	19.600	254
52	06-Mar-91 23:40:00.	19.050	31.600	25.250	34.250	34.300	19.250	254
53	06-Mar-91 23:45:50.	18.800	33.350	24.800	33.950	33.950	19.200	255
54	06-Mar-91 23:50:00.	18.650	33.450	25.450	33.850	33.850	19.200	255
55	06-Mar-91 24:00:00.	18.250	31.500	27.650	33.750	34.000	19.000	255
56	07-Mar-91 00:10:00.	18.250	29.000	29.250	33.800	34.400	18.900	255
57	07-Mar-91 00:20:00.	18.250	26.850	30.400	33.950	34.850	18.750	255
58	07-Mar-91 00:30:00.	18.300	24.900	31.250	34.150	35.200	18.700	255
59	07-Mar-91 00:40:00.	18.050	23.750	31.800	34.300	35.550	18.600	255
60	07-Mar-91 00:50:00.	18.250	22.500	32.200	34.500	35.750	18.600	255
61	07-Mar-91 01:00:00.	18.300	21.450	32.450	34.600	35.900	18.550	255
62	07-Mar-91 01:10:00.	18.300	20.700	32.650	34.750	36.000	18.550	255
63	07-Mar-91 01:20:00.	18.250	20.400	32.750	34.850	36.150	18.450	255
64	07-Mar-91 01:30:00.	18.400	20.150	32.800	35.000	36.250	18.550	255
65	07-Mar-91 01:40:00.	18.400	19.950	32.850	35.100	36.400	18.500	255
66	07-Mar-91 01:50:00.	18.200	19.800	32.900	35.250	36.450	18.350	255
67	07-Mar-91 02:00:00.	18.100	19.750	32.950	35.300	36.500	18.250	255
68	07-Mar-91 02:10:00.	18.250	19.600	32.950	35.400	36.600	18.400	255
69	07-Mar-91 02:20:00.	18.200	19.550	33.000	35.450	36.650	18.300	255
70	07-Mar-91 02:30:00.	18.250	19.550	33.000	35.500	36.700	18.350	255
71	07-Mar-91 02:40:00.	18.300	19.500	33.050	35.550	36.700	18.350	255
72	07-Mar-91 02:50:00.	18.350	19.550	33.100	35.600	36.700	18.400	255
73	07-Mar-91 03:00:00.	18.150	19.600	33.100	35.600	36.800	18.200	255
74	07-Mar-91 03:10:00.	18.050	19.550	33.150	35.650	36.800	18.050	255
75	07-Mar-91 03:20:00.	17.900	19.350	33.150	35.650	36.750	18.000	255
76	07-Mar-91 03:30:00.	17.750	19.300	33.100	35.650	36.700	17.800	255
77	07-Mar-91 03:40:00.	17.500	19.150	33.100	35.600	36.650	17.650	255
78	07-Mar-91 03:50:00.	17.350	19.000	33.100	35.600	36.650	17.550	255
79	07-Mar-91 04:00:00.	17.000	18.900	33.000	35.550	36.550	17.300	255
80	07-Mar-91 04:10:00.	16.700	18.750	32.950	35.450	36.400	17.150	255
81	07-Mar-91 04:20:00.	16.500	18.650	32.900	35.350	36.300	17.000	255
82	07-Mar-91 04:30:00.	16.250	18.500	32.800	35.250	36.200	16.800	255
83	07-Mar-91 04:40:00.	16.100	18.350	32.700	35.150	36.050	16.600	255
84	07-Mar-91 04:50:00.	15.900	18.250	32.600	35.100	35.950	16.450	255
85	07-Mar-91 05:00:00.	15.850	18.150	32.500	34.950	35.850	16.350	255
86	07-Mar-91 05:10:00.	15.700	18.050	32.400	34.850	35.750	16.150	255
87	07-Mar-91 05:20:00.	15.750	18.000	32.300	34.750	35.650	16.150	255
88	07-Mar-91 05:30:00.	15.650	17.900	32.200	34.700	35.550	16.000	255
89	07-Mar-91 05:40:00.	15.350	17.750	32.100	34.600	35.500	15.800	255
90	07-Mar-91 05:50:00.	15.450	17.600	32.000	34.550	35.400	15.850	255
91	07-Mar-91 06:00:00.	15.500	17.550	31.900	34.500	35.350	15.900	255
92	07-Mar-91 06:10:00.	15.750	17.500	31.800	34.450	35.300	16.000	255
93	07-Mar-91 06:20:00.	16.050	17.500	31.750	34.400	35.250	16.150	255
94	07-Mar-91 06:30:00.	16.200	17.600	31.650	34.350	35.200	16.150	255
95	07-Mar-91 06:40:00.	16.450	17.650	31.600	34.300	35.200	16.250	255
96	07-Mar-91 06:50:00.	20.050	17.850	31.550	34.300	35.200	16.500	255
97	07-Mar-91 07:00:00.	22.500	18.150	31.600	34.350	35.450	16.850	255
98	07-Mar-91 07:10:00.	24.500	18.550	31.650	34.450	35.650	17.300	255
99	07-Mar-91 07:20:00.	25.600	18.950	31.800	34.600	35.900	17.450	255



## APPENDIX 3.6.6

### ON SITE CONTAINER TEMPERATURE READINGS

File 22

60- Watt Heat Load

2,25 Amp Cooling

Container on site

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.

Ch 2 Outside heat sink

Ch 3 Inside heat sink

Ch 4 Inside floor level

Ch 5 Inside globe level

Ch 6 Outside globe level

Ch 19B 255=Off 254=On

## Channel Readings

Data file - FILE22

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Event/Digital readings  
Recording period :  
    Start : 07-Mar-91 16:30:00.  
    Finish : 08-Mar-91 14:30:14.  
Readings per channel: 142

All readings

Rdg no:	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19 B
0	07-Mar-91 16:30:00.	27.950	43.500	34.000	35.950	34.450	25.550	255
1	07-Mar-91 16:30:00.	27.950	43.500	34.000	35.950	34.450	25.550	255
2	07-Mar-91 16:40:00.	28.150	40.400	35.350	36.600	37.250	25.850	255
3	07-Mar-91 16:42:20.	28.300	40.050	35.600	36.700	37.550	26.100	254
4	07-Mar-91 16:50:00.	27.900	40.500	34.150	36.950	37.950	25.600	254
5	07-Mar-91 17:00:00.	27.600	43.050	32.100	36.950	37.700	25.500	254
6	07-Mar-91 17:10:00.	25.700	43.600	30.650	36.650	36.950	24.850	254
7	07-Mar-91 17:20:00.	26.000	45.150	29.500	36.200	36.150	24.950	254
8	07-Mar-91 17:30:00.	25.500	46.800	28.650	35.800	35.600	24.800	254
9	07-Mar-91 17:40:00.	25.150	47.550	28.050	35.400	35.200	24.700	254
10	07-Mar-91 17:50:00.	24.850	48.550	27.550	35.000	34.750	24.550	254
11	07-Mar-91 17:57:00.	24.800	49.250	27.300	34.750	34.500	24.550	255
12	07-Mar-91 18:00:00.	24.650	48.850	27.800	34.700	34.500	24.600	255
13	07-Mar-91 18:10:00.	24.250	44.550	30.300	34.650	34.650	24.450	255
14	07-Mar-91 18:20:00.	23.350	40.850	32.100	34.750	34.950	24.200	255
15	07-Mar-91 18:30:00.	22.750	38.200	33.250	34.800	35.150	23.700	255
16	07-Mar-91 18:40:00.	22.200	32.250	34.000	34.800	35.150	22.500	255
17	07-Mar-91 18:50:00.	21.600	29.300	34.300	34.750	35.100	21.950	255
18	07-Mar-91 19:00:00.	20.600	25.850	34.300	34.600	34.950	21.000	255
19	07-Mar-91 19:10:00.	20.350	24.200	34.000	34.400	34.600	20.800	255
20	07-Mar-91 19:20:00.	20.250	22.900	33.650	34.200	34.350	20.700	255
21	07-Mar-91 19:30:00.	20.000	22.200	33.200	33.950	34.150	20.450	255
22	07-Mar-91 19:40:00.	19.800	21.750	32.750	33.700	33.900	20.350	255
23	07-Mar-91 19:50:00.	19.750	21.500	32.350	33.500	33.650	20.250	255
24	07-Mar-91 20:00:00.	19.550	21.350	31.950	33.250	33.450	20.200	255
25	07-Mar-91 20:10:00.	19.500	21.250	31.600	33.000	33.250	20.250	255
26	07-Mar-91 20:20:00.	19.150	21.100	31.300	32.750	33.000	19.800	255
27	07-Mar-91 20:30:00.	18.900	20.700	31.000	32.550	32.750	19.450	255
28	07-Mar-91 20:40:00.	18.850	20.500	30.700	32.300	32.500	19.400	255
29	07-Mar-91 20:50:00.	18.750	20.300	30.400	32.050	32.250	19.300	255
30	07-Mar-91 21:00:00.	18.850	20.200	30.150	31.850	32.100	19.400	255
31	07-Mar-91 21:10:00.	18.800	20.150	29.900	31.650	31.900	19.450	255
32	07-Mar-91 21:20:00.	18.800	20.100	29.700	31.500	31.750	19.350	255
33	07-Mar-91 21:30:00.	18.900	20.100	29.550	31.350	31.600	19.450	255
34	07-Mar-91 21:40:00.	18.800	20.050	29.350	31.250	31.550	19.350	255
35	07-Mar-91 21:50:00.	18.950	20.100	29.200	31.100	31.500	19.500	255
36	07-Mar-91 22:00:00.	18.900	20.050	29.050	31.000	31.400	19.450	255

37	07-Mar-91 22:10:00.	18.450	19.950	28.950	30.850	31.300	19.050	255
38	07-Mar-91 22:20:00.	18.250	19.900	28.850	30.750	31.250	18.900	255
39	07-Mar-91 22:30:00.	18.350	19.900	28.750	30.650	31.150	19.150	255
40	07-Mar-91 22:40:00.	18.800	20.000	28.650	30.550	31.050	19.450	255
41	07-Mar-91 22:50:00.	18.700	20.000	28.600	30.500	31.050	19.400	255
42	07-Mar-91 23:00:00.	18.750	20.050	28.550	30.450	30.950	19.450	255
43	07-Mar-91 23:10:00.	18.450	20.000	28.450	30.400	30.900	19.300	255
44	07-Mar-91 23:20:00.	18.250	19.950	28.400	30.300	30.800	19.150	255
45	07-Mar-91 23:30:00.	18.250	19.900	28.350	30.200	30.700	19.100	255
46	07-Mar-91 23:40:00.	17.900	19.650	28.300	30.150	30.650	18.650	255
47	07-Mar-91 23:50:00.	18.100	19.550	28.200	30.050	30.550	18.800	255
48	07-Mar-91 24:00:00.	17.750	19.400	28.100	29.950	30.500	18.500	255
49	08-Mar-91 00:10:00.	17.650	19.350	28.050	29.850	30.400	18.600	255
50	08-Mar-91 00:20:00.	17.500	19.350	27.950	29.800	30.200	18.700	255
51	08-Mar-91 00:30:00.	17.300	19.350	27.850	29.700	30.100	18.600	255
52	08-Mar-91 00:40:00.	16.950	19.350	27.750	29.600	29.950	18.500	255
53	08-Mar-91 00:50:00.	16.400	19.300	27.650	29.500	29.900	17.950	255
54	08-Mar-91 01:00:00.	16.300	19.100	27.550	29.350	29.700	17.650	255
55	08-Mar-91 01:10:00.	16.350	19.100	27.450	29.250	29.600	17.650	255
56	08-Mar-91 01:20:00.	16.350	19.000	27.350	29.100	29.500	17.800	255
57	08-Mar-91 01:30:00.	16.300	19.000	27.250	29.000	29.400	17.650	255
58	08-Mar-91 01:40:00.	16.150	18.900	27.200	28.950	29.350	17.550	255
59	08-Mar-91 01:50:00.	16.500	18.750	27.100	28.850	29.250	17.650	255
60	08-Mar-91 02:00:00.	16.650	18.700	27.000	28.750	29.150	17.700	255
61	08-Mar-91 02:10:00.	16.700	18.600	26.950	28.700	29.100	17.700	255
62	08-Mar-91 02:20:00.	16.650	18.550	26.850	28.650	29.100	17.650	255
63	08-Mar-91 02:30:00.	16.500	18.450	26.800	28.600	29.000	17.550	255
64	08-Mar-91 02:40:00.	16.350	18.400	26.700	28.500	28.950	17.350	255
65	08-Mar-91 02:50:00.	16.300	18.400	26.650	28.450	28.850	17.450	255
66	08-Mar-91 03:00:00.	16.350	18.350	26.550	28.400	28.800	17.400	255
67	08-Mar-91 03:10:00.	16.450	18.350	26.500	28.350	28.750	17.500	255
68	08-Mar-91 03:20:00.	16.400	18.350	26.450	28.300	28.750	17.500	255
69	08-Mar-91 03:30:00.	16.500	18.300	26.400	28.250	28.700	17.500	255
70	08-Mar-91 03:40:00.	16.400	18.300	26.350	28.200	28.700	17.550	255
71	08-Mar-91 03:50:00.	15.900	18.250	26.300	28.200	28.650	17.200	255
72	08-Mar-91 04:00:00.	15.650	18.200	26.250	28.150	28.550	17.000	255
73	08-Mar-91 04:10:00.	15.650	18.150	26.200	28.050	28.450	16.900	255
74	08-Mar-91 04:20:00.	15.700	18.150	26.150	28.000	28.400	17.150	255
75	08-Mar-91 04:30:00.	15.650	18.100	26.100	27.950	28.350	16.850	255
76	08-Mar-91 04:40:00.	15.600	17.950	26.050	27.900	28.300	16.600	255
77	08-Mar-91 04:50:00.	15.550	17.750	26.000	27.850	28.250	16.350	255
78	08-Mar-91 05:00:00.	15.550	17.650	25.950	27.800	28.200	16.450	255
79	08-Mar-91 05:10:00.	15.700	17.600	25.850	27.750	28.200	16.500	255
80	08-Mar-91 05:20:00.	16.000	17.600	25.800	27.700	28.100	16.850	255
81	08-Mar-91 05:30:00.	15.950	17.500	25.750	27.650	28.100	16.700	255
82	08-Mar-91 05:40:00.	15.650	17.400	25.700	27.600	28.100	16.350	255
83	08-Mar-91 05:50:00.	15.700	17.350	25.650	27.550	28.050	16.500	255
84	08-Mar-91 06:00:00.	15.850	17.350	25.550	27.500	28.000	16.650	255
85	08-Mar-91 06:10:00.	15.950	17.350	25.500	27.500	27.950	16.650	255
86	08-Mar-91 06:20:00.	16.100	17.450	25.500	27.450	27.950	16.700	255
87	08-Mar-91 06:30:00.	16.450	17.600	25.450	27.450	27.950	16.900	255
88	08-Mar-91 06:40:00.	17.000	17.850	25.450	27.450	28.000	17.550	255
89	08-Mar-91 06:50:00.	23.100	18.250	25.450	27.450	28.050	18.200	255
90	08-Mar-91 07:00:00.	26.650	18.750	25.550	27.550	28.400	18.700	255
91	08-Mar-91 07:10:00.	28.050	19.250	25.700	27.750	28.750	19.100	255
92	08-Mar-91 07:20:00.	28.250	19.750	25.900	27.950	29.100	19.300	255
93	08-Mar-91 07:30:00.	32.250	20.350	26.200	28.200	29.500	20.000	255
94	08-Mar-91 07:40:00.	31.050	20.900	26.500	28.500	29.900	20.050	255
95	08-Mar-91 07:50:00.	35.100	21.550	26.850	28.800	30.300	20.650	255
96	08-Mar-91 08:00:00.	34.100	22.150	27.200	29.100	30.700	20.850	255
97	08-Mar-91 08:10:00.	34.050	22.800	27.600	29.500	31.150	20.900	255
98	08-Mar-91 08:20:00.	34.300	23.400	28.000	29.850	31.550	20.850	255

99	08-Mar-91 08:30:00.	34.150	24.000	28.450	30.300	32.100	21.250	255
100	08-Mar-91 08:40:00.	34.250	24.500	28.900	30.650	32.550	21.250	255
101	08-Mar-91 08:50:00.	34.500	25.000	29.400	31.100	33.000	21.800	255
102	08-Mar-91 09:00:00.	35.100	25.700	29.850	31.450	33.400	22.250	255
103	08-Mar-91 09:00:20.	35.500	25.750	29.900	31.450	33.400	22.200	254
104	08-Mar-91 09:00:30.	35.700	25.850	29.900	31.500	33.450	22.250	255
105	08-Mar-91 09:10:00.	35.450	26.400	30.350	31.850	33.850	21.950	255
106	08-Mar-91 09:20:00.	35.400	26.800	30.800	32.250	34.300	21.800	255
107	08-Mar-91 09:30:00.	33.700	27.250	31.300	32.650	34.650	22.100	255
108	08-Mar-91 09:40:00.	34.950	27.550	31.750	32.950	35.000	22.100	255
109	08-Mar-91 09:50:00.	38.250	28.050	32.150	33.250	35.300	22.400	255
110	08-Mar-91 10:00:00.	36.450	28.550	32.600	33.650	35.700	22.900	255
111	08-Mar-91 10:10:00.	34.500	28.800	33.000	34.000	36.050	23.000	255
112	08-Mar-91 10:20:00.	36.200	29.450	33.450	34.350	36.400	23.100	255
113	08-Mar-91 10:30:00.	35.400	29.900	33.850	34.750	36.900	23.200	255
114	08-Mar-91 10:40:00.	36.950	30.750	34.350	35.100	37.350	23.700	255
115	08-Mar-91 10:41:40.	38.150	31.000	34.400	35.200	37.450	24.000	254
116	08-Mar-91 10:50:00.	32.750	33.000	32.550	35.500	37.550	23.750	254
117	08-Mar-91 11:00:00.	33.900	37.700	30.400	35.400	36.800	24.050	254
118	08-Mar-91 11:10:00.	36.900	40.950	28.950	35.250	36.350	24.600	254
119	08-Mar-91 11:20:00.	34.950	44.600	28.200	35.200	36.200	24.450	254
120	08-Mar-91 11:30:00.	32.000	44.250	27.750	35.050	36.050	23.850	254
121	08-Mar-91 11:40:00.	33.550	44.600	27.400	34.850	35.650	24.200	254
122	08-Mar-91 11:41:40.	35.200	45.450	27.300	34.800	35.550	24.550	255
123	08-Mar-91 11:50:00.	31.500	44.600	29.200	34.800	35.750	24.400	255
124	08-Mar-91 12:00:00.	29.150	40.650	31.300	35.000	36.100	24.150	255
125	08-Mar-91 12:10:00.	31.600	39.150	32.800	35.100	36.300	24.950	255
126	08-Mar-91 12:20:00.	31.600	37.900	34.000	35.500	37.150	25.550	255
127	08-Mar-91 12:27:50.	29.600	36.300	34.750	35.750	37.550	24.950	254
128	08-Mar-91 12:30:00.	29.550	35.950	34.600	35.800	37.550	24.850	254
129	08-Mar-91 12:40:00.	29.100	38.750	32.200	35.850	37.300	24.750	254
130	08-Mar-91 12:50:00.	29.000	42.600	30.450	35.700	36.700	25.150	254
131	08-Mar-91 13:00:00.	30.450	45.850	29.400	35.600	36.600	25.800	254
132	08-Mar-91 13:10:00.	29.900	48.100	28.750	35.550	36.550	26.300	254
133	08-Mar-91 13:20:00.	30.050	49.400	28.400	35.450	36.300	25.750	254
134	08-Mar-91 13:30:00.	30.000	50.700	28.200	35.350	36.200	25.400	254
135	08-Mar-91 13:40:00.	31.050	51.850	28.100	35.300	36.150	25.950	254
136	08-Mar-91 13:50:00.	30.950	52.350	28.200	35.350	36.350	26.100	254
137	08-Mar-91 14:00:00.	32.950	52.500	28.350	35.500	36.650	26.850	254
138	08-Mar-91 14:06:40.	32.900	51.700	28.150	34.900	34.600	26.650	255
139	08-Mar-91 14:10:00.	Underrange	Underrange	Underrange	Underrange	Underrange	Underrange	255
140	08-Mar-91 14:20:00.	Underrange	Underrange	Underrange	Underrange	Underrange	Underrange	255
141	08-Mar-91 14:30:00.	Underrange	Underrange	Underrange	Underrange	Underrange	Underrange	255

Ch 2 Ch 3 Ch 5 Ch 6

degC



16: 00: 00. 20: 00: 00. 04: 00: 00. 08: 00: 00. 12: 00: 00.

07-Mar-91

## APPENDIX 3.6.7

### ON SITE CONTAINER TEMPERATURE READINGS

File 23

100 Watt heat load

2,5 Amp cooling

Container on site

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.

Ch 2 Outside heat sink

Ch 3 Inside heat sink

Ch 4 Inside floor level

Ch 5 Inside globe level

Ch 6 Outside globe level

Ch 19B 255=Off 254=On

## Channel Readings

Data file - FILE23

**Recorder details:**

Recorder number : 38  
 Squirrel type : 1206

**Run details:**

Run number : 1  
 Channels used : 7  
 Recording Interval : 00:10:00.  
 Non-averaged time interval readings  
 Event/Digital readings  
 Recording period :  
     Start : 08-Mar-91 16:00:00.  
     Finish : 11-Mar-91 07:30:01.  
 Readings per channel: 401

All readings

Rdg no.	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19 B
0	08-Mar-91 16:00:00.	31.400	56.250	33.450	40.350	41.500	26.800	254
1	08-Mar-91 16:00:00.	31.400	56.250	33.450	40.350	41.500	26.800	254
2	08-Mar-91 16:10:00.	32.050	55.700	33.650	40.550	41.500	27.650	254
3	08-Mar-91 16:20:00.	31.000	55.800	33.800	40.750	41.800	27.000	254
4	08-Mar-91 16:30:00.	28.850	55.200	33.900	40.850	41.650	26.050	254
5	08-Mar-91 16:40:00.	27.750	54.900	33.850	40.750	41.500	25.750	254
6	08-Mar-91 16:50:00.	27.600	55.650	33.750	40.600	41.200	26.050	254
7	08-Mar-91 17:00:00.	28.250	55.300	33.700	40.550	41.050	26.600	254
8	08-Mar-91 17:10:00.	27.950	54.950	33.650	40.550	41.050	26.300	254
9	08-Mar-91 17:20:00.	28.050	53.650	33.600	40.500	40.950	26.300	254
10	08-Mar-91 17:30:00.	28.350	54.350	33.550	40.400	41.000	26.250	254
11	08-Mar-91 17:40:00.	27.950	54.800	33.450	40.350	41.000	26.000	254
12	08-Mar-91 17:50:00.	27.550	55.050	33.400	40.300	40.850	25.850	254
13	08-Mar-91 18:00:00.	27.250	54.950	33.350	40.150	40.800	25.800	254
14	08-Mar-91 18:10:00.	26.600	54.600	33.300	40.100	40.650	25.450	254
15	08-Mar-91 18:20:00.	25.200	54.200	33.200	40.000	40.500	24.950	254
16	08-Mar-91 18:30:00.	23.800	53.800	33.100	39.750	40.100	24.250	254
17	08-Mar-91 18:40:00.	22.700	53.600	32.850	39.500	39.700	23.750	254
18	08-Mar-91 18:50:00.	21.650	52.750	32.600	39.150	39.250	23.450	254
19	08-Mar-91 19:00:00.	21.500	53.500	32.350	38.900	38.900	23.200	254
20	08-Mar-91 19:10:00.	21.650	53.450	32.100	38.650	38.700	23.100	254
21	08-Mar-91 19:20:00.	21.800	53.250	31.900	38.400	38.500	23.050	254
22	08-Mar-91 19:30:00.	21.700	52.900	31.700	38.150	38.300	23.050	254
23	08-Mar-91 19:40:00.	22.250	53.850	31.550	37.950	38.150	23.000	254
24	08-Mar-91 19:50:00.	22.050	53.750	31.400	37.800	38.050	22.900	254
25	08-Mar-91 20:00:00.	21.800	53.600	31.300	37.650	37.950	22.800	254
26	08-Mar-91 20:10:00.	22.500	53.650	31.200	37.450	37.800	22.800	254
27	08-Mar-91 20:20:00.	22.400	47.750	31.050	37.300	37.700	22.400	254
28	08-Mar-91 20:30:00.	21.650	46.100	30.700	37.200	37.650	21.900	254
29	08-Mar-91 20:40:00.	21.100	43.250	30.100	36.950	37.400	21.450	254
30	08-Mar-91 20:50:00.	20.900	40.600	29.450	36.650	37.050	21.150	254
31	08-Mar-91 21:00:00.	20.750	39.100	28.700	36.300	36.650	20.950	254
32	08-Mar-91 21:10:00.	20.500	39.650	28.050	35.950	36.200	20.850	254
33	08-Mar-91 21:20:00.	20.300	37.800	27.400	35.600	35.800	20.550	254
34	08-Mar-91 21:30:00.	20.000	37.650	26.750	35.250	35.450	20.350	254
35	08-Mar-91 21:32:40.	19.850	37.850	26.600	35.150	35.300	20.250	255
36	08-Mar-91 21:40:00.	19.800	35.600	28.050	35.000	35.250	20.200	255
37	08-Mar-91 21:50:00.	19.600	31.550	30.000	35.050	35.550	20.150	255

38	08-Mar-91 22:00:00.	19.700	27.350	31.300	35.200	35.950	20.050	255
39	08-Mar-91 22:10:00.	19.400	25.400	32.150	35.350	36.300	19.850	255
40	08-Mar-91 22:20:00.	19.300	23.950	32.750	35.500	36.650	19.700	255
41	08-Mar-91 22:30:00.	19.350	22.750	33.150	35.600	36.900	19.650	255
42	08-Mar-91 22:40:00.	19.300	22.050	33.400	35.750	37.100	19.450	255
43	08-Mar-91 22:50:00.	19.250	21.450	33.550	35.900	37.150	19.450	255
44	08-Mar-91 22:51:50.	19.250	21.350	33.550	35.900	37.200	19.450	254
45	08-Mar-91 23:00:00.	19.250	23.650	31.350	35.850	36.850	19.450	254
46	08-Mar-91 23:10:00.	19.550	26.450	28.850	35.550	36.150	19.650	254
47	08-Mar-91 23:20:00.	19.450	28.450	27.100	35.150	35.500	19.550	254
48	08-Mar-91 23:25:00.	19.350	29.150	26.400	34.950	35.200	19.500	255
49	08-Mar-91 23:30:00.	19.250	27.600	27.000	34.750	35.050	19.450	255
50	08-Mar-91 23:40:00.	19.200	24.450	28.600	34.650	35.100	19.400	255
51	08-Mar-91 23:50:00.	19.250	22.450	29.750	34.650	35.350	19.500	255
52	08-Mar-91 24:00:00.	19.250	21.300	30.500	34.750	35.550	19.500	255
53	09-Mar-91 00:10:00.	19.150	20.850	31.050	34.800	35.750	19.450	255
54	09-Mar-91 00:20:00.	19.250	20.350	31.450	34.900	35.950	19.450	255
55	09-Mar-91 00:30:00.	19.100	20.150	31.750	35.000	36.000	19.400	255
56	09-Mar-91 00:40:00.	19.100	20.000	32.000	35.100	36.100	19.350	255
57	09-Mar-91 00:50:00.	18.900	19.900	32.200	35.200	36.300	19.150	255
58	09-Mar-91 01:00:00.	18.950	19.750	32.350	35.250	36.400	19.200	255
59	09-Mar-91 01:10:00.	18.900	19.750	32.450	35.350	36.400	19.150	255
60	09-Mar-91 01:20:00.	18.850	19.700	32.600	35.450	36.450	19.100	255
61	09-Mar-91 01:30:00.	18.700	19.650	32.700	35.500	36.550	18.950	255
62	09-Mar-91 01:40:00.	18.600	19.600	32.750	35.550	36.600	18.800	255
63	09-Mar-91 01:50:00.	18.400	19.500	32.850	35.550	36.700	18.600	255
64	09-Mar-91 02:00:00.	18.500	19.400	32.900	35.600	36.600	18.550	255
65	09-Mar-91 02:10:00.	18.400	19.300	32.900	35.600	36.600	18.400	255
66	09-Mar-91 02:20:00.	18.300	19.200	32.900	35.600	36.650	18.400	255
67	09-Mar-91 02:30:00.	18.250	19.200	32.900	35.600	36.650	18.350	255
68	09-Mar-91 02:40:00.	18.150	19.100	32.900	35.600	36.700	18.250	255
69	09-Mar-91 02:50:00.	18.250	19.200	32.950	35.550	36.750	18.250	255
70	09-Mar-91 03:00:00.	18.150	19.300	32.950	35.600	36.750	18.200	255
71	09-Mar-91 03:10:00.	18.100	19.200	32.950	35.600	36.750	18.100	255
72	09-Mar-91 03:20:00.	18.000	19.200	33.000	35.600	36.750	18.050	255
73	09-Mar-91 03:30:00.	17.800	19.150	33.000	35.600	36.750	17.900	255
74	09-Mar-91 03:40:00.	17.600	19.100	33.000	35.550	36.700	17.750	255
75	09-Mar-91 03:50:00.	17.500	19.100	33.000	35.550	36.700	17.700	255
76	09-Mar-91 04:00:00.	17.350	19.100	33.000	35.550	36.650	17.550	255
77	09-Mar-91 04:10:00.	17.200	19.000	32.950	35.500	36.650	17.450	255
78	09-Mar-91 04:20:00.	17.250	18.950	32.950	35.450	36.500	17.550	255
79	09-Mar-91 04:30:00.	17.300	18.950	32.900	35.450	36.450	17.650	255
80	09-Mar-91 04:40:00.	17.450	18.950	32.850	35.400	36.450	17.700	255
81	09-Mar-91 04:50:00.	17.300	18.900	32.800	35.350	36.400	17.550	255
82	09-Mar-91 05:00:00.	17.100	18.900	32.800	35.350	36.400	17.350	255
83	09-Mar-91 05:10:00.	17.100	18.850	32.750	35.300	36.400	17.300	255
84	09-Mar-91 05:20:00.	17.300	18.800	32.750	35.300	36.350	17.350	255
85	09-Mar-91 05:30:00.	17.600	18.950	32.750	35.300	36.400	17.600	255
86	09-Mar-91 05:40:00.	17.700	19.100	32.750	35.350	36.450	17.550	255
87	09-Mar-91 05:50:00.	17.650	19.200	32.800	35.400	36.550	17.350	255
88	09-Mar-91 06:00:00.	17.800	19.350	32.800	35.450	36.600	17.500	255
89	09-Mar-91 06:10:00.	18.050	19.550	32.900	35.500	36.650	17.700	255
90	09-Mar-91 06:20:00.	18.150	19.800	32.900	35.500	36.700	17.750	255
91	09-Mar-91 06:30:00.	18.450	20.000	33.000	35.600	36.800	17.850	255
92	09-Mar-91 06:40:00.	18.450	20.150	33.100	35.700	36.950	17.900	255
93	09-Mar-91 06:50:00.	18.750	20.350	33.200	35.800	37.050	18.200	255
94	09-Mar-91 06:53:50.	19.000	20.500	33.250	35.800	37.150	18.300	254
95	09-Mar-91 07:00:00.	19.450	22.700	31.650	35.800	36.950	18.600	254
96	09-Mar-91 07:10:00.	19.900	28.400	29.150	35.600	36.200	18.850	254
97	09-Mar-91 07:20:00.	20.150	33.250	27.550	35.300	35.600	19.050	254
98	09-Mar-91 07:27:20.	20.550	35.800	26.750	35.000	35.200	19.100	255
99	09-Mar-91 07:30:00.	20.950	36.400	27.050	34.950	35.200	19.250	255
100	09-Mar-91 07:40:00.	29.750	34.250	29.250	35.000	35.500	20.150	255

101	09-Mar-91 07:50:00.	25.100	32.400	31.050	35.400	36.450	20.250	255
102	09-Mar-91 08:00:00.	24.100	30.450	32.400	35.750	37.200	20.350	255
103	09-Mar-91 08:00:40.	24.050	30.450	32.500	35.750	37.200	20.350	254
104	09-Mar-91 08:10:00.	25.050	33.000	30.900	35.950	37.300	20.500	254
105	09-Mar-91 08:20:00.	24.950	37.200	29.400	35.950	37.000	20.750	254
106	09-Mar-91 08:30:00.	25.400	39.950	28.500	35.850	36.700	20.750	254
107	09-Mar-91 08:40:00.	30.000	42.900	28.000	35.750	36.500	21.050	254
108	09-Mar-91 08:50:00.	33.400	45.250	27.800	35.700	36.450	21.800	254
109	09-Mar-91 09:00:00.	35.950	46.200	27.900	35.800	36.800	22.050	254
110	09-Mar-91 09:10:00.	33.050	47.350	28.100	35.950	37.200	21.950	254
111	09-Mar-91 09:20:00.	34.950	47.950	28.350	36.050	37.350	22.300	254
112	09-Mar-91 09:30:00.	35.900	49.200	28.600	36.200	37.650	22.850	254
113	09-Mar-91 09:40:00.	29.800	49.150	28.950	36.450	37.900	22.150	254
114	09-Mar-91 09:50:00.	33.350	50.000	29.200	36.550	37.950	23.350	254
115	09-Mar-91 10:00:00.	34.600	50.650	29.500	36.700	38.050	22.850	254
116	09-Mar-91 10:10:00.	35.200	50.650	29.850	36.950	38.450	24.300	254
117	09-Mar-91 10:20:00.	36.050	51.950	30.250	37.200	38.900	24.000	254
118	09-Mar-91 10:30:00.	37.400	52.650	30.650	37.500	39.350	23.700	254
119	09-Mar-91 10:40:00.	35.100	53.250	31.000	37.800	39.600	24.050	254
120	09-Mar-91 10:50:00.	35.700	53.850	31.350	38.050	39.850	24.300	254
121	09-Mar-91 11:00:00.	36.650	54.350	31.700	38.300	40.150	24.450	254
122	09-Mar-91 11:10:00.	32.550	54.000	32.000	38.550	40.350	24.850	254
123	09-Mar-91 11:20:00.	32.350	53.600	32.200	38.700	40.400	24.750	254
124	09-Mar-91 11:30:00.	35.500	54.800	32.450	38.950	40.700	25.350	254
125	09-Mar-91 11:40:00.	35.900	55.200	32.700	39.200	40.950	25.500	254
126	09-Mar-91 11:50:00.	37.200	55.150	33.000	39.500	41.350	26.300	254
127	09-Mar-91 12:00:00.	32.300	54.400	33.250	39.800	41.800	25.700	254
128	09-Mar-91 12:10:00.	32.050	54.800	33.550	40.100	42.050	25.150	254
129	09-Mar-91 12:20:00.	33.200	56.100	33.750	40.300	42.050	26.150	254
130	09-Mar-91 12:30:00.	34.050	56.200	34.000	40.500	42.250	26.750	254
131	09-Mar-91 12:40:00.	33.550	57.100	34.150	40.700	42.400	26.550	254
132	09-Mar-91 12:50:00.	31.250	55.150	34.300	40.850	42.450	25.650	254
133	09-Mar-91 13:00:00.	29.950	55.050	34.300	40.850	42.050	25.300	254
134	09-Mar-91 13:10:00.	32.700	55.300	34.250	40.900	42.050	26.800	254
135	09-Mar-91 13:20:00.	32.900	56.650	34.350	41.050	42.450	26.700	254
136	09-Mar-91 13:30:00.	32.700	56.350	34.550	41.300	42.850	26.800	254
137	09-Mar-91 13:40:00.	31.150	56.400	34.650	41.450	42.750	26.150	254
138	09-Mar-91 13:50:00.	30.750	55.500	34.700	41.500	42.600	26.100	254
139	09-Mar-91 14:00:00.	32.300	55.800	34.650	41.500	42.450	27.350	254
140	09-Mar-91 14:10:00.	32.900	56.500	34.700	41.700	42.800	27.600	254
141	09-Mar-91 14:20:00.	32.050	56.000	34.800	41.850	43.050	26.900	254
142	09-Mar-91 14:30:00.	32.650	56.700	34.850	42.000	43.050	27.750	254
143	09-Mar-91 14:40:00.	32.150	54.200	35.000	42.150	43.100	27.200	254
144	09-Mar-91 14:50:00.	32.500	55.800	35.000	42.300	43.350	27.750	254
145	09-Mar-91 15:00:00.	31.050	54.950	35.050	42.450	43.350	27.300	254
146	09-Mar-91 15:10:00.	31.800	56.050	35.100	42.500	43.200	27.950	254
147	09-Mar-91 15:20:00.	30.800	54.850	35.150	42.600	43.100	27.700	254
148	09-Mar-91 15:30:00.	30.750	53.550	35.050	42.600	43.000	27.700	254
149	09-Mar-91 15:40:00.	31.300	54.150	34.950	42.600	43.050	27.950	254
150	09-Mar-91 15:50:00.	30.900	53.700	34.850	42.600	43.150	27.950	254
151	09-Mar-91 16:00:00.	30.800	51.800	34.750	42.600	42.900	27.850	254
152	09-Mar-91 16:10:00.	30.700	50.850	34.550	42.600	42.850	27.850	254
153	09-Mar-91 16:20:00.	30.500	51.850	34.350	42.550	42.850	27.700	254
154	09-Mar-91 16:30:00.	30.100	50.100	34.150	42.450	42.650	27.800	254
155	09-Mar-91 16:40:00.	30.150	49.700	34.000	42.450	42.500	27.950	254
156	09-Mar-91 16:50:00.	29.650	48.250	33.800	42.350	42.450	27.750	254
157	09-Mar-91 17:00:00.	29.500	49.550	33.600	42.200	42.300	27.750	254
158	09-Mar-91 17:10:00.	29.200	49.850	33.450	42.100	42.150	27.600	254
159	09-Mar-91 17:20:00.	28.800	51.100	33.350	41.950	42.100	27.300	254
160	09-Mar-91 17:30:00.	28.350	50.950	33.250	41.800	41.950	27.450	254
161	09-Mar-91 17:40:00.	27.750	52.000	33.200	41.550	41.850	27.100	254
162	09-Mar-91 17:50:00.	27.100	52.300	33.150	41.350	41.600	26.700	254

163	09-Mar-91	18:00:00.	26.350	52.200	33.100	41.150	41.300	26.300	254
164	09-Mar-91	18:10:00.	25.300	52.450	33.000	40.850	41.050	25.750	254
165	09-Mar-91	18:20:00.	24.400	52.500	32.900	40.550	40.700	25.500	254
166	09-Mar-91	18:30:00.	23.800	52.600	32.750	40.200	40.300	25.250	254
167	09-Mar-91	18:40:00.	23.150	52.950	32.650	39.900	40.000	24.700	254
168	09-Mar-91	18:50:00.	22.900	53.900	32.500	39.600	39.600	24.500	254
169	09-Mar-91	19:00:00.	23.050	54.950	32.400	39.350	39.400	24.200	254
170	09-Mar-91	19:10:00.	23.550	54.550	32.300	39.050	39.250	24.100	254
171	09-Mar-91	19:20:00.	24.050	54.500	32.250	38.900	39.200	24.200	254
172	09-Mar-91	19:30:00.	24.150	55.050	32.200	38.800	39.200	24.300	254
173	09-Mar-91	19:40:00.	24.250	54.950	32.250	38.700	39.200	24.200	254
174	09-Mar-91	19:50:00.	24.550	55.400	32.250	38.650	39.200	24.200	254
175	09-Mar-91	20:00:00.	24.500	55.350	32.250	38.650	39.250	24.250	254
176	09-Mar-91	20:10:00.	24.400	54.950	32.200	38.600	39.200	24.300	254
177	09-Mar-91	20:20:00.	23.800	52.750	32.200	38.550	39.100	23.750	254
178	09-Mar-91	20:30:00.	23.700	52.700	32.100	38.450	39.000	23.500	254
179	09-Mar-91	20:40:00.	23.500	52.850	32.000	38.400	38.900	23.400	254
180	09-Mar-91	20:50:00.	23.400	54.750	31.900	38.300	38.800	23.300	254
181	09-Mar-91	21:00:00.	23.100	54.600	31.850	38.200	38.700	23.150	254
182	09-Mar-91	21:10:00.	22.300	54.000	31.750	38.050	38.500	22.950	254
183	09-Mar-91	21:20:00.	22.100	52.300	31.650	37.900	38.300	22.900	254
184	09-Mar-91	21:30:00.	21.600	52.950	31.500	37.750	38.150	22.600	254
185	09-Mar-91	21:40:00.	21.200	53.400	31.350	37.600	37.900	22.000	254
186	09-Mar-91	21:50:00.	20.550	52.750	31.150	37.400	37.700	21.750	254
187	09-Mar-91	22:00:00.	20.150	52.300	31.000	37.200	37.500	21.300	254
188	09-Mar-91	22:10:00.	20.000	52.600	30.800	37.050	37.350	21.150	254
189	09-Mar-91	22:20:00.	19.850	52.400	30.600	36.800	37.150	21.000	254
190	09-Mar-91	22:30:00.	20.000	52.400	30.450	36.650	36.950	21.000	254
191	09-Mar-91	22:40:00.	19.900	52.400	30.300	36.500	36.850	20.850	254
192	09-Mar-91	22:50:00.	19.850	52.050	30.100	36.350	36.700	20.900	254
193	09-Mar-91	23:00:00.	19.750	52.000	29.950	36.200	36.550	21.000	254
194	09-Mar-91	23:10:00.	19.500	51.350	29.800	36.050	36.450	20.700	254
195	09-Mar-91	23:20:00.	19.400	52.250	29.700	35.950	36.300	20.500	254
196	09-Mar-91	23:30:00.	19.400	52.000	29.550	35.750	36.050	20.350	254
197	09-Mar-91	23:40:00.	19.350	51.600	29.400	35.600	35.900	20.450	254
198	09-Mar-91	23:50:00.	19.950	50.500	29.250	35.500	35.800	20.650	254
199	10-Mar-91	00:00:00.	19.800	48.600	29.050	35.400	35.750	20.500	254
200	10-Mar-91	00:10:00.	19.700	47.550	28.750	35.250	35.650	20.300	254
201	10-Mar-91	00:20:00.	19.550	46.150	28.400	35.100	35.500	20.050	254
202	10-Mar-91	00:28:30.	19.450	44.750	28.100	34.950	35.300	19.950	255
203	10-Mar-91	00:30:00.	19.400	44.700	28.200	34.950	35.300	19.950	255
204	10-Mar-91	00:40:00.	19.450	39.200	30.650	35.050	35.600	19.950	255
205	10-Mar-91	00:50:00.	19.250	34.050	32.350	35.250	36.150	19.800	255
206	10-Mar-91	01:00:00.	19.150	30.500	33.450	35.500	36.700	19.700	255
207	10-Mar-91	01:10:00.	19.100	27.550	34.150	35.700	37.050	19.650	255
208	10-Mar-91	01:16:00.	19.050	26.450	34.400	35.800	37.250	19.550	254
209	10-Mar-91	01:20:00.	19.050	26.750	33.550	35.850	37.250	19.550	254
210	10-Mar-91	01:30:00.	19.150	30.450	30.800	35.800	36.550	19.700	254
211	10-Mar-91	01:40:00.	19.150	33.950	28.900	35.500	35.800	19.850	254
212	10-Mar-91	01:49:40.	18.800	37.600	27.650	35.200	35.300	19.700	255
213	10-Mar-91	01:50:00.	18.800	37.700	27.600	35.200	35.300	19.700	255
214	10-Mar-91	02:00:00.	18.500	36.050	29.450	35.000	35.250	19.400	255
215	10-Mar-91	02:10:00.	18.450	32.950	31.150	35.100	35.550	19.400	255
216	10-Mar-91	02:20:00.	18.400	30.550	32.300	35.250	36.150	19.300	255
217	10-Mar-91	02:30:00.	18.450	28.400	33.100	35.400	36.450	19.250	255
218	10-Mar-91	02:40:00.	18.500	26.800	33.650	35.500	36.800	19.300	255
219	10-Mar-91	02:50:00.	18.400	25.200	34.050	35.650	37.000	19.050	255
220	10-Mar-91	03:00:00.	18.200	24.000	34.250	35.800	37.150	18.750	255
221	10-Mar-91	03:04:00.	18.150	23.500	34.300	35.800	37.150	18.750	254
222	10-Mar-91	03:10:00.	18.150	24.950	32.750	35.850	37.000	18.650	254
223	10-Mar-91	03:20:00.	18.200	29.350	30.050	35.600	36.100	18.700	254
224	10-Mar-91	03:30:00.	18.300	32.550	28.150	35.250	35.450	18.800	254

225	10-Mar-91 03:32:40.	18.300	33.450	27.750	35.150	35.250	18.850	255
226	10-Mar-91 03:40:00.	18.500	31.800	28.700	35.000	35.150	18.950	255
227	10-Mar-91 03:50:00.	18.250	27.800	30.200	34.950	35.300	18.650	255
228	10-Mar-91 04:00:00.	18.050	25.200	31.200	35.000	35.550	18.450	255
229	10-Mar-91 04:10:00.	17.800	23.650	31.850	35.100	35.950	18.400	255
230	10-Mar-91 04:20:00.	17.450	22.700	32.300	35.200	36.150	18.050	255
231	10-Mar-91 04:30:00.	17.450	21.900	32.600	35.200	36.200	18.000	255
232	10-Mar-91 04:40:00.	17.300	21.550	32.800	35.250	36.300	18.000	255
233	10-Mar-91 04:50:00.	17.300	21.250	32.950	35.350	36.400	18.100	255
234	10-Mar-91 05:00:00.	17.200	21.150	33.050	35.350	36.450	18.000	255
235	10-Mar-91 05:10:00.	17.300	20.900	33.100	35.400	36.450	18.150	255
236	10-Mar-91 05:20:00.	17.200	20.700	33.150	35.450	36.450	17.950	255
237	10-Mar-91 05:30:00.	17.200	20.500	33.200	35.450	36.500	17.800	255
238	10-Mar-91 05:40:00.	16.950	20.350	33.200	35.450	36.550	17.600	255
239	10-Mar-91 05:50:00.	16.950	20.250	33.200	35.500	36.550	17.600	255
240	10-Mar-91 06:00:00.	17.000	20.100	33.200	35.500	36.550	17.550	255
241	10-Mar-91 06:10:00.	17.500	20.000	33.200	35.500	36.550	18.000	255
242	10-Mar-91 06:20:00.	17.400	19.800	33.200	35.550	36.600	17.650	255
243	10-Mar-91 06:30:00.	17.600	19.750	33.200	35.550	36.600	17.700	255
244	10-Mar-91 06:40:00.	17.900	19.650	33.150	35.600	36.600	17.850	255
245	10-Mar-91 06:50:00.	22.400	19.850	33.150	35.600	36.650	18.250	255
246	10-Mar-91 07:00:00.	25.650	20.300	33.200	35.700	36.800	18.950	255
247	10-Mar-91 07:10:00.	28.600	20.800	33.300	35.800	37.100	19.450	255
248	10-Mar-91 07:11:40.	28.900	20.900	33.300	35.900	37.150	19.650	254
249	10-Mar-91 07:20:00.	29.750	24.550	31.200	36.000	37.200	19.950	254
250	10-Mar-91 07:30:00.	31.200	30.200	28.950	35.900	36.800	20.650	254
251	10-Mar-91 07:40:00.	31.600	34.700	27.650	35.700	36.400	21.050	254
252	10-Mar-91 07:50:00.	32.600	38.200	26.900	35.550	36.250	21.500	254
253	10-Mar-91 08:00:00.	34.150	40.400	26.600	35.450	36.150	21.900	254
254	10-Mar-91 08:10:00.	35.500	42.150	26.550	35.400	36.150	22.500	254
255	10-Mar-91 08:20:00.	37.000	44.400	26.700	35.450	36.400	23.050	254
256	10-Mar-91 08:30:00.	37.650	45.400	26.950	35.550	36.650	23.350	254
257	10-Mar-91 08:40:00.	37.450	46.350	27.350	35.700	36.950	23.650	254
258	10-Mar-91 08:50:00.	37.300	47.300	27.750	35.900	37.300	23.950	254
259	10-Mar-91 09:00:00.	39.850	48.700	28.250	36.200	37.650	23.800	254
260	10-Mar-91 09:10:00.	36.700	50.250	28.750	36.550	38.050	23.800	254
261	10-Mar-91 09:20:00.	38.600	51.500	29.250	36.850	38.450	24.050	254
262	10-Mar-91 09:30:00.	38.450	52.600	29.800	37.150	38.750	24.250	254
263	10-Mar-91 09:40:00.	37.150	53.150	30.300	37.450	39.100	24.300	254
264	10-Mar-91 09:50:00.	38.400	54.250	30.750	37.750	39.450	24.550	254
265	10-Mar-91 10:00:00.	39.000	54.900	31.300	38.050	39.800	24.800	254
266	10-Mar-91 10:10:00.	39.600	55.100	31.750	38.400	40.250	25.500	254
267	10-Mar-91 10:20:00.	37.300	55.450	32.200	38.700	40.600	25.450	254
268	10-Mar-91 10:30:00.	37.350	55.600	32.550	39.000	40.850	25.400	254
269	10-Mar-91 10:40:00.	40.950	55.400	32.950	39.350	41.150	25.850	254
270	10-Mar-91 10:50:00.	38.550	56.450	33.250	39.600	41.550	25.900	254
271	10-Mar-91 11:00:00.	39.500	56.750	33.650	39.950	41.950	26.900	254
272	10-Mar-91 11:10:00.	37.900	56.900	34.000	40.250	42.250	26.900	254
273	10-Mar-91 11:20:00.	38.350	57.550	34.300	40.550	42.550	27.150	254
274	10-Mar-91 11:30:00.	37.350	56.750	34.600	40.850	42.900	26.850	254
275	10-Mar-91 11:40:00.	38.200	56.800	34.850	41.150	43.200	27.300	254
276	10-Mar-91 11:50:00.	32.450	56.450	35.100	41.450	43.500	26.600	254
277	10-Mar-91 12:00:00.	35.450	57.700	35.250	41.600	43.450	27.700	254
278	10-Mar-91 12:10:00.	34.850	56.100	35.500	41.800	43.600	27.450	254
279	10-Mar-91 12:20:00.	36.450	57.650	35.600	42.000	43.800	28.750	254
280	10-Mar-91 12:30:00.	33.900	57.700	35.800	42.200	44.050	27.650	254
281	10-Mar-91 12:40:00.	34.400	58.200	36.000	42.450	44.250	28.700	254
282	10-Mar-91 12:50:00.	34.750	58.550	36.200	42.650	44.350	27.900	254
283	10-Mar-91 13:00:00.	33.650	57.850	36.450	42.900	44.500	27.600	254
284	10-Mar-91 13:10:00.	33.400	55.850	36.500	42.950	44.350	27.550	254
285	10-Mar-91 13:20:00.	35.050	58.200	36.450	43.050	44.400	28.650	254
286	10-Mar-91 13:30:00.	34.850	58.750	36.600	43.200	44.750	29.200	254

287	10-Mar-91 13:40:00.	35.500	57.750	36.750	43.450	45.000	29.100	254
288	10-Mar-91 13:50:00.	35.300	58.150	36.950	43.700	45.300	29.550	254
289	10-Mar-91 14:00:00.	35.700	57.450	37.150	43.900	45.450	29.500	254
290	10-Mar-91 14:10:00.	33.150	56.750	37.250	44.050	45.550	28.700	254
291	10-Mar-91 14:20:00.	33.550	57.350	37.200	44.100	45.250	28.900	254
292	10-Mar-91 14:30:00.	34.250	58.000	37.350	44.300	45.600	29.500	254
293	10-Mar-91 14:40:00.	34.750	58.700	37.500	44.500	45.800	29.600	254
294	10-Mar-91 14:50:00.	34.450	59.800	37.700	44.700	46.100	29.800	254
295	10-Mar-91 15:00:00.	35.100	59.000	38.000	45.000	46.300	29.900	254
296	10-Mar-91 15:10:00.	34.200	60.150	38.200	45.150	46.450	29.550	254
297	10-Mar-91 15:20:00.	31.700	59.350	38.300	45.250	46.250	28.600	254
298	10-Mar-91 15:30:00.	31.200	59.050	38.250	45.050	45.800	28.300	254
299	10-Mar-91 15:40:00.	30.850	59.250	38.150	44.850	45.450	28.650	254
300	10-Mar-91 15:50:00.	30.100	58.950	38.050	44.650	45.250	28.300	254
301	10-Mar-91 16:00:00.	29.650	57.800	37.950	44.450	44.950	28.350	254
302	10-Mar-91 16:10:00.	31.350	59.550	37.850	44.350	44.750	29.100	254
303	10-Mar-91 16:20:00.	29.750	28.600	37.900	44.350	45.000	28.300	254
304	10-Mar-91 16:30:00.	30.800	28.800	37.850	44.250	44.800	29.050	254
305	10-Mar-91 16:40:00.	28.750	27.600	37.850	44.200	44.800	27.750	254
306	10-Mar-91 16:50:00.	27.850	27.350	37.700	44.000	44.550	27.400	254
307	10-Mar-91 17:00:00.	27.200	27.000	37.450	43.700	44.050	27.000	254
308	10-Mar-91 17:10:00.	27.300	27.200	37.250	43.450	43.700	27.250	254
309	10-Mar-91 17:20:00.	26.600	26.650	37.050	43.250	43.500	26.950	254
310	10-Mar-91 17:30:00.	25.950	26.100	36.800	42.950	43.200	26.800	254
311	10-Mar-91 17:40:00.	25.450	25.750	36.550	42.700	42.850	26.450	254
312	10-Mar-91 17:50:00.	25.050	25.250	36.300	42.400	42.600	26.050	254
313	10-Mar-91 18:00:00.	25.750	25.950	36.050	42.150	42.300	26.100	254
314	10-Mar-91 18:10:00.	26.050	26.050	35.900	41.950	42.300	26.350	254
315	10-Mar-91 18:20:00.	25.600	25.350	35.700	41.800	42.250	26.000	254
316	10-Mar-91 18:30:00.	24.800	24.750	35.550	41.600	42.000	25.550	254
317	10-Mar-91 18:40:00.	24.100	24.250	35.300	41.350	41.600	25.000	254
318	10-Mar-91 18:50:00.	24.050	24.400	35.000	41.050	41.250	24.900	254
319	10-Mar-91 19:00:00.	23.900	24.150	34.800	40.850	41.050	24.600	254
320	10-Mar-91 19:10:00.	23.500	23.700	34.550	40.500	40.700	24.400	254
321	10-Mar-91 19:20:00.	22.950	23.400	34.250	40.250	40.400	24.200	254
322	10-Mar-91 19:30:00.	22.400	22.900	34.000	39.950	40.150	23.800	254
323	10-Mar-91 19:40:00.	22.350	22.850	33.700	39.700	39.850	23.650	254
324	10-Mar-91 19:50:00.	22.000	22.450	33.400	39.400	39.600	23.250	254
325	10-Mar-91 20:00:00.	21.700	22.200	33.100	39.100	39.350	23.000	254
326	10-Mar-91 20:10:00.	21.650	22.150	32.800	38.900	39.000	22.800	254
327	10-Mar-91 20:20:00.	21.600	21.950	32.550	38.650	38.800	22.650	254
328	10-Mar-91 20:30:00.	21.450	21.900	32.250	38.400	38.550	22.750	254
329	10-Mar-91 20:40:00.	21.150	21.650	32.000	38.200	38.300	22.600	254
330	10-Mar-91 20:50:00.	20.950	21.450	31.750	37.950	38.150	22.300	254
331	10-Mar-91 21:00:00.	20.700	21.350	31.550	37.700	37.950	21.850	254
332	10-Mar-91 21:10:00.	20.550	21.200	31.350	37.550	37.750	21.850	254
333	10-Mar-91 21:20:00.	20.550	21.250	31.150	37.350	37.600	21.600	254
334	10-Mar-91 21:30:00.	20.800	21.350	30.950	37.200	37.500	21.900	254
335	10-Mar-91 21:40:00.	20.700	21.200	30.750	37.050	37.400	21.650	254
336	10-Mar-91 21:50:00.	20.400	20.950	30.600	36.900	37.250	21.250	254
337	10-Mar-91 22:00:00.	20.350	20.950	30.450	36.750	37.100	21.250	254
338	10-Mar-91 22:10:00.	20.350	20.800	30.300	36.650	37.000	21.300	254
339	10-Mar-91 22:20:00.	20.150	20.650	30.150	36.500	36.850	21.000	254
340	10-Mar-91 22:30:00.	20.350	20.750	30.000	36.350	36.700	21.300	254
341	10-Mar-91 22:40:00.	20.450	20.750	29.850	36.250	36.650	21.450	254
342	10-Mar-91 22:50:00.	20.400	20.700	29.700	36.100	36.450	21.350	254
343	10-Mar-91 23:00:00.	20.300	20.650	29.500	35.950	36.300	21.300	254
344	10-Mar-91 23:10:00.	20.100	20.500	29.300	35.850	36.200	21.100	254
345	10-Mar-91 23:20:00.	20.150	20.500	29.150	35.700	36.050	21.050	254
346	10-Mar-91 23:30:00.	19.950	20.350	28.950	35.600	35.950	20.750	254
347	10-Mar-91 23:40:00.	19.850	20.250	28.800	35.500	35.800	20.750	254
348	10-Mar-91 23:50:00.	19.600	20.150	28.650	35.350	35.700	20.600	254
349	11-Mar-91 00:00:00.	19.450	19.900	28.500	35.200	35.550	20.300	254

350	11-Mar-91 00:10:00.	19.350	19.850	28.350	35.100	35.450	20.350	254
351	11-Mar-91 00:20:00.	20.100	20.350	28.200	34.950	35.250	21.000	254
352	11-Mar-91 00:30:00.	20.000	20.300	28.000	34.850	35.250	20.800	254
353	11-Mar-91 00:38:10.	19.800	20.200	27.800	34.800	35.150	20.600	255
354	11-Mar-91 00:40:00.	19.650	20.150	28.050	34.800	35.150	20.500	255
355	11-Mar-91 00:50:00.	19.450	20.000	30.650	34.900	35.550	20.400	255
356	11-Mar-91 01:00:00.	19.050	19.550	32.500	35.200	36.200	19.800	255
357	11-Mar-91 01:10:00.	18.750	19.200	33.800	35.450	36.800	19.400	255
358	11-Mar-91 01:20:00.	18.650	19.100	34.600	35.700	37.150	19.300	255
359	11-Mar-91 01:26:20.	18.450	18.850	34.900	35.800	37.300	19.350	254
360	11-Mar-91 01:30:00.	18.550	18.950	34.150	35.850	37.350	19.400	254
361	11-Mar-91 01:40:00.	18.350	18.750	31.450	35.800	36.800	19.100	254
362	11-Mar-91 01:50:00.	18.150	18.600	29.550	35.600	35.900	18.900	254
363	11-Mar-91 02:00:00.	18.250	18.700	28.250	35.250	35.400	19.050	254
364	11-Mar-91 02:02:30.	18.300	18.650	28.000	35.200	35.250	19.050	255
365	11-Mar-91 02:10:00.	18.500	18.850	29.250	35.050	35.200	19.200	255
366	11-Mar-91 02:20:00.	18.400	18.700	31.000	35.100	35.500	19.200	255
367	11-Mar-91 02:30:00.	18.300	18.550	32.200	35.250	36.050	18.950	255
368	11-Mar-91 02:40:00.	18.650	18.800	32.950	35.400	36.400	19.400	255
369	11-Mar-91 02:50:00.	18.850	19.000	33.400	35.500	36.650	19.600	255
370	11-Mar-91 03:00:00.	18.650	18.750	33.700	35.650	36.900	19.350	255
371	11-Mar-91 03:10:00.	18.750	18.850	33.900	35.750	37.050	19.550	255
372	11-Mar-91 03:20:00.	19.150	19.150	34.000	35.900	37.150	19.850	255
373	11-Mar-91 03:29:10.	18.800	18.950	34.050	35.950	37.200	19.800	254
374	11-Mar-91 03:30:00.	18.900	18.950	34.000	35.950	37.200	19.850	254
375	11-Mar-91 03:40:00.	18.650	18.750	31.050	35.900	36.700	19.600	254
376	11-Mar-91 03:50:00.	18.950	19.050	28.800	35.600	35.850	19.850	254
377	11-Mar-91 03:58:10.	18.600	18.750	27.550	35.250	35.350	19.700	255
378	11-Mar-91 04:00:00.	18.500	18.650	27.600	35.200	35.200	19.450	255
379	11-Mar-91 04:10:00.	18.600	18.800	29.450	35.050	35.250	19.400	255
380	11-Mar-91 04:20:00.	18.200	18.400	30.900	35.100	35.450	19.100	255
381	11-Mar-91 04:30:00.	18.750	18.800	31.900	35.200	35.850	19.600	255
382	11-Mar-91 04:40:00.	19.050	19.000	32.650	35.300	36.300	19.900	255
383	11-Mar-91 04:50:00.	18.900	18.950	33.100	35.450	36.550	19.800	255
384	11-Mar-91 05:00:00.	19.050	19.100	33.450	35.600	36.800	19.800	255
385	11-Mar-91 05:10:00.	19.300	19.250	33.650	35.750	37.050	20.100	255
386	11-Mar-91 05:20:00.	17.750	18.300	33.800	35.800	37.150	18.150	255
387	11-Mar-91 05:30:00.	17.050	17.400	33.850	35.850	37.050	17.950	255
388	11-Mar-91 05:40:00.	17.150	17.400	33.850	35.800	36.950	17.750	255
389	11-Mar-91 05:50:00.	18.050	18.050	33.800	35.800	36.850	18.600	255
390	11-Mar-91 06:00:00.	17.950	17.950	33.750	35.800	36.850	18.350	255
391	11-Mar-91 06:10:00.	17.800	17.850	33.700	35.850	36.950	18.200	255
392	11-Mar-91 06:20:00.	17.850	17.850	33.600	35.850	36.900	18.100	255
393	11-Mar-91 06:30:00.	18.400	18.250	33.550	35.900	36.900	18.650	255
394	11-Mar-91 06:40:00.	19.100	18.750	33.550	35.900	36.950	19.200	255
395	11-Mar-91 06:50:00.	23.100	19.900	33.550	35.950	37.100	19.650	255
396	11-Mar-91 06:55:20.	24.500	20.800	33.550	36.050	37.200	19.950	254
397	11-Mar-91 07:00:00.	26.400	20.800	32.450	36.100	37.200	20.100	254
398	11-Mar-91 07:10:00.	27.950	21.200	29.750	35.950	36.800	20.850	254
399	11-Mar-91 07:20:00.	23.850	20.750	28.050	35.750	36.350	20.750	254
400	11-Mar-91 07:30:00.	26.400	21.050	26.900	35.450	35.800	20.950	254

Ch 6

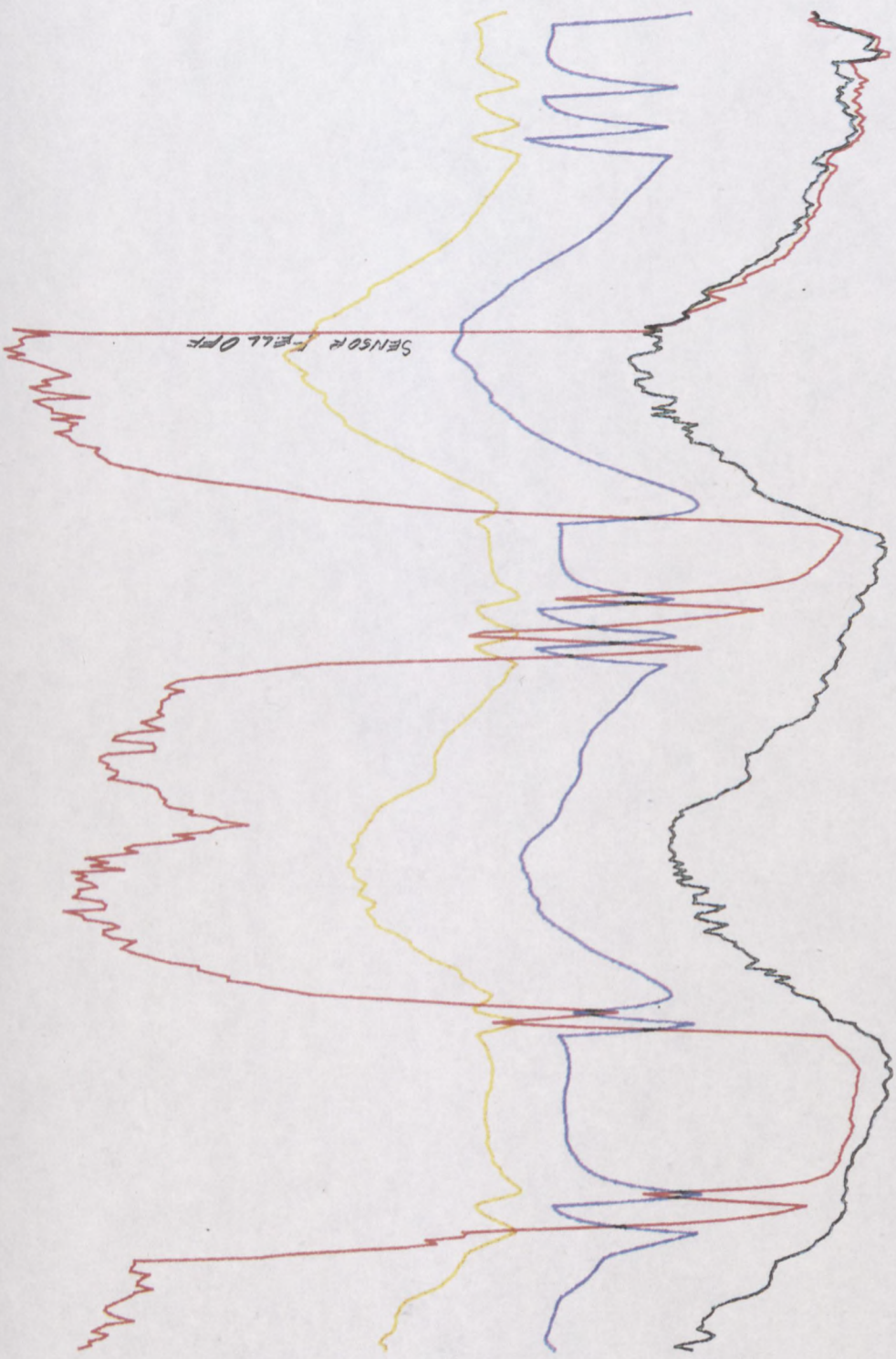
Ch 5

Ch 3

Ch 2

degC

60.00  
55.00  
50.00  
45.00  
40.00  
35.00  
30.00  
25.00  
20.00  
15.00



12: 00: 00 .  
11-Mar-91

00: 00: 00 .

12: 00: 00 .

00: 00: 00 .  
10-Mar-91

12: 00: 00 .

24: 00: 00 .

12: 00: 00 .  
08-Mar-91

Ch 8

Ch 5

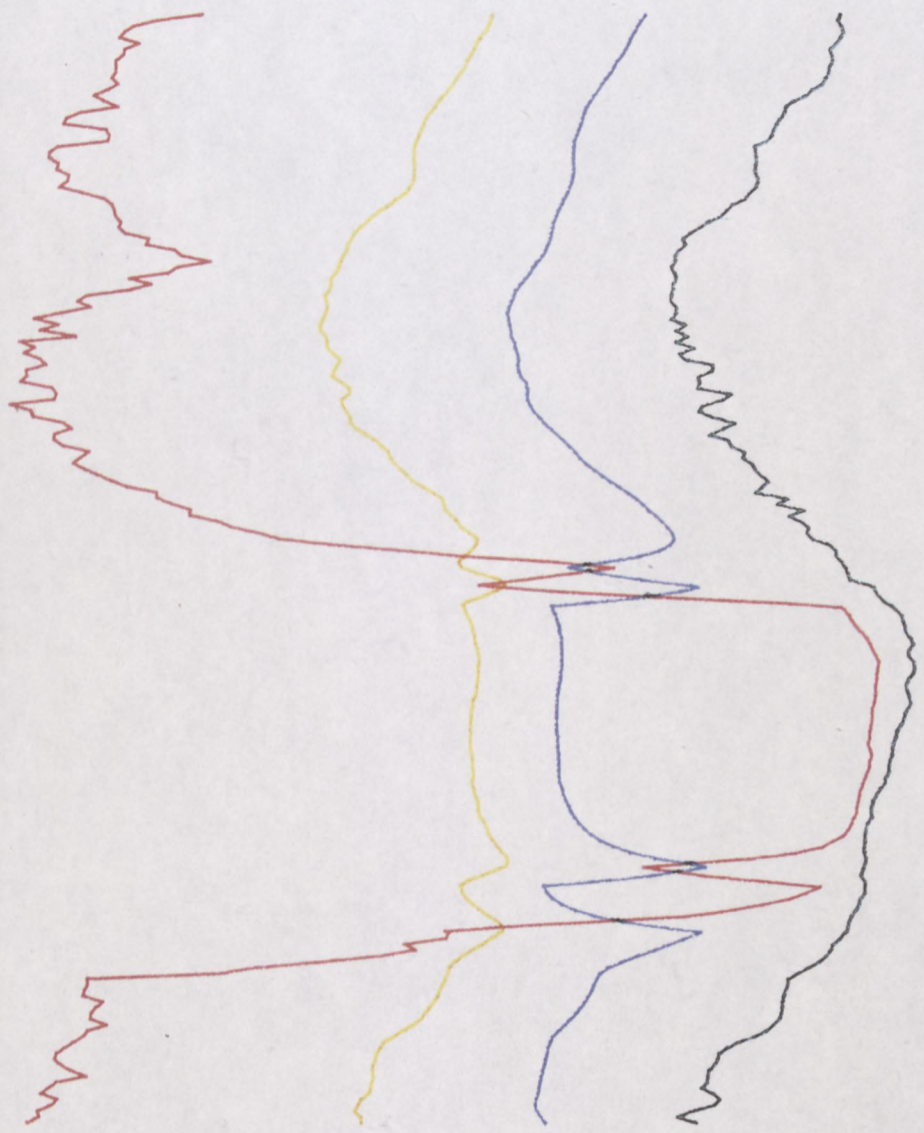
Ch 3

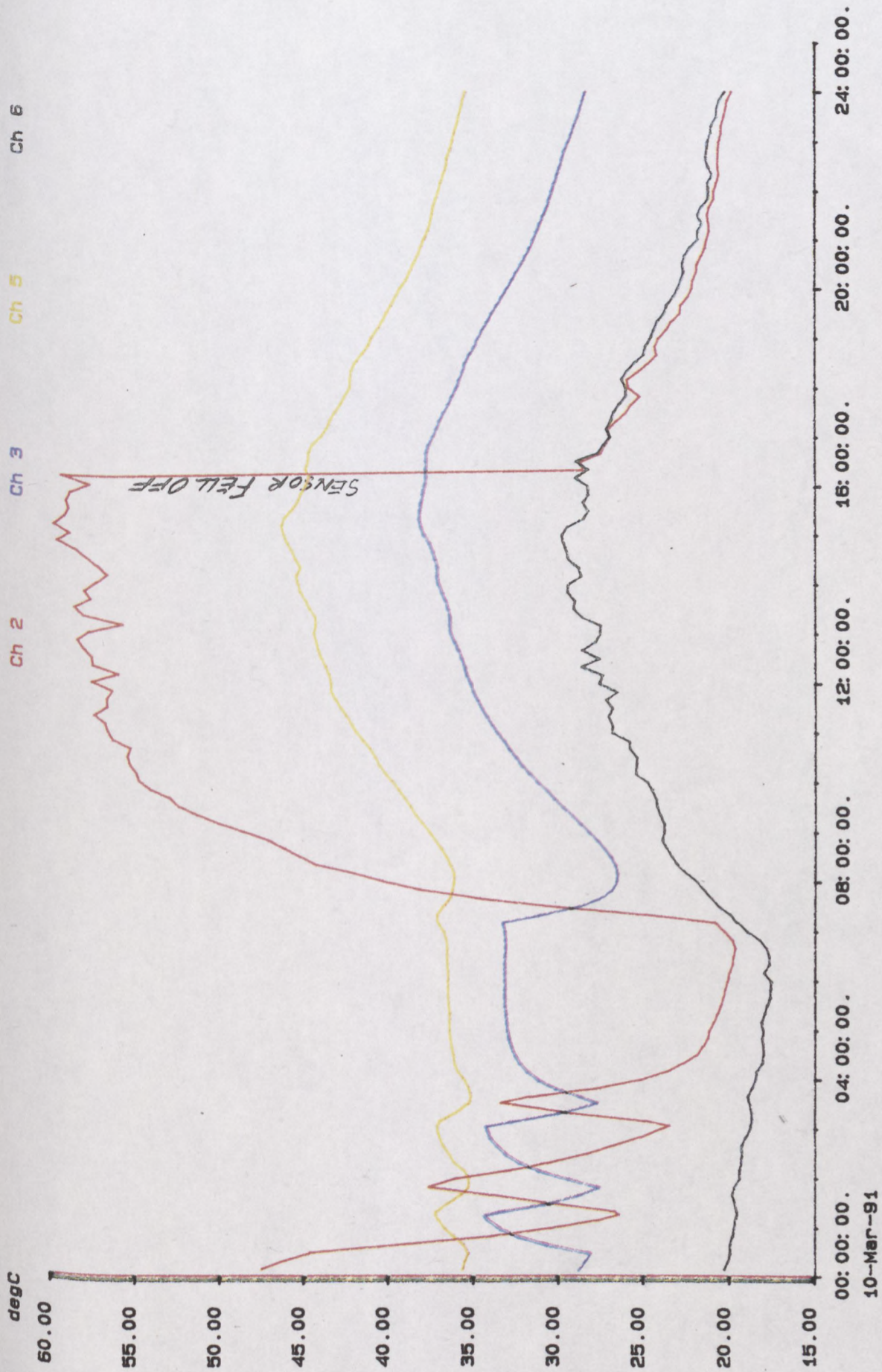
Ch 2

degC

60.00  
55.00  
50.00  
45.00  
40.00  
35.00  
30.00  
25.00  
20.00  
15.00

12: 00: 00.  
08-Mar-91  
24: 00: 00.  
12: 00: 00.  
00: 00: 00.  
10-Mar-91  
12: 00: 00.





10-Mar-91

Ch 6

Ch 5

Ch 3

Ch 2

degC

60.00  
55.00  
50.00  
45.00  
40.00  
35.00  
30.00  
25.00  
20.00  
15.00



SENSOR FAIL OFF

00:00:00.  
10-Mar-91

12:00:00.

24:00:00.

12:00:00.  
11-Mar-91

## APPENDIX 3.7.1

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 28  
100 Watt heat load  
2,25 Amp cooling  
Container in climatic chamber  
Sol-air Program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level  
Ch 19 B 255=Off 254=On

## Channel Readings

Data file - FILE28

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Event/Digital readings  
Recording period :  
    Start : 19-Mar-91 14:00:00.  
    Finish : 20-Mar-91 14:00:01.  
Readings per channel: 173

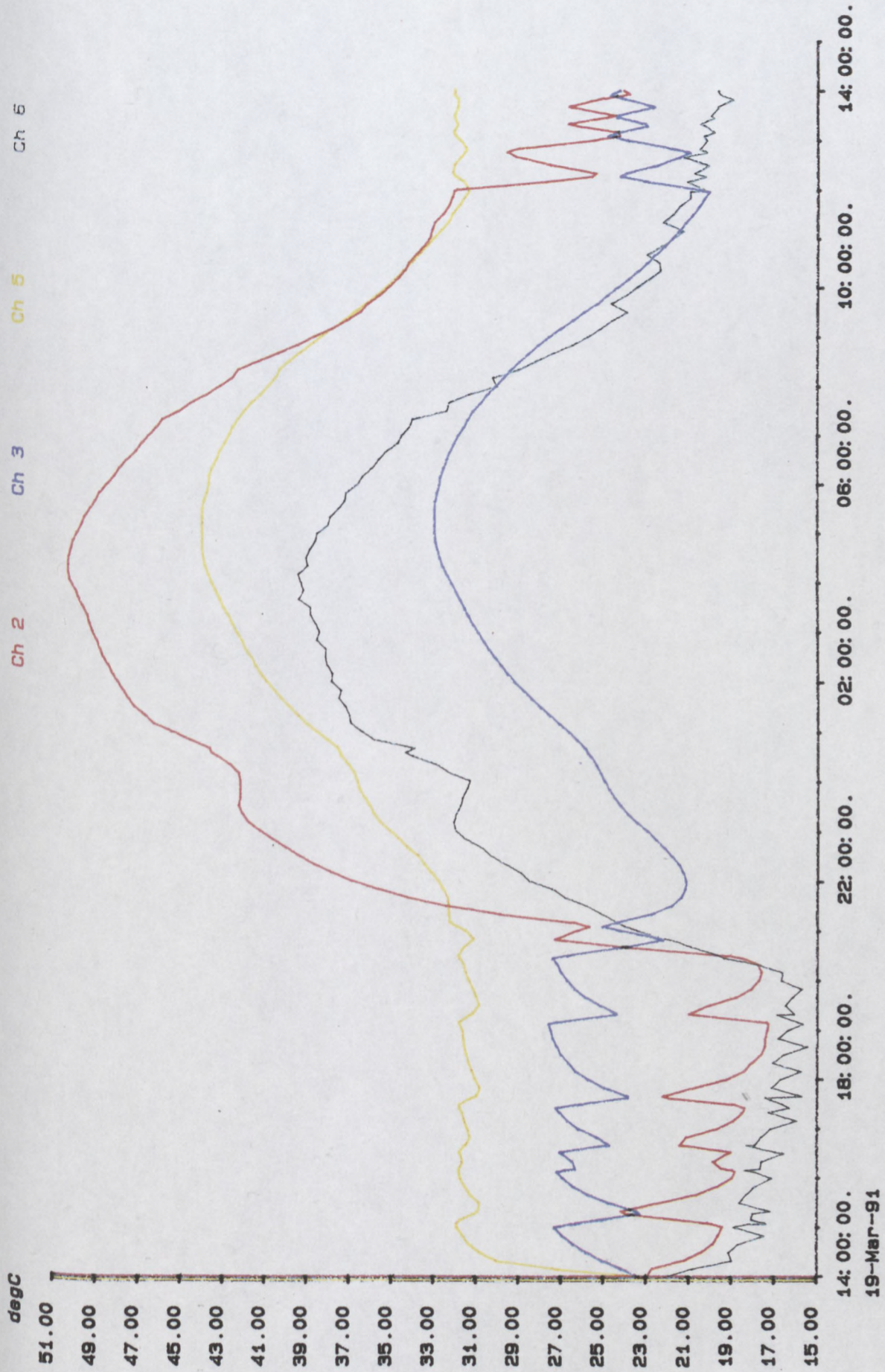
All readings

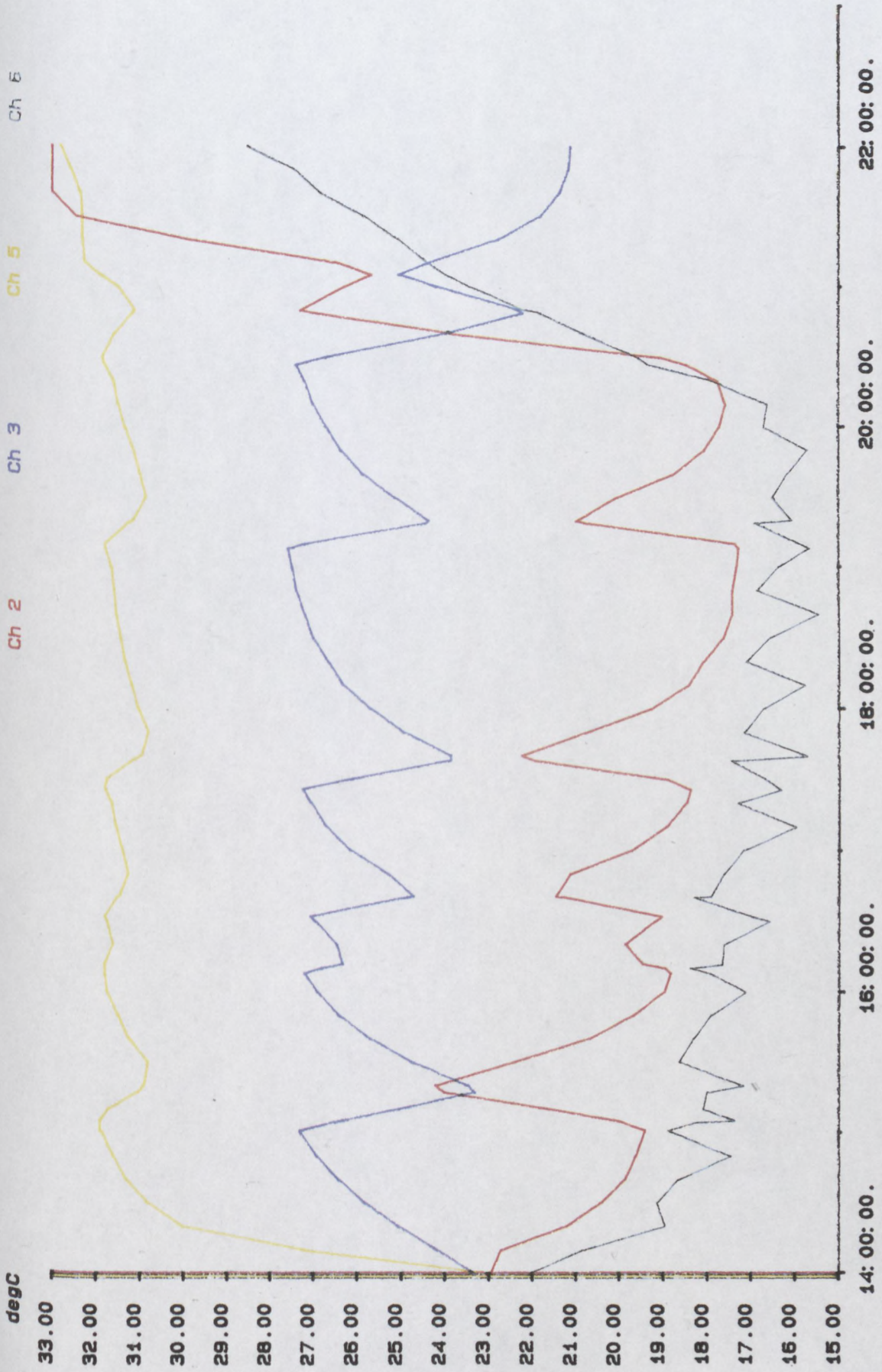
Rdg no	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19 B
0	19-Mar-91 14:00:00.	21.500	22.950	23.300	22.900	22.900	22.100	255
1	19-Mar-91 14:00:00.	21.500	22.950	23.300	22.900	22.900	22.100	255
2	19-Mar-91 14:10:00.	21.500	22.700	24.150	24.550	27.150	20.850	255
3	19-Mar-91 14:20:00.	19.400	21.200	25.050	25.900	30.000	18.950	255
4	19-Mar-91 14:30:00.	19.300	20.400	25.800	26.650	30.800	19.150	255
5	19-Mar-91 14:40:00.	18.850	19.850	26.400	27.200	31.300	18.650	255
6	19-Mar-91 14:50:00.	18.650	19.600	26.900	27.600	31.600	17.450	255
7	19-Mar-91 15:00:00.	18.900	19.400	27.300	27.900	31.850	18.800	255
8	19-Mar-91 15:00:50.	18.950	19.400	27.300	27.900	31.900	18.900	254
9	19-Mar-91 15:04:30.	19.050	19.950	26.500	28.000	31.900	18.200	255
10	19-Mar-91 15:05:10.	18.650	20.100	26.300	28.000	31.900	17.350	254
11	19-Mar-91 15:10:00.	18.450	21.600	25.050	28.050	31.700	18.100	254
12	19-Mar-91 15:17:10.	18.950	24.000	23.300	27.950	31.050	18.000	255
13	19-Mar-91 15:20:00.	18.100	24.200	23.450	27.900	30.900	17.150	255
14	19-Mar-91 15:30:00.	18.950	22.400	24.750	27.900	30.800	18.650	255
15	19-Mar-91 15:40:00.	18.400	20.650	25.700	28.000	31.250	18.300	255
16	19-Mar-91 15:50:00.	18.050	19.650	26.400	28.100	31.500	17.900	255
17	19-Mar-91 16:00:00.	17.550	18.950	26.900	28.200	31.750	17.100	255
18	19-Mar-91 16:07:50.	18.050	18.800	27.200	28.250	31.800	17.950	254
19	19-Mar-91 16:10:00.	18.350	18.950	26.800	28.250	31.800	18.400	254
20	19-Mar-91 16:11:40.	18.250	19.450	26.300	28.250	31.800	17.650	255
21	19-Mar-91 16:20:00.	17.800	19.850	26.450	28.250	31.600	17.600	255
22	19-Mar-91 16:30:00.	17.350	19.150	26.950	28.300	31.750	16.550	255
23	19-Mar-91 16:31:50.	17.400	19.000	27.050	28.300	31.800	16.950	254
24	19-Mar-91 16:40:00.	18.300	21.250	24.850	28.250	31.500	18.300	254
25	19-Mar-91 16:40:30.	18.250	21.450	24.700	28.250	31.450	17.900	255
26	19-Mar-91 16:50:00.	17.750	21.100	25.300	28.150	31.250	17.600	255
27	19-Mar-91 17:00:00.	17.350	19.700	26.150	28.200	31.400	17.150	255
28	19-Mar-91 17:10:00.	17.050	18.900	26.700	28.200	31.550	15.950	255
29	19-Mar-91 17:20:00.	17.500	18.450	27.050	28.200	31.650	17.300	255
30	19-Mar-91 17:25:40.	17.400	18.350	27.250	28.250	31.800	16.300	254
31	19-Mar-91 17:30:00.	17.050	18.900	26.100	28.250	31.750	16.650	254
32	19-Mar-91 17:38:00.	17.850	21.950	23.850	28.100	31.150	17.450	255
33	19-Mar-91 17:40:00.	17.000	22.250	23.850	28.050	30.950	15.700	255
34	19-Mar-91 17:50:00.	17.350	20.750	24.950	28.000	30.800	17.150	255
35	19-Mar-91 18:00:00.	16.900	19.250	25.700	28.000	31.050	16.700	255
36	19-Mar-91 18:10:00.	16.500	18.400	26.300	28.050	31.200	15.750	255
37	19-Mar-91 18:20:00.	17.150	18.050	26.650	28.050	31.350	17.100	255

38	19-Mar-91	18:30:00.	16.700	17.600	27.000	28.100	31.450	16.550	255
39	19-Mar-91	18:40:00.	16.300	17.400	27.200	28.150	31.550	15.450	255
40	19-Mar-91	18:50:00.	16.950	17.400	27.400	28.150	31.600	16.850	255
41	19-Mar-91	19:00:00.	16.600	17.300	27.500	28.250	31.650	16.350	255
42	19-Mar-91	19:08:00.	16.500	17.250	27.600	28.300	31.800	15.650	254
43	19-Mar-91	19:10:00.	16.400	17.350	27.200	28.300	31.800	15.900	254
44	19-Mar-91	19:18:50.	17.200	20.650	24.450	28.150	31.250	16.900	255
45	19-Mar-91	19:20:00.	16.900	21.000	24.350	28.150	31.150	16.050	255
46	19-Mar-91	19:30:00.	16.750	20.050	25.150	28.050	30.850	16.500	255
47	19-Mar-91	19:40:00.	16.500	18.750	25.850	28.050	31.000	16.150	255
48	19-Mar-91	19:50:00.	16.500	18.050	26.350	28.100	31.150	15.700	255
49	19-Mar-91	20:00:00.	16.850	17.700	26.700	28.150	31.350	16.700	255
50	19-Mar-91	20:10:00.	16.850	17.550	27.000	28.200	31.500	16.600	255
51	19-Mar-91	20:20:00.	17.700	17.750	27.200	28.300	31.600	17.900	255
52	19-Mar-91	20:26:50.	19.150	18.450	27.400	28.400	31.800	19.350	254
53	19-Mar-91	20:30:00.	19.450	19.050	26.700	28.500	31.850	19.600	254
54	19-Mar-91	20:40:00.	20.750	23.800	23.950	28.500	31.550	20.850	254
55	19-Mar-91	20:48:40.	21.800	26.900	22.200	28.450	31.150	21.850	255
56	19-Mar-91	20:50:00.	22.050	27.300	22.300	28.450	31.100	22.200	255
57	19-Mar-91	21:00:00.	23.150	26.250	24.200	28.700	31.500	23.450	255
58	19-Mar-91	21:05:00.	23.700	25.650	25.050	28.900	31.900	24.000	254
59	19-Mar-91	21:10:00.	24.200	26.400	24.350	29.100	32.250	24.400	254
60	19-Mar-91	21:20:00.	24.950	29.850	22.750	29.250	32.300	25.100	254
61	19-Mar-91	21:30:00.	25.850	32.450	21.800	29.400	32.300	25.850	254
62	19-Mar-91	21:40:00.	26.700	34.250	21.350	29.550	32.350	26.850	254
63	19-Mar-91	21:50:00.	27.450	35.650	21.150	29.750	32.550	27.450	254
64	19-Mar-91	22:00:00.	28.400	36.900	21.100	30.000	32.800	28.550	254
65	19-Mar-91	22:10:00.	28.950	37.800	21.250	30.300	33.100	28.950	254
66	19-Mar-91	22:20:00.	29.650	38.650	21.450	30.600	33.450	29.650	254
67	19-Mar-91	22:30:00.	30.300	39.350	21.800	30.950	33.750	30.350	254
68	19-Mar-91	22:40:00.	30.850	40.000	22.150	31.300	34.250	30.800	254
69	19-Mar-91	22:50:00.	31.500	40.650	22.550	31.650	34.650	31.550	254
70	19-Mar-91	23:00:00.	32.050	41.250	22.950	32.100	35.100	32.000	254
71	19-Mar-91	23:10:00.	32.350	41.800	23.450	32.550	35.550	32.100	254
72	19-Mar-91	23:20:00.	32.200	42.100	23.850	32.900	35.850	31.950	254
73	19-Mar-91	23:30:00.	32.100	42.300	24.200	33.200	36.050	31.750	254
74	19-Mar-91	23:40:00.	32.000	42.200	24.500	33.550	36.300	31.650	254
75	19-Mar-91	23:50:00.	31.800	42.200	24.750	33.750	36.550	31.450	254
76	19-Mar-91	24:00:00.	31.650	42.200	24.950	34.000	36.650	31.300	254
77	20-Mar-91	00:10:00.	32.200	42.300	25.150	34.200	36.800	32.300	254
78	20-Mar-91	00:20:00.	32.950	42.700	25.350	34.450	37.050	32.900	254
79	20-Mar-91	00:30:00.	33.900	43.300	25.600	34.700	37.400	34.050	254
80	20-Mar-91	00:34:30.	34.250	43.600	25.750	34.800	37.450	34.400	255
81	20-Mar-91	00:34:40.	34.300	43.650	25.750	34.800	37.450	34.350	254
82	20-Mar-91	00:40:00.	33.900	43.750	25.950	35.000	37.700	33.600	254
83	20-Mar-91	00:50:00.	35.600	44.600	26.250	35.350	38.050	35.900	254
84	20-Mar-91	01:00:00.	36.400	45.450	26.650	35.700	38.550	36.500	254
85	20-Mar-91	01:10:00.	36.950	46.350	27.100	36.100	39.050	37.000	254
86	20-Mar-91	01:20:00.	37.100	46.750	27.550	36.550	39.450	37.050	254
87	20-Mar-91	01:30:00.	37.350	47.250	28.000	36.950	39.850	37.250	254
88	20-Mar-91	01:40:00.	37.550	47.550	28.400	37.300	40.250	37.550	254
89	20-Mar-91	01:50:00.	37.650	47.800	28.800	37.700	40.600	37.450	254
90	20-Mar-91	02:00:00.	37.950	48.050	29.200	38.000	40.950	37.900	254
91	20-Mar-91	02:10:00.	37.950	48.300	29.550	38.300	41.250	37.850	254
92	20-Mar-91	02:20:00.	38.200	48.500	29.850	38.650	41.500	38.100	254
93	20-Mar-91	02:30:00.	38.300	48.750	30.150	38.900	41.700	38.200	254
94	20-Mar-91	02:40:00.	38.400	48.900	30.450	39.200	42.000	38.150	254
95	20-Mar-91	02:50:00.	38.650	49.050	30.700	39.450	42.150	38.600	254
96	20-Mar-91	03:00:00.	38.650	49.250	30.950	39.700	42.400	38.450	254
97	20-Mar-91	03:10:00.	38.850	49.400	31.200	39.900	42.600	38.650	254
98	20-Mar-91	03:20:00.	39.000	49.500	31.400	40.100	42.800	38.900	254
99	20-Mar-91	03:30:00.	39.100	49.700	31.600	40.300	43.050	38.900	254

100	20-Mar-91 03:40:00.	39.450	49.900	31.800	40.500	43.200	39.450	254
101	20-Mar-91 03:50:00.	39.450	50.050	32.000	40.700	43.400	39.200	254
102	20-Mar-91 04:00:00.	39.650	50.300	32.200	40.900	43.600	39.350	254
103	20-Mar-91 04:10:00.	39.700	50.400	32.400	41.100	43.750	39.500	254
104	20-Mar-91 04:20:00.	39.450	50.400	32.600	41.250	43.900	39.000	254
105	20-Mar-91 04:30:00.	39.450	50.350	32.750	41.400	44.000	39.100	254
106	20-Mar-91 04:40:00.	39.250	50.250	32.850	41.500	44.050	38.900	254
107	20-Mar-91 04:50:00.	39.000	50.150	32.950	41.600	44.050	38.650	254
108	20-Mar-91 05:00:00.	38.850	49.950	33.000	41.650	44.050	38.550	254
109	20-Mar-91 05:10:00.	38.550	49.750	33.000	41.700	44.050	38.050	254
110	20-Mar-91 05:20:00.	38.400	49.600	33.000	41.700	44.050	37.950	254
111	20-Mar-91 05:30:00.	38.050	49.350	33.000	41.700	44.050	37.550	254
112	20-Mar-91 05:40:00.	37.750	49.100	32.950	41.700	43.950	37.250	254
113	20-Mar-91 05:50:00.	37.600	48.900	32.850	41.600	43.800	37.200	254
114	20-Mar-91 06:00:00.	37.200	48.550	32.750	41.550	43.700	36.650	254
115	20-Mar-91 06:10:00.	36.950	48.200	32.700	41.500	43.700	36.400	254
116	20-Mar-91 06:20:00.	36.500	47.950	32.550	41.400	43.550	35.950	254
117	20-Mar-91 06:30:00.	36.200	47.600	32.400	41.250	43.350	35.650	254
118	20-Mar-91 06:40:00.	35.800	47.200	32.250	41.150	43.200	35.300	254
119	20-Mar-91 06:50:00.	35.400	46.900	32.050	40.950	42.950	34.750	254
120	20-Mar-91 07:00:00.	35.100	46.550	31.850	40.800	42.750	34.550	254
121	20-Mar-91 07:10:00.	34.750	46.200	31.600	40.600	42.550	34.200	254
122	20-Mar-91 07:20:00.	34.550	45.900	31.400	40.400	42.300	34.050	254
123	20-Mar-91 07:30:00.	33.100	45.100	31.150	40.150	42.000	32.400	254
124	20-Mar-91 07:40:00.	32.950	44.550	30.800	39.850	41.650	32.300	254
125	20-Mar-91 07:50:00.	31.950	43.800	30.500	39.550	41.200	31.350	254
126	20-Mar-91 08:00:00.	31.200	43.200	30.100	39.250	40.850	30.050	254
127	20-Mar-91 08:10:00.	30.800	42.600	29.750	38.900	40.500	30.300	254
128	20-Mar-91 08:20:00.	29.850	42.300	29.400	38.650	40.300	29.050	254
129	20-Mar-91 08:30:00.	29.000	41.350	29.000	38.250	39.850	28.250	254
130	20-Mar-91 08:40:00.	28.150	40.400	28.550	37.850	39.350	27.450	254
131	20-Mar-91 08:50:00.	27.350	39.450	28.100	37.400	38.800	26.500	254
132	20-Mar-91 09:00:00.	26.500	38.650	27.600	36.950	38.300	25.750	254
133	20-Mar-91 09:10:00.	25.800	37.800	27.050	36.400	37.750	25.150	254
134	20-Mar-91 09:20:00.	25.350	37.100	26.450	35.900	37.200	24.600	254
135	20-Mar-91 09:30:00.	24.950	36.500	25.900	35.450	36.700	23.900	254
136	20-Mar-91 09:40:00.	25.150	36.150	25.300	34.900	36.200	24.700	254
137	20-Mar-91 09:50:00.	24.500	35.600	24.850	34.450	35.700	24.000	254
138	20-Mar-91 10:00:00.	24.000	35.150	24.350	33.950	35.250	23.450	254
139	20-Mar-91 10:10:00.	23.600	34.750	23.850	33.450	34.800	22.900	254
140	20-Mar-91 10:20:00.	23.350	34.400	23.400	33.100	34.450	22.350	254
141	20-Mar-91 10:30:00.	23.450	34.200	22.950	32.650	34.050	22.400	254
142	20-Mar-91 10:40:00.	23.400	33.850	22.600	32.250	33.700	23.000	254
143	20-Mar-91 10:50:00.	22.850	33.500	22.150	31.900	33.350	22.350	254
144	20-Mar-91 11:00:00.	22.450	33.200	21.800	31.550	33.000	21.800	254
145	20-Mar-91 11:10:00.	22.250	33.100	21.450	31.200	32.650	21.250	254
146	20-Mar-91 11:20:00.	22.700	32.950	21.150	30.900	32.300	22.250	254
147	20-Mar-91 11:30:00.	22.150	32.550	20.800	30.550	32.100	21.750	254
148	20-Mar-91 11:40:00.	21.850	32.300	20.500	30.300	31.800	21.450	254
149	20-Mar-91 11:50:00.	21.600	32.150	20.250	30.000	31.550	20.950	254
150	20-Mar-91 11:58:10.	21.800	32.050	20.000	29.800	31.350	20.950	255
151	20-Mar-91 12:00:00.	21.350	31.900	20.350	29.750	31.350	20.200	255
152	20-Mar-91 12:10:00.	21.400	27.750	22.950	29.850	31.650	21.100	255
153	20-Mar-91 12:16:30.	20.850	25.550	24.250	30.050	32.050	20.200	254
154	20-Mar-91 12:20:00.	21.050	25.350	24.000	30.050	32.150	20.750	254
155	20-Mar-91 12:30:00.	20.850	27.550	22.500	29.950	32.050	20.050	254
156	20-Mar-91 12:40:00.	21.500	29.200	21.450	29.750	31.700	21.300	254
157	20-Mar-91 12:45:50.	20.700	29.600	20.950	29.600	31.500	20.150	255
158	20-Mar-91 12:50:00.	20.850	29.050	21.700	29.550	31.450	20.500	255
159	20-Mar-91 13:00:00.	20.400	25.500	23.850	29.700	31.800	20.150	255
160	20-Mar-91 13:05:30.	20.550	24.250	24.800	29.850	32.000	20.300	254
161	20-Mar-91 13:10:00.	20.600	24.350	24.250	29.850	32.100	19.800	254

162	20-Mar-91 13:17:30.	20.500	26.300	22.950	29.800	31.900	20.200	255
163	20-Mar-91 13:20:00.	20.700	26.700	23.050	29.750	31.900	20.500	255
164	20-Mar-91 13:27:40.	20.200	24.850	24.400	29.850	32.050	19.800	254
165	20-Mar-91 13:30:00.	20.300	24.450	24.350	29.850	32.050	19.950	254
166	20-Mar-91 13:40:00.	20.050	26.550	22.700	29.750	31.850	19.600	254
167	20-Mar-91 13:40:40.	20.100	26.650	22.600	29.700	31.850	19.650	255
168	20-Mar-91 13:50:00.	19.950	25.150	24.050	29.750	31.850	18.900	255
169	20-Mar-91 13:54:00.	19.800	24.150	24.700	29.800	32.050	19.400	254
170	20-Mar-91 13:56:00.	19.850	23.800	24.600	29.850	32.050	19.550	255
171	20-Mar-91 13:56:10.	19.850	23.800	24.600	29.850	32.050	19.550	254
172	20-Mar-91 14:00:00.	20.100	24.450	23.950	29.800	32.000	19.800	254





19-Mar-91

## APPENDIX 3.7.2

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 30  
100 Watt heat load  
2,25 Amp cooling  
Container in climatic chamber  
Stepped program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level

## Channel Readings

Data file - FILE30

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

Run number : 1  
Channels used : 18  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 13-May-91 15:00:00.  
    Finish : 14-May-91 21:00:01.  
Readings per channel: 181

All readings

Rdn no:	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC
0	13-May-91 15:00:00.	19.700	18.750	19.300	21.500	106.350	20.100
1	13-May-91 15:10:00.	22.300	22.700	18.650	22.550	26.400	22.600
2	13-May-91 15:20:00.	22.650	22.700	20.450	23.750	26.700	22.450
3	13-May-91 15:30:00.	21.750	22.200	22.100	24.850	27.950	21.500
4	13-May-91 15:40:00.	21.900	22.050	23.500	25.700	28.900	21.700
5	13-May-91 15:50:00.	21.850	21.950	24.650	26.500	29.700	21.600
6	13-May-91 16:00:00.	21.850	21.950	25.650	27.200	30.500	21.600
7	13-May-91 16:10:00.	21.950	22.000	26.600	27.900	31.150	21.700
8	13-May-91 16:20:00.	21.850	22.050	27.400	28.500	31.750	21.550
9	13-May-91 16:30:00.	21.950	22.150	28.100	29.000	32.350	21.650
10	13-May-91 16:40:00.	21.900	22.200	28.700	29.550	32.900	21.600
11	13-May-91 16:50:00.	21.950	22.300	29.250	30.050	33.350	21.650
12	13-May-91 17:00:00.	21.950	22.350	29.750	30.500	33.700	21.650
13	13-May-91 17:10:00.	21.950	22.450	30.200	30.800	34.050	21.650
14	13-May-91 17:20:00.	21.900	22.500	30.600	31.200	34.400	21.550
15	13-May-91 17:30:00.	22.000	22.550	30.950	31.500	34.650	21.650
16	13-May-91 17:40:00.	21.900	22.550	31.300	31.800	34.850	21.550
17	13-May-91 17:50:00.	21.950	22.600	31.550	32.050	35.050	21.600
18	13-May-91 18:00:00.	22.000	22.650	31.750	32.250	35.200	21.650
19	13-May-91 18:10:00.	24.050	23.400	32.000	32.550	35.450	23.700
20	13-May-91 18:20:00.	23.700	23.750	32.300	32.900	35.850	23.350
21	13-May-91 18:30:00.	23.950	24.100	32.650	33.200	36.150	23.550
22	13-May-91 18:40:00.	24.000	24.250	32.900	33.450	36.450	23.550
23	13-May-91 18:50:00.	23.950	24.400	33.150	33.700	36.650	23.550
24	13-May-91 19:00:00.	24.000	24.500	33.450	34.000	36.900	23.600
25	13-May-91 19:10:00.	24.100	24.550	33.650	34.250	37.150	23.650
26	13-May-91 19:20:00.	24.050	24.650	33.900	34.500	37.350	23.650
27	13-May-91 19:30:00.	24.150	24.700	34.150	34.650	37.550	23.700
28	13-May-91 19:40:00.	24.250	24.800	34.350	34.850	37.650	23.800
29	13-May-91 19:50:00.	24.100	24.850	34.550	35.050	37.800	23.650
30	13-May-91 20:00:00.	23.500	24.750	34.700	35.200	37.900	23.000
31	13-May-91 20:10:00.	23.700	24.650	34.850	35.350	37.950	23.300
32	13-May-91 20:20:00.	23.850	24.650	34.950	35.450	38.050	23.400
33	13-May-91 20:30:00.	23.850	24.650	35.050	35.550	38.150	23.450
34	13-May-91 20:40:00.	24.000	24.700	35.200	35.650	38.200	23.550
35	13-May-91 20:50:00.	24.050	24.750	35.250	35.750	38.300	23.600

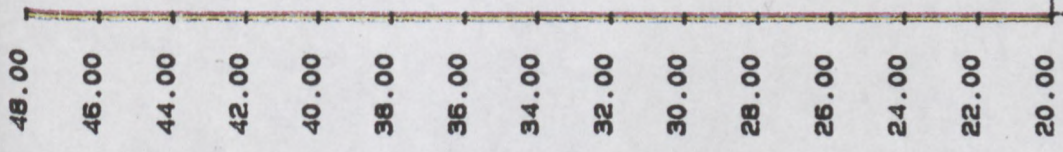
36	13-May-91	21:00:00	25.100	24.950	35.350	35.800	38.400	24.850
37	13-May-91	21:10:00	25.750	25.600	35.500	36.050	38.650	25.300
38	13-May-91	21:20:00	25.950	26.000	35.700	36.250	38.950	25.500
39	13-May-91	21:30:00	25.850	26.250	35.850	36.500	39.250	25.400
40	13-May-91	21:40:00	26.000	26.450	36.050	36.700	39.450	25.500
41	13-May-91	21:50:00	26.000	26.550	36.300	36.900	39.550	25.500
42	13-May-91	22:00:00	25.850	26.600	36.450	37.100	39.750	25.350
43	13-May-91	22:10:00	25.950	26.650	36.650	37.250	39.900	25.450
44	13-May-91	22:20:00	26.150	28.750	34.850	37.300	39.600	25.600
45	13-May-91	22:30:00	26.300	32.750	32.250	37.050	38.650	25.700
46	13-May-91	22:40:00	26.650	35.350	30.450	36.700	37.950	26.000
47	13-May-91	22:50:00	26.600	33.400	31.850	36.600	37.750	25.600
48	13-May-91	23:00:00	25.800	30.600	33.200	36.600	38.050	25.150
49	13-May-91	23:10:00	25.800	28.950	34.150	36.700	38.300	25.100
50	13-May-91	23:20:00	25.700	27.950	34.800	36.800	38.650	25.050
51	13-May-91	23:30:00	25.750	27.350	35.350	36.950	38.950	25.050
52	13-May-91	23:40:00	26.000	27.100	35.700	37.050	39.300	25.150
53	13-May-91	23:50:00	25.850	26.900	36.050	37.250	39.550	25.100
54	13-May-91	24:00:00	27.850	27.150	36.300	37.400	39.750	26.050
55	14-May-91	00:10:00	27.750	28.300	35.700	37.650	39.950	26.350
56	14-May-91	00:20:00	27.950	30.350	35.200	37.700	39.700	26.650
57	14-May-91	00:30:00	28.000	29.750	35.700	37.900	39.900	26.800
58	14-May-91	00:40:00	28.000	33.350	33.200	37.800	39.500	26.850
59	14-May-91	00:50:00	28.000	36.150	31.350	37.550	38.850	26.950
60	14-May-91	01:00:00	28.200	37.950	30.100	37.250	38.200	27.100
61	14-May-91	01:10:00	28.300	38.850	29.350	36.950	37.700	27.200
62	14-May-91	01:20:00	28.100	35.550	31.550	37.000	38.000	27.200
63	14-May-91	01:30:00	28.050	32.750	33.250	37.200	38.650	27.150
64	14-May-91	01:40:00	27.850	31.000	34.500	37.450	39.150	27.050
65	14-May-91	01:50:00	27.650	29.850	35.400	37.700	39.600	26.900
66	14-May-91	02:00:00	27.600	29.250	35.750	37.900	39.900	26.850
67	14-May-91	02:10:00	28.100	32.850	33.400	37.900	39.500	27.100
68	14-May-91	02:20:00	28.150	35.950	31.500	37.650	38.900	27.150
69	14-May-91	02:30:00	28.400	37.900	30.200	37.400	38.300	27.300
70	14-May-91	02:40:00	28.500	38.400	30.100	37.200	37.950	27.450
71	14-May-91	02:50:00	27.700	34.650	32.250	37.300	38.400	27.000
72	14-May-91	03:00:00	28.650	32.200	33.750	37.450	38.900	27.400
73	14-May-91	03:10:00	29.600	31.350	34.900	37.750	39.500	28.200
74	14-May-91	03:20:00	29.850	31.450	35.000	38.100	40.050	28.500
75	14-May-91	03:30:00	29.950	35.500	32.800	38.150	39.800	28.600
76	14-May-91	03:40:00	30.050	38.200	31.350	38.050	39.250	28.750
77	14-May-91	03:50:00	30.300	39.850	30.350	37.900	38.800	28.950
78	14-May-91	04:00:00	30.400	40.500	30.350	37.800	38.600	29.100
79	14-May-91	04:10:00	29.600	36.700	32.700	37.950	39.050	28.700
80	14-May-91	04:20:00	29.700	34.000	34.400	38.200	39.750	28.800
81	14-May-91	04:30:00	29.800	34.400	33.850	38.400	40.050	28.800
82	14-May-91	04:40:00	30.200	37.550	32.100	38.350	39.650	29.000
83	14-May-91	04:50:00	29.650	39.500	30.950	38.200	39.200	28.800
84	14-May-91	05:00:00	29.700	40.450	30.100	37.950	38.700	28.750
85	14-May-91	05:10:00	30.150	41.150	29.500	37.750	38.400	28.950
86	14-May-91	05:20:00	30.400	40.800	29.950	37.650	38.300	29.200
87	14-May-91	05:30:00	29.500	36.650	32.350	37.800	38.750	28.700
88	14-May-91	05:40:00	29.450	33.900	34.050	38.050	39.450	28.650
89	14-May-91	05:50:00	29.900	32.450	35.350	38.300	39.950	28.850
90	14-May-91	06:00:00	31.500	35.300	33.500	38.400	39.950	29.600
91	14-May-91	06:10:00	31.800	38.650	31.900	38.350	39.550	30.150
92	14-May-91	06:20:00	31.800	40.750	30.900	38.350	39.300	30.350
93	14-May-91	06:30:00	31.950	41.950	30.300	38.300	39.100	30.500
94	14-May-91	06:40:00	32.050	42.750	29.850	38.200	39.000	30.700

95	14-May-91	06:50:00.	32.050	43.300	29.550	38.100	38.900	30.800
96	14-May-91	07:00:00.	31.650	43.450	29.300	38.000	38.700	30.600
97	14-May-91	07:10:00.	31.800	43.450	29.100	37.850	38.550	30.700
98	14-May-91	07:20:00.	31.950	43.550	28.950	37.800	38.450	30.750
99	14-May-91	07:30:00.	31.950	43.600	28.850	37.700	38.450	30.800
100	14-May-91	07:40:00.	31.600	40.750	31.000	37.850	38.650	30.650
101	14-May-91	07:50:00.	31.300	37.200	33.300	38.200	39.350	30.500
102	14-May-91	08:00:00.	31.900	35.150	34.750	38.550	40.150	30.800
103	14-May-91	08:10:00.	31.800	38.050	32.950	38.700	40.100	30.700
104	14-May-91	08:20:00.	31.850	40.200	32.200	38.700	39.800	30.800
105	14-May-91	08:30:00.	32.000	38.100	33.400	38.900	40.100	30.850
106	14-May-91	08:40:00.	31.850	40.250	32.100	38.900	39.950	30.800
107	14-May-91	08:50:00.	31.950	39.100	33.000	39.000	40.050	30.900
108	14-May-91	09:00:00.	33.750	41.150	32.000	39.000	39.950	31.700
109	14-May-91	09:10:00.	33.650	40.750	32.550	39.200	40.200	32.000
110	14-May-91	09:20:00.	33.800	42.700	31.700	39.250	40.250	32.300
111	14-May-91	09:30:00.	34.000	43.950	31.200	39.250	40.150	32.500
112	14-May-91	09:40:00.	33.900	44.500	31.000	39.300	40.150	32.550
113	14-May-91	09:50:00.	33.900	45.000	30.750	39.300	40.100	32.650
114	14-May-91	10:00:00.	34.000	45.350	30.650	39.300	40.150	32.750
115	14-May-91	10:10:00.	33.950	45.450	30.600	39.300	40.100	32.750
116	14-May-91	10:20:00.	34.000	45.150	30.750	39.300	40.150	32.800
117	14-May-91	10:30:00.	34.050	45.400	30.650	39.350	40.150	32.800
118	14-May-91	10:40:00.	33.950	45.450	30.550	39.350	40.100	32.800
119	14-May-91	10:50:00.	33.950	45.300	30.650	39.350	40.100	32.850
120	14-May-91	11:00:00.	34.000	45.250	30.700	39.350	40.100	32.900
121	14-May-91	11:10:00.	34.000	45.300	30.700	39.350	40.150	32.850
122	14-May-91	11:20:00.	33.950	45.300	30.650	39.350	40.150	32.900
123	14-May-91	11:30:00.	34.100	45.350	30.750	39.350	40.050	32.900
124	14-May-91	11:40:00.	33.950	45.200	30.750	39.350	40.100	32.850
125	14-May-91	11:50:00.	34.000	45.300	30.750	39.350	40.100	32.900
126	14-May-91	12:00:00.	35.750	45.600	30.650	39.350	40.150	33.700
127	14-May-91	12:10:00.	35.700	46.300	30.650	39.450	40.350	34.000
128	14-May-91	12:20:00.	35.850	46.900	30.750	39.600	40.500	34.300
129	14-May-91	12:30:00.	36.050	47.100	30.800	39.700	40.650	34.550
130	14-May-91	12:40:00.	35.950	47.250	30.950	39.750	40.700	34.550
131	14-May-91	12:50:00.	35.950	47.400	31.050	39.850	40.800	34.650
132	14-May-91	13:00:00.	36.050	47.500	31.150	39.950	40.850	34.700
133	14-May-91	13:10:00.	35.900	47.550	31.250	40.050	40.950	34.700
134	14-May-91	13:20:00.	35.900	47.600	31.300	40.150	41.050	34.750
135	14-May-91	13:30:00.	36.050	47.650	31.400	40.200	41.100	34.800
136	14-May-91	13:40:00.	35.900	47.650	31.450	40.250	41.150	34.700
137	14-May-91	13:50:00.	35.900	47.600	31.500	40.300	41.200	34.800
138	14-May-91	14:00:00.	35.950	47.650	31.550	40.400	41.250	34.800
139	14-May-91	14:10:00.	35.900	47.700	31.550	40.400	41.250	34.750
140	14-May-91	14:20:00.	35.950	47.650	31.600	40.450	41.350	34.800
141	14-May-91	14:30:00.	36.000	47.750	31.650	40.500	41.350	34.800
142	14-May-91	14:40:00.	35.950	47.700	31.650	40.550	41.400	34.800
143	14-May-91	14:50:00.	35.900	47.650	31.750	40.600	41.400	34.800
144	14-May-91	15:00:00.	37.700	47.900	31.750	40.600	41.450	35.650
145	14-May-91	15:10:00.	37.600	48.450	31.850	40.750	41.650	35.950
146	14-May-91	15:20:00.	37.900	48.850	32.000	40.900	41.800	36.300
147	14-May-91	15:30:00.	38.000	49.150	32.200	41.050	42.050	36.450
148	14-May-91	15:40:00.	37.950	49.300	32.350	41.150	42.150	36.500
149	14-May-91	15:50:00.	37.950	49.400	32.500	41.350	42.350	36.550
150	14-May-91	16:00:00.	38.050	49.450	32.700	41.500	42.500	36.650
151	14-May-91	16:10:00.	37.900	49.450	32.800	41.600	42.650	36.600
152	14-May-91	16:20:00.	37.950	49.550	32.950	41.700	42.750	36.650
153	14-May-91	16:30:00.	38.000	49.550	33.050	41.800	42.900	36.700

154	14-May-91 16:40:00.	37.900	49.550	33.150	41.950	43.000	36.650
155	14-May-91 16:50:00.	37.900	49.600	33.250	42.050	43.050	36.700
156	14-May-91 17:00:00.	38.050	49.550	33.350	42.100	43.100	36.750
157	14-May-91 17:10:00.	37.950	49.600	33.400	42.150	43.100	36.700
158	14-May-91 17:20:00.	37.950	49.550	33.450	42.200	43.150	36.700
159	14-May-91 17:30:00.	38.000	49.600	33.450	42.250	43.200	36.750
160	14-May-91 17:40:00.	37.950	49.600	33.500	42.300	43.200	36.700
161	14-May-91 17:50:00.	37.950	49.650	33.550	42.300	43.200	36.750
162	14-May-91 18:00:00.	39.650	49.900	33.550	42.350	43.300	37.500
163	14-May-91 18:10:00.	39.500	50.450	33.650	42.500	43.450	37.800
164	14-May-91 18:20:00.	39.750	50.800	33.800	42.650	43.700	38.150
165	14-May-91 18:30:00.	39.950	51.100	34.000	42.850	43.850	38.300
166	14-May-91 18:40:00.	39.800	51.250	34.150	42.950	43.950	38.300
167	14-May-91 18:50:00.	39.800	51.250	34.300	43.100	44.100	38.400
168	14-May-91 19:00:00.	39.950	51.250	34.450	43.250	44.200	38.450
169	14-May-91 19:10:00.	39.850	51.350	34.600	43.350	44.350	38.400
170	14-May-91 19:20:00.	39.850	51.400	34.650	43.450	44.450	38.450
171	14-May-91 19:30:00.	39.850	51.350	34.800	43.550	44.550	38.500
172	14-May-91 19:40:00.	39.800	51.450	34.850	43.650	44.650	38.450
173	14-May-91 19:50:00.	39.750	51.400	34.950	43.750	44.750	38.450
174	14-May-91 20:00:00.	39.850	51.400	35.050	43.800	44.800	38.450
175	14-May-91 20:10:00.	39.750	51.450	35.150	43.900	44.900	38.450
176	14-May-91 20:20:00.	39.750	51.500	35.200	43.950	44.950	38.450
177	14-May-91 20:30:00.	39.800	51.450	35.250	44.050	45.000	38.450
178	14-May-91 20:40:00.	39.750	51.500	35.350	44.050	45.050	38.450
179	14-May-91 20:50:00.	39.750	51.500	35.350	44.150	45.100	38.450
180	14-May-91 21:00:00.	39.750	51.450	35.450	44.200	45.150	38.450

Ch 2 Ch 3 Ch 5 Ch 6

degC



12: 00: 00.  
13-May-91

24: 00: 00.

12: 00: 00.

00: 00: 00.  
15-May-91

## APPENDIX 3.7.3

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 31  
100 Watt heat load  
2,25 Amp cooling  
Container in climatic chamber  
Sol-air program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level  
Ch 19 255= Off 254= On

## Channel Readings

Data file - FILE31

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

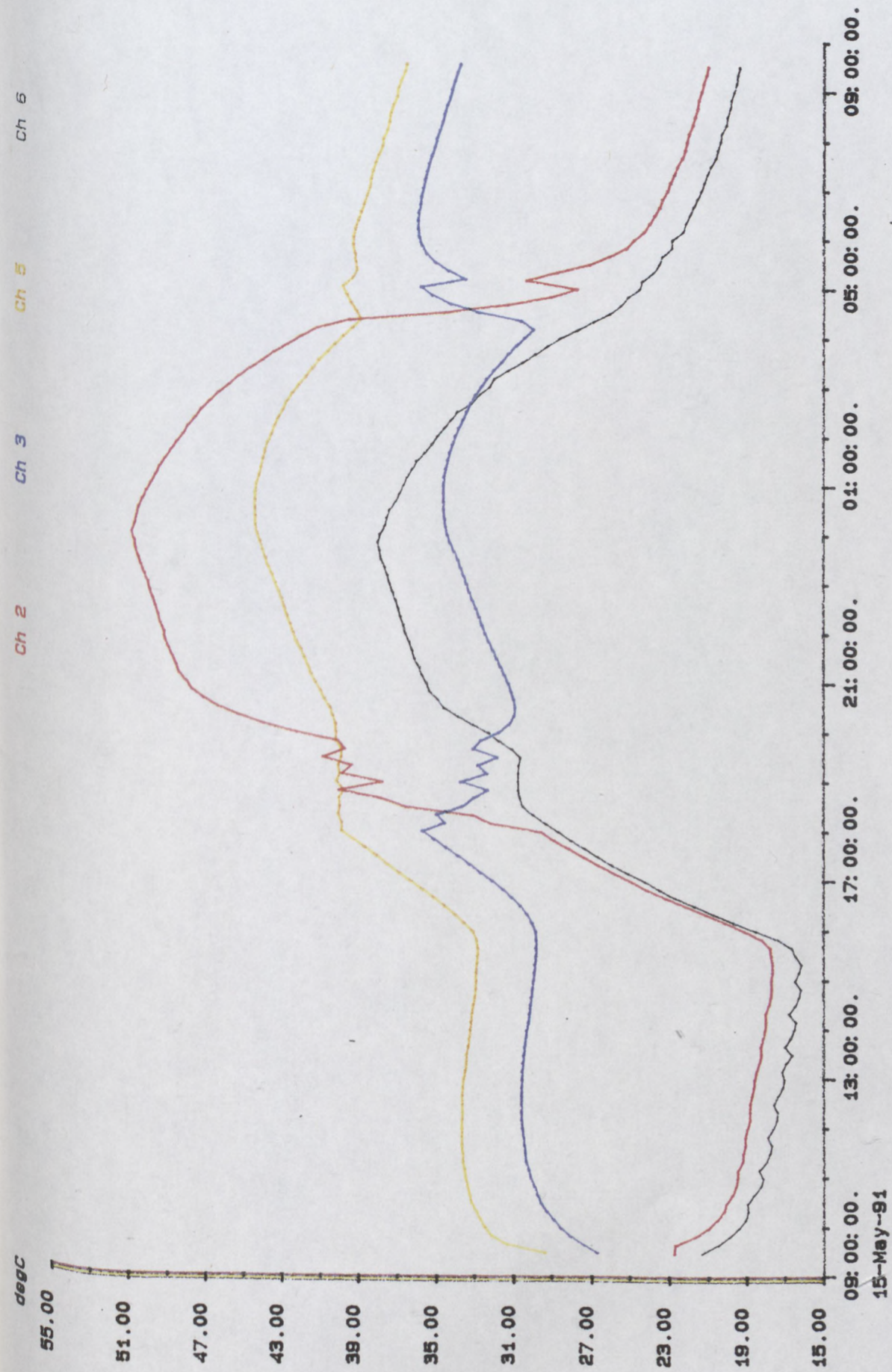
Run number : 2  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 15-May-91 09:30:00.  
    Finish : 16-May-91 09:30:01.  
Readings per channel: 145

All readings

Rdg no	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19
0	15-May-91 09:30:00.	22.450	22.700	26.650	26.400	29.300	21.350	255
1	15-May-91 09:40:00.	20.450	22.650	27.400	27.750	31.300	20.500	255
2	15-May-91 09:50:00.	19.700	21.650	28.050	28.600	32.100	19.900	255
3	15-May-91 10:00:00.	19.200	20.950	28.550	29.250	32.450	19.400	255
4	15-May-91 10:10:00.	18.800	20.500	28.900	29.800	32.700	19.050	255
5	15-May-91 10:20:00.	18.600	20.150	29.250	30.200	32.900	18.900	255
6	15-May-91 10:30:00.	19.250	20.000	29.550	30.550	33.150	18.950	255
7	15-May-91 10:40:00.	18.650	19.700	29.750	30.800	33.250	18.600	255
8	15-May-91 10:50:00.	18.300	19.500	29.900	31.000	33.350	18.250	255
9	15-May-91 11:00:00.	18.050	19.400	30.100	31.150	33.450	18.100	255
10	15-May-91 11:10:00.	18.750	19.400	30.200	31.250	33.500	18.350	255
11	15-May-91 11:20:00.	18.100	19.150	30.350	31.350	33.600	17.950	255
12	15-May-91 11:30:00.	17.850	19.100	30.400	31.450	33.600	17.750	255
13	15-May-91 11:40:00.	17.600	19.000	30.450	31.500	33.650	17.650	255
14	15-May-91 11:50:00.	18.400	19.000	30.500	31.500	33.650	17.900	255
15	15-May-91 12:00:00.	17.850	18.900	30.550	31.550	33.650	17.600	255
16	15-May-91 12:10:00.	17.550	18.750	30.600	31.550	33.650	17.400	255
17	15-May-91 12:20:00.	17.350	18.750	30.600	31.550	33.600	17.350	255
18	15-May-91 12:30:00.	18.050	18.750	30.600	31.550	33.650	17.600	255
19	15-May-91 12:40:00.	17.550	18.650	30.600	31.550	33.650	17.350	255
20	15-May-91 12:50:00.	17.250	18.550	30.600	31.500	33.600	17.100	255
21	15-May-91 13:00:00.	16.900	18.500	30.550	31.500	33.550	17.000	255
22	15-May-91 13:10:00.	17.450	18.400	30.550	31.450	33.450	17.150	255
23	15-May-91 13:20:00.	17.050	18.250	30.500	31.400	33.400	16.900	255
24	15-May-91 13:30:00.	16.650	18.150	30.450	31.350	33.400	16.600	255
25	15-May-91 13:40:00.	17.250	18.200	30.400	31.250	33.300	17.000	255
26	15-May-91 13:50:00.	16.900	18.050	30.350	31.200	33.250	16.700	255
27	15-May-91 14:00:00.	16.650	17.950	30.300	31.200	33.200	16.500	255
28	15-May-91 14:10:00.	16.300	17.900	30.200	31.100	33.150	16.400	255
29	15-May-91 14:20:00.	17.200	17.950	30.150	31.050	33.100	16.800	255
30	15-May-91 14:30:00.	16.650	17.750	30.100	31.000	33.050	16.450	255
31	15-May-91 14:40:00.	16.350	17.650	30.050	30.900	32.950	16.250	255
32	15-May-91 14:50:00.	16.050	17.600	30.000	30.900	32.900	16.150	255
33	15-May-91 15:00:00.	16.850	17.650	29.950	30.800	32.900	16.500	255
34	15-May-91 15:10:00.	16.450	17.550	29.900	30.800	32.900	16.250	255
35	15-May-91 15:20:00.	16.200	17.550	29.850	30.750	32.850	16.100	255

36	15-May-91	15:30:00.	16.650	17.650	29.800	30.700	32.800	16.450	255
37	15-May-91	15:40:00.	17.200	17.700	29.800	30.700	32.800	16.650	255
38	15-May-91	15:50:00.	18.200	18.150	29.800	30.750	32.900	17.350	255
39	15-May-91	16:00:00.	19.800	19.050	29.850	30.900	33.100	18.500	255
40	15-May-91	16:10:00.	21.150	20.050	30.050	31.150	33.550	19.650	255
41	15-May-91	16:20:00.	22.400	21.100	30.300	31.450	34.000	20.700	255
42	15-May-91	16:30:00.	23.550	22.150	30.650	31.850	34.550	21.700	255
43	15-May-91	16:40:00.	24.400	23.150	31.100	32.300	35.100	22.700	255
44	15-May-91	16:50:00.	25.350	24.100	31.550	32.850	35.700	23.500	255
45	15-May-91	17:00:00.	26.050	24.900	32.100	33.350	36.300	24.250	255
46	15-May-91	17:10:00.	26.900	25.750	32.700	33.900	36.900	25.100	255
47	15-May-91	17:20:00.	27.850	26.600	33.250	34.500	37.500	25.950	255
48	15-May-91	17:30:00.	28.550	27.400	33.850	35.050	38.050	26.700	255
49	15-May-91	17:40:00.	29.100	28.150	34.500	35.650	38.650	27.400	255
50	15-May-91	17:50:00.	30.000	28.900	35.100	36.250	39.250	28.100	255
51	15-May-91	18:00:00.	30.450	29.550	35.750	36.850	39.850	28.700	255
52	15-May-91	18:10:00.	31.150	32.200	34.550	37.300	39.850	29.350	255
53	15-May-91	18:20:00.	31.850	33.100	35.000	37.800	40.050	30.000	254
54	15-May-91	18:30:00.	32.350	36.600	33.650	38.050	39.950	30.550	255
55	15-May-91	18:40:00.	32.250	37.850	33.050	38.300	40.000	30.700	254
56	15-May-91	18:50:00.	32.200	40.050	32.300	38.450	39.750	30.800	255
57	15-May-91	19:00:00.	32.000	37.750	33.750	38.700	40.150	30.800	254
58	15-May-91	19:10:00.	31.850	39.900	32.350	38.800	39.950	30.800	254
59	15-May-91	19:20:00.	31.750	39.350	32.850	38.900	40.050	30.750	254
60	15-May-91	19:30:00.	31.600	40.900	31.800	38.900	39.850	30.650	254
61	15-May-91	19:40:00.	32.300	39.700	33.100	39.000	39.850	31.150	255
62	15-May-91	19:50:00.	33.350	40.100	32.700	39.150	40.200	31.800	254
63	15-May-91	20:00:00.	34.200	42.300	31.750	39.250	40.150	32.350	254
64	15-May-91	20:10:00.	34.950	44.000	31.200	39.350	40.200	33.150	254
65	15-May-91	20:20:00.	35.950	45.350	30.950	39.450	40.350	33.900	254
66	15-May-91	20:30:00.	36.800	46.400	30.900	39.600	40.500	34.650	254
67	15-May-91	20:40:00.	36.900	47.150	31.000	39.750	40.800	34.950	254
68	15-May-91	20:50:00.	37.200	47.750	31.150	39.950	41.000	35.400	254
69	15-May-91	21:00:00.	37.350	48.050	31.300	40.150	41.250	35.550	254
70	15-May-91	21:10:00.	37.400	48.450	31.500	40.400	41.500	35.800	254
71	15-May-91	21:20:00.	37.600	48.600	31.700	40.600	41.650	35.950	254
72	15-May-91	21:30:00.	37.850	48.800	31.900	40.800	41.850	36.200	254
73	15-May-91	21:40:00.	37.900	49.000	32.100	41.000	42.050	36.300	254
74	15-May-91	21:50:00.	37.950	49.200	32.300	41.200	42.300	36.450	254
75	15-May-91	22:00:00.	38.200	49.250	32.500	41.400	42.450	36.650	254
76	15-May-91	22:10:00.	38.250	49.450	32.650	41.550	42.600	36.750	254
77	15-May-91	22:20:00.	38.400	49.550	32.800	41.700	42.750	36.900	254
78	15-May-91	22:30:00.	38.550	49.700	32.950	41.850	42.900	37.000	254
79	15-May-91	22:40:00.	38.600	49.850	33.150	42.050	43.050	37.150	254
80	15-May-91	22:50:00.	38.850	50.000	33.300	42.200	43.200	37.300	254
81	15-May-91	23:00:00.	39.000	50.100	33.450	42.350	43.400	37.450	254
82	15-May-91	23:10:00.	39.100	50.300	33.600	42.550	43.550	37.550	254
83	15-May-91	23:20:00.	39.350	50.450	33.750	42.750	43.750	37.700	254
84	15-May-91	23:30:00.	39.500	50.600	33.900	42.900	43.900	37.900	254
85	15-May-91	23:40:00.	39.550	50.750	34.100	43.050	44.050	37.950	254
86	15-May-91	23:50:00.	39.600	50.800	34.300	43.250	44.200	38.050	254
87	15-May-91	24:00:00.	39.200	50.950	34.450	43.400	44.350	37.900	254
88	16-May-91	00:10:00.	38.850	50.750	34.550	43.500	44.450	37.650	254
89	16-May-91	00:20:00.	38.700	50.650	34.600	43.550	44.400	37.550	254
90	16-May-91	00:30:00.	38.500	50.550	34.650	43.550	44.450	37.400	254
91	16-May-91	00:40:00.	38.150	50.350	34.650	43.600	44.450	37.100	254
92	16-May-91	00:50:00.	37.950	50.150	34.650	43.550	44.400	36.900	254
93	16-May-91	01:00:00.	37.700	49.900	34.650	43.550	44.350	36.700	254

94	16-May-91 01:10:00.	37.550	49.650	34.600	43.500	44.200	36.500	254
95	16-May-91 01:20:00.	37.300	49.450	34.500	43.450	44.100	36.250	254
96	16-May-91 01:30:00.	37.100	49.150	34.400	43.350	44.000	36.000	254
97	16-May-91 01:40:00.	36.500	48.850	34.300	43.300	43.900	35.600	254
98	16-May-91 01:50:00.	36.100	48.550	34.150	43.150	43.750	35.250	254
99	16-May-91 02:00:00.	35.750	48.200	34.000	43.050	43.550	34.950	254
100	16-May-91 02:10:00.	35.300	47.950	33.800	42.850	43.400	34.600	254
101	16-May-91 02:20:00.	34.900	47.550	33.600	42.650	43.200	34.250	254
102	16-May-91 02:30:00.	34.650	47.250	33.400	42.450	42.950	33.900	254
103	16-May-91 02:40:00.	33.600	46.800	33.200	42.250	42.750	33.200	254
104	16-May-91 02:50:00.	33.250	46.350	32.950	42.000	42.450	32.800	254
105	16-May-91 03:00:00.	32.550	45.800	32.650	41.700	42.100	32.250	254
106	16-May-91 03:10:00.	32.500	45.300	32.350	41.450	41.750	32.000	254
107	16-May-91 03:20:00.	31.600	44.700	32.000	41.150	41.400	31.300	254
108	16-May-91 03:30:00.	30.800	44.050	31.600	40.800	41.050	30.550	254
109	16-May-91 03:40:00.	30.050	43.450	31.250	40.400	40.600	29.900	254
110	16-May-91 03:50:00.	29.400	42.700	30.850	40.050	40.200	29.250	254
111	16-May-91 04:00:00.	28.700	42.000	30.400	39.600	39.750	28.600	254
112	16-May-91 04:10:00.	27.700	41.150	29.950	39.200	39.250	27.750	254
113	16-May-91 04:20:00.	26.650	39.450	30.600	38.750	38.800	26.950	255
114	16-May-91 04:30:00.	25.400	34.600	32.800	38.600	39.050	26.050	255
115	16-May-91 04:40:00.	25.000	31.300	34.250	38.500	39.350	25.450	255
116	16-May-91 04:50:00.	25.000	29.050	35.200	38.450	39.550	25.100	255
117	16-May-91 05:00:00.	24.200	27.700	35.800	38.450	39.800	24.500	254
118	16-May-91 05:10:00.	24.450	30.350	33.450	38.200	39.250	24.350	255
119	16-May-91 05:20:00.	23.800	28.750	34.350	37.950	39.000	23.800	255
120	16-May-91 05:30:00.	23.550	27.100	35.050	37.900	39.100	23.500	255
121	16-May-91 05:40:00.	23.600	26.050	35.500	37.700	39.150	23.350	255
122	16-May-91 05:50:00.	23.000	25.150	35.750	37.650	39.250	22.850	255
123	16-May-91 06:00:00.	23.300	24.750	35.900	37.500	39.200	22.850	255
124	16-May-91 06:10:00.	22.550	24.250	35.950	37.400	39.100	22.300	255
125	16-May-91 06:20:00.	22.450	23.950	35.950	37.250	38.950	22.150	255
126	16-May-91 06:30:00.	22.150	23.700	35.900	37.050	38.800	21.950	255
127	16-May-91 06:40:00.	21.950	23.450	35.800	36.900	38.650	21.750	255
128	16-May-91 06:50:00.	21.800	23.300	35.750	36.700	38.500	21.550	255
129	16-May-91 07:00:00.	21.600	23.050	35.650	36.550	38.350	21.350	255
130	16-May-91 07:10:00.	21.450	22.900	35.550	36.450	38.300	21.200	255
131	16-May-91 07:20:00.	21.350	22.700	35.450	36.300	38.200	21.050	255
132	16-May-91 07:30:00.	21.200	22.550	35.350	36.150	38.050	20.850	255
133	16-May-91 07:40:00.	20.850	22.300	35.200	36.000	37.900	20.600	255
134	16-May-91 07:50:00.	20.750	22.150	35.050	35.900	37.700	20.500	255
135	16-May-91 08:00:00.	20.650	22.050	34.950	35.700	37.650	20.350	255
136	16-May-91 08:10:00.	20.600	21.950	34.800	35.550	37.450	20.300	255
137	16-May-91 08:20:00.	20.350	21.750	34.650	35.450	37.350	20.050	255
138	16-May-91 08:30:00.	20.300	21.650	34.550	35.300	37.300	20.000	255
139	16-May-91 08:40:00.	20.150	21.500	34.400	35.150	37.150	19.850	255
140	16-May-91 08:50:00.	20.100	21.450	34.250	35.000	36.950	19.800	255
141	16-May-91 09:00:00.	19.900	21.300	34.150	34.850	36.900	19.650	255
142	16-May-91 09:10:00.	19.800	21.200	34.000	34.750	36.750	19.500	255
143	16-May-91 09:20:00.	19.700	21.050	33.850	34.600	36.550	19.450	255
144	16-May-91 09:30:00.	19.650	20.950	33.700	34.500	36.450	19.350	255



## APPENDIX 3.7.4

### CLIMATIC CHAMBER

#### CONTAINER TEMPERATURE READINGS

File 32

60 Watt heat load

2,25 Amp cooling

Container in climatic chamber

Sol-air program

#### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.

Ch 2 Outside heat sink

Ch 3 Inside heat sink

Ch 4 Inside floor level

Ch 5 Inside globe level

Ch 6 Outside globe level

Ch 19 255=Off 254=On

## Channel Readings

Data file - FILE32

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

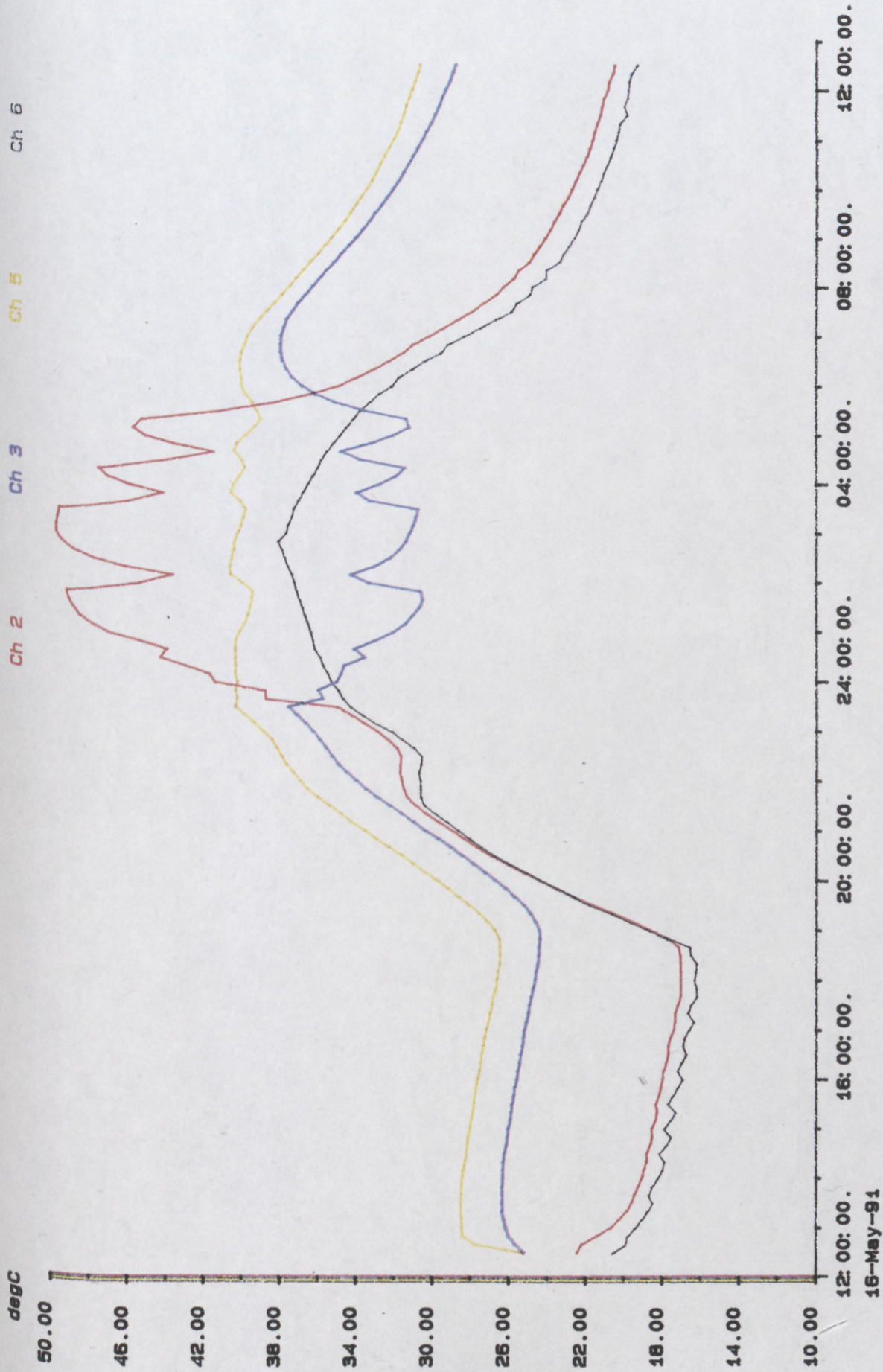
Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 16-May-91 12:30:00.  
    Finish : 17-May-91 12:30:01.  
Readings per channel: 145

All readings

Rdn no	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19
0	16-May-91 12:30:00.	22.250	22.500	25.200	25.000	25.300	20.600	255
1	16-May-91 12:40:00.	19.800	22.200	25.650	25.850	27.750	19.900	255
2	16-May-91 12:50:00.	19.900	21.450	26.000	26.250	28.400	19.800	255
3	16-May-91 13:00:00.	19.450	20.700	26.150	26.500	28.450	19.400	255
4	16-May-91 13:10:00.	19.000	20.250	26.250	26.650	28.450	19.050	255
5	16-May-91 13:20:00.	18.600	19.850	26.350	26.800	28.500	18.750	255
6	16-May-91 13:30:00.	18.200	19.600	26.350	26.900	28.500	18.450	255
7	16-May-91 13:40:00.	18.750	19.450	26.350	26.900	28.450	18.700	255
8	16-May-91 13:50:00.	18.700	19.250	26.350	26.900	28.450	18.500	255
9	16-May-91 14:00:00.	18.250	19.050	26.300	26.900	28.400	18.200	255
10	16-May-91 14:10:00.	17.850	18.950	26.300	26.850	28.350	17.950	255
11	16-May-91 14:20:00.	17.500	18.800	26.250	26.800	28.250	17.850	255
12	16-May-91 14:30:00.	18.450	18.800	26.200	26.750	28.200	18.150	255
13	16-May-91 14:40:00.	17.800	18.600	26.100	26.700	28.150	17.750	255
14	16-May-91 14:50:00.	17.450	18.500	26.050	26.650	28.100	17.500	255
15	16-May-91 15:00:00.	18.250	18.550	26.000	26.550	28.000	17.900	255
16	16-May-91 15:10:00.	17.550	18.350	25.900	26.450	27.950	17.550	255
17	16-May-91 15:20:00.	17.150	18.250	25.850	26.400	27.850	17.250	255
18	16-May-91 15:30:00.	18.050	18.350	25.800	26.300	27.800	17.700	255
19	16-May-91 15:40:00.	17.500	18.150	25.700	26.250	27.750	17.400	255
20	16-May-91 15:50:00.	17.100	18.050	25.650	26.200	27.700	17.150	255
21	16-May-91 16:00:00.	16.700	17.950	25.550	26.100	27.600	16.900	255
22	16-May-91 16:10:00.	17.350	17.900	25.500	26.000	27.500	17.200	255
23	16-May-91 16:20:00.	17.000	17.750	25.400	25.950	27.450	16.950	255
24	16-May-91 16:30:00.	16.600	17.650	25.350	25.850	27.400	16.700	255
25	16-May-91 16:40:00.	16.900	17.650	25.250	25.800	27.300	16.900	255
26	16-May-91 16:50:00.	16.850	17.550	25.200	25.700	27.250	16.800	255
27	16-May-91 17:00:00.	16.500	17.350	25.150	25.650	27.150	16.550	255
28	16-May-91 17:10:00.	16.150	17.300	25.050	25.550	27.050	16.300	255
29	16-May-91 17:20:00.	16.550	17.300	24.950	25.450	26.950	16.650	255
30	16-May-91 17:30:00.	16.500	17.150	24.900	25.350	26.850	16.450	255
31	16-May-91 17:40:00.	16.150	17.000	24.800	25.300	26.800	16.150	255
32	16-May-91 17:50:00.	16.000	17.000	24.700	25.150	26.650	16.200	255
33	16-May-91 18:00:00.	16.450	17.000	24.600	25.100	26.600	16.300	255
34	16-May-91 18:10:00.	16.300	17.000	24.550	25.050	26.550	16.200	255
35	16-May-91 18:20:00.	16.050	17.000	24.450	25.000	26.450	16.150	255

36	16-May-91	18:30:00	16.800	17.050	24.400	24.950	26.450	16.500	255
37	16-May-91	18:40:00	16.850	17.150	24.400	24.900	26.450	16.550	255
38	16-May-91	18:50:00	16.600	17.700	24.350	24.950	26.500	17.700	255
39	16-May-91	19:00:00	19.900	18.600	24.400	25.100	26.750	18.650	255
40	16-May-91	19:10:00	21.150	19.550	24.600	25.350	27.100	19.700	255
41	16-May-91	19:20:00	22.200	20.550	24.850	25.650	27.550	20.650	255
42	16-May-91	19:30:00	23.550	21.650	25.200	26.100	28.100	21.800	255
43	16-May-91	19:40:00	24.400	22.650	25.650	26.600	28.650	22.600	255
44	16-May-91	19:50:00	25.100	23.550	26.150	27.100	29.200	23.450	255
45	16-May-91	20:00:00	26.000	24.400	26.700	27.650	29.800	24.350	255
46	16-May-91	20:10:00	26.950	25.250	27.250	28.200	30.400	25.100	255
47	16-May-91	20:20:00	27.650	26.100	27.850	28.800	31.000	25.950	255
48	16-May-91	20:30:00	28.450	26.950	28.450	29.400	31.600	26.750	255
49	16-May-91	20:40:00	29.200	27.700	29.050	30.050	32.300	27.450	255
50	16-May-91	20:50:00	29.650	28.350	29.700	30.650	32.950	28.050	255
51	16-May-91	21:00:00	30.350	29.000	30.400	31.250	33.550	28.650	255
52	16-May-91	21:10:00	31.000	29.700	31.000	31.850	34.250	29.250	255
53	16-May-91	21:20:00	31.550	30.350	31.600	32.450	34.900	29.850	255
54	16-May-91	21:30:00	32.050	30.900	32.250	33.100	35.450	30.450	255
55	16-May-91	21:40:00	32.050	31.350	32.900	33.650	36.050	30.450	255
56	16-May-91	21:50:00	31.950	31.550	33.500	34.250	36.600	30.650	255
57	16-May-91	22:00:00	31.650	31.650	34.000	34.700	37.000	30.650	255
58	16-May-91	22:10:00	31.800	31.750	34.500	35.100	37.350	30.750	255
59	16-May-91	22:20:00	31.550	31.700	34.950	35.500	37.700	30.600	255
60	16-May-91	22:30:00	31.350	31.650	35.300	35.800	37.950	30.550	255
61	16-May-91	22:40:00	32.250	31.900	35.600	36.100	38.200	31.000	255
62	16-May-91	22:50:00	33.100	32.350	35.950	36.450	38.450	31.600	255
63	16-May-91	23:00:00	33.850	32.900	36.300	36.800	38.900	32.150	255
64	16-May-91	23:10:00	34.800	33.600	36.700	37.250	39.350	33.000	255
65	16-May-91	23:20:00	35.700	34.300	37.150	37.700	39.850	33.700	255
66	16-May-91	23:30:00	36.400	35.050	37.600	38.200	40.400	34.350	254
67	16-May-91	23:40:00	36.650	38.800	35.750	38.550	40.250	34.750	255
68	16-May-91	23:50:00	36.900	38.850	36.050	38.900	40.400	35.000	254
69	16-May-91	24:00:00	37.000	41.500	35.050	39.100	40.250	35.350	255
70	17-May-91	00:10:00	37.250	41.800	34.800	39.350	40.400	35.550	254
71	17-May-91	00:20:00	37.450	43.050	34.650	39.400	40.350	35.800	254
72	17-May-91	00:30:00	37.650	44.400	33.550	39.450	40.400	35.950	254
73	17-May-91	00:40:00	37.800	44.000	34.150	39.550	40.400	36.250	254
74	17-May-91	00:50:00	37.900	45.450	33.050	39.550	40.400	36.350	254
75	17-May-91	01:00:00	38.050	47.050	32.100	39.450	40.150	36.450	254
76	17-May-91	01:10:00	38.150	47.950	31.450	39.300	39.900	36.600	254
77	17-May-91	01:20:00	38.300	48.600	31.050	39.150	39.700	36.750	254
78	17-May-91	01:30:00	38.400	48.950	30.700	39.050	39.600	36.900	254
79	17-May-91	01:40:00	38.550	49.200	30.500	38.900	39.500	37.050	254
80	17-May-91	01:50:00	38.750	49.300	30.650	38.850	39.450	37.200	255
81	17-May-91	02:00:00	38.750	45.450	33.350	39.150	40.000	37.300	255
82	17-May-91	02:10:00	38.900	43.700	34.350	39.550	40.650	37.450	254
83	17-May-91	02:20:00	39.150	46.200	33.050	39.700	40.700	37.650	254
84	17-May-91	02:30:00	39.450	47.850	32.250	39.700	40.550	37.800	254
85	17-May-91	02:40:00	39.500	48.950	31.750	39.700	40.450	37.950	254
86	17-May-91	02:50:00	39.700	49.550	31.400	39.700	40.400	38.150	254
87	17-May-91	03:00:00	38.900	49.850	31.200	39.600	40.250	37.700	254
88	17-May-91	03:10:00	38.700	49.850	31.000	39.500	40.050	37.600	254
89	17-May-91	03:20:00	38.400	49.750	30.850	39.400	39.950	37.400	254
90	17-May-91	03:30:00	38.450	49.650	30.750	39.300	39.800	37.300	255
91	17-May-91	03:40:00	38.050	46.000	33.300	39.450	40.150	37.050	255
92	17-May-91	03:50:00	37.750	44.200	34.000	39.700	40.650	36.800	254
93	17-May-91	04:00:00	37.450	45.950	32.800	39.700	40.450	36.550	254
94	17-May-91	04:10:00	37.200	47.100	31.900	39.600	40.150	36.300	254

95	17-May-91 04:20:00.	36,900	47,600	31,450	39,400	39,850	36,050	255
96	17-May-91 04:30:00.	36,700	44,000	33,800	39,500	40,050	35,850	255
97	17-May-91 04:40:00.	36,400	41,550	34,850	39,700	40,450	35,550	254
98	17-May-91 04:50:00.	35,950	43,700	33,250	39,600	40,300	35,200	254
99	17-May-91 05:00:00.	35,550	45,150	32,050	39,350	39,800	34,850	254
100	17-May-91 05:10:00.	35,150	45,800	31,200	39,050	39,350	34,500	254
101	17-May-91 05:20:00.	34,800	45,300	31,400	38,800	39,000	34,150	255
102	17-May-91 05:30:00.	34,300	41,250	33,600	38,800	39,250	33,800	255
103	17-May-91 05:40:00.	33,700	38,400	35,150	38,850	39,500	33,300	255
104	17-May-91 05:50:00.	33,100	36,450	36,200	38,900	39,850	32,800	255
105	17-May-91 06:00:00.	32,350	34,950	36,900	39,000	40,050	32,100	255
106	17-May-91 06:10:00.	32,000	34,000	37,400	39,050	40,050	31,750	255
107	17-May-91 06:20:00.	31,350	33,100	37,700	39,000	40,150	31,050	255
108	17-May-91 06:30:00.	30,500	32,300	37,900	38,950	40,150	30,400	255
109	17-May-91 06:40:00.	29,400	31,550	38,000	38,850	40,050	29,550	255
110	17-May-91 06:50:00.	29,250	31,000	38,000	38,700	39,850	29,200	255
111	17-May-91 07:00:00.	28,300	30,200	37,950	38,550	39,700	28,350	255
112	17-May-91 07:10:00.	27,250	29,450	37,800	38,300	39,450	27,500	255
113	17-May-91 07:20:00.	26,100	28,700	37,650	38,000	39,100	26,700	255
114	17-May-91 07:30:00.	25,350	27,950	37,350	37,700	38,700	25,850	255
115	17-May-91 07:40:00.	25,450	27,350	37,050	37,300	38,250	25,600	255
116	17-May-91 07:50:00.	24,650	26,700	36,650	36,900	37,900	24,900	255
117	17-May-91 08:00:00.	24,850	26,300	36,300	36,500	37,500	24,750	255
118	17-May-91 08:10:00.	23,900	25,750	35,900	36,100	37,150	24,050	255
119	17-May-91 08:20:00.	24,350	25,500	35,550	35,700	36,750	24,050	255
120	17-May-91 08:30:00.	23,250	24,950	35,150	35,350	36,400	23,350	255
121	17-May-91 08:40:00.	23,150	24,700	34,800	34,900	36,000	23,150	255
122	17-May-91 08:50:00.	22,850	24,400	34,400	34,550	35,650	22,850	255
123	17-May-91 09:00:00.	22,700	24,100	34,000	34,150	35,300	22,600	255
124	17-May-91 09:10:00.	22,450	23,850	33,650	33,750	34,950	22,350	255
125	17-May-91 09:20:00.	22,350	23,650	33,300	33,450	34,600	22,200	255
126	17-May-91 09:30:00.	22,000	23,400	33,000	33,100	34,300	21,900	255
127	17-May-91 09:40:00.	21,900	23,200	32,650	32,750	34,000	21,750	255
128	17-May-91 09:50:00.	21,650	22,950	32,350	32,500	33,750	21,550	255
129	17-May-91 10:00:00.	21,500	22,750	32,050	32,200	33,450	21,400	255
130	17-May-91 10:10:00.	21,250	22,550	31,750	31,900	33,200	21,200	255
131	17-May-91 10:20:00.	21,200	22,350	31,500	31,650	32,950	21,050	255
132	17-May-91 10:30:00.	20,950	22,150	31,250	31,400	32,750	20,850	255
133	17-May-91 10:40:00.	20,800	21,950	31,000	31,200	32,500	20,700	255
134	17-May-91 10:50:00.	20,650	21,800	30,750	30,900	32,250	20,550	255
135	17-May-91 11:00:00.	20,550	21,650	30,500	30,700	32,000	20,400	255
136	17-May-91 11:10:00.	20,450	21,550	30,300	30,500	31,800	20,300	255
137	17-May-91 11:20:00.	20,350	21,400	30,050	30,300	31,650	20,200	255
138	17-May-91 11:30:00.	19,750	21,250	29,850	30,100	31,500	19,800	255
139	17-May-91 11:40:00.	20,200	21,150	29,650	29,950	31,350	20,000	255
140	17-May-91 11:50:00.	19,800	21,050	29,500	29,800	31,200	19,800	255
141	17-May-91 12:00:00.	19,900	20,850	29,300	29,650	31,050	19,750	255
142	17-May-91 12:10:00.	19,800	20,800	29,100	29,500	30,900	19,750	255
143	17-May-91 12:20:00.	19,800	20,600	28,950	29,350	30,750	19,600	255
144	17-May-91 12:30:00.	19,350	20,500	28,800	29,200	30,650	19,300	255



## APPENDIX 3.7.5

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 33  
60 Watt heat load  
No cooling  
Container in climatic chamber  
Stepped program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level  
Ch 19 255=Off 254=On

# Channel Readings

Data file - FILE33

**Recorder details:**

Recorder number : 38  
 Squirrel type : 1206

**Run details:**

Run number : 1  
 Channels used : 7  
 Recording Interval : 00:10:00.  
 Non-averaged time interval readings  
 Recording period :  
     Start : 20-May-91 10:00:00.  
     Finish : 21-May-91 16:00:01.  
 Readings per channel: 181

All readings

Rdn no:	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19
0	20-May-91 10:00:00.	24.800	28.500	37.150	35.900	36.750	26.800	255
1	20-May-91 10:10:00.	23.750	27.850	36.800	35.950	36.950	26.000	255
2	20-May-91 10:20:00.	22.500	26.250	36.400	35.850	36.900	24.300	255
3	20-May-91 10:30:00.	22.550	25.200	35.900	35.550	36.350	23.650	255
4	20-May-91 10:40:00.	22.150	24.500	35.400	35.200	35.900	23.000	255
5	20-May-91 10:50:00.	22.000	24.050	34.850	34.850	35.500	22.700	255
6	20-May-91 11:00:00.	22.150	23.700	34.400	34.500	35.200	22.400	255
7	20-May-91 11:10:00.	22.100	23.500	33.900	34.050	34.850	22.200	255
8	20-May-91 11:20:00.	21.700	23.300	33.550	33.700	34.550	21.850	255
9	20-May-91 11:30:00.	22.200	23.200	33.150	33.400	34.250	22.000	255
10	20-May-91 11:40:00.	22.050	23.100	32.800	33.100	34.000	21.900	255
11	20-May-91 11:50:00.	21.950	23.000	32.500	32.800	33.750	21.750	255
12	20-May-91 12:00:00.	22.000	22.950	32.200	32.550	33.500	21.750	255
13	20-May-91 12:10:00.	22.000	22.900	31.900	32.300	33.350	21.700	255
14	20-May-91 12:20:00.	21.950	22.900	31.650	32.100	33.150	21.700	255
15	20-May-91 12:30:00.	22.000	22.850	31.450	31.900	33.000	21.700	255
16	20-May-91 12:40:00.	22.000	22.800	31.300	31.700	32.850	21.650	255
17	20-May-91 12:50:00.	22.000	22.800	31.150	31.550	32.750	21.650	255
18	20-May-91 13:00:00.	22.050	22.750	30.950	31.400	32.600	21.650	255
19	20-May-91 13:10:00.	24.100	23.300	30.800	31.350	32.500	22.900	255
20	20-May-91 13:20:00.	24.050	23.800	30.800	31.400	32.700	23.050	255
21	20-May-91 13:30:00.	24.200	24.100	30.800	31.500	32.850	23.250	255
22	20-May-91 13:40:00.	24.200	24.350	30.850	31.550	32.950	23.450	255
23	20-May-91 13:50:00.	23.850	24.400	30.900	31.600	33.000	23.350	255
24	20-May-91 14:00:00.	24.000	24.400	30.950	31.600	33.050	23.400	255
25	20-May-91 14:10:00.	23.850	24.450	31.000	31.650	33.050	23.400	255
26	20-May-91 14:20:00.	24.050	24.450	31.050	31.650	33.100	23.450	255
27	20-May-91 14:30:00.	23.950	24.450	31.050	31.700	33.100	23.450	255
28	20-May-91 14:40:00.	23.900	24.450	31.100	31.700	33.100	23.450	255
29	20-May-91 14:50:00.	24.050	24.500	31.150	31.750	33.150	23.500	255
30	20-May-91 15:00:00.	24.000	24.500	31.150	31.750	33.150	23.500	255
31	20-May-91 15:10:00.	23.900	24.500	31.200	31.800	33.200	23.500	255
32	20-May-91 15:20:00.	23.850	24.500	31.200	31.800	33.150	23.450	255
33	20-May-91 15:30:00.	23.850	24.500	31.200	31.800	33.200	23.450	255
34	20-May-91 15:40:00.	24.000	24.500	31.250	31.800	33.200	23.500	255
35	20-May-91 15:50:00.	23.850	24.500	31.250	31.800	33.250	23.450	255
36	20-May-91 16:00:00.	23.850	24.500	31.250	31.850	33.200	23.500	255

37	20-May-91 16:10:00.	26.100	25.050	31.300	31.850	33.250	24.750	255
38	20-May-91 16:20:00.	25.900	25.550	31.400	32.050	33.550	24.850	255
39	20-May-91 16:30:00.	25.800	25.800	31.500	32.250	33.800	25.000	255
40	20-May-91 16:40:00.	26.000	26.050	31.650	32.400	34.000	25.150	255
41	20-May-91 16:50:00.	26.150	26.200	31.800	32.550	34.150	25.250	255
42	20-May-91 17:00:00.	26.100	26.350	32.000	32.700	34.250	25.350	255
43	20-May-91 17:10:00.	26.100	26.450	32.100	32.800	34.400	25.400	255
44	20-May-91 17:20:00.	25.900	26.400	32.250	32.900	34.500	25.300	255
45	20-May-91 17:30:00.	26.000	26.450	32.350	33.000	34.500	25.400	255
46	20-May-91 17:40:00.	25.900	26.400	32.450	33.100	34.600	25.350	255
47	20-May-91 17:50:00.	25.850	26.400	32.550	33.150	34.650	25.300	255
48	20-May-91 18:00:00.	25.950	26.400	32.600	33.200	34.650	25.350	255
49	20-May-91 18:10:00.	25.800	26.400	32.650	33.250	34.750	25.350	255
50	20-May-91 18:20:00.	25.950	26.450	32.700	33.250	34.750	25.350	255
51	20-May-91 18:30:00.	26.000	26.450	32.750	33.350	34.800	25.350	255
52	20-May-91 18:40:00.	25.850	26.450	32.800	33.350	34.850	25.350	255
53	20-May-91 18:50:00.	25.950	26.450	32.850	33.400	34.850	25.350	255
54	20-May-91 19:00:00.	25.950	26.450	32.900	33.450	34.950	25.350	255
55	20-May-91 19:10:00.	28.000	27.000	32.950	33.500	34.950	26.650	255
56	20-May-91 19:20:00.	27.850	27.450	33.050	33.700	35.250	26.750	255
57	20-May-91 19:30:00.	28.000	27.800	33.200	33.850	35.550	26.900	255
58	20-May-91 19:40:00.	27.850	27.950	33.400	34.050	35.700	26.950	255
59	20-May-91 19:50:00.	27.900	28.100	33.550	34.200	35.850	27.050	255
60	20-May-91 20:00:00.	28.000	28.200	33.700	34.350	35.950	27.150	255
61	20-May-91 20:10:00.	27.900	28.250	33.850	34.500	36.100	27.150	255
62	20-May-91 20:20:00.	27.800	28.250	34.000	34.600	36.200	27.150	255
63	20-May-91 20:30:00.	27.900	28.300	34.100	34.650	36.300	27.200	255
64	20-May-91 20:40:00.	27.950	28.350	34.250	34.750	36.350	27.250	255
65	20-May-91 20:50:00.	27.800	28.350	34.350	34.850	36.450	27.150	255
66	20-May-91 21:00:00.	27.900	28.350	34.450	34.950	36.550	27.200	255
67	20-May-91 21:10:00.	27.950	28.350	34.550	35.000	36.600	27.250	255
68	20-May-91 21:20:00.	27.900	28.400	34.600	35.100	36.650	27.250	255
69	20-May-91 21:30:00.	27.850	28.400	34.650	35.100	36.650	27.200	255
70	20-May-91 21:40:00.	27.950	28.400	34.700	35.200	36.700	27.250	255
71	20-May-91 21:50:00.	27.950	28.400	34.750	35.200	36.750	27.250	255
72	20-May-91 22:00:00.	27.800	28.400	34.800	35.250	36.800	27.200	255
73	20-May-91 22:10:00.	29.900	29.200	34.850	35.400	36.950	28.550	255
74	20-May-91 22:20:00.	30.050	29.550	35.000	35.550	37.250	28.700	255
75	20-May-91 22:30:00.	29.850	29.800	35.200	35.700	37.400	28.700	255
76	20-May-91 22:40:00.	29.850	29.950	35.350	35.850	37.550	28.850	255
77	20-May-91 22:50:00.	29.900	30.100	35.500	35.950	37.700	28.900	255
78	20-May-91 23:00:00.	29.850	30.150	35.650	36.150	37.850	28.900	255
79	20-May-91 23:10:00.	29.750	30.150	35.800	36.250	37.950	28.950	255
80	20-May-91 23:20:00.	29.850	30.200	35.900	36.400	38.100	28.950	255
81	20-May-91 23:30:00.	29.850	30.250	36.050	36.500	38.200	29.000	255
82	20-May-91 23:40:00.	29.750	30.250	36.150	36.600	38.300	28.950	255
83	20-May-91 23:50:00.	29.800	30.300	36.250	36.700	38.350	29.000	255
84	20-May-91 24:00:00.	29.900	30.300	36.350	36.800	38.450	29.000	255
85	21-May-91 00:10:00.	29.850	30.300	36.450	36.850	38.500	29.000	255
86	21-May-91 00:20:00.	29.750	30.300	36.500	36.900	38.500	29.000	255
87	21-May-91 00:30:00.	29.900	30.350	36.550	36.950	38.550	29.050	255
88	21-May-91 00:40:00.	29.900	30.350	36.600	37.000	38.550	29.000	255
89	21-May-91 00:50:00.	29.800	30.350	36.650	37.050	38.600	29.000	255
90	21-May-91 01:00:00.	29.900	30.350	36.700	37.050	38.650	29.050	255
91	21-May-91 01:10:00.	31.650	31.100	36.750	37.200	38.750	30.250	255
92	21-May-91 01:20:00.	31.700	31.450	36.900	37.350	39.050	30.450	255
93	21-May-91 01:30:00.	31.800	31.750	37.050	37.550	39.250	30.650	255
94	21-May-91 01:40:00.	31.800	31.900	37.200	37.650	39.450	30.650	255
95	21-May-91 01:50:00.	31.850	32.000	37.400	37.800	39.550	30.750	255

96	21-May-91	02:00:00.	31.750	32.050	37.550	37.950	39.700	30.750	255
97	21-May-91	02:10:00.	31.800	32.100	37.700	38.050	39.750	30.850	255
98	21-May-91	02:20:00.	31.750	32.100	37.800	38.200	39.850	30.750	255
99	21-May-91	02:30:00.	31.600	32.100	37.900	38.300	39.950	30.750	255
100	21-May-91	02:40:00.	31.700	32.100	38.050	38.400	40.050	30.750	255
101	21-May-91	02:50:00.	31.750	32.150	38.100	38.500	40.150	30.750	255
102	21-May-91	03:00:00.	31.700	32.100	38.200	38.550	40.150	30.750	255
103	21-May-91	03:10:00.	31.550	32.100	38.250	38.650	40.250	30.700	255
104	21-May-91	03:20:00.	31.800	32.150	38.300	38.700	40.300	30.800	255
105	21-May-91	03:30:00.	31.750	32.200	38.400	38.750	40.400	30.800	255
106	21-May-91	03:40:00.	31.650	32.200	38.450	38.800	40.400	30.800	255
107	21-May-91	03:50:00.	31.800	32.200	38.450	38.800	40.400	30.900	255
108	21-May-91	04:00:00.	31.800	32.200	38.500	38.850	40.450	30.800	255
109	21-May-91	04:10:00.	33.750	33.000	38.600	39.000	40.600	32.100	255
110	21-May-91	04:20:00.	33.300	33.250	38.700	39.200	40.900	32.000	255
111	21-May-91	04:30:00.	33.650	33.550	38.900	39.350	41.050	32.250	255
112	21-May-91	04:40:00.	33.700	33.700	39.050	39.500	41.250	32.400	255
113	21-May-91	04:50:00.	33.500	33.800	39.250	39.650	41.350	32.350	255
114	21-May-91	05:00:00.	33.650	33.850	39.350	39.750	41.500	32.450	255
115	21-May-91	05:10:00.	33.650	33.900	39.500	39.900	41.600	32.500	255
116	21-May-91	05:20:00.	33.600	33.900	39.600	40.000	41.650	32.450	255
117	21-May-91	05:30:00.	33.600	33.950	39.700	40.100	41.700	32.500	255
118	21-May-91	05:40:00.	33.650	34.000	39.800	40.150	41.800	32.500	255
119	21-May-91	05:50:00.	33.650	34.000	39.900	40.300	41.950	32.550	255
120	21-May-91	06:00:00.	33.600	34.000	40.000	40.400	42.000	32.550	255
121	21-May-91	06:10:00.	33.650	34.050	40.050	40.400	42.050	32.550	255
122	21-May-91	06:20:00.	33.700	34.050	40.100	40.450	42.050	32.550	255
123	21-May-91	06:30:00.	33.600	34.050	40.150	40.500	42.050	32.500	255
124	21-May-91	06:40:00.	33.650	34.050	40.200	40.500	42.050	32.600	255
125	21-May-91	06:50:00.	33.700	34.100	40.300	40.600	42.150	32.550	255
126	21-May-91	07:00:00.	33.600	34.100	40.300	40.600	42.200	32.550	255
127	21-May-91	07:10:00.	35.800	34.950	40.400	40.700	42.300	34.000	255
128	21-May-91	07:20:00.	35.250	35.250	40.550	40.950	42.700	33.800	255
129	21-May-91	07:30:00.	35.700	35.500	40.700	41.050	42.850	34.150	255
130	21-May-91	07:40:00.	35.600	35.650	40.850	41.200	43.000	34.250	255
131	21-May-91	07:50:00.	35.650	35.800	41.000	41.400	43.150	34.300	255
132	21-May-91	08:00:00.	35.700	35.900	41.150	41.500	43.250	34.400	255
133	21-May-91	08:10:00.	35.750	35.950	41.250	41.600	43.350	34.400	255
134	21-May-91	08:20:00.	35.700	36.000	41.400	41.700	43.450	34.500	255
135	21-May-91	08:30:00.	35.750	36.050	41.500	41.800	43.550	34.550	255
136	21-May-91	08:40:00.	35.900	36.100	41.600	41.900	43.600	34.600	255
137	21-May-91	08:50:00.	35.800	36.150	41.700	42.000	43.700	34.600	255
138	21-May-91	09:00:00.	35.800	36.200	41.800	42.050	43.800	34.650	255
139	21-May-91	09:10:00.	35.950	36.250	41.900	42.150	43.800	34.750	255
140	21-May-91	09:20:00.	35.950	36.300	42.000	42.200	43.900	34.700	255
141	21-May-91	09:30:00.	35.800	36.300	42.050	42.300	43.950	34.700	255
142	21-May-91	09:40:00.	35.900	36.300	42.150	42.350	44.050	34.750	255
143	21-May-91	09:50:00.	35.800	36.300	42.200	42.450	44.100	34.700	255
144	21-May-91	10:00:00.	35.800	36.300	42.300	42.550	44.150	34.700	255
145	21-May-91	10:10:00.	37.600	37.050	42.350	42.700	44.300	35.900	255
146	21-May-91	10:20:00.	37.900	37.450	42.550	42.900	44.600	36.200	255
147	21-May-91	10:30:00.	37.800	37.750	42.700	43.050	44.800	36.250	255
148	21-May-91	10:40:00.	37.850	37.900	42.900	43.200	45.000	36.400	255
149	21-May-91	10:50:00.	37.950	38.050	43.050	43.350	45.150	36.450	255
150	21-May-91	11:00:00.	37.900	38.150	43.200	43.500	45.300	36.500	255
151	21-May-91	11:10:00.	37.800	38.150	43.350	43.600	45.350	36.550	255
152	21-May-91	11:20:00.	37.950	38.200	43.500	43.700	45.450	36.650	255
153	21-May-91	11:30:00.	38.000	38.250	43.600	43.800	45.550	36.650	255
154	21-May-91	11:40:00.	37.850	38.250	43.700	43.900	45.600	36.650	255
155	21-May-91	11:50:00.	37.850	38.300	43.800	44.000	45.750	36.650	255

156	21-May-91 12:00:00.	38.000	38.300	43.900	44.100	45.800	36.700	255
157	21-May-91 12:10:00.	37.900	38.300	44.000	44.200	45.900	36.650	255
158	21-May-91 12:20:00.	37.900	38.350	44.050	44.250	46.000	36.750	255
159	21-May-91 12:30:00.	38.000	38.350	44.150	44.350	46.000	36.750	255
160	21-May-91 12:40:00.	37.950	38.350	44.200	44.400	46.050	36.700	255
161	21-May-91 12:50:00.	37.850	38.350	44.250	44.450	46.100	36.700	255
162	21-May-91 13:00:00.	38.050	38.400	44.300	44.500	46.200	36.800	255
163	21-May-91 13:10:00.	39.600	39.050	44.400	44.600	46.300	37.850	255
164	21-May-91 13:20:00.	39.750	39.450	44.550	44.800	46.650	38.100	255
165	21-May-91 13:30:00.	39.750	39.750	44.750	45.000	46.850	38.200	255
166	21-May-91 13:40:00.	39.900	39.900	44.900	45.150	47.000	38.300	255
167	21-May-91 13:50:00.	39.900	40.000	45.050	45.300	47.100	38.400	255
168	21-May-91 14:00:00.	39.800	40.050	45.200	45.450	47.250	38.450	255
169	21-May-91 14:10:00.	39.900	40.150	45.350	45.600	47.300	38.550	255
170	21-May-91 14:20:00.	39.950	40.150	45.450	45.650	47.450	38.550	255
171	21-May-91 14:30:00.	39.750	40.200	45.600	45.800	47.550	38.500	255
172	21-May-91 14:40:00.	39.850	40.250	45.700	45.850	47.600	38.550	255
173	21-May-91 14:50:00.	39.950	40.300	45.800	46.000	47.650	38.650	255
174	21-May-91 15:00:00.	39.850	40.300	45.850	46.050	47.750	38.550	255
175	21-May-91 15:10:00.	39.750	40.300	45.950	46.100	47.750	38.600	255
176	21-May-91 15:20:00.	39.950	40.300	46.000	46.200	47.850	38.650	255
177	21-May-91 15:30:00.	39.850	40.300	46.100	46.250	47.900	38.650	255
178	21-May-91 15:40:00.	39.700	40.300	46.150	46.300	47.950	38.550	255
179	21-May-91 15:50:00.	39.950	40.300	46.250	46.350	48.000	38.650	255
180	21-May-91 16:00:00.	39.950	40.350	46.250	46.450	48.050	38.650	255

Ch 2 Ch 3 Ch 5 Ch 6

degC

50.00  
48.00  
46.00  
44.00  
42.00  
40.00  
38.00  
36.00  
34.00  
32.00  
30.00  
28.00  
26.00  
24.00  
22.00  
20.00

00: 00: 00.  
12: 00: 00.  
24: 00: 00.  
00: 00: 00.  
20-May-91  
21-May-91

## APPENDIX 3.7.6

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 34  
60 Watt heat load  
2,25 Amp cooling  
Container in climatic chamber  
Stepped program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level  
Ch 19 255=Off 254=On

## Channel Readings

Data file - FILE34

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 21-May-91 17:00:00.  
    Finish : 22-May-91 23:00:01.  
Readings per channel: 181

All readings

Rdo no:	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19
0	21-May-91 17:00:00.	22.100	26.900	35.000	32.350	25.550	24.250	255
1	21-May-91 17:10:00.	22.650	26.250	34.950	34.050	33.250	24.450	255
2	21-May-91 17:20:00.	22.500	25.150	34.650	34.050	34.850	23.550	255
3	21-May-91 17:30:00.	22.100	24.400	34.250	33.900	34.950	22.950	255
4	21-May-91 17:40:00.	21.950	24.000	33.800	33.700	34.750	22.650	255
5	21-May-91 17:50:00.	22.150	23.650	33.400	33.450	34.550	22.500	255
6	21-May-91 18:00:00.	21.750	23.450	33.050	33.200	34.300	22.150	255
7	21-May-91 18:10:00.	22.150	23.250	32.750	33.000	34.100	22.150	255
8	21-May-91 18:20:00.	21.900	23.150	32.450	32.750	33.950	22.050	255
9	21-May-91 18:30:00.	22.050	23.000	32.200	32.550	33.800	21.950	255
10	21-May-91 18:40:00.	22.000	22.950	31.950	32.350	33.600	21.900	255
11	21-May-91 18:50:00.	21.950	22.900	31.700	32.100	33.400	21.800	255
12	21-May-91 19:00:00.	21.900	22.800	31.500	31.850	33.200	21.750	255
13	21-May-91 19:10:00.	21.850	22.750	31.300	31.650	33.000	21.700	255
14	21-May-91 19:20:00.	21.900	22.750	31.150	31.500	32.900	21.700	255
15	21-May-91 19:30:00.	22.000	22.750	30.950	31.350	32.750	21.750	255
16	21-May-91 19:40:00.	21.950	22.700	30.800	31.250	32.650	21.700	255
17	21-May-91 19:50:00.	21.950	22.700	30.700	31.100	32.500	21.700	255
18	21-May-91 20:00:00.	21.950	22.700	30.550	31.000	32.450	21.650	255
19	21-May-91 20:10:00.	23.950	23.200	30.450	30.900	32.350	22.850	255
20	21-May-91 20:20:00.	23.750	23.650	30.450	31.000	32.550	22.900	255
21	21-May-91 20:30:00.	23.950	23.950	30.500	31.050	32.700	23.150	255
22	21-May-91 20:40:00.	23.900	24.100	30.550	31.150	32.750	23.200	255
23	21-May-91 20:50:00.	23.850	24.200	30.600	31.200	32.900	23.300	255
24	21-May-91 21:00:00.	23.900	24.300	30.650	31.250	32.950	23.350	255
25	21-May-91 21:10:00.	23.950	24.350	30.750	31.300	33.000	23.400	255
26	21-May-91 21:20:00.	23.850	24.350	30.800	31.350	33.050	23.400	255
27	21-May-91 21:30:00.	23.900	24.400	30.850	31.400	33.100	23.450	255
28	21-May-91 21:40:00.	23.950	24.400	30.900	31.450	33.150	23.450	255
29	21-May-91 21:50:00.	23.850	24.400	30.950	31.500	33.200	23.400	255
30	21-May-91 22:00:00.	23.850	24.400	31.000	31.550	33.200	23.450	255
31	21-May-91 22:10:00.	23.900	24.400	31.050	31.600	33.250	23.450	255
32	21-May-91 22:20:00.	23.950	24.400	31.050	31.600	33.250	23.450	255
33	21-May-91 22:30:00.	23.800	24.400	31.100	31.650	33.300	23.400	255
34	21-May-91 22:40:00.	23.900	24.400	31.150	31.650	33.300	23.450	255
35	21-May-91 22:50:00.	24.000	24.450	31.150	31.650	33.300	23.450	255

36		21-May-91	23:00:00.		23,850		24,400		31,200		31,700		33,350		23,450		255
37		21-May-91	23:10:00.		25,900		25,250		31,250		31,800		33,450		24,750		255
38		21-May-91	23:20:00.		25,550		25,550		31,350		32,000		33,700		24,700		255
39		21-May-91	23:30:00.		25,800		25,850		31,500		32,100		33,900		24,950		255
40		21-May-91	23:40:00.		25,850		26,050		31,600		32,250		34,050		25,100		255
41		21-May-91	23:50:00.		25,850		26,150		31,800		32,400		34,250		25,150		255
42		21-May-91	24:00:00.		25,950		26,200		31,900		32,550		34,350		25,200		255
43		22-May-91	00:10:00.		25,900		26,250		32,050		32,700		34,450		25,200		255
44		22-May-91	00:20:00.		25,800		26,300		32,200		32,800		34,550		25,200		255
45		22-May-91	00:30:00.		25,900		26,350		32,300		32,900		34,650		25,250		255
46		22-May-91	00:40:00.		25,950		26,350		32,400		32,950		34,750		25,250		255
47		22-May-91	00:50:00.		25,800		26,350		32,500		33,050		34,750		25,200		255
48		22-May-91	01:00:00.		25,850		26,400		32,550		33,150		34,850		25,300		255
49		22-May-91	01:10:00.		26,000		26,400		32,650		33,200		34,900		25,350		255
50		22-May-91	01:20:00.		25,950		26,400		32,700		33,250		34,950		25,300		255
51		22-May-91	01:30:00.		25,850		26,400		32,750		33,300		34,950		25,250		255
52		22-May-91	01:40:00.		25,900		26,400		32,800		33,350		35,000		25,300		255
53		22-May-91	01:50:00.		25,950		26,450		32,900		33,350		35,050		25,300		255
54		22-May-91	02:00:00.		25,850		26,400		32,900		33,400		35,100		25,300		255
55		22-May-91	02:10:00.		27,850		27,250		33,000		33,550		35,250		26,650		255
56		22-May-91	02:20:00.		28,100		27,600		33,150		33,700		35,550		26,850		255
57		22-May-91	02:30:00.		27,950		27,850		33,300		33,900		35,750		26,950		255
58		22-May-91	02:40:00.		27,800		28,000		33,450		34,050		35,900		26,950		255
59		22-May-91	02:50:00.		27,900		28,150		33,650		34,250		36,050		27,050		255
60		22-May-91	03:00:00.		27,950		28,200		33,800		34,400		36,200		27,100		255
61		22-May-91	03:10:00.		27,850		28,250		33,900		34,500		36,300		27,100		255
62		22-May-91	03:20:00.		27,850		28,300		34,050		34,650		36,400		27,150		255
63		22-May-91	03:30:00.		28,000		28,350		34,200		34,750		36,500		27,200		255
64		22-May-91	03:40:00.		27,950		28,350		34,300		34,800		36,600		27,200		255
65		22-May-91	03:50:00.		27,850		28,350		34,400		34,900		36,700		27,200		255
66		22-May-91	04:00:00.		27,900		28,400		34,500		35,000		36,750		27,200		255
67		22-May-91	04:10:00.		28,000		28,400		34,600		35,100		36,800		27,250		255
68		22-May-91	04:20:00.		27,900		28,400		34,650		35,150		36,850		27,200		255
69		22-May-91	04:30:00.		27,850		28,400		34,700		35,200		36,900		27,200		255
70		22-May-91	04:40:00.		27,950		28,400		34,750		35,250		36,950		27,200		255
71		22-May-91	04:50:00.		28,000		28,450		34,800		35,300		37,000		27,250		255
72		22-May-91	05:00:00.		27,850		28,400		34,850		35,350		37,050		27,200		255
73		22-May-91	05:10:00.		29,750		29,200		34,950		35,450		37,150		28,400		255
74		22-May-91	05:20:00.		29,950		29,600		35,100		35,600		37,450		28,650		255
75		22-May-91	05:30:00.		29,800		29,800		35,250		35,800		37,650		28,700		255
76		22-May-91	05:40:00.		29,750		29,950		35,450		35,950		37,800		28,800		255
77		22-May-91	05:50:00.		29,900		30,100		35,550		36,100		37,950		28,900		255
78		22-May-91	06:00:00.		29,900		30,150		35,700		36,200		38,000		28,900		255
79		22-May-91	06:10:00.		29,750		30,200		35,800		36,300		38,050		28,900		255
80		22-May-91	06:20:00.		29,850		30,250		35,950		36,400		38,200		28,950		255
81		22-May-91	06:30:00.		29,950		30,300		36,050		36,550		38,300		29,050		255
82		22-May-91	06:40:00.		29,800		30,300		36,150		36,650		38,400		29,000		255
83		22-May-91	06:50:00.		29,850		30,350		36,250		36,700		38,400		29,050		255
84		22-May-91	07:00:00.		29,950		30,350		36,300		36,800		38,500		29,100		255
85		22-May-91	07:10:00.		29,900		30,350		36,400		36,850		38,550		29,050		255
86		22-May-91	07:20:00.		29,800		30,350		36,450		36,900		38,550		29,000		255
87		22-May-91	07:30:00.		29,900		30,400		36,550		36,950		38,600		29,050		255
88		22-May-91	07:40:00.		29,950		30,400		36,550		36,950		38,650		29,050		255
89		22-May-91	07:50:00.		29,850		30,400		36,650		37,050		38,650		29,050		255
90		22-May-91	08:00:00.		29,750		30,400		36,650		37,050		38,700		29,000		255
91		22-May-91	08:10:00.		31,700		31,200		36,750		37,200		38,800		30,350		255
92		22-May-91	08:20:00.		31,950		31,550		36,900		37,400		39,100		30,550		255
93		22-May-91	08:30:00.		31,850		31,800		37,050		37,550		39,350		30,650		255
94		22-May-91	08:40:00.		31,900		32,000		37,200		37,700		39,500		30,800		255

95	22-May-91	08:50:00.	31.900	32.100	37.400	37.900	39.600	30.800	255
96	22-May-91	09:00:00.	31.900	32.150	37.550	38.000	39.750	30.900	255
97	22-May-91	09:10:00.	31.800	32.200	37.650	38.150	39.850	30.900	255
98	22-May-91	09:20:00.	31.900	32.250	37.800	38.250	39.950	30.950	255
99	22-May-91	09:30:00.	32.000	32.300	37.900	38.350	40.000	31.000	255
100	22-May-91	09:40:00.	31.850	32.300	38.000	38.400	40.100	30.950	255
101	22-May-91	09:50:00.	31.800	32.300	38.100	38.500	40.150	30.950	255
102	22-May-91	10:00:00.	32.050	32.350	38.200	38.600	40.250	31.050	255
103	22-May-91	10:10:00.	31.850	32.350	38.300	38.650	40.300	30.950	255
104	22-May-91	10:20:00.	31.800	32.350	38.350	38.700	40.400	31.000	255
105	22-May-91	10:30:00.	31.900	33.400	37.600	38.750	40.300	31.000	255
106	22-May-91	10:40:00.	32.000	33.200	37.800	38.750	40.250	31.000	255
107	22-May-91	10:50:00.	31.850	32.900	38.050	38.800	40.300	31.000	255
108	22-May-91	11:00:00.	31.850	32.700	38.200	38.800	40.350	31.000	255
109	22-May-91	11:10:00.	33.750	34.050	37.400	38.900	40.400	32.200	254
110	22-May-91	11:20:00.	33.850	35.500	37.200	39.000	40.350	32.450	255
111	22-May-91	11:30:00.	33.850	36.650	36.150	39.050	40.400	32.550	255
112	22-May-91	11:40:00.	33.950	36.700	36.650	39.050	40.250	32.700	255
113	22-May-91	11:50:00.	34.000	35.900	37.000	39.150	40.450	32.750	254
114	22-May-91	12:00:00.	33.850	37.700	36.050	39.100	40.250	32.800	255
115	22-May-91	12:10:00.	33.850	36.450	36.950	39.200	40.400	32.850	254
116	22-May-91	12:20:00.	34.000	38.050	35.800	39.200	40.300	32.900	255
117	22-May-91	12:30:00.	33.900	36.800	36.750	39.250	40.400	32.900	255
118	22-May-91	12:40:00.	33.850	37.550	36.200	39.250	40.350	32.900	255
119	22-May-91	12:50:00.	33.900	37.400	36.100	39.300	40.400	32.950	254
120	22-May-91	13:00:00.	34.000	36.950	36.650	39.300	40.400	32.950	254
121	22-May-91	13:10:00.	33.850	38.400	35.600	39.250	40.200	32.900	255
122	22-May-91	13:20:00.	33.850	38.900	36.650	39.300	40.350	32.950	255
123	22-May-91	13:30:00.	34.000	37.850	35.800	39.300	40.350	33.000	255
124	22-May-91	13:40:00.	33.900	36.850	36.700	39.350	40.400	32.950	254
125	22-May-91	13:50:00.	33.850	38.400	35.600	39.300	40.250	32.950	255
126	22-May-91	14:00:00.	34.000	36.950	36.600	39.350	40.350	33.000	255
127	22-May-91	14:10:00.	35.750	38.900	35.350	39.400	40.400	34.150	254
128	22-May-91	14:20:00.	35.800	39.350	35.800	39.500	40.450	34.350	254
129	22-May-91	14:30:00.	35.950	40.950	34.600	39.550	40.400	34.600	254
130	22-May-91	14:40:00.	35.950	40.100	35.600	39.600	40.450	34.650	254
131	22-May-91	14:50:00.	35.950	41.600	34.500	39.600	40.400	34.700	255
132	22-May-91	15:00:00.	35.900	40.700	34.950	39.700	40.500	34.750	254
133	22-May-91	15:10:00.	35.950	41.500	34.950	39.700	40.450	34.850	254
134	22-May-91	15:20:00.	36.000	41.800	34.550	39.700	40.400	34.850	255
135	22-May-91	15:30:00.	35.900	41.500	34.550	39.700	40.450	34.850	254
136	22-May-91	15:40:00.	35.900	41.250	35.150	39.700	40.450	34.850	254
137	22-May-91	15:50:00.	36.000	41.950	34.500	39.700	40.400	34.900	255
138	22-May-91	16:00:00.	35.950	41.900	34.200	39.700	40.400	34.900	254
139	22-May-91	16:10:00.	35.800	41.500	34.850	39.700	40.400	34.900	255
140	22-May-91	16:20:00.	35.950	41.650	34.300	39.750	40.450	34.950	255
141	22-May-91	16:30:00.	36.000	42.050	34.550	39.700	40.400	34.950	255
142	22-May-91	16:40:00.	35.850	41.450	34.550	39.750	40.500	34.850	254
143	22-May-91	16:50:00.	35.800	41.450	34.950	39.750	40.450	34.950	255
144	22-May-91	17:00:00.	36.050	42.050	34.400	39.700	40.400	35.000	255
145	22-May-91	17:10:00.	37.650	42.650	34.150	39.800	40.550	36.050	254
146	22-May-91	17:20:00.	37.800	45.000	33.000	39.750	40.500	36.300	255
147	22-May-91	17:30:00.	37.900	44.450	33.450	39.800	40.550	36.450	254
148	22-May-91	17:40:00.	37.950	44.950	33.600	39.800	40.550	36.550	254
149	22-May-91	17:50:00.	37.800	45.400	33.200	39.800	40.550	36.600	254
150	22-May-91	18:00:00.	37.850	45.800	32.950	39.800	40.500	36.650	255
151	22-May-91	18:10:00.	38.000	45.250	33.300	39.850	40.600	36.700	254
152	22-May-91	18:20:00.	37.900	45.450	33.500	39.850	40.550	36.700	254
153	22-May-91	18:30:00.	37.750	46.050	32.800	39.850	40.550	36.650	255

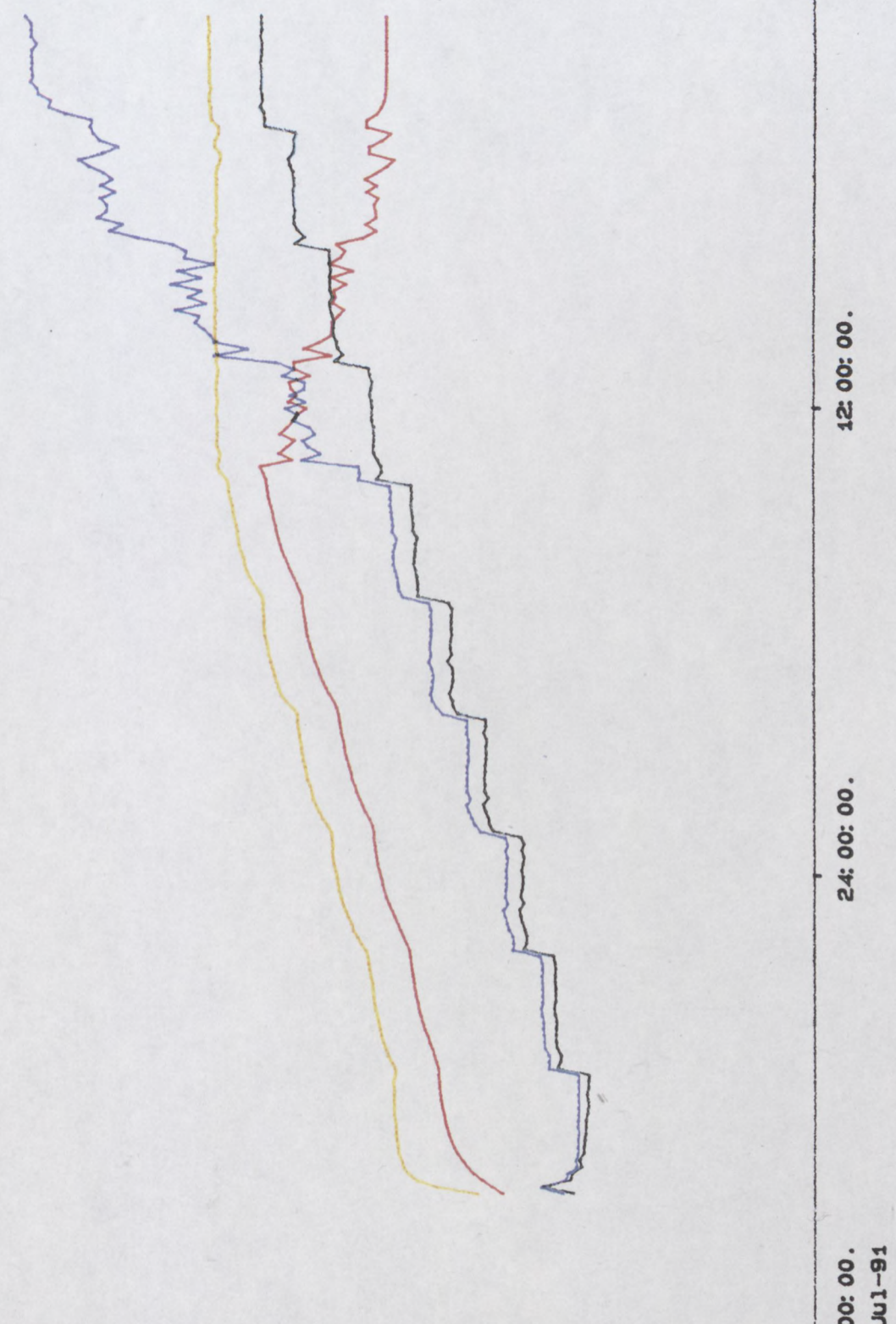
154	22-May-91 18:40:00.	37,800	45,750	33,100	39,850	40,550	36,700	254
155	22-May-91 18:50:00.	37,950	46,100	32,900	39,850	40,500	36,750	254
156	22-May-91 19:00:00.	37,800	46,100	32,900	39,850	40,550	36,700	254
157	22-May-91 19:10:00.	37,900	46,050	32,800	39,850	40,500	36,750	255
158	22-May-91 19:20:00.	37,900	45,550	33,100	39,900	40,600	36,800	254
159	22-May-91 19:30:00.	37,850	45,750	33,450	39,850	40,550	36,700	254
160	22-May-91 19:40:00.	37,800	45,800	32,950	39,850	40,600	36,700	254
161	22-May-91 19:50:00.	37,900	45,400	33,250	39,900	40,600	36,800	254
162	22-May-91 20:00:00.	37,950	46,000	33,050	39,850	40,550	36,800	254
163	22-May-91 20:10:00.	39,500	46,700	32,750	39,950	40,650	37,900	254
164	22-May-91 20:20:00.	39,700	48,250	32,100	39,950	40,700	38,100	254
165	22-May-91 20:30:00.	39,750	49,250	31,650	39,950	40,700	38,200	254
166	22-May-91 20:40:00.	39,750	49,850	31,550	39,950	40,600	38,300	254
167	22-May-91 20:50:00.	39,700	49,500	31,750	39,950	40,650	38,350	254
168	22-May-91 21:00:00.	39,800	49,850	31,600	39,950	40,650	38,450	254
169	22-May-91 21:10:00.	39,800	49,900	31,600	39,950	40,650	38,450	254
170	22-May-91 21:20:00.	39,750	50,100	31,550	39,950	40,650	38,450	254
171	22-May-91 21:30:00.	39,750	50,150	31,500	39,950	40,650	38,550	254
172	22-May-91 21:40:00.	39,850	49,950	31,700	39,950	40,700	38,550	254
173	22-May-91 21:50:00.	39,900	50,050	31,700	39,950	40,650	38,550	254
174	22-May-91 22:00:00.	39,700	50,100	31,600	39,950	40,650	38,500	254
175	22-May-91 22:10:00.	39,700	50,350	31,500	39,950	40,600	38,500	254
176	22-May-91 22:20:00.	39,700	50,250	31,500	39,950	40,650	38,500	254
177	22-May-91 22:30:00.	39,700	50,250	31,500	40,000	40,650	38,450	254
178	22-May-91 22:40:00.	39,700	50,400	31,400	39,950	40,650	38,500	254
179	22-May-91 22:50:00.	39,750	50,350	31,450	39,950	40,650	38,550	254
180	22-May-91 23:00:00.	39,750	50,250	31,550	39,950	40,650	38,500	254

Ch 2 Ch 3 Ch 5 Ch 6

degC

55.00  
50.00  
45.00  
40.00  
35.00  
30.00  
25.00  
20.00  
15.00  
10.00

12:00:00.  
09-JUL-91  
24:00:00.  
12:00:00.  
00:00:00.  
11-JUL-91



## APPENDIX 3.7.7

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 35  
100 Watt heat load  
No cooling  
Container in climatic chamber  
Sol-Air program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level  
Ch 19 255=Off 254=On

## Channel Readings

Data file - FILE35

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 04-Jun-91 15:00:00.  
    Finish : 05-Jun-91 15:00:01.  
Readings per channel: 145

All readings

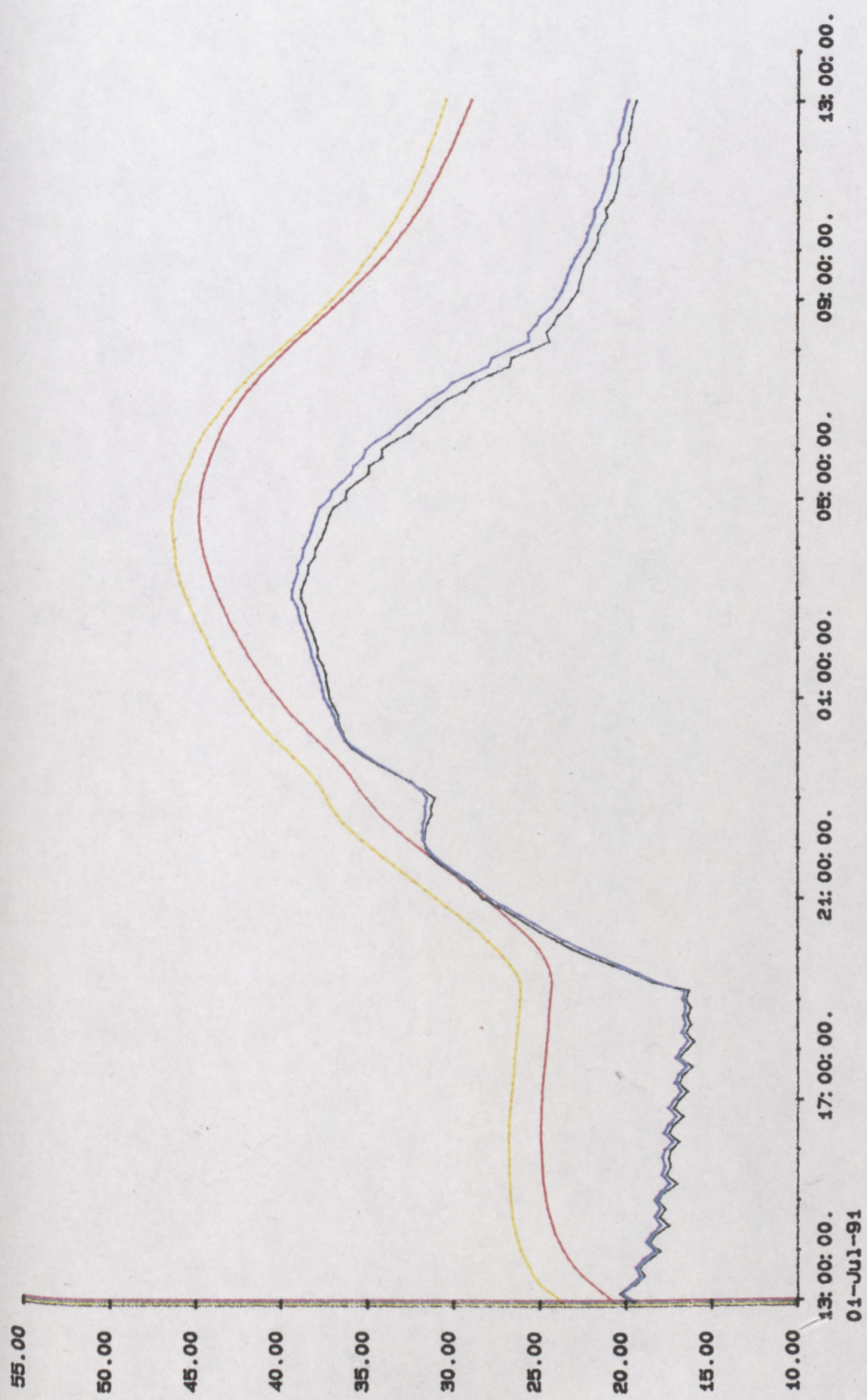
Rdg no	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 7
0	04-Jun-91 15:00:00.	26.850	33.050	30.200	32.350	32.250	27.700	255
1	04-Jun-91 15:10:00.	21.450	33.950	27.050	33.850	36.550	20.250	255
2	04-Jun-91 15:20:00.	19.850	34.400	24.250	34.500	37.300	19.400	255
3	04-Jun-91 15:30:00.	19.600	34.500	22.650	34.750	37.250	19.200	255
4	04-Jun-91 15:40:00.	19.350	34.500	21.650	34.850	37.250	18.950	255
5	04-Jun-91 15:50:00.	19.350	34.500	21.050	34.950	37.300	19.050	255
6	04-Jun-91 16:00:00.	18.850	34.350	20.500	34.900	37.200	18.550	255
7	04-Jun-91 16:10:00.	18.400	34.150	20.050	34.800	37.000	18.000	255
8	04-Jun-91 16:20:00.	17.950	34.000	19.650	34.650	36.850	17.300	255
9	04-Jun-91 16:30:00.	18.700	33.850	19.700	34.550	36.700	18.450	255
10	04-Jun-91 16:40:00.	18.250	33.700	19.450	34.350	36.600	17.900	255
11	04-Jun-91 16:50:00.	17.800	33.550	19.200	34.150	36.400	17.250	255
12	04-Jun-91 17:00:00.	18.650	33.400	19.400	33.950	36.200	18.350	255
13	04-Jun-91 17:10:00.	18.000	33.250	19.050	33.800	36.050	17.700	255
14	04-Jun-91 17:20:00.	17.600	33.100	18.850	33.600	35.900	17.150	255
15	04-Jun-91 17:30:00.	18.200	32.950	18.950	33.400	35.700	17.900	255
16	04-Jun-91 17:40:00.	17.800	32.750	18.800	33.200	35.500	17.500	255
17	04-Jun-91 17:50:00.	17.350	32.650	18.600	33.000	35.400	16.950	255
18	04-Jun-91 18:00:00.	17.950	32.500	18.750	32.900	35.250	17.650	255
19	04-Jun-91 18:10:00.	17.550	32.350	18.500	32.750	35.150	17.250	255
20	04-Jun-91 18:20:00.	17.250	32.250	18.400	32.650	35.050	16.850	255
21	04-Jun-91 18:30:00.	17.800	32.100	18.500	32.500	34.900	17.450	255
22	04-Jun-91 18:40:00.	17.250	32.050	18.250	32.350	34.800	16.950	255
23	04-Jun-91 18:50:00.	16.900	31.900	18.100	32.250	34.750	16.450	255
24	04-Jun-91 19:00:00.	17.350	31.800	18.150	32.050	34.550	17.050	255
25	04-Jun-91 19:10:00.	16.950	31.600	17.950	31.900	34.400	16.600	255
26	04-Jun-91 19:20:00.	16.600	31.500	17.750	31.800	34.250	16.150	255
27	04-Jun-91 19:30:00.	16.850	31.400	17.800	31.650	34.100	16.550	255
28	04-Jun-91 19:40:00.	16.650	31.300	17.650	31.550	34.000	16.300	255
29	04-Jun-91 19:50:00.	17.050	31.200	17.750	31.450	33.900	16.700	255
30	04-Jun-91 20:00:00.	16.600	31.050	17.550	31.350	33.800	16.250	255
31	04-Jun-91 20:10:00.	16.200	31.000	17.350	31.250	33.650	15.800	255
32	04-Jun-91 20:20:00.	16.500	30.850	17.350	31.150	33.550	16.150	255
33	04-Jun-91 20:30:00.	16.150	30.750	17.250	31.050	33.500	15.700	255
34	04-Jun-91 20:40:00.	16.400	30.700	17.300	31.000	33.450	16.050	255
35	04-Jun-91 20:50:00.	16.450	30.600	17.300	30.900	33.350	16.100	255

36	04-Jun-91	21:00:00	16.200	30.550	17.200	30.800	33.300	15.800	255
37	04-Jun-91	21:10:00	16.750	30.500	17.350	30.750	33.300	16.450	255
38	04-Jun-91	21:20:00	17.900	30.500	17.900	30.800	33.300	17.750	255
39	04-Jun-91	21:30:00	19.400	30.550	18.900	30.900	33.450	19.200	255
40	04-Jun-91	21:40:00	20.750	30.750	19.950	31.150	33.800	20.550	255
41	04-Jun-91	21:50:00	22.000	31.050	21.050	31.450	34.200	21.800	255
42	04-Jun-91	22:00:00	23.100	31.400	22.100	31.850	34.750	22.900	255
43	04-Jun-91	22:10:00	24.050	31.850	23.100	32.300	35.250	23.800	255
44	04-Jun-91	22:20:00	25.050	32.400	24.100	32.850	35.800	24.750	255
45	04-Jun-91	22:30:00	25.950	32.950	24.950	33.400	36.450	25.650	255
46	04-Jun-91	22:40:00	26.550	33.450	25.750	33.900	36.950	26.300	255
47	04-Jun-91	22:50:00	27.400	34.050	26.600	34.550	37.550	27.100	255
48	04-Jun-91	23:00:00	28.350	34.650	27.450	35.100	38.200	28.050	255
49	04-Jun-91	23:10:00	29.000	35.250	28.200	35.700	38.700	28.650	255
50	04-Jun-91	23:20:00	29.450	35.850	28.800	36.300	39.450	29.100	255
51	04-Jun-91	23:30:00	30.100	36.500	29.500	36.950	40.000	29.750	255
52	04-Jun-91	23:40:00	30.850	37.150	30.150	37.600	40.650	30.450	255
53	04-Jun-91	23:50:00	31.450	37.750	30.750	38.200	41.250	31.050	255
54	04-Jun-91	24:00:00	31.800	38.300	31.300	38.800	41.900	31.450	255
55	05-Jun-91	00:10:00	32.000	38.900	31.750	39.450	42.500	31.600	255
56	05-Jun-91	00:20:00	31.950	39.500	32.000	40.000	43.050	31.500	255
57	05-Jun-91	00:30:00	31.700	39.950	32.050	40.550	43.500	31.300	255
58	05-Jun-91	00:40:00	31.500	40.400	31.650	41.000	43.900	31.150	255
59	05-Jun-91	00:50:00	31.550	40.800	31.700	41.400	44.250	31.200	255
60	05-Jun-91	01:00:00	31.500	41.150	31.600	41.750	44.550	31.050	255
61	05-Jun-91	01:10:00	31.450	41.450	31.550	42.050	44.850	31.000	255
62	05-Jun-91	01:20:00	32.650	41.850	32.600	42.400	45.150	32.250	255
63	05-Jun-91	01:30:00	33.550	42.150	33.350	42.750	45.450	33.100	255
64	05-Jun-91	01:40:00	34.500	42.500	34.150	43.200	45.900	33.900	255
65	05-Jun-91	01:50:00	35.350	42.900	35.000	43.600	46.450	34.800	255
66	05-Jun-91	02:00:00	36.150	43.300	35.800	44.050	46.950	35.700	255
67	05-Jun-91	02:10:00	36.600	43.800	36.300	44.550	47.500	36.050	255
68	05-Jun-91	02:20:00	36.900	44.250	36.650	45.100	47.950	36.300	255
69	05-Jun-91	02:30:00	36.950	44.750	36.800	45.550	48.450	36.400	255
70	05-Jun-91	02:40:00	37.050	45.200	37.050	46.000	48.850	36.500	255
71	05-Jun-91	02:50:00	37.300	45.600	37.300	46.450	49.300	36.750	255
72	05-Jun-91	03:00:00	37.650	46.050	37.550	46.900	49.650	37.050	255
73	05-Jun-91	03:10:00	37.600	46.450	37.650	47.250	50.050	37.050	255
74	05-Jun-91	03:20:00	37.800	46.850	37.800	47.600	50.450	37.250	255
75	05-Jun-91	03:30:00	37.900	47.200	37.950	47.950	50.700	37.400	255
76	05-Jun-91	03:40:00	38.050	47.500	38.100	48.250	51.000	37.450	255
77	05-Jun-91	03:50:00	38.250	47.850	38.250	48.550	51.300	37.650	255
78	05-Jun-91	04:00:00	38.200	48.200	38.350	48.800	51.500	37.650	255
79	05-Jun-91	04:10:00	38.400	48.450	38.500	49.100	51.750	37.850	255
80	05-Jun-91	04:20:00	38.650	48.750	38.700	49.350	52.000	38.050	255
81	05-Jun-91	04:30:00	38.850	49.000	38.900	49.550	52.250	38.250	255
82	05-Jun-91	04:40:00	38.850	49.200	39.000	49.800	52.400	38.300	255
83	05-Jun-91	04:50:00	39.050	49.450	39.150	50.050	52.600	38.500	255
84	05-Jun-91	05:00:00	39.350	49.650	39.400	50.200	52.800	38.700	255
85	05-Jun-91	05:10:00	39.400	49.850	39.500	50.450	53.000	38.800	255
86	05-Jun-91	05:20:00	39.250	49.450	39.450	50.600	53.200	38.700	255
87	05-Jun-91	05:30:00	39.200	49.600	39.400	50.750	53.300	38.650	255
88	05-Jun-91	05:40:00	39.100	49.750	39.350	50.850	53.350	38.550	255
89	05-Jun-91	05:50:00	38.400	49.900	38.800	50.950	53.350	37.900	255
90	05-Jun-91	06:00:00	38.450	50.000	38.750	50.950	53.350	37.900	255
91	05-Jun-91	06:10:00	38.250	50.000	38.650	50.950	53.300	37.800	255
92	05-Jun-91	06:20:00	37.900	50.050	38.350	50.950	53.350	37.400	255
93	05-Jun-91	06:30:00	37.450	50.050	37.950	50.950	53.300	36.950	255
94	05-Jun-91	06:40:00	37.550	50.000	37.950	50.950	53.200	37.000	255

95	05-Jun-91	06:50:00.	37.150	49.950	37.550	50.900	53.100	36.550	255
96	05-Jun-91	07:00:00.	36.650	49.900	37.150	50.800	53.000	36.150	255
97	05-Jun-91	07:10:00.	36.200	49.750	36.800	50.700	52.850	35.750	255
98	05-Jun-91	07:20:00.	35.750	49.650	36.400	50.600	52.700	35.350	255
99	05-Jun-91	07:30:00.	35.350	49.500	36.050	50.450	52.550	34.950	255
100	05-Jun-91	07:40:00.	34.950	49.350	35.600	50.250	52.350	34.550	255
101	05-Jun-91	07:50:00.	34.800	49.150	35.500	50.050	52.100	34.400	255
102	05-Jun-91	08:00:00.	34.400	49.000	35.000	49.850	51.950	33.900	255
103	05-Jun-91	08:10:00.	33.650	48.800	34.350	49.650	51.750	33.250	255
104	05-Jun-91	08:20:00.	33.050	48.550	33.850	49.450	51.500	32.800	255
105	05-Jun-91	08:30:00.	32.750	48.250	33.550	49.150	51.200	32.400	255
106	05-Jun-91	08:40:00.	31.450	48.000	32.450	48.900	50.950	31.150	255
107	05-Jun-91	08:50:00.	31.500	47.750	32.250	48.550	50.600	31.100	255
108	05-Jun-91	09:00:00.	30.950	47.400	31.750	48.250	50.250	30.700	255
109	05-Jun-91	09:10:00.	29.100	47.100	30.400	47.900	49.900	29.000	255
110	05-Jun-91	09:20:00.	29.550	46.650	30.350	47.550	49.350	29.100	255
111	05-Jun-91	09:30:00.	28.300	46.250	29.200	47.100	48.900	27.950	255
112	05-Jun-91	09:40:00.	28.200	45.800	28.850	46.650	48.450	27.800	255
113	05-Jun-91	09:50:00.	26.850	45.350	27.750	46.200	47.950	26.600	255
114	05-Jun-91	10:00:00.	26.100	44.850	26.950	45.650	47.400	25.750	255
115	05-Jun-91	10:10:00.	25.300	44.300	26.250	45.150	46.900	25.050	255
116	05-Jun-91	10:20:00.	24.500	43.800	25.400	44.600	46.350	24.200	255
117	05-Jun-91	10:30:00.	25.100	43.250	25.700	44.100	45.800	24.750	255
118	05-Jun-91	10:40:00.	24.200	42.750	24.900	43.600	45.300	23.900	255
119	05-Jun-91	10:50:00.	22.900	42.200	24.100	43.150	44.800	22.950	255
120	05-Jun-91	11:00:00.	23.700	41.700	24.300	42.600	44.350	23.450	255
121	05-Jun-91	11:10:00.	22.800	41.250	23.550	42.150	43.900	22.600	255
122	05-Jun-91	11:20:00.	23.050	40.700	23.750	41.650	43.450	22.850	255
123	05-Jun-91	11:30:00.	22.550	40.250	23.200	41.200	42.900	22.250	255
124	05-Jun-91	11:40:00.	23.000	39.750	23.450	40.700	42.550	22.700	255
125	05-Jun-91	11:50:00.	22.350	39.350	22.900	40.300	42.150	22.100	255
126	05-Jun-91	12:00:00.	22.200	38.950	22.800	39.950	41.850	22.050	255
127	05-Jun-91	12:10:00.	21.800	38.550	22.400	39.600	41.550	21.600	255
128	05-Jun-91	12:20:00.	21.850	38.200	22.450	39.250	41.150	21.700	255
129	05-Jun-91	12:30:00.	21.350	37.850	21.950	38.850	40.850	21.150	255
130	05-Jun-91	12:40:00.	21.700	37.500	22.150	38.550	40.500	21.550	255
131	05-Jun-91	12:50:00.	21.250	37.200	21.750	38.250	40.300	21.000	255
132	05-Jun-91	13:00:00.	21.050	36.900	21.600	37.950	40.000	20.950	255
133	05-Jun-91	13:10:00.	20.350	36.600	21.000	37.650	39.750	20.250	255
134	05-Jun-91	13:20:00.	21.050	36.300	21.500	37.450	39.550	20.850	255
135	05-Jun-91	13:30:00.	20.600	36.050	21.050	37.200	39.400	20.400	255
136	05-Jun-91	13:40:00.	19.850	35.800	20.600	37.000	39.150	19.950	255
137	05-Jun-91	13:50:00.	20.600	35.600	21.000	36.750	38.900	20.450	255
138	05-Jun-91	14:00:00.	19.800	35.400	20.350	36.550	38.700	19.700	255
139	05-Jun-91	14:10:00.	20.250	35.150	20.650	36.350	38.550	20.150	255
140	05-Jun-91	14:20:00.	19.950	34.950	20.300	36.150	38.350	19.700	255
141	05-Jun-91	14:30:00.	20.250	34.750	20.550	35.900	38.150	20.050	255
142	05-Jun-91	14:40:00.	19.850	34.550	20.200	35.750	37.950	19.650	255
143	05-Jun-91	14:50:00.	19.150	34.350	19.750	35.550	37.800	19.150	255
144	05-Jun-91	15:00:00.	19.950	34.150	20.250	35.400	37.650	19.750	255

Ch 2 Ch 3 Ch 5 Ch 6

degC



01-Jul-91

## APPENDIX 3.7.8

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 36

100 Watt heat load

2,5 Amp cooling

Container in climatic chamber

Stepped program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.

Ch 2 Outside heat sink

Ch 3 Inside heat sink

Ch 4 Inside floor level

Ch 5 Inside globe level

Ch 6 Outside globe level

Ch 19 255=Off 254=On

## Channel Readings

Data file - FILE36

**Recorder details:**

Recorder number : 38  
 Squirrel type : 1206

**Run details:**

Run number : 1  
 Channels used : 7  
 Recording Interval : 00:10:00.  
 Non-averaged time interval readings  
 Recording period :  
     Start : 12-Jun-91 09:30:00.  
     Finish : 13-Jun-91 15:30:01.  
 Readings per channel: 181

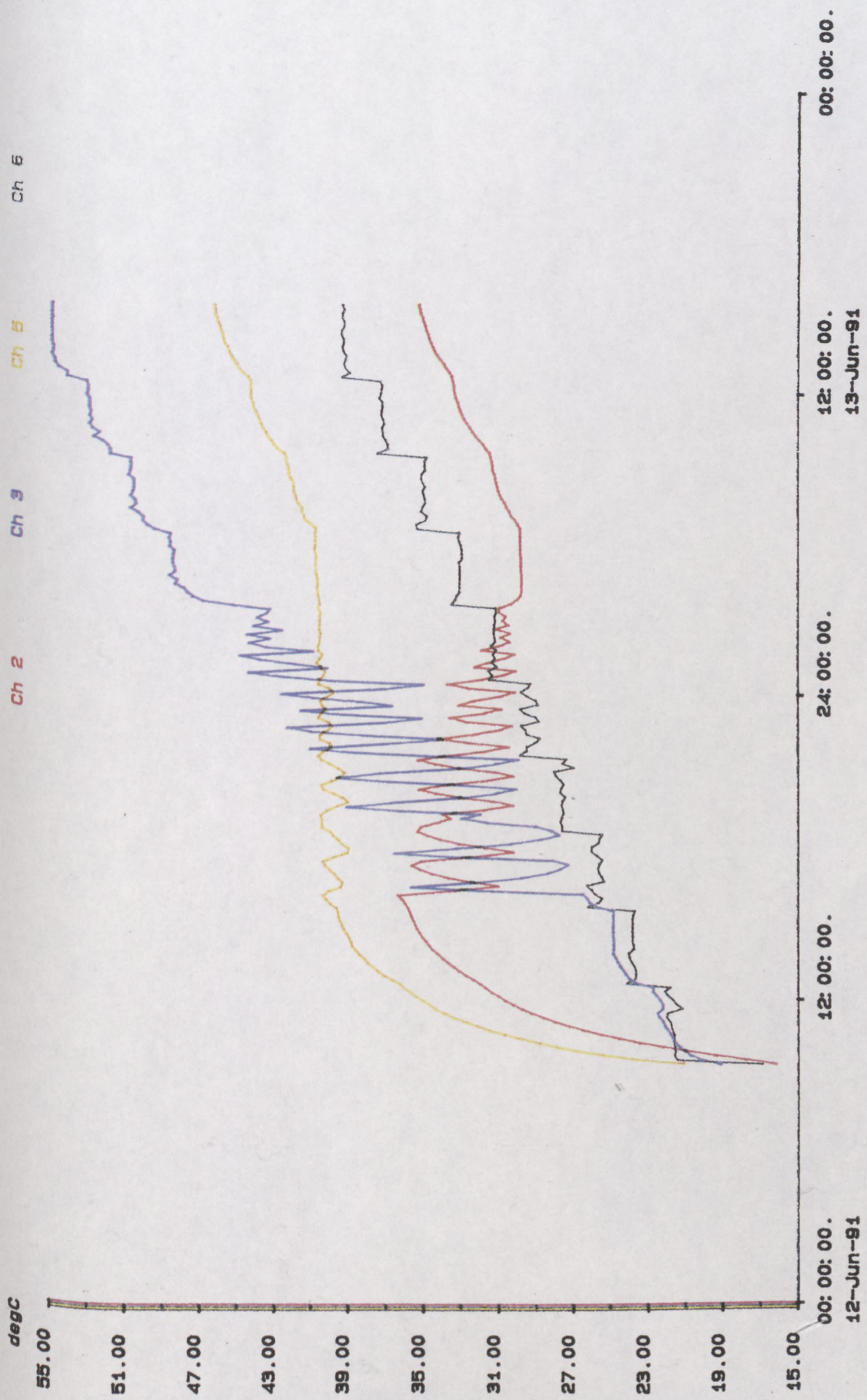
All readings :

Rdc no:	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19
0	12-Jun-91 09:30:00.	17.150	16.150	19.100	19.400	21.100	16.850	255
1	12-Jun-91 09:40:00.	21.700	17.750	20.150	20.850	23.650	21.150	255
2	12-Jun-91 09:50:00.	21.900	19.350	20.700	22.250	25.300	21.600	255
3	12-Jun-91 10:00:00.	21.650	20.850	21.000	23.550	26.700	21.500	255
4	12-Jun-91 10:10:00.	21.750	22.200	21.300	24.700	27.850	21.550	255
5	12-Jun-91 10:20:00.	21.850	23.450	21.550	25.600	28.850	21.600	255
6	12-Jun-91 10:30:00.	21.800	24.500	21.700	26.800	29.800	21.600	255
7	12-Jun-91 10:40:00.	21.750	25.500	21.800	27.700	30.700	21.600	255
8	12-Jun-91 10:50:00.	21.950	26.400	21.950	28.450	31.500	21.700	255
9	12-Jun-91 11:00:00.	21.950	27.200	22.100	29.150	32.150	21.750	255
10	12-Jun-91 11:10:00.	21.950	27.950	22.200	29.800	32.750	21.800	255
11	12-Jun-91 11:20:00.	22.200	28.600	22.400	30.400	33.400	22.000	255
12	12-Jun-91 11:30:00.	22.050	29.200	22.500	30.950	33.900	21.900	255
13	12-Jun-91 11:40:00.	21.350	29.750	22.200	31.400	34.400	21.100	255
14	12-Jun-91 11:50:00.	21.700	30.200	22.200	31.800	34.700	21.450	255
15	12-Jun-91 12:00:00.	21.800	30.650	22.350	32.200	35.050	21.650	255
16	12-Jun-91 12:10:00.	22.100	31.000	22.550	32.550	35.450	21.900	255
17	12-Jun-91 12:20:00.	22.400	31.400	22.750	32.900	35.750	22.100	255
18	12-Jun-91 12:30:00.	21.850	31.700	22.700	33.200	36.100	21.750	255
19	12-Jun-91 12:40:00.	24.300	32.000	23.600	33.450	36.300	24.100	255
20	12-Jun-91 12:50:00.	23.800	32.350	23.950	33.800	36.700	23.600	255
21	12-Jun-91 13:00:00.	23.900	32.750	24.150	34.200	37.150	23.600	255
22	12-Jun-91 13:10:00.	23.800	33.100	24.300	34.550	37.450	23.600	255
23	12-Jun-91 13:20:00.	23.900	33.400	24.450	34.800	37.700	23.700	255
24	12-Jun-91 13:30:00.	24.100	33.700	24.600	35.100	38.000	23.850	255
25	12-Jun-91 13:40:00.	24.250	34.000	24.700	35.350	38.200	23.950	255
26	12-Jun-91 13:50:00.	24.150	34.250	24.850	35.600	38.450	24.000	255
27	12-Jun-91 14:00:00.	23.850	34.550	24.800	35.800	38.650	23.700	255
28	12-Jun-91 14:10:00.	24.000	34.750	24.800	35.950	38.850	23.750	255
29	12-Jun-91 14:20:00.	23.950	34.900	24.800	36.150	38.900	23.800	255
30	12-Jun-91 14:30:00.	24.000	35.100	24.850	36.300	39.000	23.800	255
31	12-Jun-91 14:40:00.	23.950	35.250	24.850	36.450	39.150	23.800	255
32	12-Jun-91 14:50:00.	24.050	35.400	24.850	36.550	39.300	23.800	255
33	12-Jun-91 15:00:00.	24.050	35.500	24.850	36.650	39.400	23.800	255
34	12-Jun-91 15:10:00.	24.050	35.600	24.850	36.800	39.500	23.800	255
35	12-Jun-91 15:20:00.	24.000	35.700	24.850	36.900	39.600	23.750	255

36	12-Jun-91	15:30:00.	23.750	35.800	24.850	36.950	39.600	23.650	255
37	12-Jun-91	15:40:00.	26.600	35.900	25.750	37.050	39.700	26.200	255
38	12-Jun-91	15:50:00.	25.850	36.050	26.100	37.250	40.000	25.600	255
39	12-Jun-91	16:00:00.	25.550	36.200	26.250	37.450	40.250	25.400	255
40	12-Jun-91	16:10:00.	25.950	36.450	26.500	37.650	40.450	25.800	254
41	12-Jun-91	16:20:00.	26.450	33.350	32.000	37.650	40.100	26.000	254
42	12-Jun-91	16:30:00.	26.800	31.000	35.800	37.400	39.450	26.250	255
43	12-Jun-91	16:40:00.	25.750	32.550	32.200	37.350	39.350	25.300	255
44	12-Jun-91	16:50:00.	25.700	33.700	29.750	37.400	39.600	25.450	255
45	12-Jun-91	17:00:00.	25.800	34.600	28.400	37.550	39.800	25.600	255
46	12-Jun-91	17:10:00.	25.900	35.250	27.700	37.650	40.050	25.650	255
47	12-Jun-91	17:20:00.	25.750	35.700	27.250	37.800	40.300	25.550	255
48	12-Jun-91	17:30:00.	25.600	35.150	28.100	37.900	40.450	25.400	254
49	12-Jun-91	17:40:00.	26.100	32.200	33.550	37.700	39.850	25.700	254
50	12-Jun-91	17:50:00.	26.600	30.200	36.650	37.400	39.100	26.000	254
51	12-Jun-91	18:00:00.	26.350	31.750	33.300	37.300	39.000	26.000	255
52	12-Jun-91	18:10:00.	25.900	33.150	30.350	37.300	39.400	25.600	255
53	12-Jun-91	18:20:00.	25.800	34.150	28.700	37.400	39.600	25.550	255
54	12-Jun-91	18:30:00.	25.650	34.850	27.750	37.550	39.850	25.400	255
55	12-Jun-91	18:40:00.	27.750	35.400	28.200	37.700	40.050	27.600	255
56	12-Jun-91	18:50:00.	27.850	35.200	29.050	37.950	40.500	27.600	254
57	12-Jun-91	19:00:00.	28.100	34.300	31.650	38.050	40.500	27.700	255
58	12-Jun-91	19:10:00.	28.000	33.600	33.000	38.200	40.500	27.600	255
59	12-Jun-91	19:20:00.	27.800	34.050	32.000	38.300	40.550	27.500	254
60	12-Jun-91	19:30:00.	28.050	31.800	36.350	38.200	40.200	27.550	254
61	12-Jun-91	19:40:00.	28.250	30.200	39.150	37.950	39.650	27.650	254
62	12-Jun-91	19:50:00.	28.000	31.300	36.650	37.800	39.050	27.550	255
63	12-Jun-91	20:00:00.	27.700	33.100	33.000	37.950	39.350	27.400	255
64	12-Jun-91	20:10:00.	28.050	34.400	31.150	38.150	39.850	27.700	255
65	12-Jun-91	20:20:00.	28.000	35.350	30.050	38.450	40.400	27.650	255
66	12-Jun-91	20:30:00.	27.650	33.850	33.000	38.600	40.550	27.500	254
67	12-Jun-91	20:40:00.	28.200	31.650	37.100	38.400	39.950	27.700	254
68	12-Jun-91	20:50:00.	28.550	30.200	39.700	38.200	39.450	27.950	254
69	12-Jun-91	21:00:00.	28.700	31.250	37.400	38.100	39.250	28.050	255
70	12-Jun-91	21:10:00.	27.400	33.150	33.150	38.150	39.600	26.950	255
71	12-Jun-91	21:20:00.	28.000	34.450	31.200	38.350	40.000	27.600	255
72	12-Jun-91	21:30:00.	27.600	35.400	29.950	38.600	40.500	27.350	255
73	12-Jun-91	21:40:00.	30.350	33.700	34.650	38.800	40.700	29.900	254
74	12-Jun-91	21:50:00.	30.150	31.750	38.750	38.800	40.450	29.500	254
75	12-Jun-91	22:00:00.	30.150	30.450	41.150	38.700	39.950	29.500	254
76	12-Jun-91	22:10:00.	29.450	32.550	37.150	38.750	40.050	29.000	255
77	12-Jun-91	22:20:00.	29.250	34.300	34.000	39.000	40.600	28.800	255
78	12-Jun-91	22:30:00.	30.150	32.400	38.050	39.050	40.600	29.550	254
79	12-Jun-91	22:40:00.	30.150	31.000	41.050	39.000	40.200	29.600	254
80	12-Jun-91	22:50:00.	30.550	30.300	42.400	38.900	39.950	29.850	255
81	12-Jun-91	23:00:00.	29.300	32.800	37.150	39.000	40.150	28.850	255
82	12-Jun-91	23:10:00.	29.650	33.700	35.150	39.200	40.700	29.050	254
83	12-Jun-91	23:20:00.	30.250	31.850	39.350	39.250	40.550	29.650	254
84	12-Jun-91	23:30:00.	30.550	30.850	41.650	39.150	40.250	29.900	255
85	12-Jun-91	23:40:00.	29.450	33.200	36.700	39.250	40.500	28.900	255
86	12-Jun-91	23:50:00.	29.700	32.350	38.350	39.250	40.600	29.050	254
87	12-Jun-91	24:00:00.	30.100	30.950	40.950	39.100	40.200	29.500	254
88	13-Jun-91	00:10:00.	30.550	30.150	42.700	39.000	39.850	29.850	255
89	13-Jun-91	00:20:00.	29.950	32.650	37.300	39.050	40.100	29.450	255
90	13-Jun-91	00:30:00.	29.700	33.800	35.050	39.300	40.700	29.300	254
91	13-Jun-91	00:40:00.	32.300	31.950	40.000	39.300	40.600	31.550	254
92	13-Jun-91	00:50:00.	32.100	30.800	42.650	39.350	40.400	31.350	254
93	13-Jun-91	01:00:00.	32.350	30.100	44.500	39.350	40.300	31.600	254
94	13-Jun-91	01:10:00.	31.600	32.350	40.150	39.500	40.550	31.100	255

95	13-Jun-91	01:20:00.	32.050	31.600	41.950	39.600	40.800	31.400	254
96	13-Jun-91	01:30:00.	31.850	30.700	43.850	39.650	40.600	31.200	254
97	13-Jun-91	01:40:00.	32.050	30.150	44.950	39.600	40.450	31.350	254
98	13-Jun-91	01:50:00.	31.750	32.000	40.900	39.700	40.700	31.150	254
99	13-Jun-91	02:00:00.	32.250	31.000	43.550	39.750	40.700	31.450	254
100	13-Jun-91	02:10:00.	31.800	30.400	44.500	39.750	40.600	31.200	254
101	13-Jun-91	02:20:00.	31.900	30.950	43.300	39.750	40.600	31.250	254
102	13-Jun-91	02:30:00.	32.100	30.400	44.600	39.700	40.550	31.300	254
103	13-Jun-91	02:40:00.	31.900	31.250	42.650	39.750	40.650	31.250	254
104	13-Jun-91	02:50:00.	31.950	30.500	44.250	39.750	40.600	31.250	254
105	13-Jun-91	03:00:00.	31.900	30.850	43.400	39.750	40.600	31.200	254
106	13-Jun-91	03:10:00.	31.900	30.650	44.050	39.750	40.600	31.250	254
107	13-Jun-91	03:20:00.	31.800	31.050	43.500	39.700	40.550	31.150	255
108	13-Jun-91	03:30:00.	31.850	31.000	43.300	39.750	40.700	31.150	254
109	13-Jun-91	03:40:00.	34.400	30.400	45.300	39.750	40.600	33.550	254
110	13-Jun-91	03:50:00.	34.200	30.050	46.900	39.850	40.650	33.350	254
111	13-Jun-91	04:00:00.	34.000	29.850	47.450	39.950	40.700	33.250	254
112	13-Jun-91	04:10:00.	33.850	29.800	47.750	40.000	40.750	33.100	254
113	13-Jun-91	04:20:00.	33.850	29.800	47.950	40.050	40.750	33.100	254
114	13-Jun-91	04:30:00.	33.850	29.800	48.400	40.100	40.750	33.100	254
115	13-Jun-91	04:40:00.	33.950	29.800	48.300	40.150	40.750	33.100	254
116	13-Jun-91	04:50:00.	33.900	29.800	48.750	40.150	40.800	33.100	254
117	13-Jun-91	05:00:00.	33.900	29.850	48.400	40.200	40.850	33.100	254
118	13-Jun-91	05:10:00.	33.850	29.850	48.450	40.200	40.850	33.100	254
119	13-Jun-91	05:20:00.	34.000	29.850	48.550	40.250	40.850	33.150	254
120	13-Jun-91	05:30:00.	33.750	29.850	48.550	40.250	40.800	32.950	254
121	13-Jun-91	05:40:00.	33.750	29.900	48.500	40.250	40.850	33.000	254
122	13-Jun-91	05:50:00.	33.750	29.900	48.450	40.300	40.900	33.000	254
123	13-Jun-91	06:00:00.	33.800	29.900	48.700	40.300	40.850	33.050	254
124	13-Jun-91	06:10:00.	34.000	29.900	48.650	40.300	40.850	33.150	254
125	13-Jun-91	06:20:00.	34.050	29.900	48.750	40.300	40.850	33.200	254
126	13-Jun-91	06:30:00.	33.850	29.900	48.650	40.300	40.850	33.100	254
127	13-Jun-91	06:40:00.	36.400	29.900	49.500	40.300	40.800	35.400	254
128	13-Jun-91	06:50:00.	36.350	30.050	49.900	40.450	41.100	35.450	254
129	13-Jun-91	07:00:00.	35.750	30.200	50.150	40.650	41.400	34.950	254
130	13-Jun-91	07:10:00.	35.700	30.400	50.100	40.800	41.500	34.850	254
131	13-Jun-91	07:20:00.	36.050	30.500	50.400	40.900	41.600	35.200	254
132	13-Jun-91	07:30:00.	35.950	30.650	50.800	41.000	41.600	35.100	254
133	13-Jun-91	07:40:00.	35.800	30.750	50.500	41.150	41.800	34.950	254
134	13-Jun-91	07:50:00.	35.750	30.900	50.550	41.250	41.900	34.950	254
135	13-Jun-91	08:00:00.	35.850	31.000	50.800	41.350	41.950	35.050	254
136	13-Jun-91	08:10:00.	35.950	31.100	50.650	41.400	42.050	35.100	254
137	13-Jun-91	08:20:00.	35.800	31.150	50.600	41.500	42.050	34.950	254
138	13-Jun-91	08:30:00.	35.950	31.200	50.600	41.500	42.050	35.100	254
139	13-Jun-91	08:40:00.	36.000	31.250	50.600	41.600	42.200	35.200	254
140	13-Jun-91	08:50:00.	35.950	31.300	50.900	41.600	42.300	35.150	254
141	13-Jun-91	09:00:00.	35.700	31.400	50.800	41.700	42.300	34.950	254
142	13-Jun-91	09:10:00.	35.800	31.400	50.750	41.750	42.350	35.000	254
143	13-Jun-91	09:20:00.	35.800	31.450	50.750	41.800	42.450	35.000	254
144	13-Jun-91	09:30:00.	35.600	31.500	50.750	41.800	42.450	34.850	254
145	13-Jun-91	09:40:00.	38.250	31.550	51.850	41.950	42.550	37.500	254
146	13-Jun-91	09:50:00.	37.700	31.750	51.850	42.150	42.900	36.900	254
147	13-Jun-91	10:00:00.	37.950	31.900	52.000	42.300	43.100	36.950	254
148	13-Jun-91	10:10:00.	37.800	32.100	52.250	42.450	43.250	37.050	254
149	13-Jun-91	10:20:00.	37.950	32.300	52.750	42.600	43.450	37.200	254
150	13-Jun-91	10:30:00.	38.100	32.450	52.400	42.800	43.550	37.200	254
151	13-Jun-91	10:40:00.	38.150	32.600	52.800	42.900	43.700	37.250	254
152	13-Jun-91	10:50:00.	37.800	32.750	52.950	43.050	43.800	37.100	254
153	13-Jun-91	11:00:00.	38.000	32.900	52.800	43.200	43.900	37.200	254

154	13-Jun-91	11:10:00	38.200	33.000	52.950	43.300	44.000	37.300	254
155	13-Jun-91	11:20:00	38.150	33.100	52.850	43.400	44.100	37.250	254
156	13-Jun-91	11:30:00	37.900	33.200	52.950	43.500	44.200	37.200	254
157	13-Jun-91	11:40:00	37.950	33.250	52.950	43.550	44.250	37.200	254
158	13-Jun-91	11:50:00	38.200	33.350	52.950	43.650	44.350	37.400	254
159	13-Jun-91	12:00:00	38.100	33.400	53.100	43.700	44.350	37.300	254
160	13-Jun-91	12:10:00	37.950	33.450	53.000	43.700	44.350	37.250	254
161	13-Jun-91	12:20:00	37.950	33.450	53.000	43.750	44.350	37.200	254
162	13-Jun-91	12:30:00	38.150	33.500	53.100	43.800	44.350	37.350	254
163	13-Jun-91	12:40:00	40.050	33.550	54.150	43.850	44.500	39.350	254
164	13-Jun-91	12:50:00	39.700	33.700	54.150	44.000	44.750	38.900	254
165	13-Jun-91	13:00:00	39.950	33.850	54.600	44.150	44.950	39.150	254
166	13-Jun-91	13:10:00	40.150	34.000	54.800	44.300	45.100	39.250	254
167	13-Jun-91	13:20:00	39.900	34.200	54.850	44.450	45.250	39.150	254
168	13-Jun-91	13:30:00	39.800	34.350	55.150	44.550	45.400	39.100	254
169	13-Jun-91	13:40:00	40.100	34.500	54.900	44.750	45.500	39.300	254
170	13-Jun-91	13:50:00	40.150	34.600	54.900	44.850	45.600	39.350	254
171	13-Jun-91	14:00:00	39.950	34.700	55.150	45.000	45.750	39.250	254
172	13-Jun-91	14:10:00	39.950	34.800	55.250	45.050	45.800	39.250	254
173	13-Jun-91	14:20:00	40.200	34.850	55.100	45.150	45.850	39.400	254
174	13-Jun-91	14:30:00	40.150	34.950	55.150	45.200	45.950	39.350	254
175	13-Jun-91	14:40:00	39.900	35.000	55.250	45.300	46.000	39.200	254
176	13-Jun-91	14:50:00	39.850	35.100	55.200	45.350	46.100	39.200	254
177	13-Jun-91	15:00:00	40.150	35.150	55.250	45.450	46.150	39.350	254
178	13-Jun-91	15:10:00	40.150	35.250	55.400	45.500	46.250	39.350	254
179	13-Jun-91	15:20:00	39.800	35.300	55.350	45.550	46.250	39.200	254
180	13-Jun-91	15:30:00	40.100	35.350	55.250	45.600	46.300	39.350	254



## APPENDIX 3.7.9

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 37  
60 Watt heat load  
2,5 Amp cooling  
Container in climatic chamber  
Stepped program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level  
Ch 19 255=Off 254=On

# Channel Readings

Data file - FILE37

**Recorder details.**

Recorder number : 38  
 Squirrel type : 1206

**Run details:**

Run number : 1  
 Channels used : 7  
 Recording Interval : 00:10:00.  
 Non-averaged time interval readings  
 Recording period :  
     Start : 14-Jun-91 15:00:00.  
     Finish : 15-Jun-91 21:00:01.  
 Readings per channel: 181

All readings

Rdn no!	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19
0	14-Jun-91 15:00:00.	20.250	22.550	20.150	23.900	25.650	20.150	255
1	14-Jun-91 15:10:00.	23.450	23.100	21.700	24.500	26.200	23.350	255
2	14-Jun-91 15:20:00.	21.800	23.700	21.700	25.150	27.000	21.700	255
3	14-Jun-91 15:30:00.	22.000	24.250	21.850	25.750	27.500	21.850	255
4	14-Jun-91 15:40:00.	21.900	24.750	21.900	26.200	27.900	21.700	255
5	14-Jun-91 15:50:00.	21.800	25.150	21.950	26.650	28.250	21.750	255
6	14-Jun-91 16:00:00.	21.800	25.600	22.000	27.050	28.600	21.700	255
7	14-Jun-91 16:10:00.	21.800	26.000	22.050	27.350	28.850	21.700	255
8	14-Jun-91 16:20:00.	21.800	26.300	22.100	27.650	29.150	21.700	255
9	14-Jun-91 16:30:00.	22.000	26.650	22.150	27.950	29.350	21.800	255
10	14-Jun-91 16:40:00.	21.950	26.900	22.200	28.150	29.600	21.800	255
11	14-Jun-91 16:50:00.	21.850	27.150	22.200	28.400	29.750	21.800	255
12	14-Jun-91 17:00:00.	21.850	27.350	22.250	28.550	29.900	21.750	255
13	14-Jun-91 17:10:00.	21.800	27.550	22.250	28.750	30.050	21.750	255
14	14-Jun-91 17:20:00.	21.800	27.750	22.250	28.850	30.200	21.700	255
15	14-Jun-91 17:30:00.	21.900	27.900	22.300	29.000	30.300	21.750	255
16	14-Jun-91 17:40:00.	21.850	28.000	22.300	29.100	30.400	21.800	255
17	14-Jun-91 17:50:00.	21.750	28.150	22.300	29.250	30.500	21.700	255
18	14-Jun-91 18:00:00.	21.800	28.250	22.300	29.300	30.550	21.650	255
19	14-Jun-91 18:10:00.	24.350	28.350	23.250	29.450	30.650	24.200	255
20	14-Jun-91 18:20:00.	23.600	28.550	23.550	29.700	31.000	23.500	255
21	14-Jun-91 18:30:00.	24.200	28.750	23.900	29.900	31.300	23.900	255
22	14-Jun-91 18:40:00.	23.750	28.950	23.950	30.100	31.500	23.600	255
23	14-Jun-91 18:50:00.	23.700	29.150	24.100	30.350	31.650	23.650	255
24	14-Jun-91 19:00:00.	23.950	29.350	24.200	30.500	31.800	23.750	255
25	14-Jun-91 19:10:00.	24.050	29.550	24.250	30.650	31.900	23.750	255
26	14-Jun-91 19:20:00.	23.750	29.700	24.250	30.750	32.050	23.650	255
27	14-Jun-91 19:30:00.	23.750	29.850	24.250	30.900	32.200	23.650	255
28	14-Jun-91 19:40:00.	24.000	29.950	24.350	31.050	32.300	23.800	255
29	14-Jun-91 19:50:00.	24.000	30.100	24.300	31.150	32.400	23.700	255
30	14-Jun-91 20:00:00.	23.700	30.200	24.300	31.250	32.500	23.600	255
31	14-Jun-91 20:10:00.	23.750	30.350	24.300	31.350	32.550	23.650	255
32	14-Jun-91 20:20:00.	23.850	30.450	24.350	31.400	32.650	23.650	255
33	14-Jun-91 20:30:00.	23.900	30.500	24.350	31.500	32.700	23.650	255
34	14-Jun-91 20:40:00.	23.650	30.600	24.350	31.550	32.750	23.550	255
35	14-Jun-91 20:50:00.	23.900	30.650	24.400	31.600	32.800	23.700	255
36	14-Jun-91 21:00:00.	23.950	30.700	24.400	31.650	32.900	23.700	255

37	: 14-Jun-91 21:10:00.	25.900	30.800	25.400	31.900	33.050	25.750	255
38	: 14-Jun-91 21:20:00.	25.800	30.950	25.650	32.000	33.350	25.550	255
39	: 14-Jun-91 21:30:00.	25.750	31.150	25.900	32.200	33.550	25.550	255
40	: 14-Jun-91 21:40:00.	26.000	31.300	26.100	32.350	33.700	25.700	255
41	: 14-Jun-91 21:50:00.	25.900	31.500	26.150	32.550	33.900	25.650	255
42	: 14-Jun-91 22:00:00.	25.700	31.650	26.200	32.700	34.050	25.550	255
43	: 14-Jun-91 22:10:00.	25.850	31.800	26.250	32.800	34.150	25.650	255
44	: 14-Jun-91 22:20:00.	25.850	31.950	26.300	32.950	34.250	25.600	255
45	: 14-Jun-91 22:30:00.	25.750	32.050	26.250	33.100	34.400	25.550	255
46	: 14-Jun-91 22:40:00.	25.650	32.200	26.300	33.200	34.500	25.500	255
47	: 14-Jun-91 22:50:00.	25.950	32.300	26.350	33.250	34.550	25.700	255
48	: 14-Jun-91 23:00:00.	25.950	32.350	26.350	33.300	34.600	25.650	255
49	: 14-Jun-91 23:10:00.	25.700	32.450	26.300	33.400	34.650	25.500	255
50	: 14-Jun-91 23:20:00.	25.600	32.550	26.300	33.450	34.650	25.450	255
51	: 14-Jun-91 23:30:00.	25.850	32.600	26.350	33.500	34.750	25.600	255
52	: 14-Jun-91 23:40:00.	25.900	32.650	26.350	33.550	34.800	25.600	255
53	: 14-Jun-91 23:50:00.	25.700	32.700	26.300	33.600	34.850	25.500	255
54	: 14-Jun-91 24:00:00.	25.650	32.750	26.300	33.650	34.950	25.450	255
55	: 15-Jun-91 00:10:00.	28.000	32.850	27.400	33.800	35.050	27.700	255
56	: 15-Jun-91 00:20:00.	27.300	33.000	27.500	33.950	35.350	27.000	255
57	: 15-Jun-91 00:30:00.	27.500	33.150	27.800	34.150	35.550	27.300	255
58	: 15-Jun-91 00:40:00.	27.650	33.350	27.950	34.300	35.700	27.400	255
59	: 15-Jun-91 00:50:00.	27.850	33.450	28.050	34.500	35.800	27.500	255
60	: 15-Jun-91 01:00:00.	27.800	33.600	28.100	34.600	35.950	27.450	255
61	: 15-Jun-91 01:10:00.	27.600	33.750	28.100	34.750	36.050	27.350	255
62	: 15-Jun-91 01:20:00.	27.700	33.900	28.100	34.850	36.200	27.350	255
63	: 15-Jun-91 01:30:00.	27.700	34.000	28.150	34.950	36.300	27.350	255
64	: 15-Jun-91 01:40:00.	27.700	34.100	28.150	35.050	36.350	27.400	255
65	: 15-Jun-91 01:50:00.	27.550	34.250	28.100	35.150	36.450	27.300	255
66	: 15-Jun-91 02:00:00.	27.650	34.300	28.150	35.250	36.500	27.350	255
67	: 15-Jun-91 02:10:00.	27.800	34.400	28.150	35.300	36.550	27.400	255
68	: 15-Jun-91 02:20:00.	27.650	34.500	28.150	35.350	36.650	27.350	255
69	: 15-Jun-91 02:30:00.	27.650	34.550	28.200	35.450	36.700	27.400	255
70	: 15-Jun-91 02:40:00.	27.800	34.600	28.200	35.500	36.750	27.450	255
71	: 15-Jun-91 02:50:00.	27.700	34.650	28.200	35.550	36.800	27.350	255
72	: 15-Jun-91 03:00:00.	27.650	34.700	28.200	35.550	36.800	27.350	255
73	: 15-Jun-91 03:10:00.	30.050	34.750	29.350	35.650	36.950	29.750	255
74	: 15-Jun-91 03:20:00.	29.650	34.900	29.600	35.850	37.250	29.250	255
75	: 15-Jun-91 03:30:00.	29.500	35.100	29.700	36.050	37.450	29.050	255
76	: 15-Jun-91 03:40:00.	29.300	35.250	29.700	36.150	37.550	28.950	255
77	: 15-Jun-91 03:50:00.	29.350	35.400	29.750	36.300	37.700	28.950	255
78	: 15-Jun-91 04:00:00.	29.700	35.550	29.900	36.450	37.800	29.350	255
79	: 15-Jun-91 04:10:00.	29.650	35.650	29.950	36.550	37.900	29.250	255
80	: 15-Jun-91 04:20:00.	29.550	35.750	29.950	36.700	38.000	29.200	255
81	: 15-Jun-91 04:30:00.	29.600	35.900	30.050	36.800	38.100	29.250	255
82	: 15-Jun-91 04:40:00.	29.750	35.950	30.100	36.900	38.150	29.350	255
83	: 15-Jun-91 04:50:00.	29.750	36.050	30.100	36.950	38.200	29.350	255
84	: 15-Jun-91 05:00:00.	29.650	36.150	30.150	37.050	38.300	29.300	255
85	: 15-Jun-91 05:10:00.	29.750	36.250	30.150	37.100	38.400	29.350	255
86	: 15-Jun-91 05:20:00.	29.850	36.300	30.250	37.200	38.450	29.500	255
87	: 15-Jun-91 05:30:00.	29.600	36.400	30.200	37.250	38.500	29.200	255
88	: 15-Jun-91 05:40:00.	29.700	36.450	30.150	37.300	38.500	29.250	255
89	: 15-Jun-91 05:50:00.	29.500	36.500	30.100	37.300	38.550	29.100	255
90	: 15-Jun-91 06:00:00.	29.600	36.550	30.100	37.350	38.550	29.200	255
91	: 15-Jun-91 06:10:00.	31.900	36.550	31.000	37.400	38.600	31.500	255
92	: 15-Jun-91 06:20:00.	31.350	36.700	31.300	37.550	38.850	31.000	255
93	: 15-Jun-91 06:30:00.	31.750	36.850	31.500	37.700	39.050	31.250	255
94	: 15-Jun-91 06:40:00.	31.550	37.000	31.650	37.900	39.250	31.150	255
95	: 15-Jun-91 06:50:00.	31.500	37.150	31.750	38.050	39.350	31.150	255
96	: 15-Jun-91 07:00:00.	31.600	37.300	31.850	38.200	39.500	31.200	255

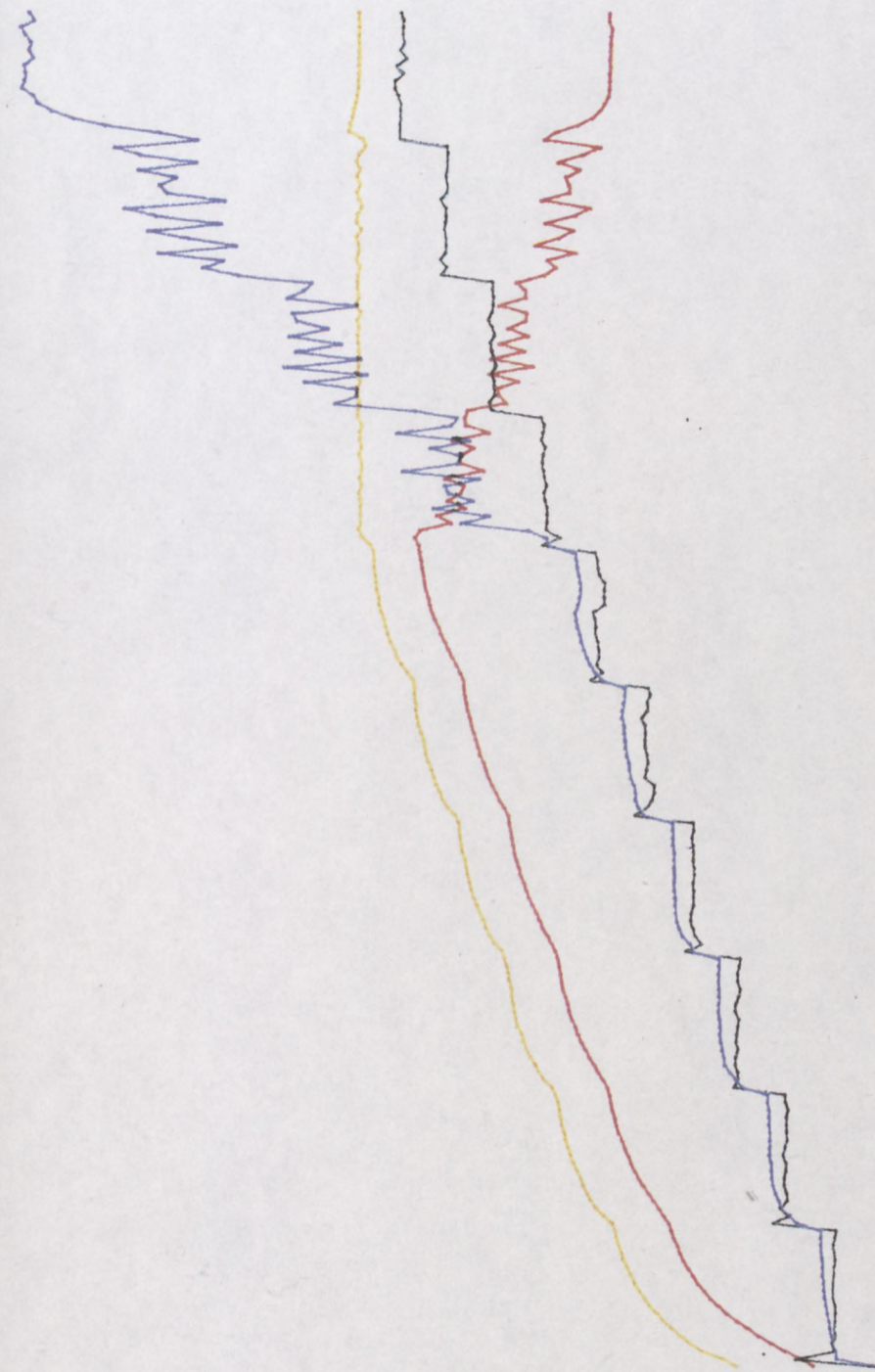
97	15-Jun-91 07:10:00.	31.750	37.450	31.900	38.300	39.600	31.300	255
98	15-Jun-91 07:20:00.	31.700	37.550	32.000	38.450	39.700	31.300	255
99	15-Jun-91 07:30:00.	31.700	37.700	32.050	38.550	39.750	31.300	255
100	15-Jun-91 07:40:00.	31.850	37.800	32.100	38.650	39.850	31.400	255
101	15-Jun-91 07:50:00.	31.300	37.900	31.950	38.700	39.950	30.900	255
102	15-Jun-91 08:00:00.	31.350	37.950	31.900	38.800	39.950	30.950	255
103	15-Jun-91 08:10:00.	31.400	38.050	31.850	38.900	40.050	30.950	255
104	15-Jun-91 08:20:00.	31.350	38.100	31.850	38.900	40.050	30.900	255
105	15-Jun-91 08:30:00.	31.500	38.150	31.950	38.950	40.100	31.150	255
106	15-Jun-91 08:40:00.	31.550	38.200	32.000	38.950	40.150	31.200	255
107	15-Jun-91 08:50:00.	31.600	38.250	32.050	39.000	40.150	31.200	255
108	15-Jun-91 09:00:00.	31.700	38.300	32.100	39.000	40.150	31.300	255
109	15-Jun-91 09:10:00.	33.700	38.350	33.150	39.100	40.300	33.400	255
110	15-Jun-91 09:20:00.	33.050	38.500	33.250	39.300	40.600	32.650	255
111	15-Jun-91 09:30:00.	33.700	38.250	33.950	39.450	40.750	33.250	254
112	15-Jun-91 09:40:00.	33.800	37.000	36.700	39.450	40.850	33.200	255
113	15-Jun-91 09:50:00.	33.650	37.650	35.500	39.550	40.700	33.200	255
114	15-Jun-91 10:00:00.	33.650	36.450	37.800	39.550	40.650	33.200	255
115	15-Jun-91 10:10:00.	33.800	37.200	36.150	39.600	40.650	33.300	255
116	15-Jun-91 10:20:00.	33.900	36.650	37.150	39.650	40.750	33.350	254
117	15-Jun-91 10:30:00.	33.650	36.500	37.350	39.600	40.800	33.200	255
118	15-Jun-91 10:40:00.	33.700	37.300	35.900	39.700	40.700	33.300	255
119	15-Jun-91 10:50:00.	33.900	35.700	39.000	39.650	40.600	33.350	255
120	15-Jun-91 11:00:00.	33.900	36.700	36.800	39.650	40.600	33.400	255
121	15-Jun-91 11:10:00.	33.700	36.650	36.650	39.700	40.750	33.350	254
122	15-Jun-91 11:20:00.	33.650	36.100	37.900	39.650	40.600	33.250	255
123	15-Jun-91 11:30:00.	33.900	37.000	36.300	39.700	40.700	33.450	255
124	15-Jun-91 11:40:00.	33.850	35.500	39.200	39.650	40.700	33.350	255
125	15-Jun-91 11:50:00.	33.650	36.450	37.050	39.700	40.600	33.300	255
126	15-Jun-91 12:00:00.	33.800	36.500	36.800	39.750	40.800	33.450	254
127	15-Jun-91 12:10:00.	35.850	36.350	38.500	39.750	40.750	35.450	255
128	15-Jun-91 12:20:00.	36.250	34.800	41.700	39.800	40.700	35.550	255
129	15-Jun-91 12:30:00.	35.700	35.100	40.800	39.900	40.800	35.300	254
130	15-Jun-91 12:40:00.	35.800	35.200	40.800	39.950	40.750	35.350	255
131	15-Jun-91 12:50:00.	36.050	34.300	42.950	39.950	40.650	35.350	255
132	15-Jun-91 13:00:00.	35.950	35.500	40.350	40.000	40.850	35.450	254
133	15-Jun-91 13:10:00.	35.700	33.700	43.800	40.000	40.700	35.250	255
134	15-Jun-91 13:20:00.	35.800	35.450	40.600	40.050	40.750	35.350	254
135	15-Jun-91 13:30:00.	36.050	34.050	43.300	40.050	40.750	35.450	254
136	15-Jun-91 13:40:00.	36.000	35.100	41.400	40.050	40.750	35.500	255
137	15-Jun-91 13:50:00.	35.750	33.900	43.550	40.050	40.800	35.300	255
138	15-Jun-91 14:00:00.	35.850	34.750	41.950	40.050	40.700	35.400	255
139	15-Jun-91 14:10:00.	36.250	34.000	43.250	40.100	40.800	35.600	254
140	15-Jun-91 14:20:00.	35.950	33.950	43.450	40.050	40.600	35.400	255
141	15-Jun-91 14:30:00.	35.700	35.100	40.800	40.100	40.850	35.350	254
142	15-Jun-91 14:40:00.	35.900	34.000	43.650	40.100	40.700	35.350	255
143	15-Jun-91 14:50:00.	35.950	34.050	42.950	40.150	40.800	35.400	254
144	15-Jun-91 15:00:00.	35.900	34.400	42.600	40.150	40.750	35.400	254
145	15-Jun-91 15:10:00.	37.900	33.250	45.600	40.150	40.750	37.450	254
146	15-Jun-91 15:20:00.	37.900	32.800	47.000	40.150	40.650	37.200	255
147	15-Jun-91 15:30:00.	38.250	33.150	46.150	40.250	40.850	37.500	254
148	15-Jun-91 15:40:00.	37.900	32.000	48.800	40.200	40.700	37.250	254
149	15-Jun-91 15:50:00.	37.750	33.650	45.650	40.200	40.700	37.250	255
150	15-Jun-91 16:00:00.	37.900	32.700	47.600	40.300	40.850	37.250	254
151	15-Jun-91 16:10:00.	38.150	32.100	49.250	40.200	40.600	37.350	255
152	15-Jun-91 16:20:00.	37.800	33.250	46.250	40.300	40.850	37.300	254
153	15-Jun-91 16:30:00.	37.900	32.050	48.900	40.300	40.800	37.250	254
154	15-Jun-91 16:40:00.	37.950	31.450	50.200	40.250	40.600	37.300	254
155	15-Jun-91 16:50:00.	38.200	33.400	46.100	40.300	40.750	37.500	254

156	15-Jun-91	17:00:00.	37.800	32.250	48.450	40.350	40.850	37.200	254
157	15-Jun-91	17:10:00.	37.800	32.300	48.800	40.300	40.650	37.200	255
158	15-Jun-91	17:20:00.	37.900	32.450	48.050	40.350	40.850	37.300	254
159	15-Jun-91	17:30:00.	37.950	31.850	49.650	40.300	40.650	37.200	255
160	15-Jun-91	17:40:00.	37.800	32.750	47.250	40.350	40.850	37.200	254
161	15-Jun-91	17:50:00.	37.900	31.750	49.550	40.300	40.700	37.200	254
162	15-Jun-91	18:00:00.	38.050	31.050	50.600	40.150	40.450	37.250	254
163	15-Jun-91	18:10:00.	39.700	33.300	47.200	40.250	40.600	39.100	255
164	15-Jun-91	18:20:00.	39.750	32.850	48.750	40.500	41.150	39.100	254
165	15-Jun-91	18:30:00.	39.850	31.950	50.950	40.550	41.100	39.100	254
166	15-Jun-91	18:40:00.	39.900	31.400	52.250	40.600	41.000	39.050	254
167	15-Jun-91	18:50:00.	39.850	31.100	53.100	40.550	40.950	39.100	254
168	15-Jun-91	19:00:00.	39.850	30.900	53.650	40.550	40.850	39.050	254
169	15-Jun-91	19:10:00.	40.000	30.750	53.850	40.500	40.800	39.200	254
170	15-Jun-91	19:20:00.	40.200	30.700	54.300	40.500	40.750	39.350	254
171	15-Jun-91	19:30:00.	40.050	30.700	54.150	40.500	40.800	39.300	254
172	15-Jun-91	19:40:00.	39.750	30.700	54.100	40.500	40.750	38.950	254
173	15-Jun-91	19:50:00.	40.050	30.650	54.200	40.500	40.750	39.250	254
174	15-Jun-91	20:00:00.	39.700	30.700	53.800	40.500	40.750	38.800	254
175	15-Jun-91	20:10:00.	39.950	30.650	54.000	40.500	40.750	39.100	254
176	15-Jun-91	20:20:00.	39.700	30.650	53.900	40.500	40.750	38.900	254
177	15-Jun-91	20:30:00.	39.850	30.650	54.150	40.500	40.750	39.000	254
178	15-Jun-91	20:40:00.	39.750	30.600	54.350	40.500	40.700	39.000	254
179	15-Jun-91	20:50:00.	39.750	30.750	53.750	40.500	40.750	38.950	254
180	15-Jun-91	21:00:00.	39.900	30.700	54.000	40.500	40.750	39.100	254

degC

55.00  
51.00  
47.00  
43.00  
39.00  
35.00  
31.00  
27.00  
23.00  
19.00  
15.00

Ch 2  
Ch 3  
Ch 5  
Ch 6



12: 00: 00.

14-Jun-91

24: 00: 00.

12: 00: 00.

00: 00: 00.

15-Jun-91

## APPENDIX 3.7.10

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 38  
60 Watt heat load  
2,5 Amp cooling  
Container in climatic chamber  
Sol-air program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level  
Ch 19 255=Off 254=On

## Channel Readings

Data file - FILE38

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

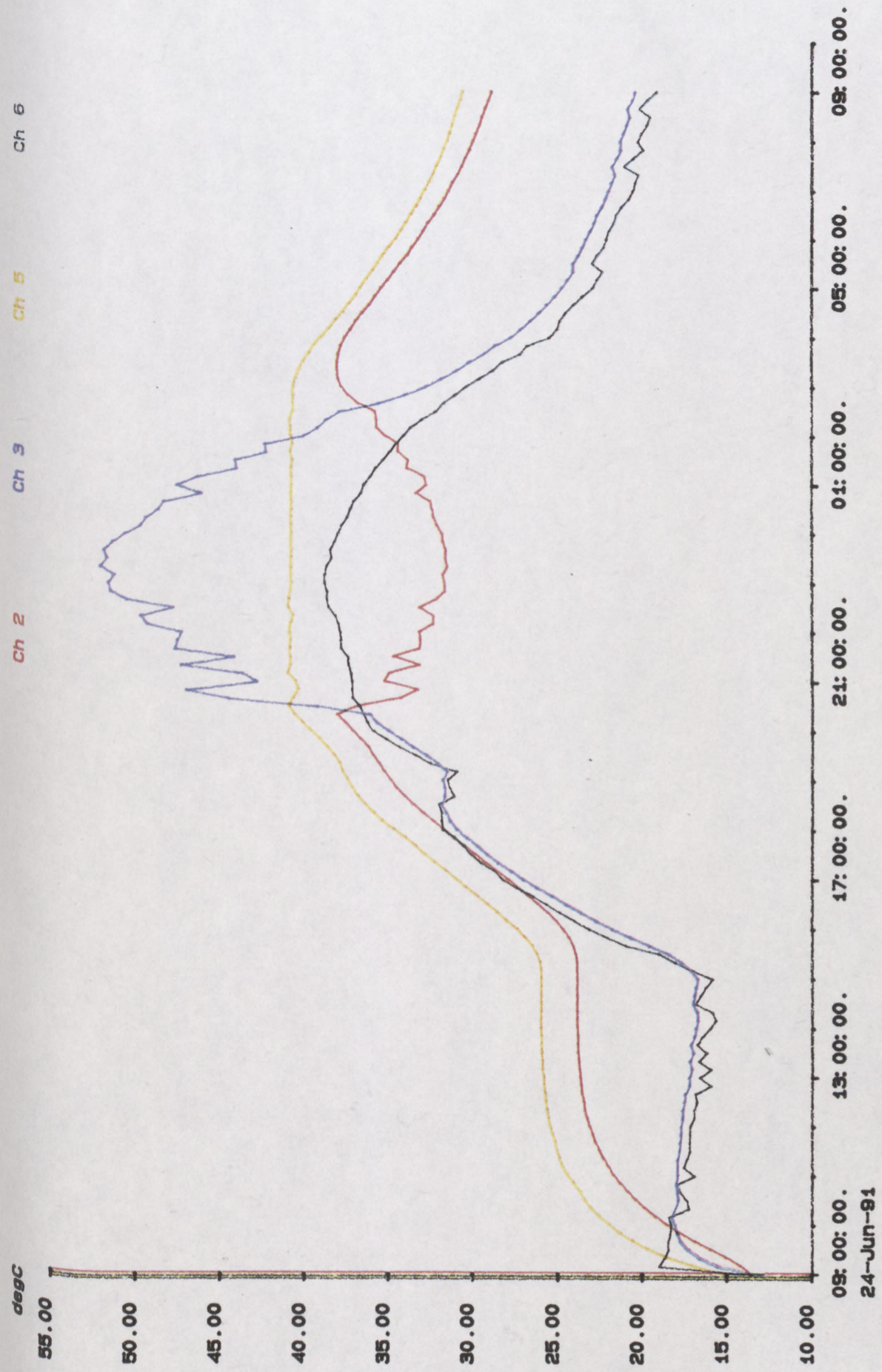
Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 24-Jun-91 09:00:00.  
    Finish : 25-Jun-91 09:00:01.  
Readings per channel: 145

All readings

Rdg no:	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19
0	24-Jun-91 09:00:00.	13.150	13.550	12.850	14.250	15.250	13.000	255
1	24-Jun-91 09:10:00.	19.300	14.200	15.500	15.300	17.050	19.000	255
2	24-Jun-91 09:20:00.	18.800	15.050	16.600	16.400	18.550	18.650	255
3	24-Jun-91 09:30:00.	18.450	16.000	17.300	17.450	19.700	18.400	255
4	24-Jun-91 09:40:00.	18.600	16.950	17.750	18.400	20.550	18.450	255
5	24-Jun-91 09:50:00.	18.450	17.800	17.950	19.250	21.350	19.300	255
6	24-Jun-91 10:00:00.	18.350	18.550	18.100	20.000	21.950	18.250	255
7	24-Jun-91 10:10:00.	18.600	19.250	18.300	20.650	22.550	18.400	255
8	24-Jun-91 10:20:00.	16.900	19.850	18.050	21.250	23.050	17.200	255
9	24-Jun-91 10:30:00.	17.550	20.400	17.850	21.700	23.450	17.350	255
10	24-Jun-91 10:40:00.	18.000	20.850	17.950	22.100	23.700	17.750	255
11	24-Jun-91 10:50:00.	18.050	21.300	18.050	22.550	24.100	17.900	255
12	24-Jun-91 11:00:00.	16.900	21.700	17.900	22.900	24.450	16.850	255
13	24-Jun-91 11:10:00.	17.800	22.000	17.950	23.250	24.750	17.550	255
14	24-Jun-91 11:20:00.	17.400	22.300	17.900	23.500	24.950	17.350	255
15	24-Jun-91 11:30:00.	17.250	22.550	17.800	23.700	25.100	17.150	255
16	24-Jun-91 11:40:00.	17.250	22.800	17.750	23.850	25.200	17.200	255
17	24-Jun-91 11:50:00.	17.200	22.950	17.700	24.050	25.350	17.150	255
18	24-Jun-91 12:00:00.	17.250	23.150	17.700	24.200	25.500	17.150	255
19	24-Jun-91 12:10:00.	16.950	23.300	17.600	24.300	25.600	16.900	255
20	24-Jun-91 12:20:00.	16.950	23.450	17.600	24.400	25.700	16.900	255
21	24-Jun-91 12:30:00.	16.800	23.500	17.500	24.450	25.750	16.750	255
22	24-Jun-91 12:40:00.	16.900	23.600	17.450	24.550	25.800	16.850	255
23	24-Jun-91 12:50:00.	15.600	23.650	17.200	24.600	25.850	15.900	255
24	24-Jun-91 13:00:00.	16.650	23.700	17.200	24.650	25.850	16.600	255
25	24-Jun-91 13:10:00.	15.900	23.750	17.050	24.750	25.950	15.900	255
26	24-Jun-91 13:20:00.	16.700	23.800	17.200	24.750	25.950	16.650	255
27	24-Jun-91 13:30:00.	16.250	23.850	16.950	24.800	26.000	16.150	255
28	24-Jun-91 13:40:00.	16.950	23.850	17.150	24.850	26.000	16.750	255
29	24-Jun-91 13:50:00.	16.500	23.850	16.900	24.850	26.000	16.400	255
30	24-Jun-91 14:00:00.	15.950	23.900	16.800	24.850	26.050	15.950	255
31	24-Jun-91 14:10:00.	15.350	23.900	16.700	24.850	26.050	15.600	255
32	24-Jun-91 14:20:00.	15.300	23.900	16.750	24.850	26.000	15.850	255
33	24-Jun-91 14:30:00.	17.050	23.900	17.000	24.850	26.000	16.850	255
34	24-Jun-91 14:40:00.	16.600	23.900	16.900	24.850	26.000	16.500	255
35	24-Jun-91 14:50:00.	16.300	23.900	16.800	24.850	26.000	16.200	255

36	24-Jun-91	15:00:00.	15.750	23.900	16.700	24.850	26.000	15.800	255
37	24-Jun-91	15:10:00.	17.000	23.900	17.100	24.850	26.000	17.000	255
38	24-Jun-91	15:20:00.	18.250	23.900	17.700	24.850	26.100	18.100	255
39	24-Jun-91	15:30:00.	19.050	24.000	18.450	25.000	26.300	19.000	255
40	24-Jun-91	15:40:00.	21.250	24.150	19.550	25.150	26.550	20.950	255
41	24-Jun-91	15:50:00.	22.350	24.400	20.650	25.450	27.000	22.050	255
42	24-Jun-91	16:00:00.	23.300	24.750	21.750	25.850	27.450	23.150	255
43	24-Jun-91	16:10:00.	24.150	25.150	22.750	26.300	28.050	24.050	255
44	24-Jun-91	16:20:00.	25.150	25.650	23.650	26.800	28.600	24.900	255
45	24-Jun-91	16:30:00.	25.900	26.200	24.550	27.350	29.200	25.700	255
46	24-Jun-91	16:40:00.	26.600	26.750	25.350	27.900	29.800	26.500	255
47	24-Jun-91	16:50:00.	27.700	27.350	26.250	28.450	30.450	27.450	255
48	24-Jun-91	17:00:00.	28.550	27.950	27.050	29.050	31.050	28.250	255
49	24-Jun-91	17:10:00.	28.800	28.600	27.750	29.700	31.650	28.700	255
50	24-Jun-91	17:20:00.	29.650	29.250	28.500	30.300	32.300	29.500	255
51	24-Jun-91	17:30:00.	30.500	29.850	29.150	30.900	32.900	30.100	255
52	24-Jun-91	17:40:00.	30.750	30.500	29.700	31.450	33.450	30.500	255
53	24-Jun-91	17:50:00.	31.250	31.150	30.350	32.100	34.050	31.050	255
54	24-Jun-91	18:00:00.	32.100	31.750	30.950	32.700	34.750	31.750	255
55	24-Jun-91	18:10:00.	32.100	32.350	31.350	33.350	35.400	31.850	255
56	24-Jun-91	18:20:00.	32.000	32.950	31.600	33.900	35.900	31.800	255
57	24-Jun-91	18:30:00.	32.250	33.550	31.850	34.500	36.400	32.000	255
58	24-Jun-91	18:40:00.	31.300	34.050	31.850	34.950	36.850	31.050	255
59	24-Jun-91	18:50:00.	31.600	34.550	31.650	35.350	37.150	31.350	255
60	24-Jun-91	19:00:00.	31.750	34.900	31.800	35.750	37.450	31.500	255
61	24-Jun-91	19:10:00.	31.200	35.250	31.500	36.050	37.750	30.900	255
62	24-Jun-91	19:20:00.	32.800	35.550	32.100	36.300	37.900	32.500	255
63	24-Jun-91	19:30:00.	33.700	35.900	32.750	36.650	38.250	33.400	255
64	24-Jun-91	19:40:00.	34.800	36.200	33.550	37.050	38.650	34.350	255
65	24-Jun-91	19:50:00.	35.600	36.650	34.250	37.450	39.150	35.150	255
66	24-Jun-91	20:00:00.	36.250	37.100	35.000	37.900	39.650	35.900	255
67	24-Jun-91	20:10:00.	36.650	37.550	35.700	38.400	40.150	36.250	255
68	24-Jun-91	20:20:00.	36.900	38.050	36.100	38.800	40.650	36.450	255
69	24-Jun-91	20:30:00.	37.150	38.800	39.250	39.300	41.000	36.700	254
70	24-Jun-91	20:40:00.	37.700	34.250	44.550	39.450	40.700	37.100	254
71	24-Jun-91	20:50:00.	37.650	33.250	47.100	39.500	40.400	37.150	255
72	24-Jun-91	21:00:00.	37.650	35.250	42.850	39.700	40.600	37.100	255
73	24-Jun-91	21:10:00.	37.650	34.950	43.700	39.950	41.050	37.200	254
74	24-Jun-91	21:20:00.	37.950	33.150	47.400	40.000	40.850	37.350	254
75	24-Jun-91	21:30:00.	37.950	34.750	44.200	40.150	40.900	37.400	254
76	24-Jun-91	21:40:00.	38.450	33.150	47.750	40.200	40.950	37.800	254
77	24-Jun-91	21:50:00.	38.400	33.100	47.600	40.200	40.850	37.800	254
78	24-Jun-91	22:00:00.	38.450	33.200	47.350	40.300	40.950	37.850	254
79	24-Jun-91	22:10:00.	38.550	32.350	49.400	40.250	40.850	37.950	254
80	24-Jun-91	22:20:00.	38.800	32.350	49.800	40.200	40.700	38.150	255
81	24-Jun-91	22:30:00.	39.250	33.200	47.850	40.400	41.050	38.550	254
82	24-Jun-91	22:40:00.	39.450	32.200	50.600	40.400	40.950	38.650	254
83	24-Jun-91	22:50:00.	39.350	31.650	51.550	40.350	40.850	38.650	254
84	24-Jun-91	23:00:00.	39.500	31.700	51.700	40.350	40.800	38.800	254
85	24-Jun-91	23:10:00.	39.450	31.800	51.300	40.400	40.850	38.750	254
86	24-Jun-91	23:20:00.	39.350	31.500	52.150	40.400	40.850	38.650	254
87	24-Jun-91	23:30:00.	38.900	31.650	51.750	40.400	40.850	38.350	254
88	24-Jun-91	23:40:00.	39.250	31.600	51.950	40.400	40.800	38.450	255
89	24-Jun-91	23:50:00.	38.800	31.800	51.400	40.400	40.850	38.150	254
90	24-Jun-91	24:00:00.	38.650	31.850	50.700	40.400	40.800	37.950	254
91	25-Jun-91	00:10:00.	38.350	32.150	49.800	40.400	40.850	37.750	254
92	25-Jun-91	00:20:00.	37.950	32.350	49.450	40.400	40.850	37.400	254
93	25-Jun-91	00:30:00.	37.800	32.450	48.750	40.400	40.850	37.200	254
94	25-Jun-91	00:40:00.	37.650	32.550	48.400	40.350	40.800	37.000	255
95	25-Jun-91	00:50:00.	37.150	33.400	46.150	40.400	40.850	36.550	254

96		25-Jun-91	01:00:00.		37.000		32.750		47.650		40.350		40.800		36.400		255
97		25-Jun-91	01:10:00.		36.600		32.900		46.400		40.350		40.800		36.000		254
98		25-Jun-91	01:20:00.		36.150		33.950		44.050		40.350		40.850		35.700		254
99		25-Jun-91	01:30:00.		35.750		33.850		44.150		40.300		40.750		35.250		255
100		25-Jun-91	01:40:00.		35.350		34.450		42.300		40.350		40.900		34.850		254
101		25-Jun-91	01:50:00.		34.950		34.450		42.400		40.300		40.750		34.500		255
102		25-Jun-91	02:00:00.		34.500		35.200		40.050		40.300		40.900		34.050		254
103		25-Jun-91	02:10:00.		34.000		35.700		39.250		40.150		40.850		33.650		255
104		25-Jun-91	02:20:00.		33.400		35.700		38.700		40.150		40.950		33.000		254
105		25-Jun-91	02:30:00.		32.350		35.800		37.900		40.000		40.700		32.150		255
106		25-Jun-91	02:40:00.		32.050		36.800		35.550		39.950		40.700		31.700		255
107		25-Jun-91	02:50:00.		31.250		37.400		34.050		39.850		40.750		31.000		255
108		25-Jun-91	03:00:00.		30.550		37.800		32.800		39.750		40.700		30.350		255
109		25-Jun-91	03:10:00.		29.700		38.000		31.850		39.650		40.550		29.550		255
110		25-Jun-91	03:20:00.		28.900		38.050		30.950		39.500		40.350		28.750		255
111		25-Jun-91	03:30:00.		28.350		38.050		30.200		39.250		40.100		28.200		255
112		25-Jun-91	03:40:00.		27.250		37.950		29.350		39.000		39.750		27.150		255
113		25-Jun-91	03:50:00.		27.000		37.800		28.700		38.650		39.450		26.750		255
114		25-Jun-91	04:00:00.		25.600		37.550		27.750		38.350		39.000		25.450		255
115		25-Jun-91	04:10:00.		24.950		37.200		27.150		37.950		38.550		25.000		255
116		25-Jun-91	04:20:00.		25.150		36.900		26.600		37.550		38.150		24.850		255
117		25-Jun-91	04:30:00.		24.750		36.500		26.100		37.150		37.700		24.500		255
118		25-Jun-91	04:40:00.		24.300		36.100		25.650		36.750		37.350		24.050		255
119		25-Jun-91	04:50:00.		23.800		35.750		25.200		36.400		36.950		23.500		255
120		25-Jun-91	05:00:00.		23.100		35.400		24.800		36.000		36.650		22.900		255
121		25-Jun-91	05:10:00.		22.750		35.000		24.450		35.650		36.300		22.650		255
122		25-Jun-91	05:20:00.		22.400		34.650		24.100		35.300		35.950		22.300		255
123		25-Jun-91	05:30:00.		23.150		34.300		24.150		34.950		35.600		22.950		255
124		25-Jun-91	05:40:00.		22.850		33.900		23.800		34.600		35.300		22.650		255
125		25-Jun-91	05:50:00.		22.550		33.600		23.550		34.250		34.950		22.250		255
126		25-Jun-91	06:00:00.		22.300		33.250		23.350		33.900		34.600		22.100		255
127		25-Jun-91	06:10:00.		22.200		32.950		23.100		33.550		34.300		21.950		255
128		25-Jun-91	06:20:00.		21.850		32.650		22.850		33.250		34.000		21.650		255
129		25-Jun-91	06:30:00.		21.800		32.300		22.700		32.950		33.700		21.500		255
130		25-Jun-91	06:40:00.		21.450		32.000		22.400		32.650		33.400		21.200		255
131		25-Jun-91	06:50:00.		20.850		31.700		22.200		32.350		33.150		20.750		255
132		25-Jun-91	07:00:00.		20.600		31.450		22.000		32.050		32.900		20.500		255
133		25-Jun-91	07:10:00.		20.460		31.200		21.800		31.800		32.650		20.350		255
134		25-Jun-91	07:20:00.		20.150		30.900		21.600		31.550		32.400		20.150		255
135		25-Jun-91	07:30:00.		21.400		30.650		21.800		31.350		32.200		21.050		255
136		25-Jun-91	07:40:00.		20.800		30.450		21.500		31.100		31.950		20.500		255
137		25-Jun-91	07:50:00.		20.000		30.200		21.250		30.900		31.750		19.900		255
138		25-Jun-91	08:00:00.		20.200		30.000		21.300		30.650		31.550		20.250		255
139		25-Jun-91	08:10:00.		20.150		29.800		21.100		30.500		31.400		20.000		255
140		25-Jun-91	08:20:00.		19.700		29.600		20.900		30.300		31.250		19.650		255
141		25-Jun-91	08:30:00.		19.350		29.450		20.700		30.150		31.100		19.450		255
142		25-Jun-91	08:40:00.		20.400		29.250		20.850		29.950		30.950		20.100		255
143		25-Jun-91	08:50:00.		19.750		29.050		20.550		29.800		30.750		19.650		255
144		25-Jun-91	09:00:00.		19.150		28.900		20.400		29.650		30.650		19.100		255



## APPENDIX 3.7.11

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 39  
100 Watt heat load  
2,5 Amp cooling  
Container in climatic chamber  
Sol-air program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level  
Ch 19 255=Off 254=On

## Channel Readings

Data file - FILE39

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 25-Jun-91 12:00:00.  
    Finish : 26-Jun-91 12:00:01.  
Readings per channel: 145

All readings

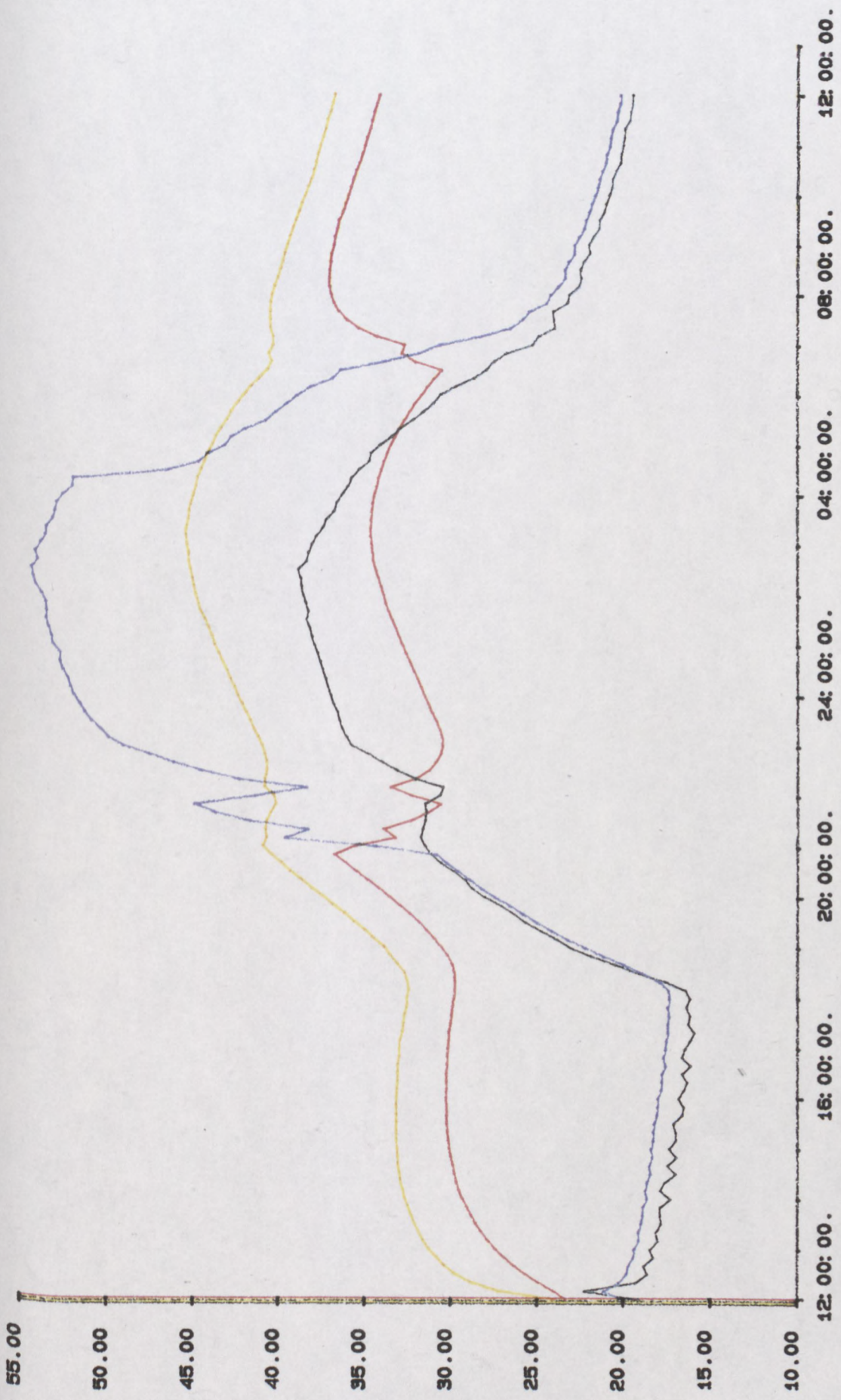
Run no	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19
0	25-Jun-91 12:00:00.	19.150	23.250	20.000	23.450	24.050	19.100	255
1	25-Jun-91 12:10:00.	22.550	24.050	21.150	24.850	27.300	22.250	255
2	25-Jun-91 12:20:00.	19.350	24.900	20.250	26.000	28.850	19.300	255
3	25-Jun-91 12:30:00.	18.650	25.650	19.800	26.950	29.750	18.800	255
4	25-Jun-91 12:40:00.	19.900	26.300	19.700	27.700	30.350	18.850	255
5	25-Jun-91 12:50:00.	18.400	26.900	19.400	28.300	30.800	19.250	255
6	25-Jun-91 13:00:00.	18.600	27.400	19.350	28.800	31.250	18.500	255
7	25-Jun-91 13:10:00.	18.150	27.850	19.100	29.250	31.600	18.000	255
8	25-Jun-91 13:20:00.	18.200	28.200	19.100	29.600	31.850	19.150	255
9	25-Jun-91 13:30:00.	17.800	28.550	18.950	29.850	32.100	17.800	255
10	25-Jun-91 13:40:00.	17.950	28.800	18.850	30.100	32.300	17.900	255
11	25-Jun-91 13:50:00.	17.950	29.050	18.850	30.350	32.500	17.900	255
12	25-Jun-91 14:00:00.	17.350	29.300	18.600	30.500	32.700	17.250	255
13	25-Jun-91 14:10:00.	18.100	29.500	18.750	30.650	32.800	17.900	255
14	25-Jun-91 14:20:00.	17.700	29.650	18.600	30.800	32.950	17.600	255
15	25-Jun-91 14:30:00.	16.950	29.750	18.400	30.900	33.000	16.950	255
16	25-Jun-91 14:40:00.	17.600	29.850	18.500	31.000	33.100	17.500	255
17	25-Jun-91 14:50:00.	16.950	29.950	18.300	31.050	33.100	16.900	255
18	25-Jun-91 15:00:00.	17.500	30.050	18.400	31.150	33.150	17.400	255
19	25-Jun-91 15:10:00.	17.050	30.100	18.250	31.200	33.200	16.950	255
20	25-Jun-91 15:20:00.	16.800	30.150	18.250	31.250	33.200	17.000	255
21	25-Jun-91 15:30:00.	17.250	30.200	18.200	31.250	33.200	17.150	255
22	25-Jun-91 15:40:00.	16.650	30.200	18.050	31.250	33.200	16.600	255
23	25-Jun-91 15:50:00.	16.300	30.200	18.000	31.300	33.200	16.500	255
24	25-Jun-91 16:00:00.	16.950	30.250	18.000	31.300	33.200	16.850	255
25	25-Jun-91 16:10:00.	16.700	30.200	17.800	31.250	33.150	16.500	255
26	25-Jun-91 16:20:00.	16.050	30.200	17.750	31.250	33.100	16.300	255
27	25-Jun-91 16:30:00.	16.700	30.200	17.750	31.250	33.100	16.650	255
28	25-Jun-91 16:40:00.	16.150	30.150	17.550	31.200	33.100	16.100	255
29	25-Jun-91 16:50:00.	16.650	30.150	17.700	31.150	33.000	16.650	255
30	25-Jun-91 17:00:00.	16.500	30.100	17.550	31.150	33.000	16.450	255
31	25-Jun-91 17:10:00.	16.300	30.050	17.500	31.100	32.950	16.150	255
32	25-Jun-91 17:20:00.	15.700	30.050	17.400	31.000	32.800	15.900	255
33	25-Jun-91 17:30:00.	16.400	29.950	17.450	30.950	32.750	16.300	255
34	25-Jun-91 17:40:00.	16.300	29.900	17.350	30.850	32.700	16.150	255
35	25-Jun-91 17:50:00.	16.550	29.850	17.450	30.750	32.550	16.400	255
36	25-Jun-91 18:00:00.	16.300	29.750	17.300	30.700	32.550	16.150	255

37	25-Jun-91	18:10:00	16.600	29.700	17.400	30.650	32.450	16.450	255
38	25-Jun-91	18:20:00	18.000	29.700	17.900	30.650	32.550	17.600	255
39	25-Jun-91	18:30:00	19.300	29.750	18.900	30.750	32.750	19.150	255
40	25-Jun-91	18:40:00	20.650	29.900	19.950	31.000	33.150	20.450	255
41	25-Jun-91	18:50:00	22.200	30.150	21.100	31.300	33.550	21.850	255
42	25-Jun-91	19:00:00	23.400	30.500	22.150	31.600	33.900	23.050	255
43	25-Jun-91	19:10:00	24.100	30.900	23.200	32.050	34.500	23.850	255
44	25-Jun-91	19:20:00	25.050	31.350	24.150	32.550	35.000	24.800	255
45	25-Jun-91	19:30:00	26.100	31.800	25.000	33.100	35.600	25.700	255
46	25-Jun-91	19:40:00	26.650	32.350	25.800	33.600	36.150	26.350	255
47	25-Jun-91	19:50:00	27.350	32.950	26.600	34.200	36.800	27.150	255
48	25-Jun-91	20:00:00	28.450	33.550	27.500	34.800	37.400	28.100	255
49	25-Jun-91	20:10:00	29.250	34.150	28.250	35.450	38.050	28.800	255
50	25-Jun-91	20:20:00	29.450	34.800	28.900	36.050	38.650	29.200	255
51	25-Jun-91	20:30:00	30.150	35.450	29.550	36.700	39.300	29.800	255
52	25-Jun-91	20:40:00	30.950	36.050	30.200	37.300	39.850	30.550	255
53	25-Jun-91	20:50:00	31.450	36.700	30.800	37.900	40.450	31.100	255
54	25-Jun-91	21:00:00	31.900	35.500	34.300	38.450	40.950	31.500	254
55	25-Jun-91	21:10:00	32.300	33.150	39.600	38.700	40.700	31.750	254
56	25-Jun-91	21:20:00	32.200	33.900	38.200	39.000	40.800	31.600	254
57	25-Jun-91	21:30:00	32.000	32.300	41.650	39.200	40.700	31.450	254
58	25-Jun-91	21:40:00	32.050	31.250	43.700	39.250	40.450	31.400	254
59	25-Jun-91	21:50:00	32.200	30.500	44.950	39.200	40.150	31.500	254
60	25-Jun-91	22:00:00	30.950	32.250	41.400	39.300	40.300	30.600	255
61	25-Jun-91	22:10:00	30.900	33.500	38.300	39.450	40.650	30.400	254
62	25-Jun-91	22:20:00	32.650	32.000	42.300	39.550	40.800	32.050	254
63	25-Jun-91	22:30:00	33.900	31.200	44.500	39.650	40.700	33.150	254
64	25-Jun-91	22:40:00	34.850	30.800	46.150	39.750	40.700	34.000	254
65	25-Jun-91	22:50:00	35.600	30.500	47.550	39.900	40.850	34.800	254
66	25-Jun-91	23:00:00	36.600	30.400	49.100	40.050	41.000	35.750	254
67	25-Jun-91	23:10:00	36.950	30.450	49.950	40.300	41.250	36.050	254
68	25-Jun-91	23:20:00	37.200	30.600	50.400	40.550	41.500	36.300	254
69	25-Jun-91	23:30:00	37.300	30.800	50.950	40.800	41.700	36.450	254
70	25-Jun-91	23:40:00	37.400	31.050	51.300	41.050	41.950	36.550	254
71	25-Jun-91	23:50:00	37.700	31.250	51.600	41.250	42.200	36.800	254
72	25-Jun-91	24:00:00	37.750	31.500	51.950	41.500	42.450	36.950	254
73	26-Jun-91	00:10:00	37.900	31.700	52.150	41.750	42.650	37.100	254
74	26-Jun-91	00:20:00	38.100	31.900	52.300	41.950	42.900	37.250	254
75	26-Jun-91	00:30:00	38.300	32.150	52.600	42.200	43.100	37.400	254
76	26-Jun-91	00:40:00	38.400	32.350	52.750	42.450	43.350	37.550	254
77	26-Jun-91	00:50:00	38.500	32.600	52.750	42.650	43.550	37.700	254
78	26-Jun-91	01:00:00	38.700	32.800	53.150	42.900	43.800	37.900	254
79	26-Jun-91	01:10:00	38.950	33.000	53.250	43.100	43.950	38.050	254
80	26-Jun-91	01:20:00	39.050	33.200	53.400	43.350	44.150	38.150	254
81	26-Jun-91	01:30:00	39.250	33.400	53.550	43.550	44.350	38.350	254
82	26-Jun-91	01:40:00	39.000	33.600	53.500	43.700	44.600	38.200	254
83	26-Jun-91	01:50:00	39.300	33.800	53.550	43.900	44.750	38.400	254
84	26-Jun-91	02:00:00	39.500	33.900	53.800	44.050	44.900	38.550	254
85	26-Jun-91	02:10:00	39.500	34.050	54.150	44.200	45.000	38.650	254
86	26-Jun-91	02:20:00	39.550	34.200	54.300	44.300	45.100	38.700	254
87	26-Jun-91	02:30:00	39.750	34.350	54.400	44.450	45.200	38.850	254
88	26-Jun-91	02:40:00	39.200	34.500	54.000	44.550	45.300	38.300	254
89	26-Jun-91	02:50:00	39.100	34.550	54.200	44.550	45.300	38.200	254
90	26-Jun-91	03:00:00	38.900	34.600	53.850	44.650	45.400	38.000	254
91	26-Jun-91	03:10:00	38.550	34.650	53.550	44.750	45.450	37.750	254
92	26-Jun-91	03:20:00	38.100	34.650	53.500	44.750	45.450	37.350	254
93	26-Jun-91	03:30:00	38.050	34.600	53.150	44.700	45.300	37.150	254
94	26-Jun-91	03:40:00	37.450	34.550	53.000	44.600	45.250	36.700	254
95	26-Jun-91	03:50:00	37.200	34.500	52.900	44.550	45.150	36.550	254

96	26-Jun-91 04:00:00.	37.050	34.400	52.550	44.450	45.000	36.250	254
97	26-Jun-91 04:10:00.	36.600	34.250	52.000	44.350	44.850	35.900	254
98	26-Jun-91 04:20:00.	36.600	34.150	51.950	44.200	44.750	35.700	254
99	26-Jun-91 04:30:00.	35.900	34.000	46.450	44.050	44.550	35.250	254
100	26-Jun-91 04:40:00.	35.450	33.850	44.650	43.900	44.350	34.700	254
101	26-Jun-91 04:50:00.	35.450	33.650	44.100	43.700	44.150	34.600	254
102	26-Jun-91 05:00:00.	34.800	33.450	43.150	43.500	43.900	34.050	254
103	26-Jun-91 05:10:00.	34.000	33.200	42.800	43.300	43.700	33.400	254
104	26-Jun-91 05:20:00.	33.550	32.950	41.950	43.050	43.400	32.900	254
105	26-Jun-91 05:30:00.	32.800	32.650	40.750	42.750	43.050	32.200	254
106	26-Jun-91 05:40:00.	32.200	32.350	40.150	42.450	42.800	31.550	254
107	26-Jun-91 05:50:00.	31.500	32.050	39.500	42.150	42.450	30.950	254
108	26-Jun-91 06:00:00.	31.350	31.650	38.850	41.800	42.050	30.550	254
109	26-Jun-91 06:10:00.	30.300	31.300	38.100	41.400	41.650	29.700	254
110	26-Jun-91 06:20:00.	29.200	30.900	36.800	40.950	41.150	28.650	254
111	26-Jun-91 06:30:00.	28.450	30.450	36.350	40.500	40.650	27.950	254
112	26-Jun-91 06:40:00.	28.050	32.050	33.950	40.100	40.400	27.500	255
113	26-Jun-91 06:50:00.	27.300	32.850	31.850	39.850	40.600	26.800	254
114	26-Jun-91 07:00:00.	25.500	32.650	30.600	39.600	40.300	25.250	255
115	26-Jun-91 07:10:00.	25.250	34.300	28.300	39.450	40.350	24.900	255
116	26-Jun-91 07:20:00.	24.000	35.350	26.550	39.350	40.500	23.950	255
117	26-Jun-91 07:30:00.	24.250	36.000	25.850	39.250	40.500	24.050	255
118	26-Jun-91 07:40:00.	24.300	36.450	25.450	39.100	40.500	24.100	255
119	26-Jun-91 07:50:00.	23.300	36.750	24.450	39.000	40.500	23.200	255
120	26-Jun-91 08:00:00.	23.250	36.900	24.200	38.900	40.400	23.100	255
121	26-Jun-91 08:10:00.	22.400	37.000	23.750	38.750	40.250	22.500	255
122	26-Jun-91 08:20:00.	22.550	37.000	23.350	38.600	40.050	22.400	255
123	26-Jun-91 08:30:00.	22.700	36.950	23.400	38.450	39.900	22.500	255
124	26-Jun-91 08:40:00.	22.400	36.900	23.150	38.300	39.750	22.250	255
125	26-Jun-91 08:50:00.	22.000	36.850	22.800	38.150	39.650	21.900	255
126	26-Jun-91 09:00:00.	22.300	36.700	22.850	37.950	39.500	22.000	255
127	26-Jun-91 09:10:00.	21.900	36.650	22.550	37.800	39.350	21.700	255
128	26-Jun-91 09:20:00.	21.500	36.500	22.250	37.650	39.200	21.550	255
129	26-Jun-91 09:30:00.	21.500	36.400	22.150	37.450	39.000	21.350	255
130	26-Jun-91 09:40:00.	21.200	36.200	21.950	37.250	38.800	21.100	255
131	26-Jun-91 09:50:00.	21.200	36.050	21.800	37.050	38.650	21.000	255
132	26-Jun-91 10:00:00.	20.950	35.900	21.600	36.900	38.450	20.800	255
133	26-Jun-91 10:10:00.	20.700	35.750	21.450	36.700	38.300	20.600	255
134	26-Jun-91 10:20:00.	20.750	35.600	21.350	36.500	38.100	20.600	255
135	26-Jun-91 10:30:00.	20.650	35.450	21.200	36.300	37.950	20.400	255
136	26-Jun-91 10:40:00.	20.300	35.250	21.000	36.150	37.800	20.150	255
137	26-Jun-91 10:50:00.	20.300	35.100	20.950	36.000	37.700	20.150	255
138	26-Jun-91 11:00:00.	20.100	34.950	20.750	35.850	37.550	20.000	255
139	26-Jun-91 11:10:00.	20.100	34.800	20.700	35.700	37.400	19.950	255
140	26-Jun-91 11:20:00.	20.050	34.650	20.600	35.550	37.250	19.900	255
141	26-Jun-91 11:30:00.	19.650	34.550	20.350	35.450	37.150	19.600	255
142	26-Jun-91 11:40:00.	19.650	34.400	20.300	35.250	36.950	19.550	255
143	26-Jun-91 11:50:00.	19.600	34.250	20.150	35.150	36.850	19.450	255
144	26-Jun-91 12:00:00.	19.600	34.100	20.150	35.000	36.700	19.450	255

Ch 6  
Ch 5  
Ch 3  
Ch 2

degC



12: 00: 00.  
16: 00: 00.  
20: 00: 00.  
24: 00: 00.  
04: 00: 00.  
08: 00: 00.  
12: 00: 00.

25-Jun-91

## APPENDIX 3.7.12

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 40  
No heat load  
No cooling  
Container in climatic chamber  
Sol-air program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level  
Ch 19 255=Off 254=On

# Channel Readings

Data file - FILE40

**Recorder details:**

Recorder number : 38  
 Squirrel type : 1206

**Run details:**

Run number : 1  
 Channels used : 7  
 Recording Interval : 00:10:00.  
 Non-averaged time interval readings  
 Recording period :  
     Start : 27-Jun-91 10:00:00.  
     Finish : 28-Jun-91 10:00:01.  
 Readings per channel: 145

All readings

Rdg no/	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19
0	27-Jun-91 10:00:00.	18.250	15.150	16.000	15.300	15.300	16.150	255
1	27-Jun-91 10:10:00.	20.050	15.200	18.950	15.300	15.400	19.900	255
2	27-Jun-91 10:20:00.	19.050	15.450	18.600	15.450	15.850	19.000	255
3	27-Jun-91 10:30:00.	18.600	15.700	18.400	15.650	16.150	18.550	255
4	27-Jun-91 10:40:00.	18.550	15.950	18.400	15.750	16.300	18.500	255
5	27-Jun-91 10:50:00.	18.400	16.150	18.300	15.900	16.450	18.350	255
6	27-Jun-91 11:00:00.	18.200	16.300	18.200	16.000	16.550	18.200	255
7	27-Jun-91 11:10:00.	18.100	16.500	18.100	16.100	16.650	18.050	255
8	27-Jun-91 11:20:00.	18.050	16.650	18.050	16.200	16.700	18.000	255
9	27-Jun-91 11:30:00.	18.000	16.750	18.000	16.300	16.750	17.950	255
10	27-Jun-91 11:40:00.	17.700	16.850	17.750	16.400	16.800	17.700	255
11	27-Jun-91 11:50:00.	17.700	16.900	17.700	16.450	16.850	17.700	255
12	27-Jun-91 12:00:00.	17.700	17.000	17.650	16.550	16.850	17.600	255
13	27-Jun-91 12:10:00.	17.450	17.000	17.550	16.600	16.900	17.450	255
14	27-Jun-91 12:20:00.	17.300	17.050	17.350	16.650	16.900	17.300	255
15	27-Jun-91 12:30:00.	17.300	17.050	17.350	16.650	16.900	17.300	255
16	27-Jun-91 12:40:00.	17.300	17.100	17.350	16.700	16.900	17.300	255
17	27-Jun-91 12:50:00.	17.200	17.100	17.250	16.750	16.900	17.200	255
18	27-Jun-91 13:00:00.	17.100	17.100	17.150	16.750	16.900	17.100	255
19	27-Jun-91 13:10:00.	17.100	17.100	17.150	16.750	16.850	17.150	255
20	27-Jun-91 13:20:00.	17.050	17.100	17.100	16.750	16.850	17.050	255
21	27-Jun-91 13:30:00.	15.850	17.050	16.450	16.750	16.850	16.150	255
22	27-Jun-91 13:40:00.	16.750	17.050	16.800	16.750	16.850	16.750	255
23	27-Jun-91 13:50:00.	16.850	17.000	16.900	16.700	16.800	16.900	255
24	27-Jun-91 14:00:00.	16.300	17.000	16.300	16.700	16.800	16.150	255
25	27-Jun-91 14:10:00.	16.800	16.950	16.750	16.700	16.700	16.800	255
26	27-Jun-91 14:20:00.	15.850	16.900	16.000	16.650	16.700	15.850	255
27	27-Jun-91 14:30:00.	16.800	16.850	16.650	16.650	16.650	16.750	255
28	27-Jun-91 14:40:00.	15.850	16.800	16.000	16.650	16.650	15.900	255
29	27-Jun-91 14:50:00.	16.500	16.750	16.500	16.600	16.600	16.500	255
30	27-Jun-91 15:00:00.	16.050	16.700	16.100	16.550	16.550	16.050	255
31	27-Jun-91 15:10:00.	15.800	16.650	16.200	16.500	16.500	16.050	255
32	27-Jun-91 15:20:00.	16.300	16.600	16.200	16.500	16.450	16.200	255
33	27-Jun-91 15:30:00.	15.600	16.550	16.050	16.450	16.400	15.900	255
34	27-Jun-91 15:40:00.	16.300	16.500	16.200	16.400	16.350	16.250	255
35	27-Jun-91 15:50:00.	15.300	16.500	15.900	16.350	16.300	15.650	255

36	27-Jun-91	16:00:00.	16.200	16.450	16.150	16.300	16.300	16.200	255
37	27-Jun-91	16:10:00.	16.600	16.400	16.400	16.300	16.250	16.500	255
38	27-Jun-91	16:20:00.	18.050	16.350	17.300	16.300	16.300	17.750	255
39	27-Jun-91	16:30:00.	19.300	16.400	18.600	16.300	16.500	19.200	255
40	27-Jun-91	16:40:00.	20.650	16.550	19.800	16.500	16.850	20.550	255
41	27-Jun-91	16:50:00.	22.200	16.850	21.150	16.700	17.300	21.950	255
42	27-Jun-91	17:00:00.	23.150	17.150	22.150	17.050	17.800	22.950	255
43	27-Jun-91	17:10:00.	24.050	17.600	23.150	17.400	18.350	23.950	255
44	27-Jun-91	17:20:00.	25.100	18.100	24.150	17.650	18.950	24.900	255
45	27-Jun-91	17:30:00.	25.950	18.600	24.900	18.350	19.550	25.650	255
46	27-Jun-91	17:40:00.	26.550	19.200	25.700	18.850	20.100	26.400	255
47	27-Jun-91	17:50:00.	27.450	19.800	26.600	19.400	20.700	27.300	255
48	27-Jun-91	18:00:00.	28.500	20.350	27.500	19.950	21.400	28.250	255
49	27-Jun-91	18:10:00.	29.000	21.050	28.100	20.500	22.000	28.800	255
50	27-Jun-91	18:20:00.	29.450	21.650	28.700	21.150	22.650	29.300	255
51	27-Jun-91	18:30:00.	30.250	22.300	29.400	21.700	23.300	30.000	255
52	27-Jun-91	18:40:00.	31.000	22.950	30.100	22.300	23.900	30.650	255
53	27-Jun-91	18:50:00.	31.300	23.600	30.550	22.900	24.500	31.100	255
54	27-Jun-91	19:00:00.	31.850	24.250	31.150	23.550	25.100	31.600	255
55	27-Jun-91	19:10:00.	32.200	24.850	31.500	24.150	25.700	31.900	255
56	27-Jun-91	19:20:00.	31.850	25.450	31.400	24.750	26.300	31.600	255
57	27-Jun-91	19:30:00.	31.550	26.000	31.400	25.250	26.750	31.450	255
58	27-Jun-91	19:40:00.	31.500	26.500	31.350	25.750	27.150	31.350	255
59	27-Jun-91	19:50:00.	31.600	26.950	31.350	26.250	27.500	31.350	255
60	27-Jun-91	20:00:00.	31.250	27.350	31.100	26.650	27.750	31.000	255
61	27-Jun-91	20:10:00.	31.600	27.700	31.450	27.000	28.000	31.500	255
62	27-Jun-91	20:20:00.	32.800	28.050	32.200	27.350	28.300	32.450	255
63	27-Jun-91	20:30:00.	33.700	28.350	32.900	27.700	28.700	33.300	255
64	27-Jun-91	20:40:00.	34.450	28.750	33.650	28.100	29.150	34.050	255
65	27-Jun-91	20:50:00.	35.350	29.150	34.550	28.500	29.650	35.000	255
66	27-Jun-91	21:00:00.	36.400	29.600	35.450	28.950	30.150	35.900	255
67	27-Jun-91	21:10:00.	36.750	30.100	35.900	29.500	30.700	36.300	255
68	27-Jun-91	21:20:00.	36.700	30.600	36.100	29.950	31.250	36.350	255
69	27-Jun-91	21:30:00.	36.900	31.100	36.400	30.450	31.650	36.550	255
70	27-Jun-91	21:40:00.	37.200	31.550	36.700	30.900	32.100	36.800	255
71	27-Jun-91	21:50:00.	37.400	32.000	36.900	31.300	32.500	36.950	255
72	27-Jun-91	22:00:00.	37.450	32.450	37.050	31.750	32.900	37.100	255
73	27-Jun-91	22:10:00.	37.650	32.800	37.250	32.100	33.250	37.250	255
74	27-Jun-91	22:20:00.	37.950	33.200	37.450	32.500	33.600	37.500	255
75	27-Jun-91	22:30:00.	37.850	33.550	37.550	32.900	33.900	37.500	255
76	27-Jun-91	22:40:00.	37.900	33.900	37.650	33.200	34.200	37.550	255
77	27-Jun-91	22:50:00.	38.250	34.250	37.900	33.550	34.500	37.800	255
78	27-Jun-91	23:00:00.	38.400	34.550	38.000	33.800	34.750	37.950	255
79	27-Jun-91	23:10:00.	38.400	34.800	38.100	34.100	35.000	38.000	255
80	27-Jun-91	23:20:00.	38.550	35.100	38.300	34.400	35.250	38.200	255
81	27-Jun-91	23:30:00.	38.850	35.350	38.500	34.650	35.500	38.400	255
82	27-Jun-91	23:40:00.	39.000	35.600	38.650	34.900	35.700	38.550	255
83	27-Jun-91	23:50:00.	38.900	35.850	38.700	35.150	35.900	38.550	255
84	27-Jun-91	24:00:00.	39.250	36.050	38.900	35.450	36.150	38.800	255
85	28-Jun-91	00:10:00.	39.300	36.300	39.000	35.600	36.400	38.850	255
86	28-Jun-91	00:20:00.	39.050	36.550	38.900	35.850	36.550	38.650	255
87	28-Jun-91	00:30:00.	38.800	36.700	38.750	36.050	36.700	38.450	255
88	28-Jun-91	00:40:00.	38.700	36.900	38.650	36.200	36.850	38.300	255
89	28-Jun-91	00:50:00.	38.650	37.050	38.550	36.400	36.900	38.200	255
90	28-Jun-91	01:00:00.	38.200	37.150	38.300	36.500	36.950	37.900	255
91	28-Jun-91	01:10:00.	38.050	37.200	38.150	36.600	37.000	37.700	255
92	28-Jun-91	01:20:00.	37.850	37.300	37.900	36.650	37.050	37.450	255
93	28-Jun-91	01:30:00.	37.600	37.300	37.650	36.700	37.000	37.200	255
94	28-Jun-91	01:40:00.	37.200	37.300	37.400	36.700	36.950	36.850	255

95	28-Jun-91	01:50:00.	36.950	37.300	37.100	36.700	36.700	36.600	255
96	28-Jun-91	02:00:00.	36.850	37.250	36.900	36.650	36.800	36.400	255
97	28-Jun-91	02:10:00.	36.450	37.200	36.600	36.600	36.700	36.050	255
98	28-Jun-91	02:20:00.	36.050	37.150	36.300	36.500	36.550	35.750	255
99	28-Jun-91	02:30:00.	35.900	37.050	36.100	36.400	36.450	35.550	255
100	28-Jun-91	02:40:00.	34.950	36.900	35.350	36.300	36.300	34.650	255
101	28-Jun-91	02:50:00.	34.750	36.750	35.000	36.100	36.050	34.400	255
102	28-Jun-91	03:00:00.	34.500	36.550	34.750	35.900	35.800	34.150	255
103	28-Jun-91	03:10:00.	33.700	36.400	34.050	35.700	35.600	33.400	255
104	28-Jun-91	03:20:00.	33.250	36.150	33.700	35.500	35.700	33.050	255
105	28-Jun-91	03:30:00.	32.700	35.900	33.150	35.200	35.000	32.400	255
106	28-Jun-91	03:40:00.	31.950	35.600	32.400	34.900	34.650	31.650	255
107	28-Jun-91	03:50:00.	31.200	35.300	31.750	34.600	34.250	30.950	255
108	28-Jun-91	04:00:00.	30.500	34.950	31.150	34.250	33.850	30.350	255
109	28-Jun-91	04:10:00.	29.950	34.600	30.550	33.850	33.450	29.800	255
110	28-Jun-91	04:20:00.	28.600	34.200	29.300	33.450	33.000	28.350	255
111	28-Jun-91	04:30:00.	28.450	33.750	29.050	33.000	32.450	28.250	255
112	28-Jun-91	04:40:00.	26.750	33.300	27.700	32.550	32.000	26.700	255
113	28-Jun-91	04:50:00.	27.000	32.800	27.550	32.050	31.450	26.800	255
114	28-Jun-91	05:00:00.	25.850	32.300	26.550	31.600	30.950	25.600	255
115	28-Jun-91	05:10:00.	24.850	31.750	25.550	31.050	30.350	24.650	255
116	28-Jun-91	05:20:00.	24.850	31.250	25.350	30.550	29.750	24.650	255
117	28-Jun-91	05:30:00.	24.400	30.650	24.950	29.950	29.200	24.300	255
118	28-Jun-91	05:40:00.	23.800	30.150	24.400	29.450	28.650	23.750	255
119	28-Jun-91	05:50:00.	23.500	29.600	24.100	25.900	28.150	23.450	255
120	28-Jun-91	06:00:00.	23.150	29.050	23.700	28.400	27.700	23.050	255
121	28-Jun-91	06:10:00.	22.850	28.550	23.400	27.900	27.200	22.750	255
122	28-Jun-91	06:20:00.	22.850	28.050	23.150	27.450	26.800	22.650	255
123	28-Jun-91	06:30:00.	22.450	27.600	22.850	27.000	26.350	22.350	255
124	28-Jun-91	06:40:00.	22.300	27.150	22.650	26.600	25.950	22.150	255
125	28-Jun-91	06:50:00.	22.050	26.700	22.450	26.200	25.600	21.950	255
126	28-Jun-91	07:00:00.	21.750	26.300	22.150	25.800	25.200	21.700	255
127	28-Jun-91	07:10:00.	21.800	25.900	22.050	25.450	24.900	21.650	255
128	28-Jun-91	07:20:00.	21.700	25.550	21.900	25.100	24.550	21.550	255
129	28-Jun-91	07:30:00.	21.500	25.150	21.700	24.800	24.300	21.300	255
130	28-Jun-91	07:40:00.	21.250	24.850	21.450	24.450	24.000	21.100	255
131	28-Jun-91	07:50:00.	20.900	24.550	21.250	24.150	23.650	20.850	255
132	28-Jun-91	08:00:00.	20.700	24.250	21.050	23.850	23.450	20.650	255
133	28-Jun-91	08:10:00.	20.700	23.950	20.850	23.600	23.150	20.500	255
134	28-Jun-91	08:20:00.	20.550	23.650	20.800	23.300	22.900	20.500	255
135	28-Jun-91	08:30:00.	20.450	23.400	20.600	23.050	22.650	20.300	255
136	28-Jun-91	08:40:00.	20.200	23.100	20.450	22.800	22.400	20.150	255
137	28-Jun-91	08:50:00.	20.200	22.850	20.350	22.600	22.150	20.050	255
138	28-Jun-91	09:00:00.	20.100	22.650	20.200	22.350	21.950	19.950	255
139	28-Jun-91	09:10:00.	19.750	22.400	20.000	22.100	21.800	19.700	255
140	28-Jun-91	09:20:00.	19.700	22.150	19.950	21.900	21.600	19.650	255
141	28-Jun-91	09:30:00.	19.750	21.950	19.900	21.700	21.400	19.650	255
142	28-Jun-91	09:40:00.	19.450	21.750	19.650	21.550	21.200	19.400	255
143	28-Jun-91	09:50:00.	19.200	21.550	19.450	21.350	21.050	19.150	255
144	28-Jun-91	10:00:00.	19.250	21.400	19.450	21.200	20.850	19.200	255

Ch 2 Ch 3 Ch 5 Ch 6

degC



## APPENDIX 3.7.13

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 41  
No heat load  
No cooling  
Container in climatic chamber  
Stepped program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level  
Ch 19 255=Off 254=On

## Channel Readings

Data file - FILE41

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 28-Jun-91 16:00:00.  
    Finish : 29-Jun-91 22:00:01.  
Readings per channel: 181

All readings

Rdg no!	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19
0	28-Jun-91 16:00:00.	21.000	19.550	20.700	19.650	19.800	20.850	255
1	28-Jun-91 16:10:00.	23.850	19.650	23.000	19.750	20.000	23.750	255
2	28-Jun-91 16:20:00.	21.650	19.900	21.600	19.950	20.350	21.600	255
3	28-Jun-91 16:30:00.	21.950	20.050	21.750	20.050	20.500	21.850	255
4	28-Jun-91 16:40:00.	21.800	20.200	21.750	20.150	20.550	21.800	255
5	28-Jun-91 16:50:00.	21.950	20.350	21.800	20.300	20.650	21.800	255
6	28-Jun-91 17:00:00.	21.950	20.500	21.750	20.350	20.700	21.800	255
7	28-Jun-91 17:10:00.	21.950	20.600	21.750	20.450	20.750	21.800	255
8	28-Jun-91 17:20:00.	21.650	20.700	21.650	20.550	20.850	21.600	255
9	28-Jun-91 17:30:00.	21.850	20.750	21.800	20.600	20.900	21.800	255
10	28-Jun-91 17:40:00.	21.800	20.850	21.750	20.700	20.950	21.750	255
11	28-Jun-91 17:50:00.	21.700	20.950	21.700	20.750	21.050	21.700	255
12	28-Jun-91 18:00:00.	21.900	21.000	21.800	20.850	21.100	21.800	255
13	28-Jun-91 18:10:00.	21.750	21.100	21.750	20.900	21.150	21.750	255
14	28-Jun-91 18:20:00.	21.700	21.150	21.700	20.950	21.200	21.700	255
15	28-Jun-91 18:30:00.	21.800	21.200	21.800	21.000	21.250	21.750	255
16	28-Jun-91 18:40:00.	21.800	21.250	21.750	21.050	21.250	21.750	255
17	28-Jun-91 18:50:00.	21.750	21.250	21.750	21.100	21.300	21.700	255
18	28-Jun-91 19:00:00.	21.850	21.300	21.900	21.150	21.300	21.750	255
19	28-Jun-91 19:10:00.	24.300	21.350	23.650	21.200	21.350	24.150	255
20	28-Jun-91 19:20:00.	23.450	21.450	23.200	21.350	21.600	23.400	255
21	28-Jun-91 19:30:00.	23.850	21.600	23.550	21.450	21.850	23.700	255
22	28-Jun-91 19:40:00.	23.650	21.800	23.550	21.600	22.050	23.650	255
23	28-Jun-91 19:50:00.	23.800	21.950	23.700	21.750	22.150	23.700	255
24	28-Jun-91 20:00:00.	24.000	22.050	23.750	21.900	22.300	23.800	255
25	28-Jun-91 20:10:00.	23.850	22.200	23.700	22.000	22.450	23.750	255
26	28-Jun-91 20:20:00.	23.700	22.350	23.700	22.150	22.550	23.650	255
27	28-Jun-91 20:30:00.	23.900	22.450	23.800	22.250	22.650	23.800	255
28	28-Jun-91 20:40:00.	24.050	22.600	23.800	22.350	22.700	23.800	255
29	28-Jun-91 20:50:00.	23.850	22.700	23.750	22.450	22.800	23.700	255
30	28-Jun-91 21:00:00.	23.650	22.750	23.700	22.550	22.850	23.650	255
31	28-Jun-91 21:10:00.	23.750	22.850	23.750	22.650	22.900	23.650	255
32	28-Jun-91 21:20:00.	23.950	22.900	23.750	22.700	22.950	23.700	255
33	28-Jun-91 21:30:00.	23.650	23.000	23.700	22.800	23.050	23.600	255
34	28-Jun-91 21:40:00.	23.800	23.050	23.800	22.850	23.100	23.700	255
35	29-Jun-91 21:50:00.	23.850	23.100	23.800	22.900	23.150	23.700	255

36	28-Jun-91	22:00:00.	23.900	23.150	23.750	22.950	23.150	23.700	255
37	28-Jun-91	22:10:00.	25.800	23.250	25.450	23.050	23.300	25.800	255
38	28-Jun-91	22:20:00.	25.550	23.400	25.250	23.200	23.600	25.350	255
39	28-Jun-91	22:30:00.	25.950	23.550	25.600	23.400	23.800	25.700	255
40	28-Jun-91	22:40:00.	25.850	23.700	25.600	23.500	24.000	25.650	255
41	28-Jun-91	22:50:00.	25.700	23.900	25.650	23.650	24.150	25.600	255
42	28-Jun-91	23:00:00.	25.850	24.050	25.750	23.800	24.250	25.700	255
43	28-Jun-91	23:10:00.	26.050	24.200	25.900	23.950	24.350	25.800	255
44	28-Jun-91	23:20:00.	25.800	24.300	25.650	24.100	24.450	25.600	255
45	28-Jun-91	23:30:00.	25.700	24.400	25.700	24.200	24.550	25.600	255
46	28-Jun-91	23:40:00.	25.950	24.550	25.850	24.300	24.650	25.800	255
47	28-Jun-91	23:50:00.	25.950	24.650	25.800	24.400	24.700	25.700	255
48	28-Jun-91	24:00:00.	25.750	24.750	25.700	24.450	24.800	25.600	255
49	29-Jun-91	00:10:00.	25.800	24.850	25.850	24.550	24.950	25.700	255
50	29-Jun-91	00:20:00.	26.050	24.900	25.900	24.650	24.900	25.850	255
51	29-Jun-91	00:30:00.	26.050	24.950	25.850	24.700	24.950	25.800	255
52	29-Jun-91	00:40:00.	25.700	25.000	25.750	24.750	25.000	25.600	255
53	29-Jun-91	00:50:00.	25.700	25.050	25.750	24.850	25.050	25.550	255
54	29-Jun-91	01:00:00.	26.000	25.150	25.850	24.900	25.100	25.750	255
55	29-Jun-91	01:10:00.	27.700	25.200	27.300	24.950	25.200	27.600	255
56	29-Jun-91	01:20:00.	27.800	25.300	27.550	25.100	25.500	27.650	255
57	29-Jun-91	01:30:00.	27.800	25.500	27.600	25.250	25.700	27.650	255
58	29-Jun-91	01:40:00.	28.050	25.650	27.700	25.400	25.900	27.750	255
59	29-Jun-91	01:50:00.	27.800	25.850	27.650	25.550	26.050	27.600	255
60	29-Jun-91	02:00:00.	27.700	26.000	27.700	25.700	26.150	27.550	255
61	29-Jun-91	02:10:00.	27.950	26.150	27.850	25.850	26.300	27.700	255
62	29-Jun-91	02:20:00.	27.950	26.250	27.800	25.950	26.400	27.700	255
63	29-Jun-91	02:30:00.	27.750	26.400	27.700	26.100	26.500	27.550	255
64	29-Jun-91	02:40:00.	27.700	26.500	27.750	26.200	26.550	27.600	255
65	29-Jun-91	02:50:00.	27.900	26.600	27.800	26.300	26.650	27.650	255
66	29-Jun-91	03:00:00.	28.050	26.700	27.800	26.400	26.700	27.750	255
67	29-Jun-91	03:10:00.	27.700	26.800	27.700	26.450	26.800	27.550	255
68	29-Jun-91	03:20:00.	27.800	26.950	27.800	26.550	26.850	27.600	255
69	29-Jun-91	03:30:00.	28.050	26.950	27.900	26.600	26.900	27.750	255
70	29-Jun-91	03:40:00.	27.900	27.000	27.800	26.700	26.950	27.650	255
71	29-Jun-91	03:50:00.	27.700	27.050	27.750	26.750	27.000	27.550	255
72	29-Jun-91	04:00:00.	27.800	27.100	27.800	26.800	27.050	27.600	255
73	29-Jun-91	04:10:00.	29.750	27.150	29.300	26.850	27.150	29.550	255
74	29-Jun-91	04:20:00.	29.800	27.300	29.500	27.000	27.450	29.600	255
75	29-Jun-91	04:30:00.	29.700	27.450	29.500	27.200	27.650	29.500	255
76	29-Jun-91	04:40:00.	29.850	27.650	29.600	27.350	27.800	29.550	255
77	29-Jun-91	04:50:00.	29.850	27.800	29.600	27.500	27.950	29.550	255
78	29-Jun-91	05:00:00.	29.650	27.950	29.550	27.650	28.100	29.450	255
79	29-Jun-91	05:10:00.	29.650	28.050	29.600	27.750	28.200	29.450	255
80	29-Jun-91	05:20:00.	29.800	28.200	29.650	27.900	28.300	29.500	255
81	29-Jun-91	05:30:00.	29.750	28.300	29.600	28.000	28.400	29.450	255
82	29-Jun-91	05:40:00.	29.500	28.400	29.550	28.100	28.450	29.300	255
83	29-Jun-91	05:50:00.	29.700	28.500	29.650	28.200	28.550	29.500	255
84	29-Jun-91	06:00:00.	29.750	28.600	29.650	28.300	28.600	29.450	255
85	29-Jun-91	06:10:00.	29.750	28.650	29.600	28.350	28.650	29.450	255
86	29-Jun-91	06:20:00.	29.650	28.750	29.650	28.450	28.700	29.450	255
87	29-Jun-91	06:30:00.	29.800	28.800	29.700	28.500	28.750	29.550	255
88	29-Jun-91	06:40:00.	29.850	28.850	29.700	28.550	28.800	29.500	255
89	29-Jun-91	06:50:00.	29.600	28.900	29.550	28.600	28.850	29.350	255
90	29-Jun-91	07:00:00.	29.600	28.950	29.650	28.650	28.850	29.400	255
91	29-Jun-91	07:10:00.	31.800	29.000	31.350	28.750	29.000	31.550	255
92	29-Jun-91	07:20:00.	31.650	29.200	31.150	28.900	29.300	31.200	255
93	29-Jun-91	07:30:00.	31.500	29.350	31.300	29.000	29.500	31.250	255
94	29-Jun-91	07:40:00.	31.550	29.500	31.400	29.200	29.650	31.300	255

95	29-Jun-91	07:50:00.	31.850	29.650	31.550	29.350	29.800	31.450	255
96	29-Jun-91	08:00:00.	31.650	29.800	31.500	29.500	29.900	31.350	255
97	29-Jun-91	08:10:00.	31.450	29.950	31.450	29.600	30.050	31.250	255
98	29-Jun-91	08:20:00.	31.600	30.100	31.550	29.700	30.150	31.350	255
99	29-Jun-91	08:30:00.	31.850	30.200	31.650	29.850	30.250	31.500	255
100	29-Jun-91	08:40:00.	31.900	30.350	31.700	29.950	30.350	31.600	255
101	29-Jun-91	08:50:00.	31.650	30.450	31.650	30.050	30.400	31.500	255
102	29-Jun-91	09:00:00.	31.650	30.500	31.650	30.150	30.500	31.450	255
103	29-Jun-91	09:10:00.	32.100	30.600	31.850	30.200	30.550	31.700	255
104	29-Jun-91	09:20:00.	31.900	30.700	31.800	30.300	30.600	31.600	255
105	29-Jun-91	09:30:00.	31.650	30.750	31.750	30.400	30.700	31.500	255
106	29-Jun-91	09:40:00.	31.900	30.850	31.850	30.450	30.750	31.650	255
107	29-Jun-91	09:50:00.	32.000	30.900	31.850	30.500	30.800	31.650	255
108	29-Jun-91	10:00:00.	31.750	30.950	31.750	30.550	30.850	31.550	255
109	29-Jun-91	10:10:00.	33.550	31.050	33.300	30.650	30.950	33.400	255
110	29-Jun-91	10:20:00.	33.950	31.200	33.600	30.800	31.250	33.650	255
111	29-Jun-91	10:30:00.	34.000	31.350	33.600	31.000	31.500	33.600	255
112	29-Jun-91	10:40:00.	33.700	31.550	33.600	31.150	31.650	33.500	255
113	29-Jun-91	10:50:00.	33.700	31.700	33.650	31.300	31.800	33.500	255
114	29-Jun-91	11:00:00.	34.000	31.850	33.800	31.450	31.950	33.650	255
115	29-Jun-91	11:10:00.	33.950	32.000	33.750	31.550	32.050	33.600	255
116	29-Jun-91	11:20:00.	33.750	32.150	33.700	31.700	32.200	33.550	255
117	29-Jun-91	11:30:00.	33.850	32.250	33.850	31.800	32.250	33.650	255
118	29-Jun-91	11:40:00.	34.100	32.400	33.900	31.900	32.350	33.750	255
119	29-Jun-91	11:50:00.	33.900	32.500	33.750	32.050	32.450	33.600	255
120	29-Jun-91	12:00:00.	33.700	32.600	33.750	32.150	32.500	33.550	255
121	29-Jun-91	12:10:00.	34.000	32.700	33.900	32.250	32.600	33.700	255
122	29-Jun-91	12:20:00.	34.150	32.750	33.900	32.300	32.650	33.750	255
123	29-Jun-91	12:30:00.	33.800	32.800	33.750	32.350	32.700	33.600	255
124	29-Jun-91	12:40:00.	33.700	32.900	33.750	32.450	32.750	33.550	255
125	29-Jun-91	12:50:00.	33.950	32.950	33.850	32.500	32.800	33.650	255
126	29-Jun-91	13:00:00.	33.900	33.000	33.800	32.550	32.850	33.650	255
127	29-Jun-91	13:10:00.	35.400	33.100	35.200	32.650	32.950	35.300	255
128	29-Jun-91	13:20:00.	35.700	33.200	35.500	32.800	33.250	35.550	255
129	29-Jun-91	13:30:00.	35.950	33.400	35.700	33.000	33.500	35.650	255
130	29-Jun-91	13:40:00.	36.000	33.550	35.700	33.150	33.650	35.700	255
131	29-Jun-91	13:50:00.	35.700	33.700	35.700	33.300	33.800	35.550	255
132	29-Jun-91	14:00:00.	35.800	33.900	35.750	33.450	33.950	35.600	255
133	29-Jun-91	14:10:00.	36.250	34.050	35.900	33.600	34.050	35.850	255
134	29-Jun-91	14:20:00.	35.850	34.150	35.750	33.700	34.150	35.600	255
135	29-Jun-91	14:30:00.	35.750	34.300	35.750	33.800	34.300	35.550	255
136	29-Jun-91	14:40:00.	35.950	34.450	35.900	33.900	34.400	35.700	255
137	29-Jun-91	14:50:00.	36.100	34.550	35.900	34.000	34.450	35.750	255
138	29-Jun-91	15:00:00.	35.750	34.600	35.750	34.100	34.550	35.600	255
139	29-Jun-91	15:10:00.	35.700	34.700	35.750	34.200	34.600	35.550	255
140	29-Jun-91	15:20:00.	36.100	34.800	35.950	34.300	34.650	35.800	255
141	29-Jun-91	15:30:00.	36.000	34.850	35.850	34.350	34.700	35.700	255
142	29-Jun-91	15:40:00.	35.750	34.900	35.750	34.450	34.750	35.550	255
143	29-Jun-91	15:50:00.	35.750	34.950	35.800	34.500	34.800	35.600	255
144	29-Jun-91	16:00:00.	36.100	35.000	35.950	34.550	34.850	35.750	255
145	29-Jun-91	16:10:00.	37.450	35.100	37.150	34.600	34.950	37.300	255
146	29-Jun-91	16:20:00.	37.650	35.250	37.400	34.750	35.250	37.450	255
147	29-Jun-91	16:30:00.	37.850	35.400	37.650	34.950	35.500	37.600	255
148	29-Jun-91	16:40:00.	38.150	35.550	37.800	35.100	35.650	37.750	255
149	29-Jun-91	16:50:00.	37.900	35.700	37.700	35.250	35.750	37.650	255
150	29-Jun-91	17:00:00.	37.700	35.850	37.700	35.400	35.900	37.550	255
151	29-Jun-91	17:10:00.	37.900	36.000	37.750	35.500	36.000	37.600	255
152	29-Jun-91	17:20:00.	38.100	36.150	37.800	35.600	36.100	37.700	255
153	29-Jun-91	17:30:00.	37.650	36.250	37.700	35.750	36.200	37.450	255

154	29-Jun-91 17:40:00.	37.700	36.400	37.700	35.850	36.300	37.450	255
155	29-Jun-91 17:50:00.	37.850	36.450	37.700	35.950	36.350	37.500	255
156	29-Jun-91 18:00:00.	37.800	36.550	37.700	36.050	36.450	37.500	255
157	29-Jun-91 18:10:00.	37.600	36.650	37.650	36.100	36.500	37.400	255
158	29-Jun-91 18:20:00.	37.800	36.700	37.750	36.200	36.550	37.550	255
159	29-Jun-91 18:30:00.	37.950	36.800	37.800	36.250	36.600	37.600	255
160	29-Jun-91 18:40:00.	37.650	36.850	37.650	36.300	36.650	37.400	255
161	29-Jun-91 18:50:00.	37.650	36.900	37.650	36.400	36.700	37.400	255
162	29-Jun-91 19:00:00.	37.800	36.950	37.700	36.450	36.700	37.500	255
163	29-Jun-91 19:10:00.	39.550	37.000	39.100	36.500	36.800	39.250	255
164	29-Jun-91 19:20:00.	39.550	37.150	39.250	36.650	37.150	39.300	255
165	29-Jun-91 19:30:00.	39.600	37.300	39.400	36.800	37.350	39.300	255
166	29-Jun-91 19:40:00.	39.750	37.450	39.450	36.950	37.500	39.350	255
167	29-Jun-91 19:50:00.	39.700	37.600	39.450	37.150	37.650	39.300	255
168	29-Jun-91 20:00:00.	39.450	37.700	39.450	37.250	37.750	39.200	255
169	29-Jun-91 20:10:00.	39.600	37.900	39.450	37.400	37.850	39.250	255
170	29-Jun-91 20:20:00.	39.700	37.950	39.500	37.450	37.950	39.300	255
171	29-Jun-91 20:30:00.	39.700	38.100	39.500	37.600	38.000	39.300	255
172	29-Jun-91 20:40:00.	39.500	38.200	39.450	37.700	38.100	39.150	255
173	29-Jun-91 20:50:00.	39.600	38.300	39.500	37.800	38.150	39.250	255
174	29-Jun-91 21:00:00.	39.700	38.350	39.500	37.850	38.200	39.250	255
175	29-Jun-91 21:10:00.	39.650	38.450	39.500	37.900	38.300	39.250	255
176	29-Jun-91 21:20:00.	39.500	38.500	39.500	38.000	38.300	39.150	255
177	29-Jun-91 21:30:00.	39.650	38.550	39.600	38.050	38.400	39.300	255
178	29-Jun-91 21:40:00.	39.700	38.600	39.550	38.100	38.400	39.250	255
179	29-Jun-91 21:50:00.	39.650	38.650	39.500	38.150	38.450	39.250	255
180	29-Jun-91 22:00:00.	39.500	38.700	39.500	38.200	38.450	39.150	255

CH 6  
CH 5  
CH 3  
CH 2

degC

55.00  
50.00  
45.00  
40.00  
35.00  
30.00  
25.00  
20.00  
15.00  
10.00



12: 00: 00.  
28-Jun-91

24: 00: 00.

12: 00: 00.

00: 00: 00.  
30-Jun-91

## APPENDIX 3.7.14

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 42  
60 Watt heat load  
No cooling  
Container in climatic chamber  
Sol-air program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level  
Ch 19 255=Off 254=On

## Channel Readings

Data file - FILE42

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

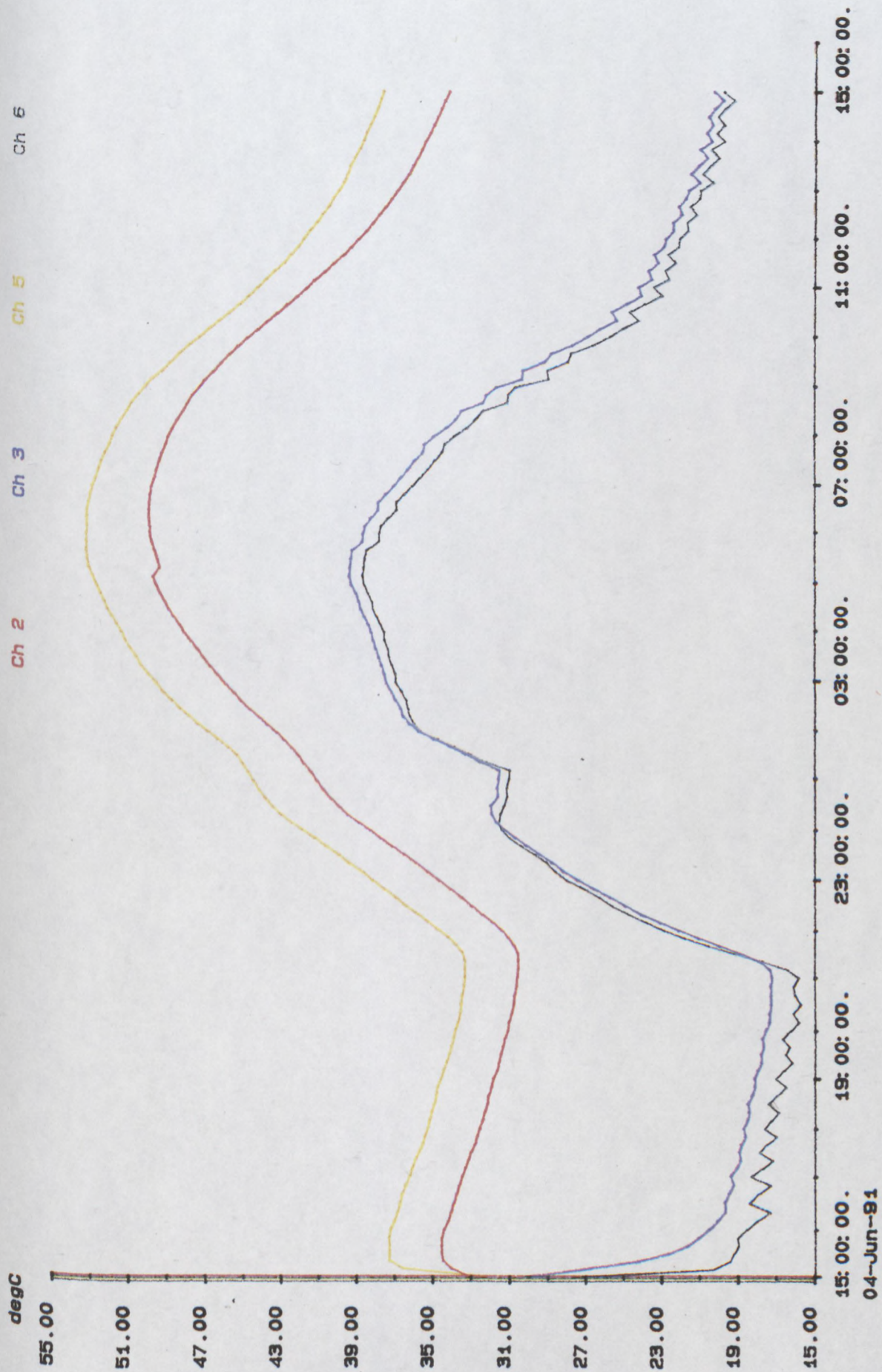
Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 01-Jul-91 13:00:00.  
    Finish : 02-Jul-91 13:00:01.  
Readings per channel: 145

All readings

Rdg no	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19
0	01-Jul-91 13:00:00.	19.700	20.650	19.450	21.950	23.700	19.600	255
1	01-Jul-91 13:10:00.	19.550	21.300	20.250	22.650	24.350	20.350	255
2	01-Jul-91 13:20:00.	19.500	21.900	19.600	23.300	25.000	19.450	255
3	01-Jul-91 13:30:00.	19.000	22.450	19.100	23.750	25.350	18.850	255
4	01-Jul-91 13:40:00.	19.350	22.900	19.400	24.150	25.600	19.200	255
5	01-Jul-91 13:50:00.	18.700	23.250	18.900	24.450	25.850	18.650	255
6	01-Jul-91 14:00:00.	18.100	23.550	18.250	24.750	26.100	17.950	255
7	01-Jul-91 14:10:00.	18.750	23.800	18.800	24.950	26.250	18.650	255
8	01-Jul-91 14:20:00.	18.350	24.050	18.450	25.150	26.400	18.250	255
9	01-Jul-91 14:30:00.	17.400	24.200	17.900	25.250	26.500	17.450	255
10	01-Jul-91 14:40:00.	18.100	24.350	18.300	25.400	26.600	18.050	255
11	01-Jul-91 14:50:00.	17.700	24.500	17.950	25.500	26.650	17.650	255
12	01-Jul-91 15:00:00.	18.350	24.600	18.300	25.550	26.700	18.150	255
13	01-Jul-91 15:10:00.	17.700	24.650	17.900	25.550	26.750	17.700	255
14	01-Jul-91 15:20:00.	16.700	24.750	17.400	25.650	26.750	16.950	255
15	01-Jul-91 15:30:00.	17.700	24.800	17.900	25.700	26.800	17.650	255
16	01-Jul-91 15:40:00.	17.500	24.800	17.650	25.750	26.800	17.350	255
17	01-Jul-91 15:50:00.	17.400	24.850	17.850	25.750	26.800	17.500	255
18	01-Jul-91 16:00:00.	17.400	24.850	17.650	25.750	26.800	17.350	255
19	01-Jul-91 16:10:00.	16.900	24.900	17.200	25.750	26.850	16.850	255
20	01-Jul-91 16:20:00.	17.600	24.900	17.750	25.750	26.800	17.500	255
21	01-Jul-91 16:30:00.	17.250	24.900	17.450	25.700	26.800	17.200	255
22	01-Jul-91 16:40:00.	16.650	24.850	17.000	25.650	26.750	16.600	255
23	01-Jul-91 16:50:00.	17.300	24.850	17.500	25.650	26.700	17.200	255
24	01-Jul-91 17:00:00.	16.850	24.800	17.100	25.600	26.850	16.850	255
25	01-Jul-91 17:10:00.	16.350	24.800	16.700	25.550	26.600	16.350	255
26	01-Jul-91 17:20:00.	17.000	24.750	17.100	25.500	26.550	16.900	255
27	01-Jul-91 17:30:00.	16.650	24.700	16.850	25.450	26.500	16.600	255
28	01-Jul-91 17:40:00.	15.950	24.650	16.400	25.400	26.500	16.050	255
29	01-Jul-91 17:50:00.	17.100	24.600	17.050	25.350	26.450	16.900	255
30	01-Jul-91 18:00:00.	16.450	24.550	16.700	25.300	26.400	16.400	255
31	01-Jul-91 18:10:00.	15.950	24.500	16.300	25.250	26.350	15.950	255
32	01-Jul-91 18:20:00.	16.650	24.450	16.700	25.200	26.300	16.500	255
33	01-Jul-91 18:30:00.	16.200	24.400	16.450	25.150	26.250	16.150	255
34	01-Jul-91 18:40:00.	16.500	24.400	16.600	25.100	26.200	16.400	255
35	01-Jul-91 18:50:00.	16.200	24.350	16.450	25.050	26.150	16.150	255

36	01-Jul-91	19:00:00.	16,650	24,300	16,650	25,000	26,100	16,500	255
37	01-Jul-91	19:10:00.	16,350	24,250	16,500	24,950	26,100	16,250	255
38	01-Jul-91	19:20:00.	18,500	24,200	18,200	25,000	26,100	18,400	255
39	01-Jul-91	19:30:00.	19,650	24,300	19,200	25,100	26,350	19,500	255
40	01-Jul-91	19:40:00.	21,000	24,450	20,300	25,300	26,700	20,700	255
41	01-Jul-91	19:50:00.	22,200	24,700	21,450	25,650	27,100	21,950	255
42	01-Jul-91	20:00:00.	23,300	25,000	22,550	26,000	27,550	23,100	255
43	01-Jul-91	20:10:00.	24,200	25,400	23,550	26,450	28,100	24,000	255
44	01-Jul-91	20:20:00.	25,200	25,900	24,500	26,950	28,600	24,950	255
45	01-Jul-91	20:30:00.	26,050	26,450	25,300	27,450	29,200	25,750	255
46	01-Jul-91	20:40:00.	26,700	27,000	26,150	28,000	29,750	26,500	255
47	01-Jul-91	20:50:00.	27,550	27,550	27,000	28,550	30,400	27,350	255
48	01-Jul-91	21:00:00.	28,700	28,150	27,900	29,150	31,000	28,350	255
49	01-Jul-91	21:10:00.	29,200	28,750	28,500	29,750	31,600	28,850	255
50	01-Jul-91	21:20:00.	29,500	29,450	29,050	30,400	32,250	29,300	255
51	01-Jul-91	21:30:00.	30,200	30,050	29,750	31,000	32,900	29,950	255
52	01-Jul-91	21:40:00.	31,000	30,700	30,450	31,600	33,500	30,650	255
53	01-Jul-91	21:50:00.	31,650	31,300	31,050	32,200	34,150	31,300	255
54	01-Jul-91	22:00:00.	31,850	31,900	31,500	32,800	34,750	31,800	255
55	01-Jul-91	22:10:00.	31,900	32,550	31,750	33,400	35,350	31,700	255
56	01-Jul-91	22:20:00.	32,000	33,150	31,800	34,000	35,900	31,650	255
57	01-Jul-91	22:30:00.	31,800	33,700	31,750	34,550	36,400	31,500	255
58	01-Jul-91	22:40:00.	31,450	34,250	31,600	35,000	36,800	31,250	255
59	01-Jul-91	22:50:00.	31,550	34,650	31,650	35,450	37,150	31,300	255
60	01-Jul-91	23:00:00.	31,400	35,050	31,500	35,800	37,400	31,050	255
61	01-Jul-91	23:10:00.	32,100	35,450	31,900	36,100	37,650	31,750	255
62	01-Jul-91	23:20:00.	32,800	35,750	32,550	36,450	37,950	32,500	255
63	01-Jul-91	23:30:00.	33,700	36,050	33,400	36,800	38,350	33,400	255
64	01-Jul-91	23:40:00.	34,850	36,450	34,250	37,200	38,800	34,350	255
65	01-Jul-91	23:50:00.	35,600	36,900	35,000	37,650	39,300	35,150	255
66	01-Jul-91	24:00:00.	36,250	37,350	35,700	38,100	39,800	35,900	255
67	02-Jul-91	00:10:00.	36,700	37,850	36,300	38,550	40,350	36,300	255
68	02-Jul-91	00:20:00.	36,950	38,350	36,550	39,050	40,850	36,450	255
69	02-Jul-91	00:30:00.	37,150	38,800	36,800	39,550	41,300	36,700	255
70	02-Jul-91	00:40:00.	37,100	39,350	36,950	39,950	41,750	36,700	255
71	02-Jul-91	00:50:00.	37,350	39,750	37,200	40,400	42,100	36,950	255
72	02-Jul-91	01:00:00.	37,700	40,150	37,500	40,750	42,450	37,200	255
73	02-Jul-91	01:10:00.	37,800	40,550	37,600	41,150	42,750	37,300	255
74	02-Jul-91	01:20:00.	37,800	40,950	37,700	41,500	43,150	37,400	255
75	02-Jul-91	01:30:00.	37,900	41,250	37,850	41,800	43,450	37,450	255
76	02-Jul-91	01:40:00.	38,050	41,600	38,000	42,150	43,750	37,600	255
77	02-Jul-91	01:50:00.	38,400	41,950	38,200	42,450	44,050	37,900	255
78	02-Jul-91	02:00:00.	38,200	42,200	38,300	42,750	44,300	37,850	255
79	02-Jul-91	02:10:00.	38,450	42,500	38,450	43,050	44,500	38,050	255
80	02-Jul-91	02:20:00.	38,650	42,750	38,600	43,300	44,750	38,200	255
81	02-Jul-91	02:30:00.	38,900	43,050	38,800	43,500	45,000	38,400	255
82	02-Jul-91	02:40:00.	39,000	43,250	38,950	43,750	45,200	38,550	255
83	02-Jul-91	02:50:00.	39,000	43,450	39,050	43,950	45,400	38,600	255
84	02-Jul-91	03:00:00.	39,350	43,700	39,350	44,200	45,600	38,850	255
85	02-Jul-91	03:10:00.	39,250	43,900	39,350	44,350	45,800	38,800	255
86	02-Jul-91	03:20:00.	39,000	44,100	39,200	44,550	46,000	38,600	255
87	02-Jul-91	03:30:00.	38,750	44,250	39,000	44,750	46,100	38,400	255
88	02-Jul-91	03:40:00.	38,750	44,400	39,000	44,900	46,250	38,350	255
89	02-Jul-91	03:50:00.	38,450	44,550	38,700	45,000	46,250	38,000	255
90	02-Jul-91	04:00:00.	38,400	44,650	38,650	45,100	46,300	37,950	255
91	02-Jul-91	04:10:00.	38,050	44,750	38,400	45,150	46,350	37,650	255
92	02-Jul-91	04:20:00.	37,900	44,800	38,200	45,200	46,400	37,450	255
93	02-Jul-91	04:30:00.	37,800	44,850	38,050	45,200	46,450	37,300	255
94	02-Jul-91	04:40:00.	37,600	44,850	37,900	45,200	46,400	37,150	255

95	02-Jul-91 04:50:00.	37,300	44,800	37,700	45,150	46,300	36,900	255
96	02-Jul-91 05:00:00.	36,650	44,750	37,150	45,100	46,200	36,200	255
97	02-Jul-91 05:10:00.	36,600	44,700	36,950	45,000	46,000	36,150	255
98	02-Jul-91 05:20:00.	35,900	44,600	36,450	44,900	45,900	35,550	255
99	02-Jul-91 05:30:00.	35,250	44,500	35,900	44,750	45,700	34,900	255
100	02-Jul-91 05:40:00.	35,250	44,300	35,750	44,550	45,450	34,850	255
101	02-Jul-91 05:50:00.	34,450	44,150	35,200	44,350	45,250	34,100	255
102	02-Jul-91 06:00:00.	34,550	43,950	35,050	44,150	45,050	34,100	255
103	02-Jul-91 06:10:00.	33,800	43,750	34,500	43,950	44,800	33,450	255
104	02-Jul-91 06:20:00.	32,850	43,550	33,700	43,700	44,550	32,550	255
105	02-Jul-91 06:30:00.	32,500	43,300	33,200	43,450	44,200	32,100	255
106	02-Jul-91 06:40:00.	31,700	43,000	32,600	43,150	43,800	31,450	255
107	02-Jul-91 06:50:00.	31,250	42,850	31,950	42,800	43,450	30,900	255
108	02-Jul-91 07:00:00.	30,600	42,300	31,350	42,450	43,050	30,300	255
109	02-Jul-91 07:10:00.	29,500	41,950	30,550	42,050	42,650	29,300	255
110	02-Jul-91 07:20:00.	29,100	41,500	30,000	41,650	42,150	28,850	255
111	02-Jul-91 07:30:00.	28,000	41,100	29,000	41,250	41,700	27,800	255
112	02-Jul-91 07:40:00.	26,800	40,600	28,000	40,750	41,150	26,700	255
113	02-Jul-91 07:50:00.	26,900	40,150	27,750	40,300	40,650	26,600	255
114	02-Jul-91 08:00:00.	25,600	39,600	26,700	39,750	40,050	25,400	255
115	02-Jul-91 08:10:00.	24,450	39,100	25,600	39,200	39,500	24,350	255
116	02-Jul-91 08:20:00.	24,850	38,500	25,600	38,650	38,900	24,600	255
117	02-Jul-91 08:30:00.	24,300	37,950	25,150	38,150	38,400	24,150	255
118	02-Jul-91 08:40:00.	24,100	37,450	24,900	37,600	37,900	23,900	255
119	02-Jul-91 08:50:00.	23,500	36,900	24,300	37,100	37,400	23,400	255
120	02-Jul-91 09:00:00.	23,250	36,400	23,950	36,600	36,950	23,050	255
121	02-Jul-91 09:10:00.	22,850	35,900	23,650	36,150	36,500	22,700	255
122	02-Jul-91 09:20:00.	22,750	35,450	23,450	35,650	36,050	22,600	255
123	02-Jul-91 09:30:00.	22,600	34,950	23,300	35,200	35,600	22,450	255
124	02-Jul-91 09:40:00.	22,600	34,500	23,100	34,800	35,300	22,350	255
125	02-Jul-91 09:50:00.	22,150	34,050	22,850	34,400	34,900	22,050	255
126	02-Jul-91 10:00:00.	21,900	33,650	22,550	34,000	34,600	21,800	255
127	02-Jul-91 10:10:00.	21,600	33,300	22,250	33,650	34,250	21,550	255
128	02-Jul-91 10:20:00.	21,650	32,950	22,150	33,350	33,900	21,550	255
129	02-Jul-91 10:30:00.	21,450	32,550	21,950	33,000	33,600	21,300	255
130	02-Jul-91 10:40:00.	21,150	32,250	21,750	32,700	33,300	21,050	255
131	02-Jul-91 10:50:00.	21,350	31,900	21,750	32,350	33,050	21,150	255
132	02-Jul-91 11:00:00.	20,950	31,600	21,400	32,100	32,750	20,750	255
133	02-Jul-91 11:10:00.	20,600	31,350	21,250	31,800	32,500	20,550	255
134	02-Jul-91 11:20:00.	20,550	31,100	21,100	31,550	32,300	20,450	255
135	02-Jul-91 11:30:00.	20,450	30,800	20,950	31,350	32,050	20,350	255
136	02-Jul-91 11:40:00.	20,450	30,600	20,900	31,100	31,800	20,350	255
137	02-Jul-91 11:50:00.	20,300	30,350	20,700	30,850	31,600	20,150	255
138	02-Jul-91 12:00:00.	20,250	30,100	20,650	30,650	31,450	20,100	255
139	02-Jul-91 12:10:00.	19,900	29,900	20,350	30,450	31,250	19,800	255
140	02-Jul-91 12:20:00.	19,850	29,700	20,350	30,250	31,050	19,800	255
141	02-Jul-91 12:30:00.	19,750	29,500	20,150	30,050	30,900	19,650	255
142	02-Jul-91 12:40:00.	19,650	29,300	20,050	29,850	30,700	19,600	255
143	02-Jul-91 12:50:00.	19,550	29,100	19,950	29,650	30,550	19,500	255
144	02-Jul-91 13:00:00.	19,450	28,900	19,800	29,500	30,400	19,350	255



## APPENDIX 3.7.15

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 43

100 Watt heat load

No cooling

Container in climatic chamber

Stepped program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.

Ch 2 Outside heat sink

Ch 3 Inside heat sink

Ch 4 Inside floor level

Ch 5 Inside globe level

Ch 6 Outside globe level

Ch 19 255=Off 254=On

## Channel Readings

Data file - FILE43

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 03-Jul-91 09:00:00.  
    Finish : 04-Jul-91 15:00:01.  
Readings per channel: 181

All readings

Rdn no	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19
0	03-Jul-91 09:00:00.	19.000	26.250	19.200	27.550	29.800	18.800	255
1	03-Jul-91 09:10:00.	22.150	26.850	21.750	28.350	30.600	22.050	255
2	03-Jul-91 09:20:00.	21.500	27.550	21.450	29.100	31.500	21.300	255
3	03-Jul-91 09:30:00.	22.100	28.150	21.900	29.800	32.100	21.800	255
4	03-Jul-91 09:40:00.	21.750	28.800	21.800	30.450	32.700	21.600	255
5	03-Jul-91 09:50:00.	21.800	29.350	21.950	31.000	33.200	21.600	255
6	03-Jul-91 10:00:00.	21.950	29.900	22.050	31.500	33.650	21.700	255
7	03-Jul-91 10:10:00.	21.950	30.400	22.050	31.900	34.050	21.700	255
8	03-Jul-91 10:20:00.	21.800	30.850	22.050	32.350	34.500	21.600	255
9	03-Jul-91 10:30:00.	21.800	31.250	22.100	32.700	34.800	21.650	255
10	03-Jul-91 10:40:00.	21.900	31.600	22.150	33.050	35.100	21.700	255
11	03-Jul-91 10:50:00.	22.000	31.950	22.200	33.350	35.350	21.750	255
12	03-Jul-91 11:00:00.	21.850	32.250	22.150	33.600	35.600	21.700	255
13	03-Jul-91 11:10:00.	21.900	32.500	22.200	33.800	35.800	21.750	255
14	03-Jul-91 11:20:00.	22.050	32.750	22.350	34.050	36.000	21.850	255
15	03-Jul-91 11:30:00.	22.200	33.000	22.450	34.250	36.200	21.950	255
16	03-Jul-91 11:40:00.	22.150	33.250	22.450	34.450	36.400	21.950	255
17	03-Jul-91 11:50:00.	21.800	33.450	22.250	34.600	36.550	21.650	255
18	03-Jul-91 12:00:00.	21.900	33.600	22.250	34.750	36.650	21.700	255
19	03-Jul-91 12:10:00.	24.300	33.750	24.150	34.850	36.800	24.100	255
20	03-Jul-91 12:20:00.	23.700	33.950	23.850	35.100	37.100	23.550	255
21	03-Jul-91 12:30:00.	24.250	34.200	24.200	35.350	37.400	23.900	255
22	03-Jul-91 12:40:00.	23.850	34.450	24.100	35.550	37.600	23.650	255
23	03-Jul-91 12:50:00.	23.750	34.650	24.100	35.750	37.800	23.600	255
24	03-Jul-91 13:00:00.	23.950	34.850	24.250	35.950	37.950	23.750	255
25	03-Jul-91 13:10:00.	24.100	35.050	24.300	36.150	38.150	23.800	255
26	03-Jul-91 13:20:00.	24.000	35.250	24.300	36.300	38.200	23.800	255
27	03-Jul-91 13:30:00.	23.950	35.450	24.350	36.450	38.400	23.800	255
28	03-Jul-91 13:40:00.	24.100	35.550	24.450	36.650	38.550	23.950	255
29	03-Jul-91 13:50:00.	24.300	35.700	24.550	36.750	38.650	24.050	255
30	03-Jul-91 14:00:00.	23.850	35.850	24.350	36.900	38.800	23.750	255
31	03-Jul-91 14:10:00.	23.850	35.950	24.350	36.950	38.850	23.700	255
32	03-Jul-91 14:20:00.	23.800	36.050	24.250	37.050	38.900	23.650	255
33	03-Jul-91 14:30:00.	24.100	36.150	24.350	37.100	38.950	23.800	255
34	03-Jul-91 14:40:00.	23.750	36.250	24.200	37.200	39.000	23.650	255

35		03-Jul-91	14:50:00.	24,050		36,300		24,400		37,250		39,050		23,850		255	
36		03-Jul-91	15:00:00.	24,050		36,400		24,350		37,300		39,100		23,800		255	
37		03-Jul-91	15:10:00.	26,300		36,450		26,150		37,400		39,200		26,100		255	
38		03-Jul-91	15:20:00.	25,650		36,550		25,850		37,550		39,500		25,500		255	
39		03-Jul-91	15:30:00.	26,250		36,750		26,250		37,750		39,700		25,900		255	
40		03-Jul-91	15:40:00.	25,850		36,900		26,100		37,950		39,900		25,600		255	
41		03-Jul-91	15:50:00.	25,850		37,100		26,200		38,100		40,050		25,700		255	
42		03-Jul-91	16:00:00.	25,850		37,300		26,250		38,250		40,200		25,700		255	
43		03-Jul-91	16:10:00.	26,050		37,450		26,300		38,400		40,350		25,800		255	
44		03-Jul-91	16:20:00.	25,900		37,550		26,250		38,500		40,450		25,700		255	
45		03-Jul-91	16:30:00.	25,850		37,650		26,300		38,650		40,500		25,700		255	
46		03-Jul-91	16:40:00.	25,900		37,800		26,300		38,700		40,600		25,700		255	
47		03-Jul-91	16:50:00.	26,000		37,900		26,300		38,800		40,650		25,750		255	
48		03-Jul-91	17:00:00.	25,900		37,950		26,250		36,900		40,750		25,700		255	
49		03-Jul-91	17:10:00.	25,800		38,050		26,300		39,000		40,850		25,650		255	
50		03-Jul-91	17:20:00.	25,950		38,150		26,350		39,000		40,850		25,750		255	
51		03-Jul-91	17:30:00.	26,050		38,150		26,350		39,100		40,850		25,750		255	
52		03-Jul-91	17:40:00.	25,850		38,200		26,250		39,100		40,850		25,650		255	
53		03-Jul-91	17:50:00.	25,800		38,250		26,300		39,100		40,900		25,700		255	
54		03-Jul-91	18:00:00.	25,950		38,300		26,350		39,200		40,950		25,750		255	
55		03-Jul-91	18:10:00.	28,000		38,350		27,950		39,200		41,050		27,800		255	
56		03-Jul-91	18:20:00.	28,050		38,450		28,050		39,450		41,300		27,750		255	
57		03-Jul-91	18:30:00.	27,800		38,650		28,100		39,600		41,500		27,650		255	
58		03-Jul-91	18:40:00.	27,850		38,800		28,200		39,700		41,650		27,650		255	
59		03-Jul-91	18:50:00.	28,000		38,950		28,250		39,850		41,800		27,700		255	
60		03-Jul-91	19:00:00.	27,800		39,100		28,200		40,000		41,950		27,600		255	
61		03-Jul-91	19:10:00.	27,800		39,250		28,250		40,150		42,050		27,650		255	
62		03-Jul-91	19:20:00.	27,900		39,350		28,300		40,300		42,150		27,700		255	
63		03-Jul-91	19:30:00.	28,050		39,500		28,300		40,350		42,200		27,750		255	
64		03-Jul-91	19:40:00.	27,850		39,600		28,300		40,500		42,350		27,650		255	
65		03-Jul-91	19:50:00.	27,800		39,700		28,300		40,600		42,500		27,650		255	
66		03-Jul-91	20:00:00.	27,850		39,800		28,300		40,700		42,600		27,600		255	
67		03-Jul-91	20:10:00.	28,050		39,850		28,300		40,750		42,600		27,750		255	
68		03-Jul-91	20:20:00.	27,800		39,950		28,250		40,850		42,600		27,600		255	
69		03-Jul-91	20:30:00.	27,750		40,000		28,300		40,900		42,700		27,600		255	
70		03-Jul-91	20:40:00.	27,900		40,050		28,300		40,950		42,750		27,650		255	
71		03-Jul-91	20:50:00.	27,950		40,100		28,300		41,000		42,800		27,650		255	
72		03-Jul-91	21:00:00.	27,750		40,150		28,200		41,050		42,850		27,550		255	
73		03-Jul-91	21:10:00.	29,850		40,250		29,950		41,150		42,950		29,650		255	
74		03-Jul-91	21:20:00.	29,500		40,400		29,700		41,350		43,300		29,150		255	
75		03-Jul-91	21:30:00.	29,750		40,550		29,950		41,500		43,450		29,450		255	
76		03-Jul-91	21:40:00.	29,700		40,700		30,000		41,700		43,600		29,450		255	
77		03-Jul-91	21:50:00.	29,750		40,900		30,150		41,800		43,750		29,550		255	
78		03-Jul-91	22:00:00.	30,000		41,050		30,300		41,950		43,900		29,650		255	
79		03-Jul-91	22:10:00.	30,050		41,200		30,250		42,150		44,050		29,650		255	
80		03-Jul-91	22:20:00.	29,750		41,350		30,100		42,300		44,150		29,450		255	
81		03-Jul-91	22:30:00.	29,700		41,450		30,150		42,400		44,250		29,450		255	
82		03-Jul-91	22:40:00.	29,950		41,600		30,300		42,500		44,350		29,600		255	
83		03-Jul-91	22:50:00.	29,950		41,700		30,250		42,650		44,500		29,600		255	
84		03-Jul-91	23:00:00.	29,750		41,800		30,200		42,750		44,550		29,500		255	
85		03-Jul-91	23:10:00.	29,650		41,850		30,150		42,800		44,600		29,400		255	
86		03-Jul-91	23:20:00.	29,850		41,950		30,300		42,900		44,700		29,550		255	
87		03-Jul-91	23:30:00.	29,950		42,050		30,300		42,950		44,750		29,600		255	
88		03-Jul-91	23:40:00.	29,750		42,100		30,200		43,050		44,800		29,500		255	
89		03-Jul-91	23:50:00.	29,800		42,150		30,250		43,100		44,900		29,500		255	
90		03-Jul-91	24:00:00.	29,950		42,200		30,350		43,150		45,000		29,650		255	

91	04-Jul-91	00:10:00.	31,800	42,300	31,900	43,250	45,100	31,500	255
92	04-Jul-91	00:20:00.	31,850	42,450	31,800	43,450	45,300	31,400	255
93	04-Jul-91	00:30:00.	31,650	42,600	31,900	43,550	45,500	31,350	255
94	04-Jul-91	00:40:00.	31,750	42,750	32,000	43,750	45,650	31,400	255
95	04-Jul-91	00:50:00.	31,800	42,950	32,050	43,900	45,800	31,400	255
96	04-Jul-91	01:00:00.	31,650	43,100	32,050	44,050	46,000	31,350	255
97	04-Jul-91	01:10:00.	31,750	43,250	32,100	44,150	46,100	31,400	255
98	04-Jul-91	01:20:00.	31,800	43,400	32,100	44,300	46,250	31,400	255
99	04-Jul-91	01:30:00.	31,800	43,500	32,100	44,400	46,250	31,400	255
100	04-Jul-91	01:40:00.	31,600	43,600	32,050	44,500	46,350	31,300	255
101	04-Jul-91	01:50:00.	31,600	43,700	32,050	44,550	46,400	31,250	255
102	04-Jul-91	02:00:00.	31,700	43,750	32,100	44,650	46,450	31,350	255
103	04-Jul-91	02:10:00.	31,750	43,800	32,100	44,750	46,450	31,350	255
104	04-Jul-91	02:20:00.	31,650	43,850	32,100	44,750	46,500	31,350	255
105	04-Jul-91	02:30:00.	31,700	43,900	32,100	44,800	46,550	31,350	255
106	04-Jul-91	02:40:00.	31,700	43,950	32,100	44,850	46,600	31,300	255
107	04-Jul-91	02:50:00.	31,700	44,000	32,100	44,900	46,650	31,300	255
108	04-Jul-91	03:00:00.	31,550	44,050	32,050	44,950	46,650	31,250	255
109	04-Jul-91	03:10:00.	33,800	44,100	33,800	45,050	46,850	33,450	255
110	04-Jul-91	03:20:00.	33,150	44,250	33,450	45,250	47,150	32,750	255
111	04-Jul-91	03:30:00.	33,650	44,400	33,800	45,400	47,300	33,200	255
112	04-Jul-91	03:40:00.	33,600	44,550	33,850	45,550	47,450	33,200	255
113	04-Jul-91	03:50:00.	33,600	44,750	33,900	45,650	47,550	33,200	255
114	04-Jul-91	04:00:00.	33,700	44,900	34,000	45,800	47,700	33,250	255
115	04-Jul-91	04:10:00.	33,650	45,050	34,000	45,950	47,900	33,250	255
116	04-Jul-91	04:20:00.	33,600	45,150	34,000	46,050	47,900	33,200	255
117	04-Jul-91	04:30:00.	33,600	45,300	34,000	46,200	47,950	33,200	255
118	04-Jul-91	04:40:00.	33,850	45,350	34,050	46,250	48,050	33,350	255
119	04-Jul-91	04:50:00.	33,750	45,450	34,000	46,350	48,150	33,300	255
120	04-Jul-91	05:00:00.	33,550	45,550	34,000	46,450	48,200	33,200	255
121	04-Jul-91	05:10:00.	33,650	45,600	34,050	46,450	48,200	33,200	255
122	04-Jul-91	05:20:00.	33,700	45,650	34,050	46,500	48,200	33,250	255
123	04-Jul-91	05:30:00.	33,650	45,700	34,050	46,550	48,200	33,200	255
124	04-Jul-91	05:40:00.	33,550	45,750	34,000	46,650	48,300	33,150	255
125	04-Jul-91	05:50:00.	33,600	45,800	34,050	46,650	48,400	33,200	255
126	04-Jul-91	06:00:00.	33,700	45,850	34,050	46,700	48,400	33,250	255
127	04-Jul-91	06:10:00.	35,900	45,900	35,800	46,800	48,450	35,500	255
128	04-Jul-91	06:20:00.	35,100	46,050	35,450	47,000	48,850	34,750	255
129	04-Jul-91	06:30:00.	35,800	46,250	35,900	47,100	48,950	35,350	255
130	04-Jul-91	06:40:00.	35,750	46,350	35,900	47,250	49,050	35,250	255
131	04-Jul-91	06:50:00.	35,700	46,500	35,900	47,350	49,200	35,250	255
132	04-Jul-91	07:00:00.	35,550	46,650	35,900	47,550	49,350	35,150	255
133	04-Jul-91	07:10:00.	35,650	46,750	35,950	47,650	49,450	35,200	255
134	04-Jul-91	07:20:00.	35,750	46,900	36,000	47,750	49,500	35,250	255
135	04-Jul-91	07:30:00.	35,750	47,000	36,000	47,800	49,550	35,250	255
136	04-Jul-91	07:40:00.	35,600	47,100	36,050	47,900	49,650	35,200	255
137	04-Jul-91	07:50:00.	35,600	47,150	36,000	47,950	49,750	35,200	255
138	04-Jul-91	08:00:00.	35,800	47,250	36,050	48,050	49,800	35,300	255
139	04-Jul-91	08:10:00.	35,700	47,300	36,000	48,100	49,900	35,200	255
140	04-Jul-91	08:20:00.	35,600	47,400	35,950	48,200	49,950	35,200	255
141	04-Jul-91	08:30:00.	35,650	47,450	36,050	48,250	50,000	35,200	255
142	04-Jul-91	08:40:00.	35,750	47,550	36,050	48,300	50,050	35,250	255
143	04-Jul-91	08:50:00.	35,750	47,550	36,050	48,350	50,050	35,300	255
144	04-Jul-91	09:00:00.	35,600	47,600	36,050	48,400	50,100	35,200	255
145	04-Jul-91	09:10:00.	37,650	47,700	37,700	48,450	50,250	37,250	255
146	04-Jul-91	09:20:00.	38,200	47,800	38,050	48,650	50,550	37,600	255
147	04-Jul-91	09:30:00.	37,950	47,950	37,950	48,800	50,700	37,400	255
148	04-Jul-91	09:40:00.	37,700	48,150	38,000	48,950	50,850	37,300	255
149	04-Jul-91	09:50:00.	37,750	48,300	38,050	49,150	50,950	37,350	255

150	04-Jul-91 10:00:00	38.050	48.450	38.250	49.250	51.150	37.550	255
151	04-Jul-91 10:10:00	37.950	48.600	38.150	49.400	51.300	37.450	255
152	04-Jul-91 10:20:00	37.700	48.750	38.100	49.550	51.400	37.300	255
153	04-Jul-91 10:30:00	37.800	48.850	38.200	49.650	51.500	37.400	255
154	04-Jul-91 10:40:00	38.050	49.000	38.300	49.800	51.550	37.550	255
155	04-Jul-91 10:50:00	37.900	49.100	38.200	49.900	51.600	37.400	255
156	04-Jul-91 11:00:00	37.650	49.150	38.100	50.000	51.700	37.300	255
157	04-Jul-91 11:10:00	37.900	49.250	38.300	50.050	51.800	37.450	255
158	04-Jul-91 11:20:00	37.950	49.350	38.300	50.150	51.850	37.500	255
159	04-Jul-91 11:30:00	37.900	49.450	38.200	50.200	51.900	37.450	255
160	04-Jul-91 11:40:00	37.700	49.500	38.200	50.300	52.000	37.400	255
161	04-Jul-91 11:50:00	37.500	49.550	38.250	50.350	52.050	37.450	255
162	04-Jul-91 12:00:00	38.000	49.600	38.300	50.400	52.050	37.500	255
163	04-Jul-91 12:10:00	39.400	49.700	39.600	50.550	52.250	39.050	255
164	04-Jul-91 12:20:00	39.700	49.900	39.950	50.700	52.550	39.400	255
165	04-Jul-91 12:30:00	39.950	50.050	40.100	50.900	52.700	39.500	255
166	04-Jul-91 12:40:00	39.950	50.200	40.050	51.000	52.900	39.450	255
167	04-Jul-91 12:50:00	39.850	50.400	40.050	51.200	53.000	39.400	255
168	04-Jul-91 13:00:00	39.700	50.550	40.050	51.350	53.150	39.350	255
169	04-Jul-91 13:10:00	39.850	50.700	40.150	51.500	53.300	39.450	255
170	04-Jul-91 13:20:00	39.950	50.850	40.200	51.600	53.400	39.450	255
171	04-Jul-91 13:30:00	39.750	50.950	40.050	51.700	53.500	39.350	255
172	04-Jul-91 13:40:00	39.650	51.050	40.150	51.850	53.600	39.350	255
173	04-Jul-91 13:50:00	39.850	51.150	40.250	51.950	53.700	39.450	255
174	04-Jul-91 14:00:00	40.000	51.250	40.300	52.050	53.750	39.500	255
175	04-Jul-91 14:10:00	39.850	51.350	40.200	52.100	53.800	39.450	255
176	04-Jul-91 14:20:00	39.750	51.400	40.250	52.150	53.850	39.450	255
177	04-Jul-91 14:30:00	39.800	51.500	40.300	52.250	53.900	39.450	255
178	04-Jul-91 14:40:00	40.050	51.500	40.350	52.250	53.950	39.550	255
179	04-Jul-91 14:50:00	39.900	51.600	40.300	52.350	54.050	39.500	255
180	04-Jul-91 15:00:00	39.750	51.650	40.250	52.400	54.100	39.450	255

degC

Ch 2 Ch 3 Ch 5 Ch 6

55.00  
50.00  
45.00  
40.00  
35.00  
30.00  
25.00  
20.00  
15.00  
10.00

00:00:00. 03-JUL-91  
12:00:00.  
24:00:00.  
12:00:00. 04-JUL-91  
00:00:00.

## APPENDIX 3.7.16

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 44  
100 Watt heat load  
3 Amp cooling  
Container in climatic chamber  
Stepped program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level  
Ch 19 255=Off 254=On

## Channel Readings

Data file - FILE44

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
Start : 08-Jul-91 08:30:00.  
Finish : 09-Jul-91 14:30:01.

Readings per channel: 181

All readings

Rdn no	Time	Ch 1 deaC	Ch 2 deaC	Ch 3 deaC	Ch 4 deaC	Ch 5 deaC	Ch 6 deaC	Ch 19
0	08-Jul-91 08:30:00.	22.150	34.800	27.350	33.650	33.750	21.750	255
1	08-Jul-91 08:40:00.	24.450	35.250	26.950	34.550	36.450	24.000	255
2	08-Jul-91 08:50:00.	22.150	35.550	24.650	35.250	37.600	21.850	255
3	08-Jul-91 09:00:00.	21.550	35.650	23.350	35.600	38.000	21.250	255
4	08-Jul-91 09:10:00.	21.950	35.650	23.150	35.900	38.150	21.650	255
5	08-Jul-91 09:20:00.	21.950	35.600	22.950	36.050	38.250	21.800	255
6	08-Jul-91 09:30:00.	21.700	35.550	22.700	36.150	38.300	21.500	255
7	08-Jul-91 09:40:00.	21.700	35.500	22.600	36.150	38.300	21.550	255
8	08-Jul-91 09:50:00.	21.850	35.450	22.600	36.200	38.300	21.650	255
9	08-Jul-91 10:00:00.	21.950	35.400	22.550	36.200	38.300	21.650	255
10	08-Jul-91 10:10:00.	21.850	35.350	22.500	36.200	38.300	21.600	255
11	08-Jul-91 10:20:00.	21.800	35.300	22.500	36.150	38.300	21.600	255
12	08-Jul-91 10:30:00.	21.900	35.250	22.550	36.150	38.250	21.700	255
13	08-Jul-91 10:40:00.	21.900	35.250	22.500	36.150	38.300	21.650	255
14	08-Jul-91 10:50:00.	21.850	35.200	22.500	36.100	38.300	21.650	255
15	08-Jul-91 11:00:00.	21.750	35.200	22.450	36.100	38.250	21.600	255
16	08-Jul-91 11:10:00.	21.900	35.200	22.550	36.050	38.250	21.700	255
17	08-Jul-91 11:20:00.	21.750	35.150	22.450	36.050	38.200	21.600	255
18	08-Jul-91 11:30:00.	21.950	35.100	22.450	35.950	38.150	21.650	255
19	08-Jul-91 11:40:00.	24.550	35.100	24.100	35.950	38.150	24.150	255
20	08-Jul-91 11:50:00.	23.650	35.150	24.000	36.050	38.350	23.500	255
21	08-Jul-91 12:00:00.	24.050	35.250	24.200	36.200	38.550	23.700	255
22	08-Jul-91 12:10:00.	23.950	35.400	24.250	36.300	38.700	23.650	255
23	08-Jul-91 12:20:00.	23.800	35.500	24.250	36.450	38.800	23.600	255
24	08-Jul-91 12:30:00.	23.750	35.600	24.350	36.550	38.900	23.600	255
25	08-Jul-91 12:40:00.	23.950	35.700	24.400	36.650	38.900	23.650	255
26	08-Jul-91 12:50:00.	24.000	35.800	24.400	36.700	39.000	23.650	255
27	08-Jul-91 13:00:00.	23.800	35.900	24.350	36.800	39.050	23.600	255
28	08-Jul-91 13:10:00.	23.750	35.950	24.350	36.900	39.150	23.600	255
29	08-Jul-91 13:20:00.	23.900	36.050	24.400	36.950	39.250	23.700	255
30	08-Jul-91 13:30:00.	24.050	36.150	24.500	37.050	39.300	23.750	255
31	08-Jul-91 13:40:00.	23.950	36.200	24.450	37.100	39.400	23.700	255
32	08-Jul-91 13:50:00.	23.850	36.300	24.500	37.150	39.450	23.700	255
33	08-Jul-91 14:00:00.	24.050	36.350	24.550	37.200	39.500	23.850	255
34	08-Jul-91 14:10:00.	24.200	36.400	24.650	37.300	39.550	23.950	255
35	08-Jul-91 14:20:00.	23.650	36.450	24.400	37.350	39.600	23.500	255

36	08-Jul-91	14:30:00.	23.900	36.550	24.500	37.400	39.650	23.700	255
37	08-Jul-91	14:40:00.	26.800	36.550	26.150	37.450	39.700	26.250	255
38	08-Jul-91	14:50:00.	25.750	36.700	25.900	37.650	39.900	25.450	255
39	08-Jul-91	15:00:00.	25.850	36.850	26.150	37.800	40.150	25.650	255
40	08-Jul-91	15:10:00.	25.700	37.050	26.200	37.950	40.300	25.500	255
41	08-Jul-91	15:20:00.	25.950	37.200	26.350	38.100	40.450	25.700	255
42	08-Jul-91	15:30:00.	26.000	37.300	26.350	38.200	40.600	25.650	255
43	09-Jul-91	15:40:00.	25.850	36.700	26.800	38.350	40.650	25.600	255
44	08-Jul-91	15:50:00.	26.050	35.150	28.950	38.350	40.400	25.700	254
45	08-Jul-91	16:00:00.	26.650	32.650	33.000	38.050	39.750	26.050	254
46	08-Jul-91	16:10:00.	27.500	32.300	34.050	37.800	39.100	26.750	255
47	08-Jul-91	16:20:00.	25.850	34.000	30.350	37.800	39.450	25.400	255
48	08-Jul-91	16:30:00.	25.700	35.100	28.500	37.900	39.700	25.400	255
49	08-Jul-91	16:40:00.	25.450	35.800	27.450	38.050	39.950	25.250	255
50	08-Jul-91	16:50:00.	26.000	36.300	27.200	38.150	40.250	25.750	255
51	08-Jul-91	17:00:00.	25.900	36.700	26.800	38.300	40.500	25.600	255
52	08-Jul-91	17:10:00.	25.950	37.000	26.650	38.400	40.600	25.650	255
53	08-Jul-91	17:20:00.	25.950	35.000	28.800	38.400	40.400	25.600	254
54	08-Jul-91	17:30:00.	26.550	32.550	32.550	38.100	39.650	26.000	254
55	08-Jul-91	17:40:00.	28.600	33.550	32.900	37.950	39.350	27.950	255
56	08-Jul-91	17:50:00.	27.900	34.900	30.550	38.150	39.850	27.500	255
57	08-Jul-91	18:00:00.	27.500	35.850	29.450	38.350	40.350	27.250	255
58	08-Jul-91	18:10:00.	27.950	35.200	30.250	38.550	40.600	27.550	254
59	08-Jul-91	18:20:00.	28.600	32.800	34.350	38.400	40.050	27.950	254
60	08-Jul-91	18:30:00.	27.200	33.000	34.100	38.300	39.750	27.200	255
61	08-Jul-91	18:40:00.	27.600	34.650	31.550	38.450	40.150	27.150	255
62	08-Jul-91	18:50:00.	27.850	35.800	30.150	38.650	40.600	27.450	254
63	08-Jul-91	19:00:00.	28.500	33.450	33.350	38.650	40.500	27.900	254
64	08-Jul-91	19:10:00.	27.350	34.250	32.550	38.650	40.300	27.000	255
65	08-Jul-91	19:20:00.	27.900	35.500	30.700	38.800	40.650	27.450	254
66	08-Jul-91	19:30:00.	27.450	34.750	31.950	38.800	40.550	27.100	255
67	08-Jul-91	19:40:00.	28.000	34.650	31.500	38.850	40.700	27.450	254
68	08-Jul-91	19:50:00.	28.150	33.800	33.850	38.750	40.300	27.650	255
69	08-Jul-91	20:00:00.	27.650	35.300	31.100	38.850	40.550	27.150	255
70	08-Jul-91	20:10:00.	28.250	33.850	32.600	38.850	40.600	27.600	254
71	08-Jul-91	20:20:00.	27.850	33.150	34.650	38.700	40.050	27.300	255
72	08-Jul-91	20:30:00.	27.950	34.850	32.000	38.750	40.400	27.450	255
73	08-Jul-91	20:40:00.	30.550	35.000	32.650	38.900	40.750	29.800	254
74	08-Jul-91	20:50:00.	30.550	32.950	36.450	38.900	40.500	29.850	254
75	08-Jul-91	21:00:00.	29.850	34.000	35.350	39.000	40.500	29.250	255
76	08-Jul-91	21:10:00.	30.050	33.850	35.250	39.150	40.900	29.350	254
77	08-Jul-91	21:20:00.	29.900	32.300	37.650	39.100	40.500	29.250	254
78	08-Jul-91	21:30:00.	29.850	33.550	36.450	39.100	40.500	29.250	255
79	08-Jul-91	21:40:00.	29.950	33.850	35.200	39.300	40.900	29.300	254
80	08-Jul-91	21:50:00.	29.800	32.950	37.450	39.300	40.650	29.200	255
81	08-Jul-91	22:00:00.	29.750	33.550	35.900	39.350	40.850	29.200	254
82	08-Jul-91	22:10:00.	29.750	32.950	37.750	39.350	40.600	29.150	255
83	08-Jul-91	22:20:00.	29.950	33.400	36.250	39.400	40.850	29.250	254
84	08-Jul-91	22:30:00.	29.950	32.100	38.250	39.350	40.650	29.250	254
85	08-Jul-91	22:40:00.	29.850	33.850	36.050	39.450	40.800	29.200	254
86	08-Jul-91	22:50:00.	29.900	32.700	37.650	39.400	40.750	29.250	254
87	08-Jul-91	23:00:00.	29.900	33.700	36.800	39.400	40.700	29.250	255
88	08-Jul-91	23:10:00.	29.800	32.700	37.400	39.450	40.800	29.200	254
89	08-Jul-91	23:20:00.	29.750	33.150	37.650	39.450	40.700	29.100	255
90	08-Jul-91	23:30:00.	30.100	32.450	37.700	39.450	40.750	29.300	254
91	08-Jul-91	23:40:00.	32.600	33.050	38.650	39.500	40.900	31.700	254
92	08-Jul-91	23:50:00.	32.700	32.050	40.400	39.600	40.850	31.600	254
93	08-Jul-91	24:00:00.	32.100	31.450	41.500	39.650	40.900	31.250	254

94	09-Jul-91	00:10:00.	32.100	31.150	42.250	39.650	40.850	31.250	254
95	09-Jul-91	00:20:00.	32.100	31.050	42.300	39.600	40.700	31.250	255
96	09-Jul-91	00:30:00.	32.050	31.600	41.350	39.700	40.850	31.250	254
97	09-Jul-91	00:40:00.	32.050	31.250	41.900	39.700	40.850	31.200	254
98	09-Jul-91	00:50:00.	32.200	31.100	42.000	39.700	40.800	31.250	255
99	09-Jul-91	01:00:00.	31.950	31.300	41.900	39.700	40.750	31.150	254
100	09-Jul-91	01:10:00.	31.850	31.400	41.650	39.700	40.800	31.100	254
101	09-Jul-91	01:20:00.	31.800	31.650	42.000	39.700	40.800	31.050	254
102	09-Jul-91	01:30:00.	32.100	31.350	41.650	39.700	40.800	31.250	254
103	09-Jul-91	01:40:00.	32.000	31.200	42.050	39.700	40.750	31.150	254
104	09-Jul-91	01:50:00.	31.950	31.150	41.950	39.700	40.800	31.150	254
105	09-Jul-91	02:00:00.	32.050	30.950	42.150	39.750	40.800	31.200	254
106	09-Jul-91	02:10:00.	31.900	30.800	42.700	39.700	40.850	31.100	254
107	09-Jul-91	02:20:00.	31.850	30.800	42.300	39.700	40.800	31.050	254
108	09-Jul-91	02:30:00.	31.850	30.850	42.300	39.700	40.750	31.050	254
109	09-Jul-91	02:40:00.	34.750	31.200	43.450	39.750	40.800	33.600	254
110	09-Jul-91	02:50:00.	34.600	31.050	44.400	39.900	41.050	33.700	254
111	09-Jul-91	03:00:00.	33.800	31.100	44.000	40.050	41.350	33.000	254
112	09-Jul-91	03:10:00.	34.150	31.150	44.650	40.200	41.400	33.150	254
113	09-Jul-91	03:20:00.	33.850	31.250	44.450	40.300	41.500	33.050	254
114	09-Jul-91	03:30:00.	33.850	31.350	44.600	40.450	41.600	33.000	254
115	09-Jul-91	03:40:00.	34.050	31.400	44.850	40.500	41.600	33.150	254
116	09-Jul-91	03:50:00.	34.050	31.450	44.850	40.550	41.650	33.100	254
117	09-Jul-91	04:00:00.	33.900	31.500	44.700	40.600	41.700	33.000	254
118	09-Jul-91	04:10:00.	34.050	31.500	44.850	40.650	41.700	33.150	254
119	09-Jul-91	04:20:00.	33.900	31.550	44.200	40.700	41.750	33.000	254
120	09-Jul-91	04:30:00.	33.850	31.550	44.550	40.700	41.750	33.000	254
121	09-Jul-91	04:40:00.	34.050	31.600	44.800	40.700	41.750	33.100	254
122	09-Jul-91	04:50:00.	34.000	31.600	45.000	40.750	41.800	33.100	254
123	09-Jul-91	05:00:00.	33.900	31.650	44.550	40.850	41.850	33.000	254
124	09-Jul-91	05:10:00.	33.900	31.750	44.350	40.900	41.950	33.050	254
125	09-Jul-91	05:20:00.	33.900	31.750	45.300	40.950	42.050	33.050	254
126	09-Jul-91	05:30:00.	33.850	31.800	44.650	40.950	42.000	33.000	254
127	09-Jul-91	05:40:00.	36.700	31.850	46.100	41.050	42.050	35.500	254
128	09-Jul-91	05:50:00.	36.650	32.000	46.900	41.200	42.300	36.650	254
129	09-Jul-91	06:00:00.	36.050	32.200	46.500	41.400	42.600	36.100	254
130	09-Jul-91	06:10:00.	35.900	32.300	46.850	41.500	42.750	34.950	254
131	09-Jul-91	06:20:00.	35.850	32.450	46.900	41.600	42.750	34.950	254
132	09-Jul-91	06:30:00.	35.950	32.550	46.550	41.700	42.900	35.000	254
133	09-Jul-91	06:40:00.	35.800	32.700	46.650	41.800	42.900	34.850	254
134	09-Jul-91	06:50:00.	35.950	32.750	46.850	41.950	43.050	35.000	254
135	09-Jul-91	07:00:00.	35.900	32.850	46.350	42.000	43.100	34.950	254
136	09-Jul-91	07:10:00.	35.950	32.950	46.500	42.050	43.150	35.000	254
137	09-Jul-91	07:20:00.	35.900	33.000	46.650	42.150	43.250	34.950	254
138	09-Jul-91	07:30:00.	35.900	33.100	46.800	42.200	43.300	34.950	254
139	09-Jul-91	07:40:00.	35.850	33.100	46.650	42.250	43.300	34.950	254
140	09-Jul-91	07:50:00.	36.050	33.150	46.350	42.300	43.350	35.050	254
141	09-Jul-91	08:00:00.	35.900	33.200	46.800	42.300	43.450	34.950	254
142	09-Jul-91	08:10:00.	35.800	33.200	46.900	42.400	43.450	34.950	254
143	09-Jul-91	08:20:00.	36.050	33.250	46.650	42.450	43.500	35.050	254
144	09-Jul-91	08:30:00.	35.900	33.300	46.500	42.450	43.550	34.950	254
145	09-Jul-91	08:40:00.	38.650	33.350	48.350	42.500	43.550	37.450	254
146	09-Jul-91	08:50:00.	38.450	33.450	48.750	42.700	43.800	37.400	254
147	09-Jul-91	09:00:00.	37.800	33.650	48.200	42.900	44.050	36.950	254
148	09-Jul-91	09:10:00.	37.800	33.850	48.400	43.100	44.250	36.900	254
149	09-Jul-91	09:20:00.	37.800	34.050	48.700	43.250	44.350	36.900	254
150	09-Jul-91	09:30:00.	38.050	34.200	48.200	43.350	44.550	37.100	254
151	09-Jul-91	09:40:00.	37.950	34.300	48.800	43.500	44.600	36.900	254
152	09-Jul-91	09:50:00.	37.950	34.450	48.850	43.600	44.700	37.050	254

153	09-Jul-91	10:00:00	37,900	34,550	48,750	43,700	44,850	36,800	254
154	09-Jul-91	10:10:00	38,150	34,650	48,700	43,800	45,000	36,850	254
155	09-Jul-91	10:20:00	37,900	34,800	48,900	43,900	45,100	36,700	254
156	09-Jul-91	10:30:00	38,150	34,850	49,000	44,000	45,150	36,850	254
157	09-Jul-91	10:40:00	37,900	34,950	48,550	44,100	45,300	36,700	254
158	09-Jul-91	10:50:00	38,050	35,000	48,750	44,150	45,300	36,800	254
159	09-Jul-91	11:00:00	37,850	35,100	48,500	44,200	45,350	36,650	254
160	09-Jul-91	11:10:00	38,100	35,150	48,900	44,300	45,450	36,850	254
161	09-Jul-91	11:20:00	38,150	35,200	48,300	44,350	45,450	36,850	254
162	09-Jul-91	11:30:00	38,100	35,200	48,800	44,350	45,500	36,800	254
163	09-Jul-91	11:40:00	40,850	35,250	50,200	44,450	45,550	36,600	254
164	09-Jul-91	11:50:00	39,950	35,450	50,950	44,650	45,800	36,450	254
165	09-Jul-91	12:00:00	39,950	35,600	50,600	44,850	46,050	36,450	254
166	09-Jul-91	12:10:00	40,000	35,800	50,700	45,050	46,250	36,500	254
167	09-Jul-91	12:20:00	40,050	35,950	50,750	45,200	46,400	36,550	254
168	09-Jul-91	12:30:00	40,000	36,150	50,400	45,350	46,600	36,550	254
169	09-Jul-91	12:40:00	39,950	36,300	50,850	45,450	46,700	36,650	254
170	09-Jul-91	12:50:00	40,150	36,400	50,950	45,600	46,800	36,800	254
171	09-Jul-91	13:00:00	39,750	36,550	50,650	45,750	46,950	36,650	254
172	09-Jul-91	13:10:00	40,050	36,650	50,750	45,850	47,100	36,700	254
173	09-Jul-91	13:20:00	40,150	36,800	50,950	45,950	47,150	36,800	254
174	09-Jul-91	13:30:00	39,800	36,850	50,750	46,050	47,300	36,550	254
175	09-Jul-91	13:40:00	40,050	36,950	50,900	46,150	47,300	36,700	254
176	09-Jul-91	13:50:00	40,200	36,950	51,150	46,150	47,250	36,800	254
177	09-Jul-91	14:00:00	39,900	37,000	50,800	46,200	47,300	36,700	254
178	09-Jul-91	14:10:00	39,950	37,050	50,900	46,250	47,300	36,650	254
179	09-Jul-91	14:20:00	39,950	37,050	50,800	46,250	47,300	36,700	254
180	09-Jul-91	14:30:00	39,950	37,100	51,000	46,250	47,300	36,750	254

degC

Ch 6

Ch 5

Ch 3

Ch 2

55.00  
50.00  
45.00  
40.00  
35.00  
30.00  
25.00  
20.00  
15.00  
10.00

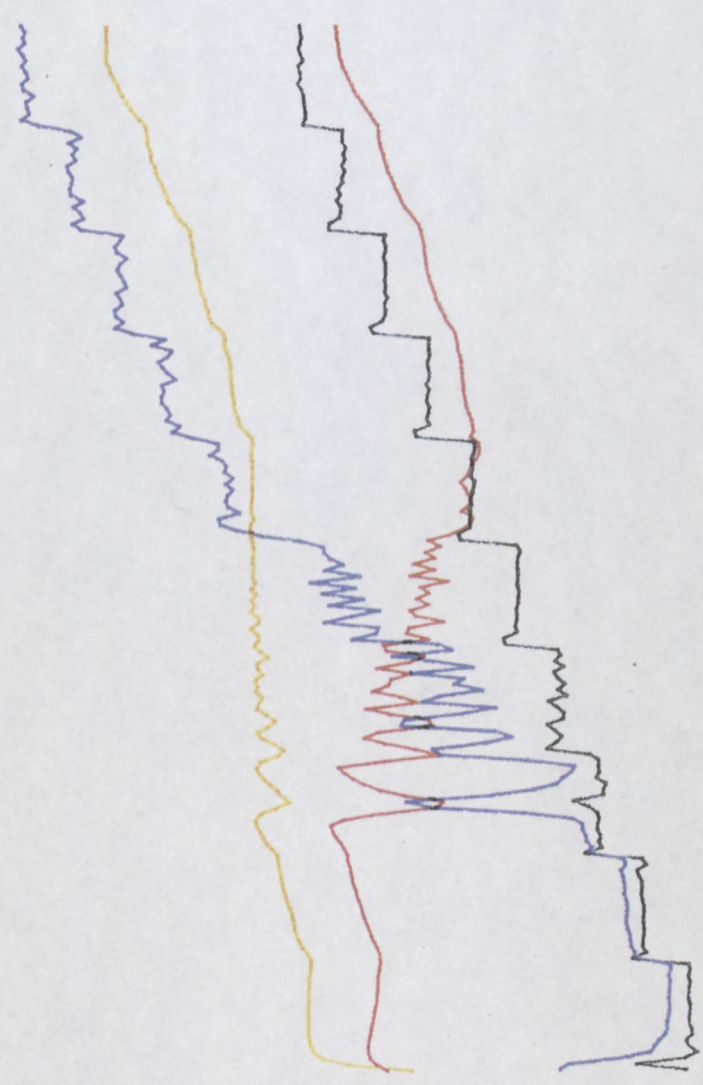
00: 00: 00.  
08-JUL-91

12: 00: 00.

24: 00: 00.

12: 00: 00.  
09-JUL-91

00: 00: 00.



## APPENDIX 3.7.17

### CLIMATIC CHAMBER CONTAINER TEMPERATURE READINGS

File 45  
60 Watt heat load  
3 Amp cooling  
Container in climatic chamber  
Stepped program

### POSITIONS OF TEMPERATURE SENSORS

Ch 1 Outside surface east.  
Ch 2 Outside heat sink  
Ch 3 Inside heat sink  
Ch 4 Inside floor level  
Ch 5 Inside globe level  
Ch 6 Outside globe level  
Ch 19 255=Off 254=On

## Channel Readings

Data file - FILE45

**Recorder details:**

Recorder number : 38  
Squirrel type : 1206

**Run details:**

Run number : 1  
Channels used : 7  
Recording Interval : 00:10:00.  
Non-averaged time interval readings  
Recording period :  
    Start : 09-Jul-91 16:00:00.  
    Finish : 10-Jul-91 22:00:01.  
Readings per channel: 181

All readings

Rdc no	Time	Ch 1 degC	Ch 2 degC	Ch 3 degC	Ch 4 degC	Ch 5 degC	Ch 6 degC	Ch 19
0	09-Jul-91 16:00:00.	21.750	26.100	22.950	27.700	27.400	22.400	255
1	09-Jul-91 16:10:00.	24.150	26.600	24.150	28.450	29.450	24.000	255
2	09-Jul-91 16:20:00.	22.100	27.100	22.850	29.100	30.500	22.550	255
3	09-Jul-91 16:30:00.	22.300	27.550	22.750	29.550	30.950	22.450	255
4	09-Jul-91 16:40:00.	21.800	27.850	22.250	29.800	31.200	21.950	255
5	09-Jul-91 16:50:00.	22.900	28.100	22.350	30.000	31.300	22.100	255
6	09-Jul-91 17:00:00.	21.750	28.350	22.200	30.150	31.450	21.850	255
7	09-Jul-91 17:10:00.	21.850	28.550	22.200	30.250	31.500	21.850	255
8	09-Jul-91 17:20:00.	21.800	28.700	22.200	30.300	31.550	21.800	255
9	09-Jul-91 17:30:00.	21.800	28.800	22.150	30.350	31.600	21.750	255
10	09-Jul-91 17:40:00.	21.950	28.900	22.200	30.350	31.600	21.750	255
11	09-Jul-91 17:50:00.	21.850	29.000	22.200	30.350	31.650	21.750	255
12	09-Jul-91 18:00:00.	21.750	29.050	22.150	30.350	31.700	21.650	255
13	09-Jul-91 18:10:00.	21.950	29.150	22.150	30.350	31.700	21.600	255
14	09-Jul-91 18:20:00.	21.800	29.200	22.150	30.350	31.700	21.600	255
15	09-Jul-91 18:30:00.	22.000	29.250	22.200	30.300	31.700	21.700	255
16	09-Jul-91 18:40:00.	21.800	29.300	22.150	30.300	31.700	21.600	255
17	09-Jul-91 18:50:00.	21.900	29.300	22.150	30.300	31.750	21.600	255
18	09-Jul-91 19:00:00.	21.700	29.350	22.150	30.250	31.650	21.550	255
19	09-Jul-91 19:10:00.	24.700	29.350	23.700	30.200	31.600	23.250	255
20	09-Jul-91 19:20:00.	23.750	29.450	23.650	30.350	31.800	23.050	255
21	09-Jul-91 19:30:00.	23.600	29.550	23.650	30.450	32.000	23.000	255
22	09-Jul-91 19:40:00.	23.650	29.650	23.900	30.550	32.100	23.250	255
23	09-Jul-91 19:50:00.	23.800	29.800	23.950	30.650	32.250	23.300	255
24	09-Jul-91 20:00:00.	23.800	29.900	23.950	30.750	32.350	23.300	255
25	09-Jul-91 20:10:00.	23.800	30.050	24.000	30.800	32.400	23.300	255
26	09-Jul-91 20:20:00.	23.600	30.150	23.950	30.900	32.500	23.250	255
27	09-Jul-91 20:30:00.	23.750	30.250	24.050	31.000	32.550	23.350	255
28	09-Jul-91 20:40:00.	23.900	30.350	24.100	31.050	32.650	23.400	255
29	09-Jul-91 20:50:00.	23.750	30.400	24.000	31.150	32.700	23.300	255
30	09-Jul-91 21:00:00.	23.650	30.500	24.000	31.200	32.750	23.300	255
31	09-Jul-91 21:10:00.	23.650	30.550	24.000	31.250	32.800	23.300	255
32	09-Jul-91 21:20:00.	23.800	30.600	24.050	31.300	32.800	23.350	255
33	09-Jul-91 21:30:00.	23.850	30.650	24.050	31.350	32.900	23.350	255
34	09-Jul-91 21:40:00.	23.650	30.700	24.000	31.400	32.950	23.300	255
35	09-Jul-91 21:50:00.	23.700	30.750	24.050	31.400	33.000	23.350	255

36	09-Jul-91	22:00:00.	23,900	30,800	24,150	31,450	33,050	23,450	255
37	09-Jul-91	22:10:00.	26,250	30,850	25,550	31,550	33,150	25,000	255
38	09-Jul-91	22:20:00.	25,550	31,000	25,500	31,750	33,400	24,800	255
39	09-Jul-91	22:30:00.	25,400	31,150	25,550	31,900	33,600	24,800	255
40	09-Jul-91	22:40:00.	25,700	31,300	25,750	32,050	33,800	24,950	255
41	09-Jul-91	22:50:00.	25,850	31,450	25,850	32,200	33,900	25,050	255
42	09-Jul-91	23:00:00.	25,900	31,600	25,950	32,350	34,050	25,150	255
43	09-Jul-91	23:10:00.	25,850	31,750	26,050	32,500	34,200	25,200	255
44	09-Jul-91	23:20:00.	25,350	31,900	25,800	32,650	34,350	24,950	255
45	09-Jul-91	23:30:00.	25,700	32,050	25,950	32,750	34,450	25,150	255
46	09-Jul-91	23:40:00.	25,550	32,150	25,900	32,850	34,550	25,050	255
47	09-Jul-91	23:50:00.	25,450	32,250	25,850	32,950	34,600	25,000	255
48	09-Jul-91	24:00:00.	25,450	32,300	25,850	33,000	34,650	25,000	255
49	10-Jul-91	00:10:00.	25,750	32,400	25,900	33,100	34,700	25,100	255
50	10-Jul-91	00:20:00.	25,550	32,500	25,850	33,150	34,800	25,000	255
51	10-Jul-91	00:30:00.	25,400	32,550	25,800	33,200	34,850	24,950	255
52	10-Jul-91	00:40:00.	25,650	32,600	25,950	33,250	34,900	25,100	255
53	10-Jul-91	00:50:00.	25,350	32,650	25,800	33,250	34,850	24,950	255
54	10-Jul-91	01:00:00.	25,750	32,700	25,950	33,300	34,900	25,150	255
55	10-Jul-91	01:10:00.	28,200	32,700	27,200	33,350	34,950	26,550	255
56	10-Jul-91	01:20:00.	27,800	32,800	27,500	33,500	35,150	26,750	255
57	10-Jul-91	01:30:00.	27,650	32,950	27,650	33,650	35,400	26,800	255
58	10-Jul-91	01:40:00.	27,800	33,150	27,800	33,850	35,550	26,950	255
59	10-Jul-91	01:50:00.	27,950	33,300	27,950	34,000	35,750	27,050	255
60	10-Jul-91	02:00:00.	27,450	33,450	27,700	34,150	35,900	26,750	255
61	10-Jul-91	02:10:00.	27,750	33,600	27,900	34,300	35,950	27,000	255
62	10-Jul-91	02:20:00.	27,750	33,700	27,900	34,400	36,050	26,950	255
63	10-Jul-91	02:30:00.	27,700	33,850	27,900	34,550	36,200	27,000	255
64	10-Jul-91	02:40:00.	27,700	33,900	27,900	34,600	36,250	26,950	255
65	10-Jul-91	02:50:00.	27,700	34,000	27,900	34,650	36,300	26,950	255
66	10-Jul-91	03:00:00.	27,500	34,100	27,800	34,750	36,400	26,900	255
67	10-Jul-91	03:10:00.	27,500	34,200	27,850	34,800	36,450	26,900	255
68	10-Jul-91	03:20:00.	27,500	34,250	27,850	34,900	36,500	26,900	255
69	10-Jul-91	03:30:00.	27,500	34,300	27,800	34,950	36,550	26,850	255
70	10-Jul-91	03:40:00.	27,850	34,400	27,950	35,000	36,600	27,050	255
71	10-Jul-91	03:50:00.	27,700	34,450	27,900	35,050	36,650	26,900	255
72	10-Jul-91	04:00:00.	27,650	34,500	27,900	35,100	36,700	26,950	255
73	10-Jul-91	04:10:00.	30,200	34,550	25,150	35,150	36,700	28,350	255
74	10-Jul-91	04:20:00.	29,750	34,650	29,500	35,300	36,950	28,600	255
75	10-Jul-91	04:30:00.	29,800	34,800	29,700	35,550	37,300	28,650	255
76	10-Jul-91	04:40:00.	29,700	35,000	29,800	35,750	37,550	28,800	255
77	10-Jul-91	04:50:00.	29,600	35,200	29,700	35,900	37,700	28,650	255
78	10-Jul-91	05:00:00.	29,450	35,350	29,650	36,050	37,800	28,600	255
79	10-Jul-91	05:10:00.	29,500	35,500	29,650	36,200	37,900	28,600	255
80	10-Jul-91	05:20:00.	29,550	35,600	29,750	36,300	38,000	28,650	255
81	10-Jul-91	05:30:00.	29,800	35,750	29,900	36,400	38,100	28,900	255
82	10-Jul-91	05:40:00.	29,500	35,850	29,750	36,550	38,200	28,650	255
83	10-Jul-91	05:50:00.	29,550	35,950	29,850	36,600	38,250	28,750	255
84	10-Jul-91	06:00:00.	29,550	36,050	29,800	36,650	38,300	28,750	255
85	10-Jul-91	06:10:00.	29,350	36,150	29,750	36,750	38,400	28,650	255
86	10-Jul-91	06:20:00.	29,450	36,200	29,750	36,800	38,450	28,700	255
87	10-Jul-91	06:30:00.	29,450	36,250	29,750	36,850	38,450	28,700	255
88	10-Jul-91	06:40:00.	29,500	36,300	29,800	36,900	38,450	28,700	255
89	10-Jul-91	06:50:00.	29,500	36,350	29,750	36,900	38,500	28,650	255
90	10-Jul-91	07:00:00.	29,700	36,400	29,900	36,950	38,500	28,850	255
91	10-Jul-91	07:10:00.	32,400	36,400	31,250	36,950	38,550	30,450	255
92	10-Jul-91	07:20:00.	31,750	36,550	31,450	37,150	38,750	30,450	255
93	10-Jul-91	07:30:00.	31,550	36,700	31,500	37,300	39,000	30,450	255
94	10-Jul-91	07:40:00.	31,500	36,850	31,550	37,450	39,200	30,500	255

95	10-Jul-91	07:50:00	31.550	37.000	31.650	37.650	39.350	30.550	255
96	10-Jul-91	08:00:00	31.700	37.150	31.750	37.750	39.450	30.650	255
97	10-Jul-91	08:10:00	31.600	37.300	31.750	37.900	39.500	30.600	255
98	10-Jul-91	08:20:00	31.450	37.450	31.750	38.050	39.650	30.550	255
99	10-Jul-91	08:30:00	31.400	37.550	31.650	38.150	39.750	30.550	255
100	10-Jul-91	08:40:00	31.300	37.650	31.550	38.200	39.800	30.450	255
101	10-Jul-91	08:50:00	31.850	37.750	31.800	38.300	39.850	30.700	255
102	10-Jul-91	09:00:00	31.500	37.800	31.750	38.350	39.900	30.650	255
103	10-Jul-91	09:10:00	31.500	37.900	31.800	38.450	40.000	30.700	255
104	10-Jul-91	09:20:00	31.650	37.950	31.850	38.500	40.050	30.750	255
105	10-Jul-91	09:30:00	31.800	38.050	31.900	38.550	40.100	30.800	255
106	10-Jul-91	09:40:00	31.750	38.150	31.900	38.650	40.200	30.750	255
107	10-Jul-91	09:50:00	31.500	38.200	31.850	38.700	40.300	30.750	255
108	10-Jul-91	10:00:00	31.750	38.250	31.950	38.750	40.300	30.800	255
109	10-Jul-91	10:10:00	34.150	38.300	33.550	38.800	40.400	32.600	255
110	10-Jul-91	10:20:00	33.850	38.450	33.450	39.000	40.700	32.300	255
111	10-Jul-91	10:30:00	33.550	38.600	33.550	39.200	40.900	32.350	254
112	10-Jul-91	10:40:00	33.600	36.900	36.450	39.300	40.750	32.550	255
113	10-Jul-91	10:50:00	33.850	37.600	35.450	39.350	40.700	32.750	255
114	10-Jul-91	11:00:00	34.000	37.150	36.100	39.450	40.900	32.750	255
115	10-Jul-91	11:10:00	33.750	36.750	36.400	39.500	40.900	32.700	255
116	10-Jul-91	11:20:00	33.650	37.550	35.750	39.550	40.850	32.700	255
117	10-Jul-91	11:30:00	33.700	37.150	36.050	39.600	40.900	32.750	254
118	10-Jul-91	11:40:00	33.900	36.850	36.900	39.600	40.850	32.850	255
119	10-Jul-91	11:50:00	33.900	36.650	36.650	39.650	40.950	32.850	255
120	10-Jul-91	12:00:00	33.800	36.150	37.300	39.700	40.900	32.850	255
121	10-Jul-91	12:10:00	33.750	37.100	36.250	39.700	40.850	32.850	255
122	10-Jul-91	12:20:00	33.950	36.850	37.050	39.700	40.900	32.950	255
123	10-Jul-91	12:30:00	33.900	36.950	36.300	39.750	40.950	32.850	254
124	10-Jul-91	12:40:00	33.650	37.050	36.200	39.750	40.900	32.800	255
125	10-Jul-91	12:50:00	33.850	35.950	37.450	39.750	40.850	32.950	254
126	10-Jul-91	13:00:00	33.950	36.800	36.850	39.700	40.800	33.000	255
127	10-Jul-91	13:10:00	36.400	36.800	37.800	39.750	40.950	34.750	254
128	10-Jul-91	13:20:00	35.600	34.850	41.050	39.850	40.850	34.300	255
129	10-Jul-91	13:30:00	35.700	36.300	39.250	39.900	40.950	34.600	255
130	10-Jul-91	13:40:00	35.900	35.450	41.050	39.950	40.950	34.650	255
131	10-Jul-91	13:50:00	36.100	34.850	41.250	40.050	41.000	34.800	254
132	10-Jul-91	14:00:00	36.050	34.800	41.600	40.050	41.000	34.900	254
133	10-Jul-91	14:10:00	35.700	34.800	42.050	40.050	40.950	34.750	255
134	10-Jul-91	14:20:00	35.950	34.500	41.800	40.100	41.000	34.850	254
135	10-Jul-91	14:30:00	36.100	34.200	43.050	40.050	40.900	34.950	255
136	10-Jul-91	14:40:00	36.150	34.800	41.450	40.150	41.000	35.000	254
137	10-Jul-91	14:50:00	35.700	34.650	42.400	40.100	40.950	34.800	255
138	10-Jul-91	15:00:00	36.000	34.750	41.700	40.150	41.050	35.000	254
139	10-Jul-91	15:10:00	36.050	34.100	43.300	40.100	40.950	34.950	255
140	10-Jul-91	15:20:00	36.150	34.950	41.700	40.150	41.000	35.000	254
141	10-Jul-91	15:30:00	35.850	33.750	42.950	40.150	40.900	34.900	255
142	10-Jul-91	15:40:00	35.900	35.000	41.050	40.150	41.000	35.000	255
143	10-Jul-91	15:50:00	36.050	34.400	42.600	40.150	40.950	35.000	254
144	10-Jul-91	16:00:00	36.150	34.150	42.500	40.150	40.950	35.000	254
145	10-Jul-91	16:10:00	38.450	34.650	43.200	40.150	41.000	36.800	254
146	10-Jul-91	16:20:00	37.550	33.250	45.000	40.250	41.050	36.250	254
147	10-Jul-91	16:30:00	38.000	32.550	46.500	40.200	40.850	36.650	254
148	10-Jul-91	16:40:00	38.200	33.150	45.800	40.250	41.000	36.850	254
149	10-Jul-91	16:50:00	38.150	32.550	47.150	40.250	40.900	36.800	254
150	10-Jul-91	17:00:00	37.900	32.600	46.650	40.250	40.900	36.750	254
151	10-Jul-91	17:10:00	38.050	32.700	46.650	40.250	40.950	36.850	254
152	10-Jul-91	17:20:00	38.150	32.450	47.000	40.250	40.900	36.850	254

153	10-Jul-91 17:30:00.	38,150	33,100	46,200	40,300	40,950	36,900	254
154	10-Jul-91 17:40:00.	37,950	32,550	47,000	40,300	40,900	36,800	255
155	10-Jul-91 17:50:00.	37,900	33,200	46,350	40,300	40,900	36,850	254
156	10-Jul-91 18:00:00.	38,050	32,550	46,850	40,300	40,950	36,900	254
157	10-Jul-91 18:10:00.	38,250	32,000	47,600	40,300	40,850	37,050	254
158	10-Jul-91 18:20:00.	38,400	31,650	48,150	40,250	40,700	37,150	254
159	10-Jul-91 18:30:00.	37,900	32,950	46,900	40,300	40,750	36,850	255
160	10-Jul-91 18:40:00.	37,900	32,950	46,050	40,400	41,050	36,800	254
161	10-Jul-91 18:50:00.	37,900	32,250	47,050	40,400	41,000	36,850	254
162	10-Jul-91 19:00:00.	37,750	31,800	47,400	40,300	40,800	36,700	254
163	10-Jul-91 19:10:00.	40,550	33,100	47,550	40,300	40,600	38,400	255
164	10-Jul-91 19:20:00.	40,050	33,100	47,450	40,550	41,200	38,400	254
165	10-Jul-91 19:30:00.	39,950	32,550	48,850	40,700	41,250	38,450	254
166	10-Jul-91 19:40:00.	40,100	32,300	49,750	40,750	41,250	38,850	254
167	10-Jul-91 19:50:00.	39,750	32,150	49,600	40,850	41,350	38,500	254
168	10-Jul-91 20:00:00.	39,800	32,100	50,250	40,900	41,350	38,550	254
169	10-Jul-91 20:10:00.	39,900	32,050	50,350	40,900	41,250	38,600	254
170	10-Jul-91 20:20:00.	39,950	32,050	50,650	40,900	41,350	38,550	254
171	10-Jul-91 20:30:00.	39,850	32,050	50,500	40,900	41,300	38,550	254
172	10-Jul-91 20:40:00.	39,750	32,050	50,600	40,900	41,300	38,600	254
173	10-Jul-91 20:50:00.	40,050	32,050	50,550	40,900	41,350	38,650	254
174	10-Jul-91 21:00:00.	39,950	32,050	50,600	40,950	41,300	38,600	254
175	10-Jul-91 21:10:00.	39,900	32,050	50,550	40,950	41,300	38,550	254
176	10-Jul-91 21:20:00.	39,700	32,050	50,300	40,950	41,350	38,550	254
177	10-Jul-91 21:30:00.	39,750	32,050	50,600	40,950	41,400	38,600	254
178	10-Jul-91 21:40:00.	39,750	32,050	50,600	40,950	41,300	38,550	254
179	10-Jul-91 21:50:00.	39,750	32,050	50,600	40,950	41,350	38,550	254
180	10-Jul-91 22:00:00.	39,850	32,050	50,900	40,950	41,400	38,550	254

degC

55.00

51.00

47.00

43.00

39.00

35.00

31.00

27.00

23.00

19.00

15.00

Ch 6

Ch 5

Ch 3

Ch 2

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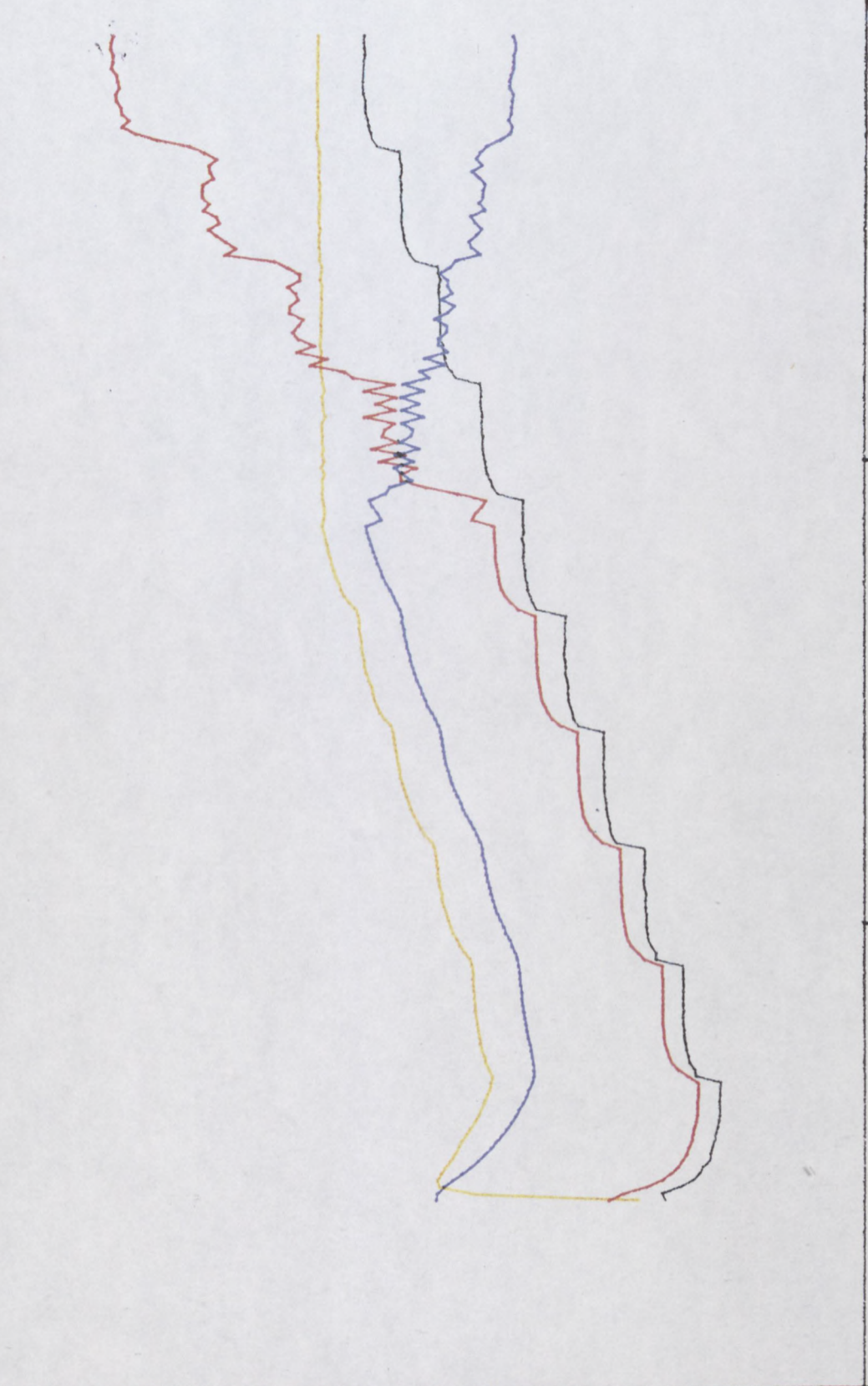
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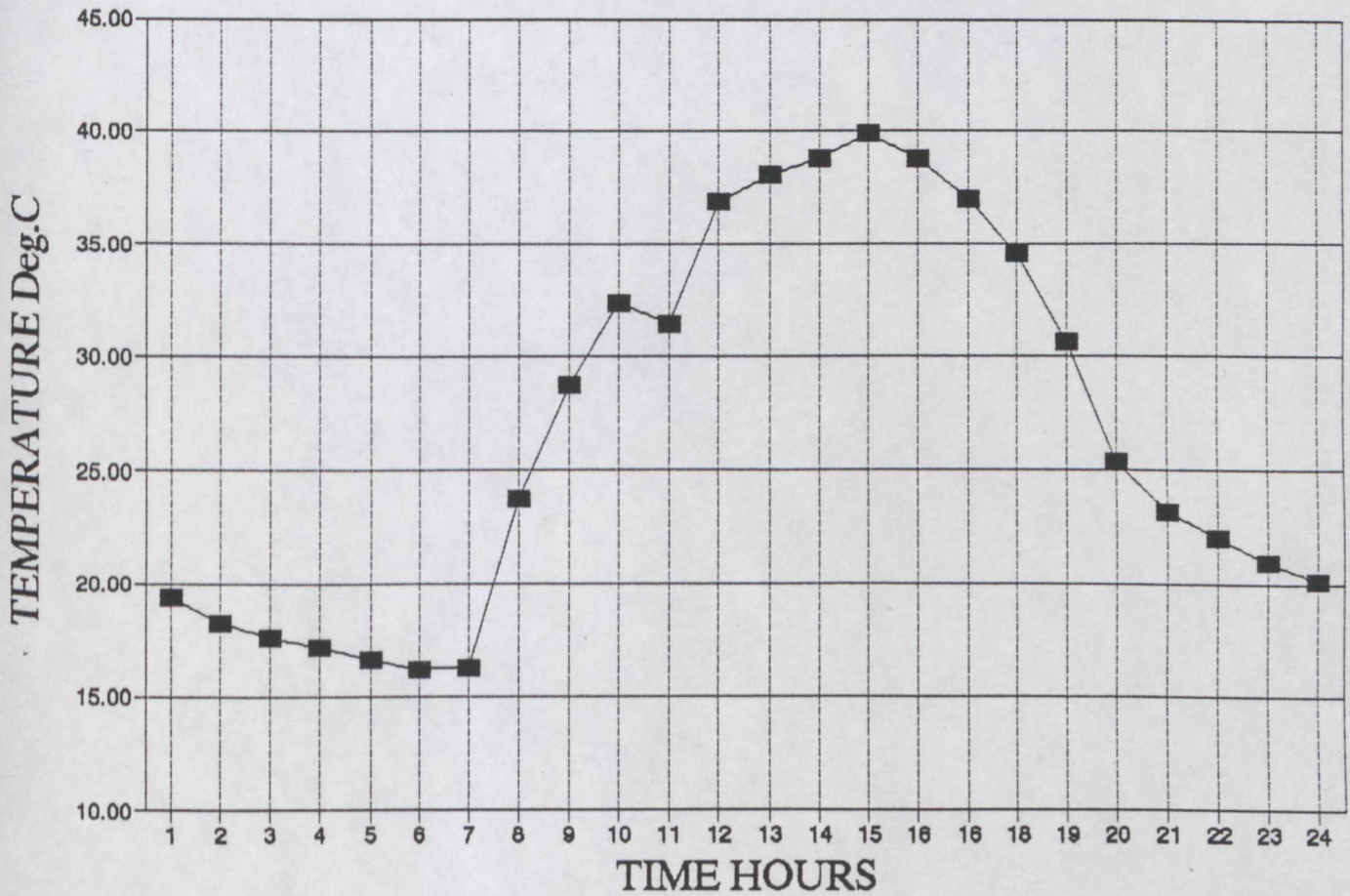
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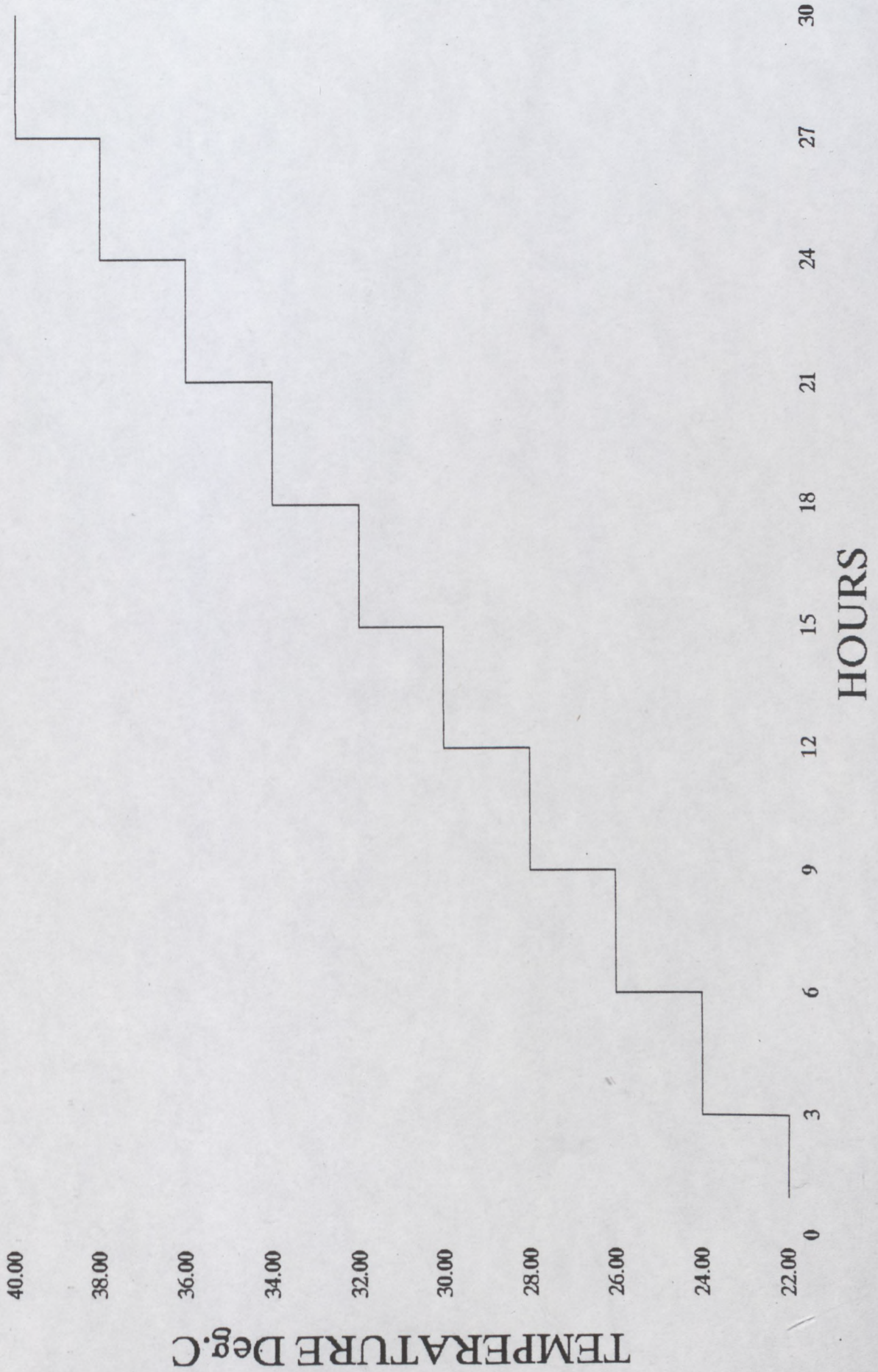
# APPENDIX 3.8 SOL-AIR GRAPH

Used In Climatic Chamber Computer



# APPENDIX 3.9 STEPPED GRAPH

Used In Climatic Chamber Computer



APPENDIX 3.10 HEAT PUMP COOLING LOAD ANALYSIS

1 Time	2 Cool Load Watts	3 Tc deg.C	4 Td	5 Th deg.C	6 Th-To	7 Seebek Co V/deg.C	8 R Ohms cm	9 K W/deg.C	10 I amps	11 Th K K	12 q Couple Watts	13 qt Device watts	14 Device <sup>16</sup> Watts	15 Vo # 1 volts	16 Time Op. minute	17 Power Watts	18 C.O.P.
1	34.89	18.3	16	34.3	-3.7	0.000421	0.04011	0.001931	2.25	307.3	0.1965	24.9553	124.78	11.264	16.777	126.7	0.985
2	32.58	17.6	16	33.8	-4.4	0.000421	0.04011	0.001931	2.25	306.6	0.1972	25.0429	125.21	11.228	16.612	126.3	0.991
3	31.26	17.2	16	33.2	-4.8	0.000421	0.04011	0.001931	2.25	306.2	0.1976	25.0829	125.46	11.205	14.948	126.1	0.995
4	28.27	16.6	16	32.6	-5.4	0.000421	0.04011	0.001931	2.25	305.6	0.1982	25.1678	125.84	11.173	13.856	125.7	1.001
5	27.95	16.2	16	32.2	-5.8	0.000421	0.04011	0.001931	2.25	305.2	0.1986	25.2178	126.09	11.152	13.300	125.5	1.005
6	28.29	16.3	16	32.3	-5.7	0.000421	0.04011	0.001931	2.25	305.3	0.1985	25.2054	126.03	11.157	13.469	125.6	1.004
7	52.83	19.1	16	35.1	-2.9	0.000421	0.04011	0.001931	2.25	306.1	0.1957	24.8553	124.26	11.308	25.506	127.2	0.977
8	68.35	21.8	16	37.8	-0.2	0.000421	0.04011	0.001931	2.25	310.8	0.1931	24.5178	122.59	11.451	33.943	128.8	0.952
9	81.56	24.1	16	40.1	2.1	0.000421	0.04011	0.001931	2.25	313.1	0.1908	24.2302	121.15	11.574	40.393	130.2	0.930
10	90.37	25.6	16	41.6	3.6	0.000421	0.04011	0.001931	2.25	314.6	0.1893	24.0427	120.21	11.654	45.105	131.1	0.917
11	96.3	27.1	16	43.1	5.1	0.000421	0.04011	0.001931	2.25	316.1	0.1878	23.8551	118.28	11.734	46.442	132.0	0.904
12	100.13	28.3	16	44.3	6.3	0.000421	0.04011	0.001931	2.25	317.3	0.1867	23.7051	116.53	11.798	50.686	132.7	0.893
13	102.5	28.4	16	45.4	7.4	0.000421	0.04011	0.001931	2.25	318.4	0.1856	23.5678	117.64	11.857	62.190	133.4	0.883
14	108.1	30.1	16	46.1	8.1	0.000421	0.04011	0.001931	2.25	319.1	0.1849	23.4801	117.40	11.894	64.225	133.8	0.877
15	101.3	30.4	16	46.4	8.4	0.000421	0.04011	0.001931	2.25	319.4	0.1846	23.4426	117.21	11.910	61.854	134.0	0.875
16	96.75	30.1	16	46.1	8.1	0.000421	0.04011	0.001931	2.25	318.1	0.1849	23.4801	117.40	11.894	49.448	133.8	0.877
17	88.64	28.3	16	45.3	7.3	0.000421	0.04011	0.001931	2.25	318.3	0.1857	23.6801	117.60	11.851	45.108	133.3	0.884
18	75.82	27.7	16	43.7	5.7	0.000421	0.04011	0.001931	2.25	316.7	0.1872	23.7801	116.80	11.786	36.160	132.4	0.898
19	58.36	25.4	16	41.4	3.4	0.000421	0.04011	0.001931	2.25	314.4	0.1895	24.0677	120.34	11.643	28.098	131.0	0.919
20	51.09	23.2	16	39.2	1.2	0.000421	0.04011	0.001931	2.25	312.2	0.1917	24.3427	121.71	11.528	25.185	129.7	0.939
21	47.12	22	16	38	0	0.000421	0.04011	0.001931	2.25	311	0.1929	24.4928	122.46	11.481	23.096	128.9	0.950
22	43.48	20.9	16	36.9	-1.1	0.000421	0.04011	0.001931	2.25	308.9	0.1939	24.6303	123.15	11.403	21.84	128.3	0.960
23	40.84	20.1	16	36.1	-1.8	0.000421	0.04011	0.001931	2.25	308.1	0.1947	24.7303	123.65	11.360	19.817	127.8	0.968
24	38.53	18.4	16	35.4	-2.6	0.000421	0.04011	0.001931	2.25	306.4	0.1954	24.8178	124.09	11.323	18.630	127.4	0.974

Min. Op. 760.12  
Hours Op. 12.669

APPENDIX 3.11 REVISED HEATPUMP COOLING LOAD ANALYSIS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Time	Cool Load Watts	T <sub>e</sub> deg.C	T <sub>d</sub>	T <sub>h</sub> deg.C	T <sub>h</sub> -T <sub>e</sub>	Seabook Cp W/deg.C	R Ohms cm	K	I ampe	Th K K	qt Couple Watts	qt Device watts	Devices % Watts	V <sub>o</sub> *1 volts	Time Op. minutes	Power Watts	C.O.P.
1	34.89	18.3	18	36.3	7.3	0.000421	0.04011	0.001931	2.25	309.3	0.1772	22.4982	112.49	11.851	18.610	133.3	0.844
2	32.58	17.6	18	35.8	6.6	0.000421	0.04011	0.001931	2.25	308.8	0.1778	22.5957	112.93	11.814	17.310	132.9	0.850
3	31.26	17.2	18	35.2	6.2	0.000421	0.04011	0.001931	2.25	308.2	0.1782	22.6357	113.18	11.793	16.972	132.7	0.863
4	28.27	16.6	18	34.6	5.6	0.000421	0.04011	0.001931	2.25	307.6	0.1789	22.7107	113.65	11.761	15.466	132.3	0.868
5	27.95	16.2	18	34.2	5.2	0.000421	0.04011	0.001931	2.25	307.2	0.1792	22.7807	113.80	11.739	14.736	132.1	0.862
6	28.29	16.3	18	34.3	5.3	0.000421	0.04011	0.001931	2.25	307.3	0.1791	22.7482	113.74	11.745	14.923	132.1	0.861
7	32.83	18.1	18	37.1	8.1	0.000421	0.04011	0.001931	2.25	310.1	0.1764	22.3981	111.89	11.894	28.304	133.8	0.837
8	68.35	21.8	18	39.8	10.8	0.000421	0.04011	0.001931	2.25	312.8	0.1737	22.0806	110.30	12.008	37.723	136.4	0.814
9	81.56	24.1	27	51.1	22.1	0.000421	0.04011	0.001931	2.25	326.1	0.1628	20.6478	103.24	12.642	47.401	142.2	0.728
10	90.37	25.6	27	52.6	23.6	0.000421	0.04011	0.001931	2.25	326.6	0.1611	20.4603	102.30	12.722	53.022	143.1	0.715
11	96.3	27.1	27	54.1	25.1	0.000421	0.04011	0.001931	2.25	327.1	0.1596	20.2728	101.36	12.802	57.003	144.0	0.704
12	100.13	28.3	29	57.3	28.3	0.000421	0.04011	0.001931	2.25	330.3	0.1565	19.8727	98.36	12.873	60.463	146.0	0.691
13	102.5	28.4	31	60.4	31.4	0.000421	0.04011	0.001931	2.25	333.4	0.1534	19.4651	97.43	13.139	63.125	147.8	0.659
14	108.1	30.1	31	61.1	32.1	0.000421	0.04011	0.001931	2.25	334.1	0.1527	19.3978	96.89	13.177	65.637	148.2	0.654
15	101.3	30.4	32	62.4	33.4	0.000421	0.04011	0.001931	2.25	335.4	0.1515	19.2351	96.18	13.248	63.197	148.0	0.645
16	95.75	30.1	30	60.1	31.1	0.000421	0.04011	0.001931	2.25	333.1	0.1537	19.6226	97.61	13.123	58.469	147.6	0.661
17	88.64	28.3	28	55.3	26.3	0.000421	0.04011	0.001931	2.25	328.3	0.1594	20.1227	100.61	12.867	52.890	144.7	0.695
18	76.82	27.7	28	53.7	24.7	0.000421	0.04011	0.001931	2.25	325.7	0.1600	20.3228	101.61	12.781	44.851	143.8	0.707
19	58.38	25.4	18	43.4	14.4	0.000421	0.04011	0.001931	2.25	316.4	0.1702	21.6105	108.05	12.231	32.408	137.6	0.785
20	51.09	23.2	18	41.2	12.2	0.000421	0.04011	0.001931	2.25	314.2	0.1723	21.8656	108.43	12.113	28.013	136.3	0.803
21	47.12	22	18	40	11	0.000421	0.04011	0.001931	2.25	313	0.1735	22.0056	110.18	12.049	28.690	135.6	0.813
22	43.48	20.9	18	38.9	9.9	0.000421	0.04011	0.001931	2.25	311.9	0.1748	22.1731	110.87	11.990	23.531	134.9	0.822
23	40.84	20.1	18	38.1	8.1	0.000421	0.04011	0.001931	2.25	311.1	0.1764	22.2731	111.37	11.948	22.003	134.4	0.829
24	38.53	18.4	18	37.4	8.4	0.000421	0.04011	0.001931	2.25	310.4	0.1781	22.3806	111.80	11.910	20.877	134.0	0.834

Mfn. Op. 882.74  
Hours Op. 14.712

APPENDIX 3.12 Date Commenced 14-12-90 Date Completed 20-12-90  
 THESE TESTS SHOW THE VARIATION OF VOLTAGE TO MAINTAIN VARIOUS  
 CONSTANT CURRENTS

TIME minutes	0.5 A	1 A	1.5 A	1.6 A	1.7 A	1.8 A	1.9 A	2 A	2 A	2.1 A	2.2 A	2.25 A
5	2.42	5.12	7.78	8.04	8.53	9.08	9.8	10.25	10.12	10.76	11.28	11.93
10	2.44	5.18	7.89	8.22	8.7	9.31	10.01	10.62	10.33	11.02	11.53	11.98
15	2.5	5.21	7.97	8.35	8.92	9.46	10.14	10.73	10.5	11.23	11.75	12.22
30	2.57	5.31	8.15	8.69	9.27	9.87	10.46	10.87	10.87	11.59	12.19	12.71
60	2.68	5.4	8.29	8.94	9.61	10.16	10.71	11.25	11.23	12	12.54	13.31

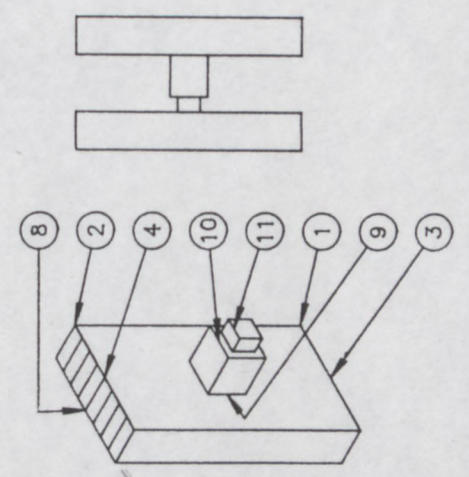
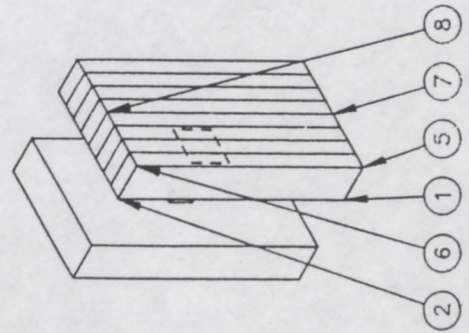
APPENDIX 3.13      AMBIENT TEMP. = 23,1 deg.C  
THESE TESTS SHOW THE AMPERAGE THAT 12 VOLTS  
WILL INDUCE AFTER THE TIME INDICATED

TIME MIN.	5	10	15	20	25	30	40	50	60
AMPS	2.401	2.3	2.263	2.193	2.168	2.145	2.12	2.1	2.09
TIME	70	80	90	100	110	120	130	140	
	2.082	2.077	2.074	2.073	2.072	2.072	2.07	2.071	

APPENDIX 3.14

THESE TESTS SHOW THE TEMPERATURES IN THE HEAT SINKS AFTER 1 HOUR OF OPERATION AT VARIOUS CONSTANT AMPERAGES THE VOLTAGE INDICATED IS AFTER 1 HOUR OF OPERATION

A	VOLTS	POSITIONS											COLD SIDE					AMB. TEMP			
		1	2	3	4	5	6	7	8	8	10	11	1	2	3	4	5		6	7	8
0.5	2.63	25.7	25.9	25.8	26.2	26.2	26.2	25.8	26.9	27.1	27.1	20.3	20.5	20.3	20.3	20.3	20.4	20.4	21.1	21.8	23
1	5.4	30.7	30.8	30.4	30.4	30.7	30.9	28.4	32.8	34.1	34.1	18.2	18.3	18.5	18.5	18.5	18.3	18.3	18.9	19.3	24.2
1.5	8.28	35.7	36	35.7	36.5	36	36.4	35	35.4	34.2	34.2	18	18.7	18.2	18.2	18.2	18.7	18.7	19.5	20	24.7
1.9	10.73	39.8	39.4	11.7	40.4	39.6	40.6	37.2	39	47.9	48	18.7	18.6	18.4	18.7	18.4	18.9	18.9	19.3	20.6	24.9
2	11.25	37.4	37.7	37.5	38.2	37.8	38.6	35.8	38	45.3	43.8	16	16	16.1	16.1	16.6	15.9	16.6	16.5	16.4	23.6
2	11.25	37.7	38.1	38.3	38.7	38.3	38.6	35.4	35.7	46.5	18.2	16.7	15.8	16	16	16	16.8	16.8	16.3	47	22.8
2.1	12.05	39.1	40.4	40.3	41.3	40.6	41.4	38.8	37.9	49.8	49.3	17.5	17.9	17.7	17.5	17.5	17.9	17.9	18.2	18	23.6
2.25	13.04	40.5	41.6	41.5	42.2	42.3	42.5	40	41.7	51	52.9	17.4	17.4	17.6	17.5	17.1	17.4	17.4	18.4	18.2	24.1
2.5	14.67	46.1	46.4	45.8	45.6	46	46.5	41.5	48.3	57.5	58.2	18.3	18.9	18.5	18.5	18.1	18.2	18.2	19.3	18.7	23
3	18.56	48.9	50	50.4	52.3	51	52.5	47.4	48	65.8	62.6	18.2	18.4	18.2	18.5	18.5	18.4	18.4	18.4	18.6	23.2
VARIES CONSTANT		39.8	38.1	40	40.1	38.5	39.4	34.4	38.3	47.4	48.3	16.9	17.1	16.8	16.8	17.3	17.2	17.2	17.5	17.2	22.8



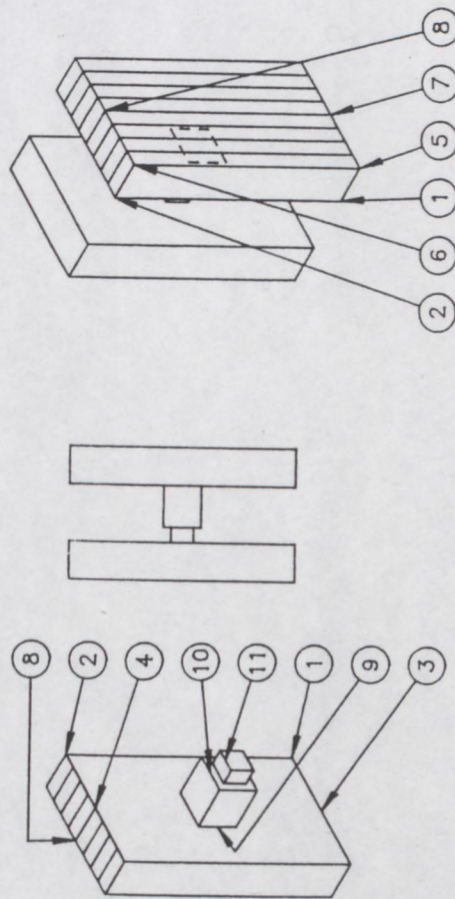
APPENDIX 3.15.1

TEN WATT LOAD R=2.7 Ohm

THESE TESTS SHOW THE TEMPERATURE IN THE HEAT SINKS FOR VARIOUS HEAT LOADS  
THE HEAT LOADS WERE ARTIFICIALLY CREATED WITH RESISTANCES SCREWED TO THE HEAT SINKS

TIME MIN.	AMBIENT deg.C	H.LOAD Watts	E.M.F. Volts	POSITIONS											
				1	2	3	4	5	6	7	8	9	10		
5	24.9	10.02	5.19	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	29.1	29.4
10	24.5	10.02	5.19	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	29.2	30.6
15	24.6	10	5.18	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	29.7	30.8
30	24.6	10.02	5.19	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	30.8	32
60	24.5	10	5.18	30.7	30.7	31	31.3	31.3	31.3	31.4	31	31.3	32.3	33.4	

I CONSTANT = (H/R) ^ 1/2 = (10/2.7) ^ 1/2 = 1.93 amp A



APPENDIX 3.15.2

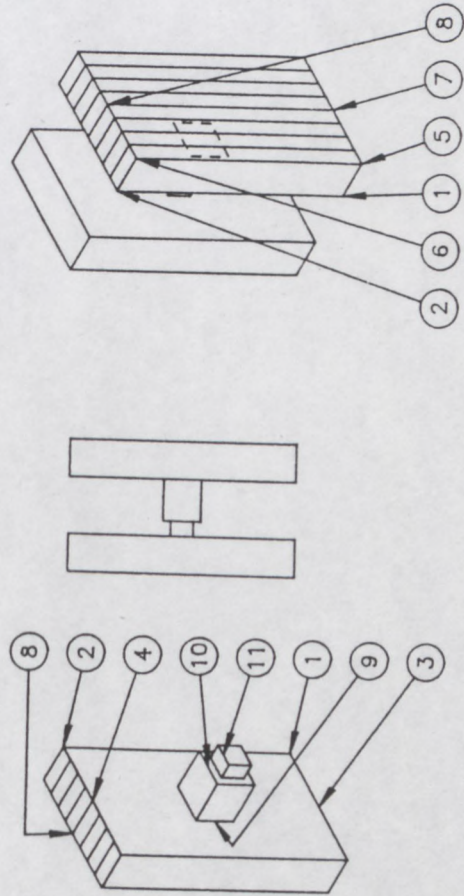
TWENTY WATT LOAD

R=2.7 Ohm

THESE TESTS SHOW THE TEMPERATURE IN THE HEAT SINKS FOR VARIOUS HEAT LOADS  
THE HEAT LOADS WERE ARTIFICIALLY CREATED WITH RESISTANCES SCREWED TO THE HEAT SINKS

TIME MIN.	AMBIENT deg.C	H.LOAD Watts	E.M.F. Volts	POSITIONS										
				1	2	3	4	5	6	7	8	9	10	
5	22.6	20.88	7.67	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	27.8
10	23.5	20.8	7.64	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	29.6
15	23.5	20.8	7.64	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	31.5
30	23.3	20.8	7.65	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	34.4
60	23.2	20.8	7.65	34.1	34.2	33.9	34.4	34.2	34.4	34.4	34	34	37.4	38.5

I CONSTANT =  $(H/R)^{1/2} = (20/2.7)^{1/2} = 2.722$  A

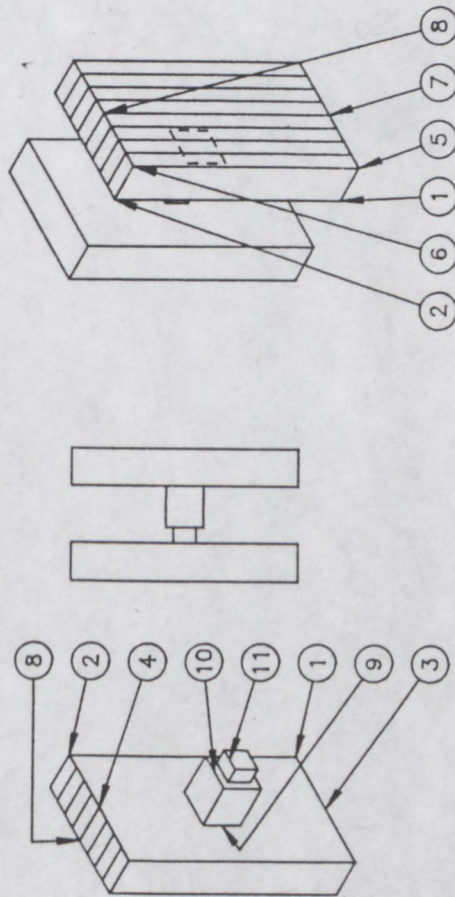


APPENDIX 3.15.3

THIRTY WATT LOAD R=2.7 Ohm  
 THESE TESTS SHOW THE TEMPERATURE IN THE HEAT SINKS FOR VARIOUS HEAT LOADS  
 THE HEAT LOADS WERE ARTIFICIALLY CREATED WITH RESISTANCES SCREWED TO THE HEAT SINKS

TIME MIN.	AMBIENT deg.C	H.LOAD Watts	E.M.F. Volts	1	2	3	4	5	6	7	8	9	10
5	23.1	31.33	9.4	nul	nul	nul	nul	nul	nul	nul	nul	28.9	31.2
10	23.1	31.33	9.4	nul	nul	nul	nul	nul	nul	nul	nul	31.2	34.1
15	23.3	31.23	9.37	nul	nul	nul	nul	nul	nul	nul	nul	31.8	37
30	23.3	31.16	9.35	nul	nul	nul	nul	nul	nul	nul	nul	37.1	40.5
60	23.3	31.16	9.35	38.1	38.4	37.7	37.3	38.2	38.8	37.7	38.7	41.7	45

I CONSTANT =  $(H/R)^{1/2} = (30/2.7)^{1/2} = 3.333 \text{ amp A}$



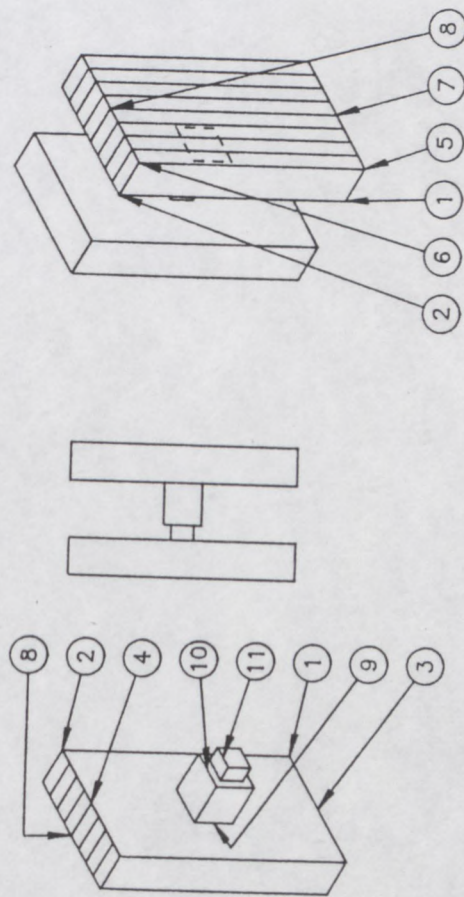
APPENDIX 3.15.4

FORTY WATT LOAD R=2.7 Ohm

THESE TESTS SHOW THE TEMPERATURE IN THE HEAT SINKS FOR VARIOUS HEAT LOADS  
THE HEAT LOADS WERE ARTIFICIALLY CREATED WITH RESISTANCES SCREWED TO THE HEAT SINKS

TIME MIN.	AMBIENT deg.C	H.L.OAD Watts	E.M.F. Volts	POSITIONS											
				1	2	3	4	5	6	7	8	9	10		
5	23.1	41.49	10.78	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	32.7	34.2
10	23.1	41.38	10.75	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	37	38.2
15	25.6	41.38	10.75	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	37.5	41.4
30	23.3	41.34	10.74	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	45.4	47.6
60	23.3	41.38	10.75	43.1	44.2	44.1	45.1	43.7	44.3	43.6	45.1	45.1	45.1	50.2	52.2
90	24.4	41.3	10.73	46.9	47.5	46.3	47.8	45.5	47.4	45.5	47	47	47	54.1	57

I CONSTANT =  $(H/R) \wedge 1/2 = (40/2.7) \wedge 1/2 = 3.849 \text{ amp A}$



APPENDIX 3.15.5

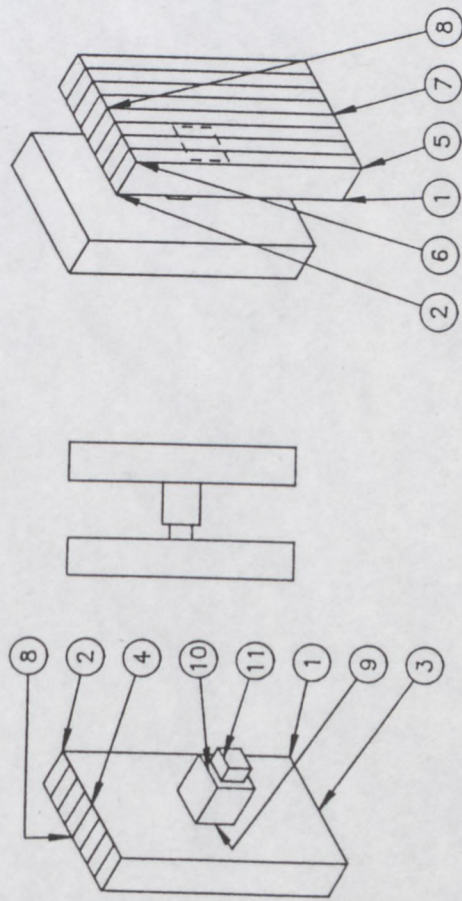
FIFTY WATT LOAD

R=2.7 Ohm

THESE TESTS SHOW THE TEMPERATURE IN THE HEAT SINKS FOR VARIOUS HEAT LOADS  
THE HEAT LOADS WERE ARTIFICIALLY CREATED WITH RESISTANCES SCREWED TO THE HEAT SINKS

TIME MIN.	AMBIENT deg.C	H.ILOAD Watts	E.M.F. Volts	1	2	3	4	5	6	7	8	9	10
5	26.6	50.03	11.58	nul	nul	nul	nul	nul	nul	nul	nul	32.7	34.2
10	25.4	50.07	11.59	nul	nul	nul	nul	nul	nul	nul	nul	37	38.2
15	25.4	50.07	11.59	nul	nul	nul	nul	nul	nul	nul	nul	37.5	41.4
30	24.8	50.03	11.59	nul	nul	nul	nul	nul	nul	nul	nul	45.4	47.6
60	24.6	50.07	11.59	47.5	49.8	47.8	50	47.8	49.2	45.4	44.9	55.7	60.5

I CONSTANT = (H/R) ^ 1/2 = (50/2.7) ^ 1/2 = 4.3 A



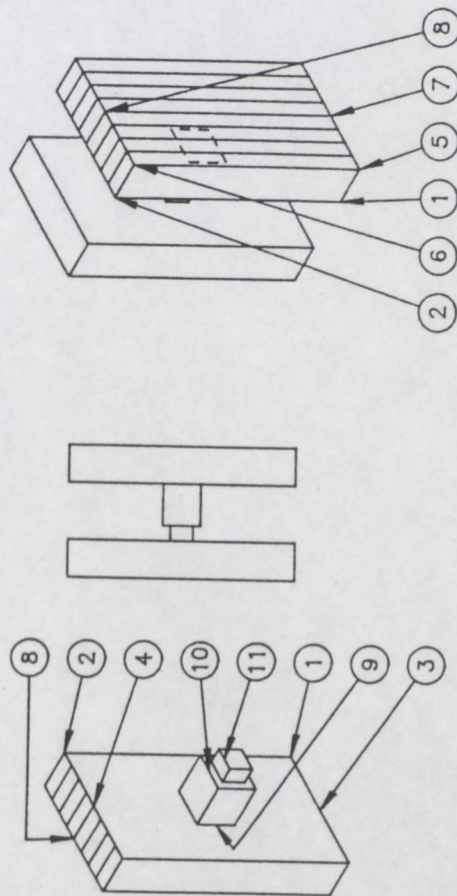
APPENDIX 3.15.6

SIXTY WATT LOAD R=2.7 Ohm

THESE TESTS SHOW THE TEMPERATURE IN THE HEAT SINKS FOR VARIOUS HEAT LOADS  
 THE HEAT LOADS WERE ARTIFICIALLY CREATED WITH RESISTANCES SCREWED TO THE HEAT SINKS

TIME MIN.	AMBIENT deg.C	H.LOAD Watts	E.M.F. Volts	POSITIONS											
				1	2	3	4	5	6	7	8	9	10		
5	23	59.86	12.71	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	39.5
10	23	59.11	12.55	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	46.1
15	24.6	59.25	12.58	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	48.5
30	24.5	59.93	12.68	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	nul	56.3
60	23.9	59.77	12.69	52.8	54	52.4	55.2	53.2	53.2	51	54.1	63.5	54.1	67.6	

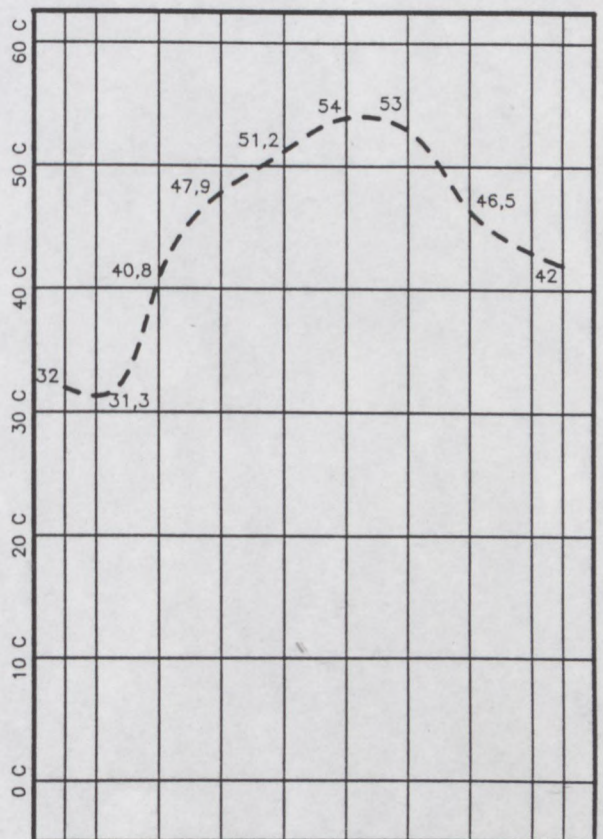
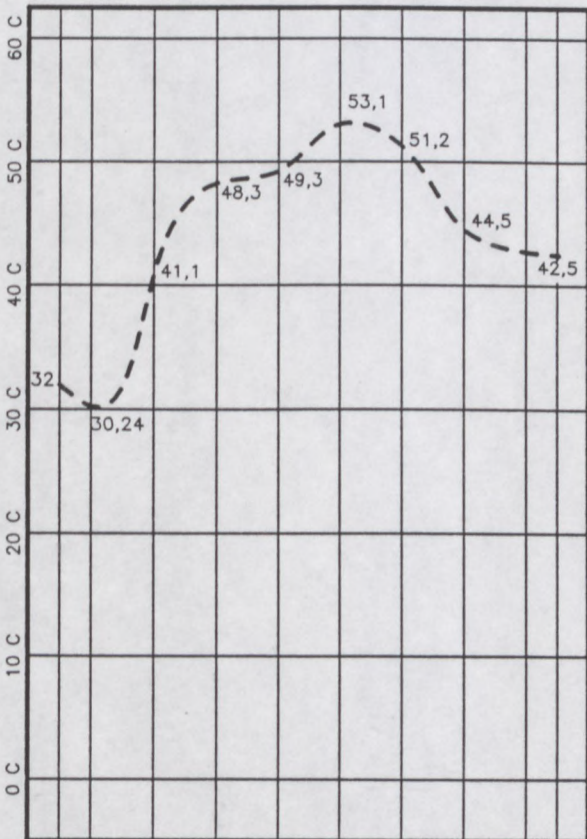
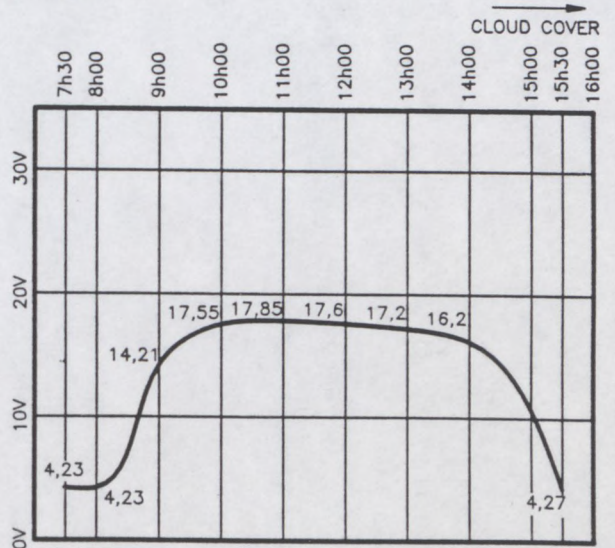
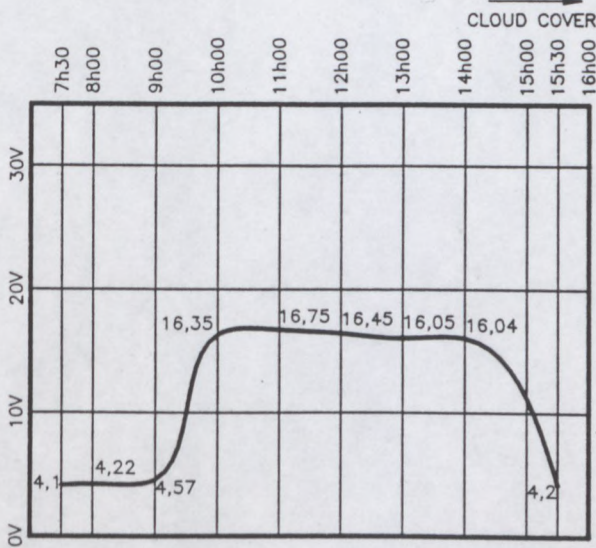
I CONSTANT = (H/R) ^ 1/2 = (60/2.7) ^ 1/2 = 4.714 A



# SOLAR PANEL VOLTAGE / TEMPERATURE GRAPHS

DATE: 01:11:90

PANEL VOLTAGE = \_\_\_\_\_  
 PANEL TEMP. = - - - - -  
 AMB. TEMP. = . . . . .



TYPE 1 48W  
CONSTANT 2A LOAD

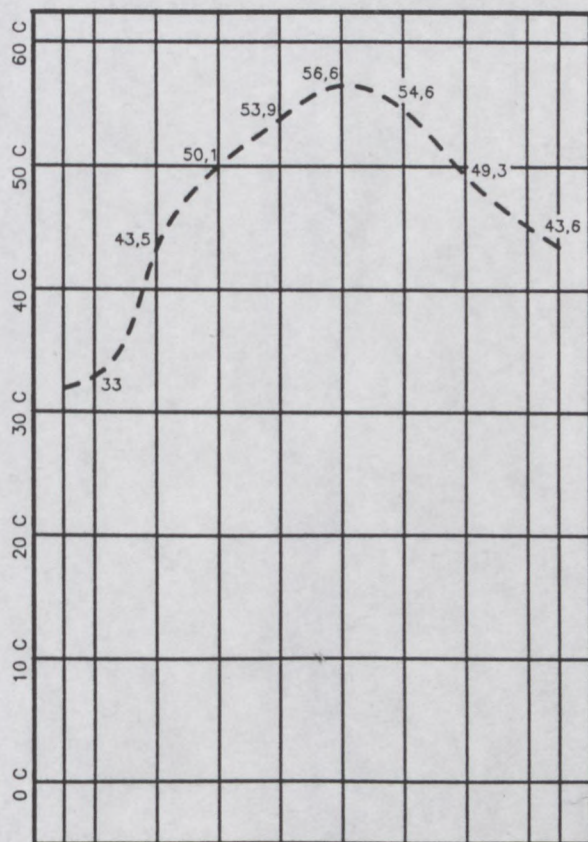
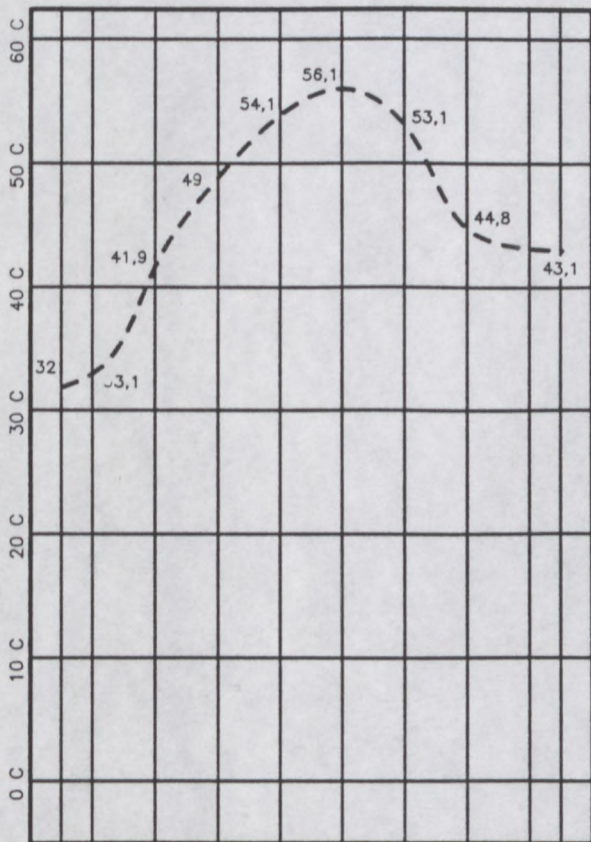
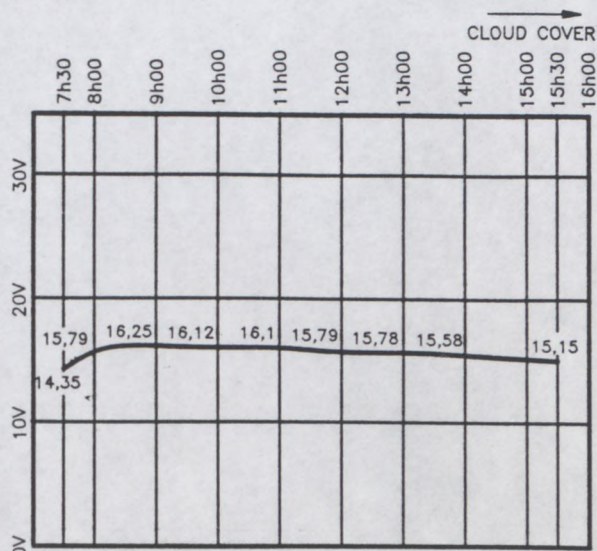
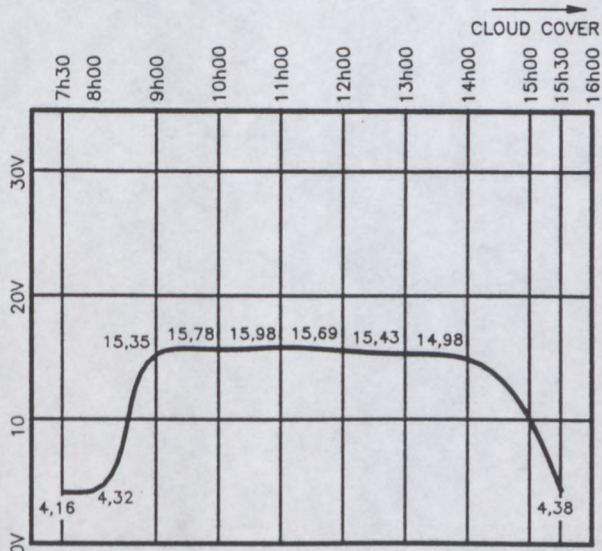
TYPE 2 50W  
CONSTANT 2A LOAD

APPENDIX 3J6.1.1

# SOLAR PANEL VOLTAGE / TEMPERATURE GRAPHS

DATE: 01:11:90

PANEL VOLTAGE = —————  
 PANEL TEMP. = - - - - -  
 AMB. TEMP. = ········



TYPE 3 50W  
CONSTANT 2A LOAD

TYPE 4 47W  
CONSTANT 1A LOAD

APPENDIX 316.1:2

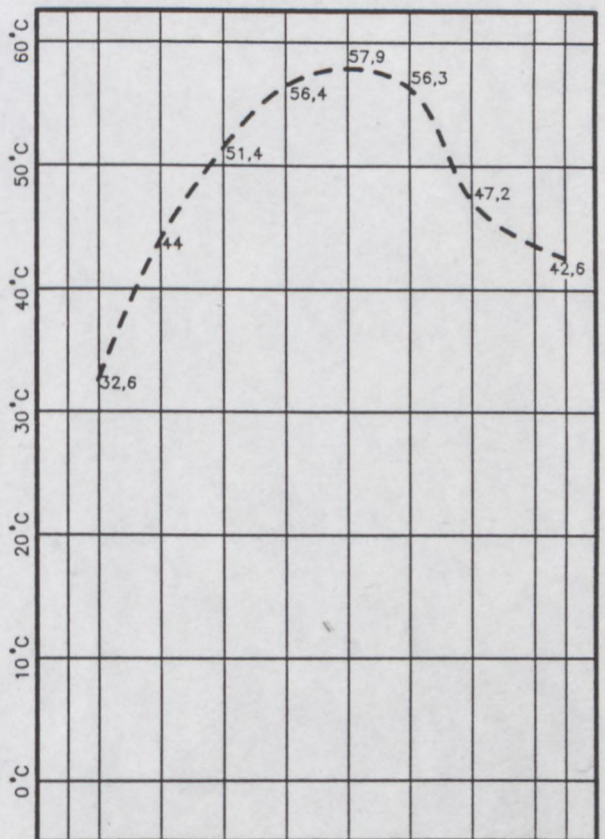
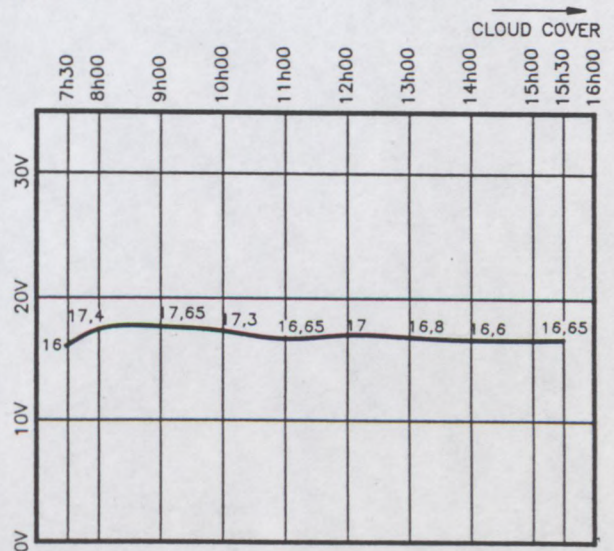
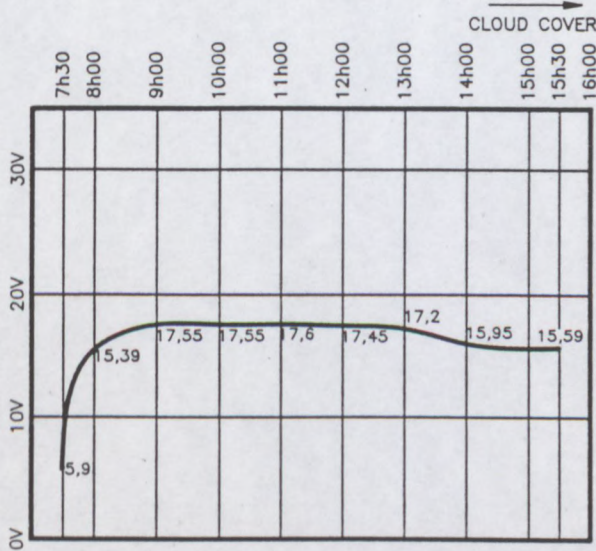
PANEL VOLTAGE = —————

PANEL TEMP. = - - - - -

AMB. TEMP. = ..... (not plotted)

# SOLAR PANEL VOLTAGE / TEMPERATURE GRAPHS

DATE: 01:11:90



TYPE 6 40W  
CONSTANT 1A LOAD

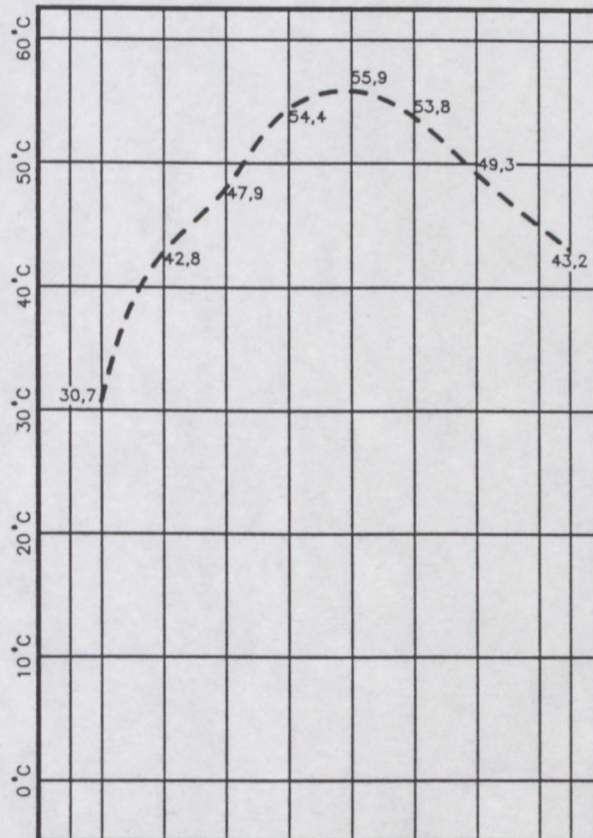
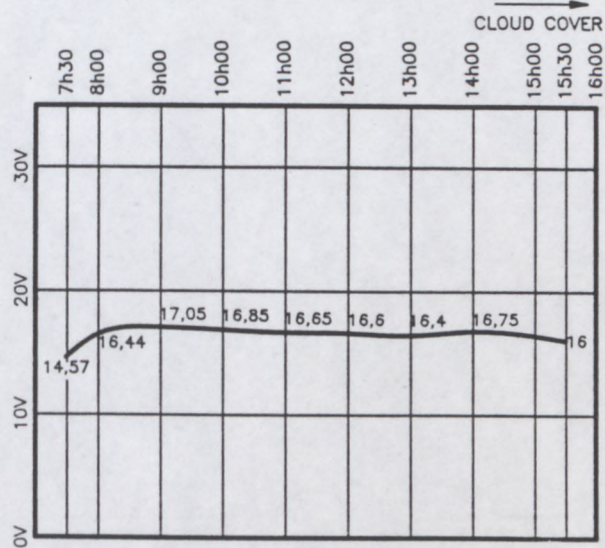
TYPE 8 55W  
CONSTANT 1A LOAD

APPENDIX 3.16.1.3

PANEL VOLTAGE = \_\_\_\_\_  
 PANEL TEMP. = \_\_\_\_\_  
 AMB. TEMP. = \_\_\_\_\_

DATE: 01:11:90

# SOLAR PANEL VOLTAGE / TEMPERATURE GRAPHS



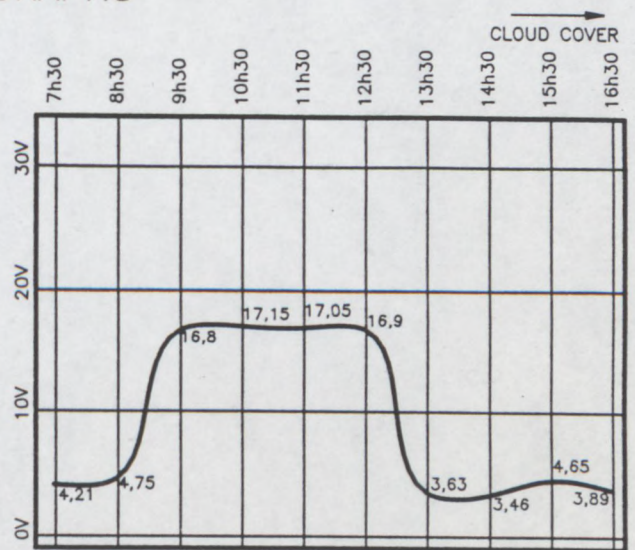
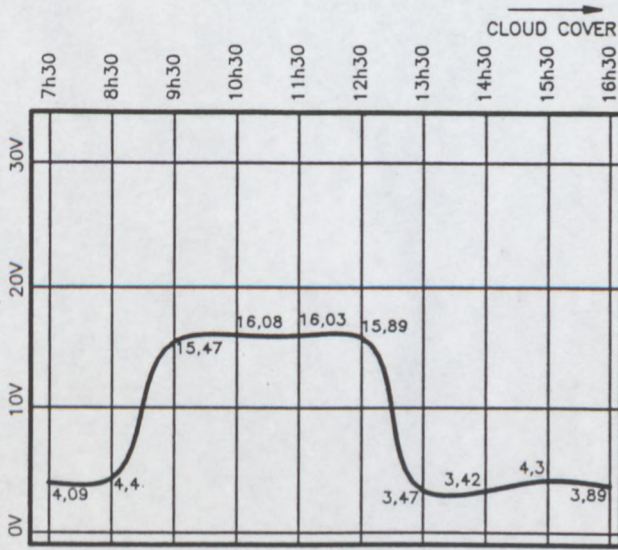
TYPE 9 50W  
 CONSTANT 1A LOAD  
 APPENDIX 3.16.1.4

# SOLAR PANEL

DATE 19:11:90

## VOLTAGE / TEMPERATURE GRAPHS




PANEL VOLTAGE = —————  
 PANEL TEMP. = - - - - -  
 AMB. TEMP. = .....  
 CLOUD COVER →



TYPE 1 48W  
 CONSTANT 2A LOAD

TYPE 2 50W  
 CONSTANT 2A LOAD

APPENDIX 3.16.2.1

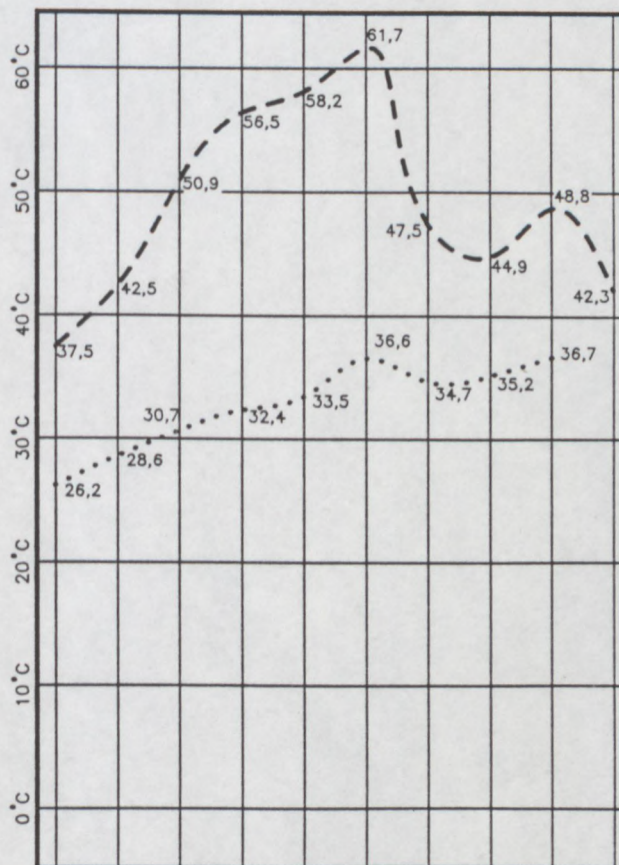
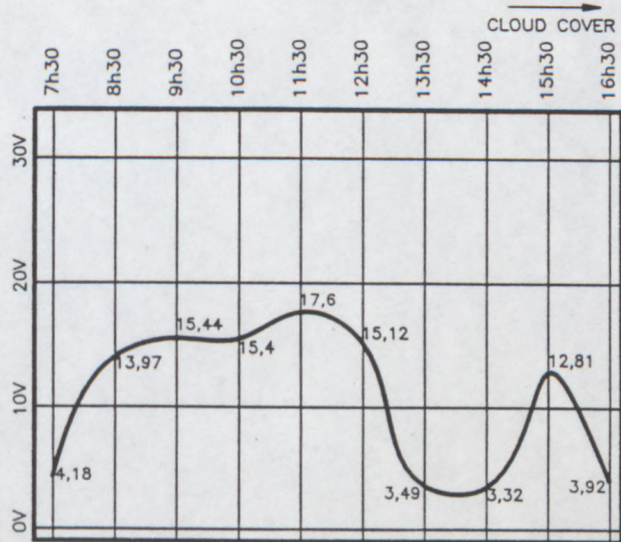
PANEL VOLTAGE =   
 PANEL TEMP. =   
 AMB. TEMP. = 

# SOLAR PANEL

## VOLTAGE / TEMPERATURE

### GRAPHS

DATE 19:11:90

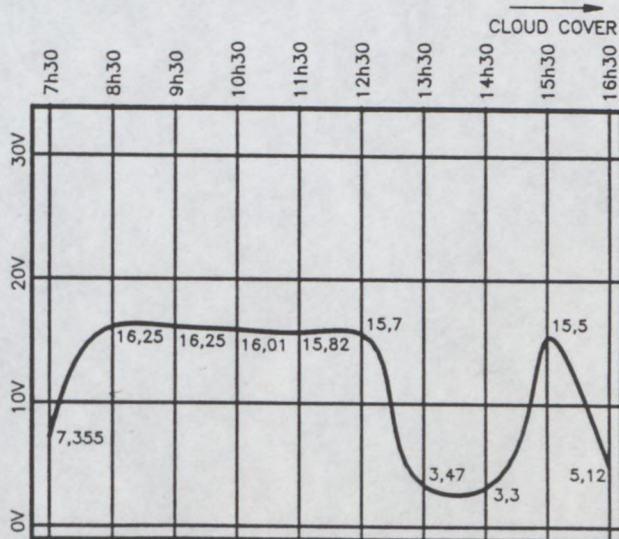
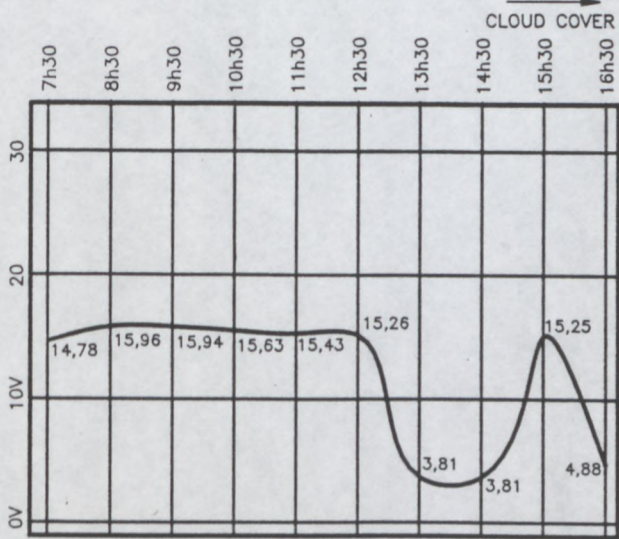


TYPE 3 50W  
 CONSTANT 2A LOAD  
 APPENDIX 3.16.2.2

# SOLAR PANEL VOLTAGE / TEMPERATURE GRAPHS

DATE 19:11:90

PANE VOLTAGE = —————  
 PANEL TEMP. = - - - - -  
 -MB. TEMP. = ·······



TYPE 4 47W  
CONSTANT 1A LOAD

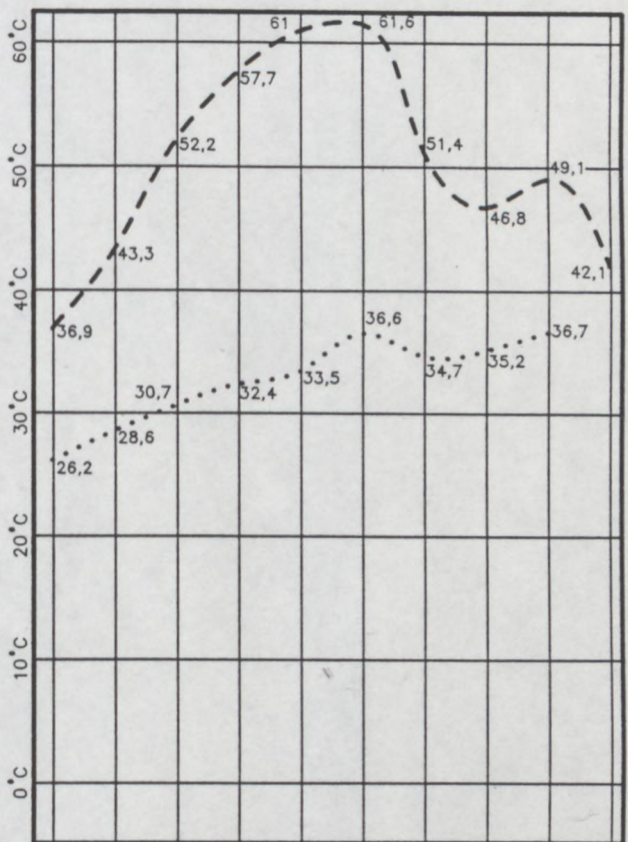
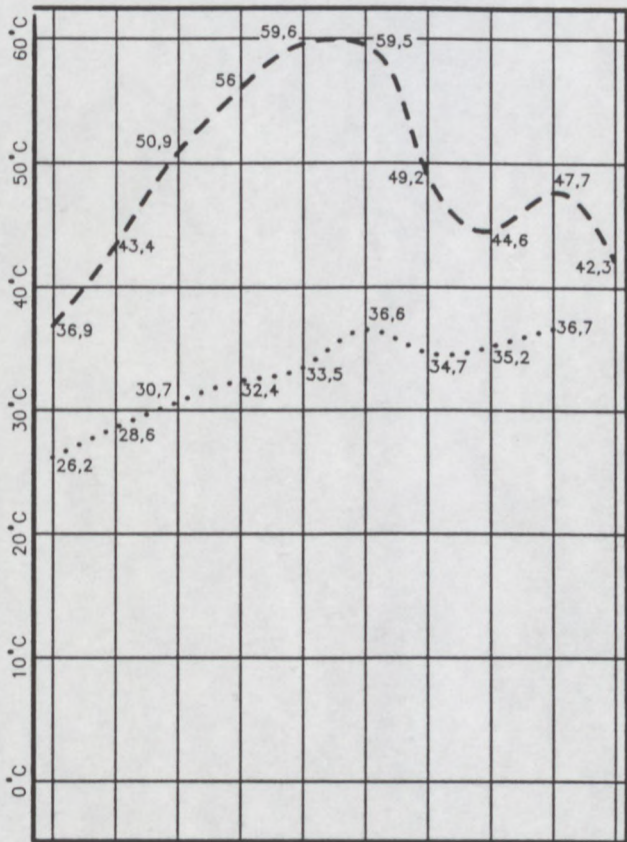
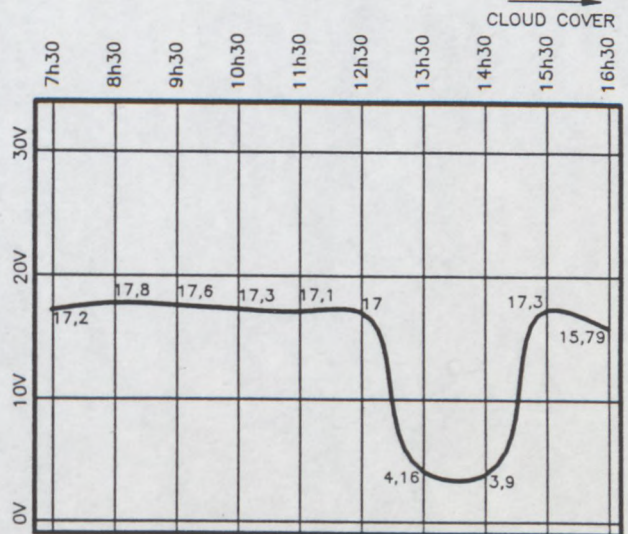
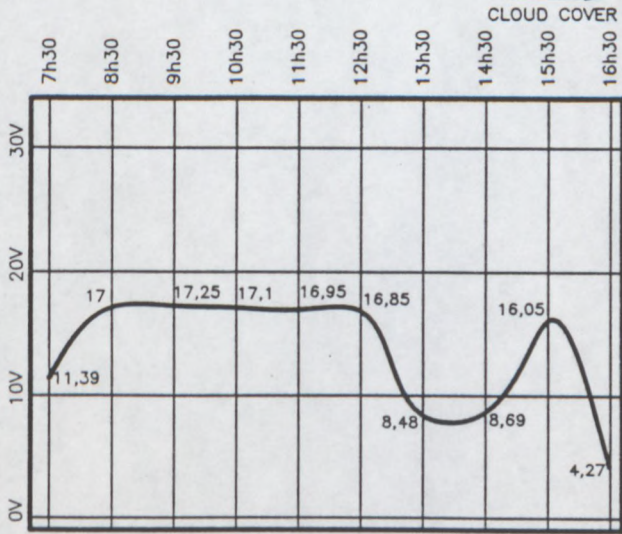
TYPE 5 55W  
CONSTANT 1A LOAD

APPENDIX 3.16.2.3

# SOLAR PANEL VOLTAGE / TEMPERATURE GRAPHS

DATE 19:11:90

PANEL VOLTAGE = —————  
 PANEL TEMP. = - - - - -  
 AMB. TEMP. = .....  
 CLOUD COVER →



TYPE 6 40W  
CONSTANT 1A LOAD

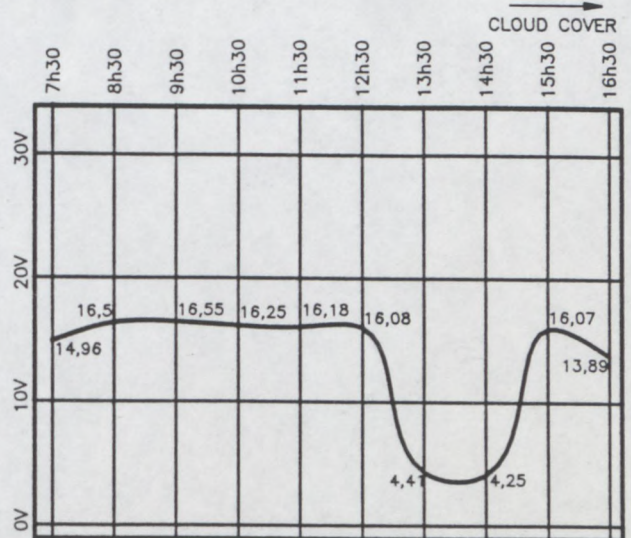
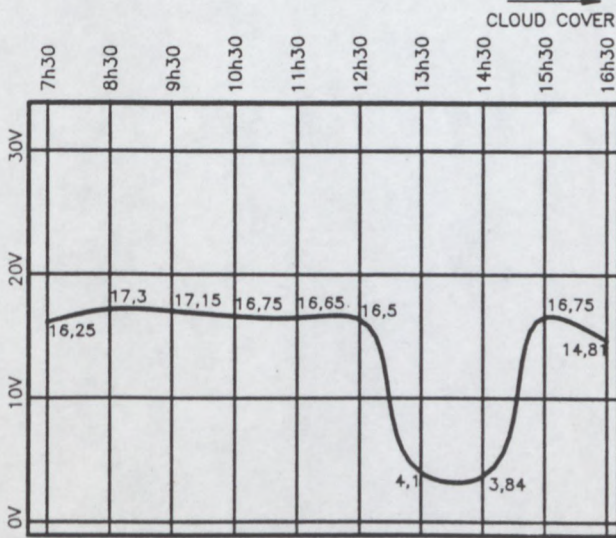
TYPE 7 55W  
CONSTANT 1A LOAD

APPENDIX 3.16.2.4

# SOLAR PANEL VOLTAGE / TEMPERATURE GRAPHS

DATE 19:11:90

PANEL VOLTAGE = —————  
 PANEL TEMP. = - - - - -  
 AMB. TEMP. = .....



TYPE 8 55W  
CONSTANT 1A LOAD

TYPE 9 50W  
CONSTANT 1A LOAD

APPENDIX 3.16.2.5

## APPENDIX 3.17.1

Nov. 26 91 10:26 OPTITRON 823 3317  
P.1.2

ARCO SOLAR, INC  
STAND-ALONE SYSTEM DESIGN PROGRAM (PV/BATTERY) VER. 5.1  
10/1/87

DESIGN PROVIDED BY : OPTITRON (PTY) LIMITED

DATE: 26/11/91                      CUSTOMER: TELKOM  
OPER: MGC                              ADDRESS : MILNERTON  
APPLICATION: INDUSTRIAL D.C.

INSOLATION DATA LOCATION: PRETORIA

LATITUDE: 25.44 Deg. S.                      LONGITUDE: 28.11 Deg. E.  
GROUND REFLECTANCE: .20 (J)  
SYSTEM VOLTAGE: 24 V.D.C.  
AVG. LOAD: 166 AH/DAY (30% NIGHT TIME)

### SELECTED SYSTEM DATA

VOLTAGE LOSS: .5 V THROUGH CABLE

<u>ARRAY</u>	<u>BATTERY</u>
TILT ANGLE: 30.0 DEGREES	DAYS OF AUTONOMY: 3.0
MAX. PWR. CURRENT: 33.5 A.	MINIMUM BAT. TEMP. 10.8 Deg.C.
MAXIMUM POWER: 1167.5 W.	TOTAL STORAGE: 620 AH
ASI M55 3.05 A. @ 17.4V.	GENERIC DEEP ANTIMONY 10AH.2V.
2 (S) x 11 (P) = 22 TOTAL	12 (S) X 62 (P) = 744 TOTAL

### SYSTEM DESIGN ANALYSIS (BASED ON 90% OF RATED OUTPUT)

MONTH	FLAT LANG	PANEL LANG	-AVG. AH/DAY- OUTPUT	LOAD	END OF MONTH CAPACITY
JAN	582	524	183.6	166.0	100.0%
FEB	528	509	179.3	166.0	100.0%
MAR	491	527	186.4	166.0	100.0%
APR	420	511	181.7	166.0	100.0%
MAY	363	494	176.4	166.0	100.0%
JUN	343	496	177.3	166.0	100.0%
JUL	356	499	178.5	166.0	100.0%
AUG	440	561	199.6	166.0	100.0%
SEP	493	555	196.5	166.0	100.0%
OCT	538	538	189.3	166.0	100.0%
NOV	576	528	185.3	166.0	100.0%
DEC	565	500	175.1	166.0	100.0%

NOTE: ARRAY TO FACE TRUE NORTH

PERFORMANCE OF SYSTEM AT INSTALLATION SITE WILL VARY  
DEPENDANT UPON WEATHER CONDITIONS AND ADEQUACY OF  
INSTALLATION AND MAINTENANCE.

APPENDIX 3.17.2

Nov. 26 91 10:26 OPTITRON 823 3317

P.1.2

ARCO SOLAR, INC

STAND-ALONE SYSTEM DESIGN PROGRAM (PV/BATTERY) VER. 5.1 10/1/87

DESIGN PROVIDED BY : OPTITRON (PTY) LIMITED

DATE: 26/11/91 CUSTOMER: TELKOM

OPER: MGC ADDRESS : MILNERTON

APPLICATION: INDUSTRIAL D.C.

INSOLATION DATA LOCATION: PRETORIA

LATITUDE: 25.44 Deg. S. LONGITUDE: 28.11 Deg. E.

GROUND REFLECTANCE: .20 (J)

SYSTEM VOLTAGE: 12 V.D.C.

AVG. LOAD: 166 AH/DAY (30% NIGHT TIME)

SELECTED SYSTEM DATA

VOLTAGE LOSS: .5 V THROUGH CABLE

<u>ARRAY</u>		<u>BATTERY</u>	
TILT ANGLE:	30.0 DEGREES	DAYS OF AUTONOMY:	3.0
MAX. PWR. CURRENT:	33.5 A.	MINIMUM BAT. TEMP.	10.8 Deg.C.
MAXIMUM POWER:	1167.5 W.	TOTAL STORAGE:	620 AH

ASI M55	3.05 A. @ 17.4V.	GENERIC DEEP ANTIMONY 10AH.2V.
2 (S) x 11 (P) = 22 TOTAL		6 (S) X 62 (P) = 372 TOTAL

SYSTEM DESIGN ANALYSIS  
(BASED ON 90% OF RATED OUTPUT)

MONTH	FLAT PANEL		-AVG. AH/DAY-		END OF MONTH
	LANG	LANG OUTPUT	LOAD	CAPACITY	
JAN	582	524	183.6	166.0	100.0%
FEB	528	509	179.3	166.0	100.0%
MAR	491	527	186.4	166.0	100.0%
APR	420	511	181.4	166.0	100.0%
MAY	363	494	176.1	166.0	100.0%
JUN	343	496	177.0	166.0	100.0%
JUL	356	499	178.3	166.0	100.0%
AUG	440	561	199.1	166.0	100.0%
SEP	493	555	196.0	166.0	100.0%
OCT	538	538	188.9	166.0	100.0%
NOV	576	528	185.0	166.0	100.0%
DEC	565	500	174.9	166.0	100.0%

NOTE: ARRAY TO FACE TRUE NORTH

PERFORMANCE OF SYSTEM AT INSTALLATION SITE WILL VARY  
DEPENDANT UPON WEATHER CONDITIONS AND ADEQUACY OF  
INSTALLATION AND MAINTENANCE.

APPENDIX 3.18

ANALYSIS OF COOLING SYSTEM USING STANDARD A.C.METHODS

Re. No.	H.P.	To E. Deg.C	Ti-G. Deg.C	Td Wal K	T Flr. Deg.C	T1 Av. Deg.C	T1d A. K	qa Watts	ql Watts	qw Watts	qc Watts
36	Off	25.10	38.40	-13.30	35.80	37.10	0.250	0.428	100	-47.36	53.07
37	Off	25.75	38.65	-12.90	36.05	37.35	0.250	0.428	100	-45.94	54.49
38	Off	25.95	38.95	-13.00	36.25	37.60	0.275	0.470	100	-46.29	54.18
39	Off	25.85	39.25	-13.40	36.50	37.88	0.200	0.342	100	-47.72	52.62
40	Off	26.00	39.45	-13.45	36.70	38.08	0.150	0.256	100	-47.90	52.36
41	Off	26.00	39.55	-13.55	36.90	38.23	0.200	0.342	100	-48.25	52.09
42	On	25.85	39.75	-13.90	37.10	38.43	0.150	0.256	100	-49.50	50.76
43	On	25.95	39.90	-13.95	37.25	38.58	-0.125	-0.214	100	-49.68	50.11
44	On	26.15	39.60	-13.45	37.30	38.45	-0.600	-1.026	100	-47.90	51.08
45	On	26.30	38.65	-12.35	37.05	37.85	-0.525	-0.898	100	-43.98	55.12
46	On	26.65	37.95	-11.30	36.70	37.33	-0.150	-0.256	100	-40.24	59.50
47	On	26.60	37.75	-11.15	36.60	37.18	0.150	0.256	100	-39.71	60.55
48	Off	25.80	38.05	-12.25	36.60	37.33	0.175	0.299	100	-43.62	56.68
49	Off	25.80	38.30	-12.50	36.70	37.50	-5.325	-9.106	100	-44.51	48.38
50	Off	25.70	38.65	-12.95	25.70	32.18	5.775	9.875	100	-46.11	63.76
51	Off	25.75	38.95	-13.20	36.95	37.95	0.225	0.385	100	-47.01	53.38
52	Off	26.00	39.30	-13.30	37.05	38.18	0.225	0.385	100	-47.36	53.02
53	On	25.85	39.55	-13.70	37.25	38.40	0.175	0.299	100	-48.79	51.51
54	On	27.85	39.75	-11.90	37.40	38.58	0.225	0.385	100	-42.38	58.01
55	On	27.75	39.95	-12.20	37.65	38.80	-0.100	-0.171	100	-43.44	56.38
56	Off	27.95	39.70	-11.75	37.70	38.70	0.200	0.342	100	-41.84	58.50
57	On	28.00	39.90	-11.90	37.90	38.90	-0.250	-0.428	100	-42.38	57.20
58	On	28.00	39.50	-11.50	37.80	38.65	-0.450	-0.769	100	-40.95	58.28
59	On	28.00	38.85	-10.85	37.55	38.20	-1.475	-2.522	100	-38.64	58.84
60	On	28.20	36.20	-8.00	37.25	36.73	0.600	1.026	100	-28.49	72.54
61	Off	28.30	37.70	-9.40	36.95	37.33					

- To E. = Temperature of the outside skin of the container
- Ti-G = Temperature of the inside skin of the container half way up.
- T Flr. = Temperature of the inside floor level.
- Td Wal = Temperature difference across the Insulated walls
- T1 Av. = The average temperature inside the container.
- T1d A. = The difference in temperature of the present reading to the next reading using average inside temperatures.
- qa = The heat load imparted to the air inside the container.
- ql = The heat load inside the container.
- qw = The heat load conducted through the walls of the container.
- qc = Estimated cooling load

APPENDIX 3.19 CONVENTIONAL ANALYSIS  
 NO COOLING 100 W LOAD STEPPED TEMPERATURE PROGRAM

Re. No.	T5 Deg.C	T6 Deg.C	Td A. K	Td Wal K	qa Watts	qw Watts	ql Watts	Un Acc Watts
90	45.00	29.65	0.10	15.35	0.171	54.6767	100	45.1523
91	45.10	31.50	0.20	13.60	0.342	48.4432	100	51.2148
92	45.30	31.40	0.20	13.90	0.342	49.5118	100	50.1462
93	45.50	31.35	0.15	14.15	0.256	50.4023	100	49.3412
94	45.65	31.40	0.15	14.25	0.256	50.7585	100	48.9850
95	45.80	31.40	0.20	14.40	0.342	51.2928	100	48.3652
96	46.00	31.35	0.10	14.65	0.171	52.1833	100	47.6457
97	46.10	31.40	0.15	14.70	0.256	52.3614	100	47.3821
98	46.25	31.40	0.00	14.85	0.000	52.8957	100	47.1043
99	46.25	31.40	0.10	14.85	0.171	52.8957	100	46.9333
100	46.35	31.30	0.05	15.05	0.085	53.6081	100	46.3064
101	46.40	31.25	-0.15	15.15	-0.256	53.9643	100	46.2922
102	46.25	31.35	0.20	14.90	0.342	53.0738	100	46.5842
103	46.45	31.35	0.00	15.10	0.000	53.7862	100	46.2138
104	46.45	31.35	0.10	15.10	0.171	53.7862	100	46.0428
105	46.55	31.35	0.05	15.20	0.086	54.1424	100	45.7721
106	46.60	31.30	0.05	15.30	0.085	54.4986	100	45.4159
107	46.65	31.30	0.00	15.35	0.000	54.6767	100	45.3233
108	46.65	31.25	0.20	15.40	0.342	54.8548	100	44.8032
109	46.85	33.45	0.30	13.40	0.513	47.7308	100	51.7562
110	47.15	32.75	0.15	14.40	0.256	51.2928	100	48.4507
111	47.30	33.20	0.15	14.10	0.257	50.2242	100	49.5193
112	47.45	33.20	0.10	14.25	0.171	50.7585	100	49.0705
113	47.55	33.20	0.15	14.35	0.257	51.1147	100	48.6288
114	47.70	33.25						

T5 = Outside Temperature.

T6 = Inside temperature.

Td A. = Temperature difference present reading / next reading.

Td W. = Temperature difference across the container wall.

qa = Heat absorbed by the container air.

qw = Heat conducted across the wall.

ql = 100 Watt heat load.

Un Acc = Heat unaccounted for.

APPENDIX 3.20 CONVENTIONAL ANALYSIS  
NO LOAD STEPPED TEMPERATURE PROGRAM

Re. No	T5 Deg.C	T6 Deg.C	Td A. K	Td Wal K	qa Watts	qw Watts
126	32.85	33.65	0.10	0.800	0.1710	2.8496
127	32.95	35.30	0.30	2.350	0.5130	8.3707
128	33.25	35.55	0.25	2.300	0.4275	8.1926
129	33.50	35.65	0.15	2.150	0.2565	7.6583
130	33.65	35.70	0.15	2.050	0.2565	7.3021
131	33.80	35.55	0.15	1.750	0.2565	6.2335
132	33.95	35.60	0.10	1.650	0.1710	5.8773
133	34.05	35.85	0.10	1.800	0.1710	6.4116
134	34.15	35.60	0.15	1.450	0.2565	5.1649
135	34.30	35.55	0.10	1.250	0.1710	4.4525
136	34.40	35.60	0.05	1.200	0.0855	4.2744
137	34.45	35.75	0.10	1.300	0.1710	4.6306
138	34.55	35.60	0.05	1.050	0.0855	3.7401
139	34.60	35.55	0.05	0.950	0.0855	3.3839
140	34.65	35.80	0.05	1.150	0.0855	4.0963
141	34.70	35.70	0.05	1.000	0.0855	3.5620
142	34.75	35.55				

T5 = Inside temperature of the container.

T6 = Outside temperature.

Td A. = Temperature difference present to next reading

Td W. = Temperature difference across the container wall.

qa = Heat absorbed by the air in the container.

qw = Heat entering through the walls of the container.

Re. = Reading number.

## APPENDIX 3.21

## COOLING 2,25 Amps 100 Watts LOAD STEPPED GRAPH MATHS APPROACH

Td1 K	Re. No.	T2 In °C	T2 Out °C	Td2 K	H.L.T.R. Watts	H.Pumped Watts	T.R.H.P W/Sq.m/deg.C
15.1	109	40.20	32.00	8.20	54.3046	45.6954	1.1826
15.1	110	40.25	32.30	7.95	52.6490	47.3510	1.2640
15.1	111	40.15	32.50	7.65	50.6623	49.3377	1.3687
15.1	112	40.15	32.55	7.60	50.3311	49.6689	1.3870
15.1	113	40.10	32.65	7.45	49.3377	50.6623	1.4432
15.1	114	40.15	32.75	7.40	49.0068	50.9934	1.4624
15.1	115	40.10	32.75	7.35	48.6755	51.3245	1.4819
15.1	116	40.15	32.80	7.35	48.6755	51.3245	1.4819
15.1	117	40.15	32.80	7.35	48.6755	51.3245	1.4819
15.1	118	40.10	32.80	7.30	48.3444	51.6556	1.5017
15.1	119	40.10	32.85	7.25	48.0132	51.9868	1.5218
15.1	120	40.10	32.90	7.20	47.6821	52.3179	1.5421
15.1	121	40.10	32.85	7.25	48.0132	51.9868	1.5218
15.1	122	40.15	32.90	7.25	48.0132	51.9868	1.5218
15.1	123	40.05	32.90	7.15	47.3510	52.6490	1.5627
15.1	124	40.10	32.85	7.25	48.0132	51.9868	1.5218
15.1	125	40.10	32.90	7.20	47.6821	52.3179	1.5421
15.1	126	40.15	33.70	6.45	42.7152	57.2848	1.8848
15.1	127	40.35	34.00	6.35	42.0530	57.9470	1.9367
15.1	128	40.50	34.30	6.20	41.0598	58.9404	2.0175
15.1	129	40.65	34.55	6.10	40.3974	59.6026	2.0736
15.1	130	40.70	34.55	6.15	40.7285	59.2715	2.0453
15.1	131	40.80	34.65	6.15	40.7285	59.2715	2.0453
15.1	132	40.85	34.70	6.15	40.7285	59.2715	2.0453
15.1	133	40.95	34.70	6.25	41.3907	58.6093	1.9901
15.1	134	41.05	34.75	6.30	41.7219	58.2781	1.9632
15.1	135	41.10	34.80	6.30	41.7219	58.2781	1.9632
15.1	136	41.15	34.70	6.45	42.7152	57.2848	1.8848
15.1	137	41.20	34.80	6.40	42.3841	57.6159	1.9105
15.1	138	41.25	34.80	6.45	42.7152	57.2848	1.8848
15.1	139	41.25	34.75	6.50	43.0484	56.9536	1.8595
15.1	140	41.35	34.80	6.55	43.3775	56.6225	1.8346
15.1	141	41.35	34.80	6.55	43.3775	56.6225	1.8346
15.1	142	41.40	34.80	6.60	43.7086	56.2914	1.8101
15.1	143	41.40	34.80	6.60	43.7086	56.2914	1.8101
15.1	144	41.45	35.65	5.80	38.4108	61.5894	2.2536
15.1	145	41.65	35.95	5.70	37.7483	62.2517	2.3178
15.1	146	41.80	36.30	5.50	36.4238	63.5762	2.4532
15.1	147	42.05	36.45	5.60	37.0861	62.9139	2.3843
15.1	148	42.15	36.50	5.65	37.4172	62.5828	2.3507
15.1	149	42.35	36.55	5.80	38.4108	61.5894	2.2536
15.1	150	42.50	36.65	5.85	38.7417	61.2583	2.2223
15.1	151	42.65	36.80	6.05	40.0662	59.9338	2.1024
15.1	152	42.75	36.85	6.10	40.3974	59.6026	2.0736
15.1	153	42.90	36.70	6.20	41.0598	58.9404	2.0175
15.1	154	43.00	36.65	6.35	42.0530	57.9470	1.9367
15.1	155	43.05	36.70	6.35	42.0530	57.9470	1.9367
15.1	156	43.10	36.75	6.35	42.0530	57.9470	1.9367
15.1	157	43.10	36.70	6.40	42.3841	57.6159	1.9105
15.1	158	43.15	36.70	6.45	42.7152	57.2848	1.8848
15.1	159	43.20	36.75	6.45	42.7152	57.2848	1.8848
15.1	160	43.20	36.70	6.50	43.0484	56.9536	1.8595
15.1	161	43.20	36.75	6.45	42.7152	57.2848	1.8848

H.L.T.R. = Heat Lost via thermal resistance of the container

H.Pumped = Heat pumped by thermoelectric cooler

T.R.H.P. = Thermal resistance of heat pump.

Thermal Resistance of the container is constant at ? 1.4

T.L.T.C. = Time of Last Temperature Change.

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