# STEADY STATE THERMAL PERFORMANCE

OF A

HIGH TEMPERATURE REACTOR FUEL ELEMENT

by

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#### SUMMARY

The safe and economic operation of a nuclear reactor is highly dependent upon the detailed knowledge of the steady state thermal and hydraulic characteristics of the fuel.

Various designs of HTR fuel element are discussed and the Tubular Interacting concept is described in more detail. This design, the one adopted for the Oldbury 'B' tender, was the one on which the analytical methods, described in this thesis, were based.

The spatial and time distributions of heat generation, and fast neutron dose, are discussed and methods described which have been developed to determine spatial and time distributions of channel mass flow rate and coolant outlet temperature.

With these distributions as boundary conditions, methods (involving the use of computer programs) are described which analyse the thermal performance of a fuel element. Particular emphasis has been given to three important aspects of fuel behaviour. The heat transfer and pressure drop characteristics of the coolant passages are investigated analytically. Dimensional change caused by thermal and irradition effects has a marked effect upon fuel element temperatures and this phenomenon is studied in some depth: Methods have also been developed which postulate the form and development of corrosive attack of the fuel channel and determine the thermal and hydraulic effects of such corrosion.

Using all these methods detailed spatial and time dependent temperature distributions are determined for a single fuel element. Spatial distributions of peak fuel channel temperatures at a particular moment in the reactor core life (Snapshot) are also determined and, by making certain statistical observations, expected frequency distributions are found. to Judy

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#### PREFACE

This research was carried out in the Thermal Performance Group of Systems Department of The Nuclear Power Group, and formed part of High Temperature Reactor design studies instigated by TNPG and the Central Electricity Generating Board.

I would like to express my gratitude to TNPG, in particular Mr. R. Rutherford and Mr. P.E.J. French, for allowing me to pursue this research. I would also like to thank Dr. P.N. Cooper of the University of Aston in Birmingham and Dr. E.C. Cobb of TNPG for their encouragement and helpful criticism. My thanks are also due to the Editorial Staff of TNPG, especially Mrs. E.J. Eyes, for the production of this thesis.

# CHAPTER 1

## INTRODUCTION

# The High Temperature Reactor

The High Temperature Reactor is the logical development of the United Kingdom gas cooled reactor programme. The HTR (Mk III) system follows on from the Magnox (Mk I) and Advanced Gas Cooled Reactor (Mk II) systems.

The AGR has stainless steel clad  $UO_2$  fuel, cooled by  $CO_2$ , achieving core power densities of about 2.8 MW/m<sup>3</sup>. Fuel ratings and boiler inlet coolant temperatures are limited by fission product release from the  $UO_2$  fuel, contained within the can, and by temperature limitations of the can itself.

The graphite moderator is resident in the core for the full thirty years' life of the reactor and must therefore be maintained below about  $400^{\circ}$ C to avoid excessive corrosion and irradiation induced distortion. This is achieved by means of a steel baffle allowing the CO<sub>2</sub> to cool the moderator before the fuel. This baffle presents many design and operational problems.

The HTR has been designed to overcome the restrictions of the AGR system and to provide further development potential. The main characteristics of the HTR that contribute to the desirability of the system can be summarised as follows:

(i) Coated UO<sub>2</sub> particles which act as efficient fission product retention spheres are embedded and clad in graphite. Inert helium is the coolant with its high thermal conductivity and specific heat. A high core power density (e.g. 8.4 MW/m<sup>3</sup>) is the result.

(ii) The whole active core is replaceable allowing the moderator to be run at higher temperatures.

- (iii) Higher operating fuel, moderator and coolant temperatures resulting in greater heat transfer and overall plant efficiencies.
- (iv) Large negative fuel temperature reactivity coefficient.
- (v) Uranium ore and separative costs are lower because of the higher power densities.
- (vi) As a result of the high plant efficiencies (41%) there are reduced requirements for cooling water allowing stations to be located inland, close to load centres.
- (vii) In the longer term, the high coolant temperatures facilitate process heating (e.g. aluminium smelting) and direct cycle conversion (e.g. gas turbines).

Fig 1/1 shows the main features of a typical HTR.

## Fuel element thermal performance calculations

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As with all reactor systems 'safety' and 'economics' are opposing considerations. In order to make a desirable compromise a detailed knowledge of the contributory factors must be obtained.

For an HTR core the most important 'safety' factors are fission product release and core structural integrity. The opposing economic considerations would be high core power densities and operating temperatures (efficiencies).

Fission product release from the fuel and the structural behaviour of the core components are chiefly dependent upon their thermal and irradiation histories. Thermal performance calculations on the fuel and moderator are therefore required as one important step in achieving the lowest capital and operating costs of a 'safe' reactor system.

This thesis describes the steps taken to determine the steady state thermal performance of an HTR fuel element; from basic station parameters

to complete temperature and coolant distributions required for 'safety' calculations. It should be noted that the steady state performance must be backed up by studies of the transient and fault conditions of the reactor.

# CHAPTER 2

# DESIGN OF HTR FUEL ELEMENTS

The fundamental temperature dependent component of the HTR system is the fuel particle. The composition of the particle, its incorporation in the fuel bed and particle failure modes are described in section 1 of this chapter. In section 2 the various fuel element design concepts are discussed which have been considered over the last few years. Finally, in section 3, the design concept adopted for the Oldbury 'B' tender is described in rather more detail and the optimisation of its geometry briefly discussed.

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#### 1 Fuel particle and matrix

1.1 Composition of the fuel particle and matrix

The coated particle concept was devised to perform as its own fission product retaining vessel; such a system allowing higher irradiations than pellet (AGR) type fuel. These particles, of approximately  $1100 \,\mu$ m in diameter, are shown in Fig 2/1, made available by VOICE (1).

The fission product retention is achieved by a series of 'shells' surrounding the UO<sub>2</sub> kernel. Fig 2/1 shows a section through a typical particle. The UO<sub>2</sub> kernel (800  $\mu$  m diameter) has immediately adjacent a coating of porous pyrocarbon (100  $\mu$  m diameter). This buffer layer, as well as providing additional fission product accomodation space, also acts as a sacrificial layer for arresting fission fragments. A high density isotropic (HDI) pyrocarbon pressure retaining layer is then deposited (110  $\mu$  m) followed by a metallic fission product retention layer of SiC. The 'pre-stressing' of the inner HDI pyrocarbon and SiC layers is achieved by another coating of (HDI) pyrocarbon (50  $\mu$ m) which also provides protection against external chemical attack. The thickness of the coatings has been chosen to give a compromise between high heavy metal densities and particle integrity.

There are two methods by which the particles are bonded together:

(i) 'Loose-bonding'

The particles are bound together by a resin-graphite 'glue' producing high heavy metal densities. Under irradiation, however, the bonding has a tendency to break down allowing particles to become free.

# (ii) 'Compacting'

Here the particles are placed in a die with graphite and

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compacted at high temperatures. The heavy metal densities achieved (1g/cc) are not as high as with the loose bonding method because of the risk of particle fracturing but the compacts so formed are highly stable under irradiation.

A more detailed description of irradiation experience, types of graphite etc. can be found in BISHOP ( $\underline{2}$ ). The bonding method finally adopted for the Oldbury 'B' tender design (partly as a result of the BISHOP committee work) was the compacting process; high integrity being preferred to low cost - at least for the first HTR.

# 1.2 Failure modes of the fuel particle

There have been two failure modes recognised from the limited irradiation experience available and they will now be briefly described. Further details can be obtained from BISHOP (2) who has attempted to quantify these failure phenomena so as to provide limiting criteria in design studies.

## (i) Amoeba attack

This is believed to be a chemically induced failure where the creation of free oxygen from the fission of the uranium allows oxidation of the buffer layer. It is a reversible process and the oxidation of carbon on one side of the kernel is accompanied by carbon deposition on the other side; the cross-kernel temperature difference ( $\Delta T$ ) causing this effect. Kernel rating (Q), absolute temperature (T) and irradiation (t) are also believed to be important variables; the amoeba attack building up in a cumulative way throughout the fuel dwell. After a certain degree of attack the particle becomes sufficiently weakened for the internal pressure to cause failure and the emmission of fission products. BISHOP (2) has

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quantified this effect in the following way.

Since it is not possible to state a specific limit on amoeba attack which, once exceeded, will cause the particle to fail, BISHOP has defined a limit after which the particle is said to be 'at risk' i.e. the amoeba life, F, is equal to 1.0 when this limit has been reached. F is given by (see GREEN (3)):

 $F = 0.072t (Q \Delta T)^{\frac{1}{2}} \exp\left[6.7 - \frac{21200}{T + \Delta T}\right] \qquad \dots 1$ where t is in days, Q in W/cm<sup>3</sup>,  $\Delta T$  and T in <sup>o</sup>K.

## (ii) Pressure failure

During irradiation of the fuel the PyC will shrink giving a compressive stress in the stable SiC layer. Shrinkage of the inner PyC layer will give further compressive stress in the SiC before, possibly, becoming detached. As the fission gas pressure builds up, the compressive stress in the SiC reduces until it finally goes into tension where upon it is assumed to fail, so allowing metallic fission products to escape. The fission gas pressure is dependent upon burn-up and instantaneous temperature and unlike amoeba failure is independent of temperature history. WALTHER (<u>4</u>) has provided a mathematical model of the stresses within the particle and CONWAY-JONES (<u>5</u>) describes how this model can be used to supply the limiting criteria on particle temperature and burn-up.

# Fuel element and moderator block designs

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As described above one of the essential features of the HTR is the integration of fuel and moderator such that, on refuelling, moderator is also replaced. A common feature of most designs considered to date is a hexagonal brick between 350 and 500 mm A/F which is the basic refuelling unit. Columns of these bricks contain the fuel and control channels and it is with the type and distribution of fuel within the brick where conceptual variations have been applied. These designs can be divided into two categories arising from independent experimental experience of the USA and the UK:

(i) fuel pin concepts (UK)

(ii) integral brick (USA)

(The Pebble Bed reactor, studied in West Germany, will not be considered here.)

The fuel pin concepts are those design where the brick has a number of channels containing fuel encased in graphite and cooled by helium passing over the pin. The integral brick designs are of a more homogeneous type where the fuel and moderator are closely integrated by having a large number of small channels; some containing fuel compacts and some passing coolant.

## 2.1 Fuel pin designs

The most important of the various designs considered in the UK are the Hollow-rod, Teledial and Tubular (non-interacting and interacting) designs. These are shown schematically in Fig 2/2 reproduced from SMITH (6)

(i) Hollow-rod

This is a cylindrical compact in a cylindrical graphite can with three longitudinal anti-bowing ribs. Coolant passes through the annular channel between can and channel wall. This design has

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the advantage of simplicity of thermal and hydraulic analysis, (e.g. the position of peak fuel temperature is fixed at the inner compact surface). With limited heat transfer surface, however, thermal ratings are low. The compact is unrestrained providing low compact stresses and therefore large (up to 1.0 mm) interface gaps can develope with irradiation producing high fuel temperatures at the end-of-life when the burn-up is at a maximum. From particle 'pressure' failure considerations this is undesirable.

# (ii) <u>Teledial</u>

This is a cylindrical graphite tube with three anti-bowing ribs. Within the wall of the tube are contained a number of small cylindrical compacts. Coolant passes either side of the graphite annulus. With this design there are the advantages of a large wetted perimeter, low fuel shrinkage and small gaps. It is however a complex design with high stresses within the graphite. There are also increased costs arising from the larger number of compacts. Higher enrichments are also required because of the more homogeneous nature of the fuel and moderator.

# (iii) <u>Tubular (Non-interacting and interacting)</u>

With these designs annular compacts are contained between graphite sleeves and coolant can pass within the inner sleeve and in the annular passage formed by the outer sleeve and channel wall. In the non-interacting case the clearance between compact inner surface and the outer surface of the inner can is chosen so as to ensure no interaction throughout the fuel dwell. This gives low compact stresses but leads to higher fuel temperatures owing

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to large gaps forming. In the interacting design the initial clearance is chosen so as to give interaction early in the fuel dwell producing smaller gaps at the cost of higher compact stresses. The tubular designs although more complex than the Hollow rod has the advantage of a larger wetted surface producing lower temperatures and higher power densities. These tubular designs are formed by trepanning a graphite rod to form the two sleeves which are connected at one end. There are therefore limitations on inner-outer sleeve temperature differences caused by unacceptable stresses in this end region. Two major disadvantages are common to all these designs:

- (i) high manufacturing costs of fuel pins
- (ii) heterogeneous nature of the fuel which leads to high fuel temperatures.

Both these faults can be overcome (with the inevitable introduction of others) by the adoption of an Integral Brick.

#### 2.2 Integral Brick

This design, developed by Gulf General Atomic, has a lattice, usually triangular, of a large number (200 - 400) of holes containing fuel or coolant. The GGA design has 252 compacts and 126 coolant passages so that one coolant channel accepts heat from two compacts, assuming symmetry.

With such a large number of compacts and coolant channels temperature drops are lower than with pin designs resulting in lower fuel temperatures. This is further enhanced by the reduced fuel shrinkage and interface gaps. In general, apart from its analytical complexity, the IB is, thermally, a highly desirable design as it goes a long way towards the ideal heat transfer system where the fuel and coolant are intimately mixed (e.g.

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as in a fluidised bed). There are however three major disadvantages:

- (i) high compact manufacturing costs arising from the large numbers
- (ii) high stresses within the brick
- (iii) higher enrichments resulting from worsening resonance integrals in this homogeneous design.

In an attempt to lessen these problems compromise designs have been proposed - the Semi-Integral Bricks. Instead of solid fuel compacts they are made annular with an inner protective graphite sleeve and coolant is allowed to pass within. There are also a similar number of compacts as in the pin designs (seventeen approximately). The Semi-Integral design overcomes the compact manufacturing cost problem but suffers from inferior heat transfer and probably higher graphite stresses. More detail of this design together with the I.B. can be found in a comparative exercise carried out by the Author: BALLARD (7).

#### The tubular interacting design

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At the time of the Oldbury 'B' Enquiry Specification (September 1970) it was believed that the Tal. design was the most satisfactory as a fuel element for the first HTR. The advantages of the I.B. although highly attractive could not be substantiated by irradiation experience in the UK. The T.I. design was probably the most attractive economically, of the pin type elements and the two major problems of compact and sleeve stressing were relieved in the former by further, more detailed, analysis and in the latter by optimisation of the pin geometry.

It should be noted, however, that at the time of writing this thesis the I.B. appears to be the favourite for the first HTR. This probably results from increased American influence over the last two years.

For the vast majority of the work described the methods have been applied to the T.I. element which will now be described in more detail.

#### 3.1 Optimisation of fuel element geometry

Before the fuel pin and channel dimensions can be optimised there are certain overall design constraints which must be considered:

- (i) active core height decided by core size considerations
- (ii) fuel compact thickness and diameter manufacturing limitations
- (iii) fuel area derived from reactor physics considerations
- (iv) sleeve thickness manufacturing and stress limitations

With these limitations in mind the geometry is chosen so as to achieve, for the T.I. design, the maximum channel power and minimum pressure drop without exceeding the limits on fuel and graphite peak temperatures and inner-outer graphite sleeve temperature differences.

The optimisation of a T.I. element is a complex procedure and although the Author was intimately involved in choosing the final T.I.

dimensions the work is not believed relevant to the main object of the thesis and will therefore not be related here, (See BALLARD  $(\underline{8})$ .) The Tubular Interacting fuel element and moderator block geometry

3.2

The final fuel element dimensions chosen for the Oldbury 'B' tender are given in Table 5/1 and Fig 2/3 is a drawing of the pin. It will be observed that the compacts are retained within the sleeves by a screwed end-cap which is at the downstream or bottom end of the pin for fuel corrosion reasons. (See Chapter 4, section 4.)

The fuel block, containing seventeen fuel channels is shown in Fig 2/4 and Fig 2/5 shows a control brick where there are nine fuel and three control channels containing, typically, one grey rod, one black rod and one secondary shutdown device, respectively.

## CHAPTER 3

#### THE REACTOR ENVIRONMENT

Before the performance of the fuel element can be examined in depth the conditions under which it will exist in the reactor must first be studied.

The aspects in which the reactor environment influences the performance of a single fuel element are as follows:

- (i) heat generation distribution within the fuel element and associated moderator
- (ii) distribution of fast neutron damage dose within the fuel and moderator
- (iii) coolant mass flow rate through the fuel channel
- (iv) thermal interaction between the fuel channel and its neighbours.

Items (i) and (ii) are dealt with only briefly in section 1 since the Author made only a small contribution to their derivation. Item (iii) in which the Author was intimately involved is discussed in more detail in sections 2 - 5.

In the case of the fuel pin type of elements (e.g. the hollow rod and tubular interacting elements) there is very little thermal interaction between fuel channels in a block and certainly as far as fuel element temperatures are concerned, fuel channels can be examined in isolation in this respect.

In summary, therefore, the object of this chapter is to provide the complete distributions of heat generation, channel flow and coolant outlet temperature in the HTR core which is the basic data required for the work described in Chapters 4 and 5.

# Time and spatial distributions of heat generation and damage dose Axial rating distribution

The method of calculations of the axial rating profile using the one dimensional two-neutron energy groups code BLAZE is described in OLDBURY \*B\* TENDER (9).

Initially just one enrichment was specified axially and the conventional axial temperature profile was obtained where there is a large fuel temperature differential between channel inlet and outlet. In this HTR design the limiting criterion on fuel rating is fuel temperature and there are large incentives to reduce these temperatures without de-rating the core. It was realised that this could be done by having more than one enrichment axially, the higher enrichments towards inlet.

From studies carried out by the Author it was found that substantial fuel temperature reductions could be obtained with just two axial enrichments where the enrichment boundary is between the second and third brick from inlet.

The enrichments were initially chosen to give equal fuel temperatures at the 2m and 4m level. This 'equi-temperature' criterion, however, neglects the effect of rating on partical failure and the enrichments should be chosen to meet an 'equi-amoeba failure risk' criterion.

There are two major factors which need to be considered and which prevent the full benefits of a multi-axial enrichment scheme from being realised.

# (i) Coolant leakage

As explained in section 5 of this chapter certain columns in the periphery of the core, with large thermal and fast neutron dose gradients, bow and by interaction with their neighbours

form gaps at their brick ends. Coolant flow can therefore bypass the channels upstream of these gaps producing higher temperatures at these positions. A dual axial enrichment scheme which increases the rating in the top bricks could raise temperatures in this region above the design limits. Fortunately it is unlikely the highest rated column will be a leaking column.

# (ii) Compact corrosion

As discussed in Chapter 4, section 4, the protection of the fuel compact depends upon the high temperature graphite reacting with the water as it permeates through the sleeves. Towards inlet however, the graphite temperatures are lower and if the fuel temperatures are near the design limit resulting from the dual enrichment scheme the fuel could suffer appreciable chemical attack.

In conclusion, therefore, the dual axial enrichments were chosen (e.g. inner region, 4.74%, 5.88%) so that the fuel temperatures at the 2m peak were still well below the 4m temperatures (approximately  $100^{\circ}$ C, see Fig 5/1) and the design limit. Even with this safety margin fuel temperature reductions of approximately  $60^{\circ}$ C over the normal single enrichment scheme were obtained.

The axial rating shape is dependent on: the radial position in the core, the proximity of control rods and their degree of insertion. It will also depend upon fuel and moderator temperature and there is a certain amount of iteration between the reactor physics and thermal performance calculations to obtain the correct axial profile.

The axial rating profile for a particular channel will vary with the irradiation of that channel. As the irradiation proceeds the high

rating peaks will burnup at a faster rate than the lower rated positions.

For the purposes of the work in this thesis the axial rating profiles which apply to the peak rated channel in an equilibrium core have been used. Fig 3/1 shows the profile for different times in the dwell.

1.2 Radial rating distribution

The channel power distribution for an equilibrium core has been calculated using a 2-group SNAP model with six triangular meshes per column. A more detailed description of the method can be found in the OLDBURY 'B' TENDER (2). Each column in the core has been represented and the program calculates life average rating values at the centroid of each of the six equilateral triangles making up the hexagonal bricks (Fig 3/2).

There are two radial enrichments chosen (5.2% mean inner, 6.7% mean outer) to give equal peak pin powers in the two regions of the core (Fig 3/3).

From this SNAP information both column and channel powers are determined. The column powers are found by taking the arithmetic mean of the six values which are themselves normalised to a core mean of 10<sup>4</sup>. Channel powers are found by first calculating an effective column gradient.

By referring to Fig 3/2; if  $y_c$  is the distance of the centroid from the brick centre and  $y_p$  is the distance of the furthest fuel channel from the brick centre then the across column gradient is defined as:

$$G = \frac{y_p}{y_c} \cdot \frac{\hat{r}}{r}$$

Where  $\hat{\mathbf{r}}$  is the peak value of the centroid rating values and  $\overline{\mathbf{r}}$  is the arithmetic mean.

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From Fig 3/2  $y_p = 178$  mm and therefore  ${}^{y}p/y_c = 1.33$ (NB It is believed that across column gradients will burn down over life. However, no firm data on the magnitude of the effect is as yet, available.

The column power is proportional to  $\overline{\mathbf{r}}$  and it is now necessary to find the constant of proportionality.

 $W_F$  = total fuel channel flow  $\overline{T}_{2C}$  = mixed core outlet temperature of coolant  $\overline{T}_{1C}$  = inlet temperature of coolant  $N_F$  = number of fuel channels  $C_p$  = coolant specific heat mean channel power,  $\overline{Q}_{CH} = C_p (\overline{T}_{2C} - T_{1C})$ and  $\overline{Q}_{CH} = 10^4$  on the SNAP power map.

If Nc is the number of fuel channels within a column then: column power =  $\frac{\overline{Q}_{CH}Nc}{10^4}$   $\overline{r}$  .....3

From OLDBURY 'B' TENDER (9) and core data given in Table 3/1 the value of  $\overline{Q}_{CH}$  is 397 kW.

Fig 3/3 shows the spatial distribution of column average powers  $(\vec{r})$ and across column gradients for a 1/6 sector of the core.

The peak rated channel power (life mean), 514 kW, has been determined from this power map but also includes a margin for fuel management.

1.3 Time evolution of channel power

Owing to the burn-up of fissile atoms there is a reduction in the rating as the irradiation of a fuel element proceeds. This is offset to some extent by the creation of further fissile atoms in the form of  $239_{Pu}$ . The fuel is left in the core until a particular burn-up (MWd/Te)

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has been achieved and since different columns have different ratings there is consequently a whole spectrum of fuel residence times.

The residence time assumed for the peak rated channel is 770 days at 75% load factor. This dwell is consistent with a burn-up of 72000 MWd/Te. The age factor is defined as the ratio of the start of life channel rating to the life average value. The program BLAZE has been used to calculate the age factors for different regions of the core. The results are reported in OLDBURY 'B' TENDER (2). The peak rated channel is assumed to lie in the inner region of the core and therefore, according to this data, has an age factor of 1.18.

It is a good approximation to assume that the channel power falls linearly with time and Fig 3/4 shows the evolution of peak rated channel power with dwell. (OLDBURY 'B' TENDER (9)).

#### 1.4 Fine structure effects

## (i) Axial effects

These arise from the presence of burnable poisons which are only present in the initial loadings. At equilibrium there will be no appreciable axial perturbations.

# (ii) Across pin gradients

These gradients are only important for channels at the edge of the core or close to control rods. A peak rated channel is not likely to occupy either of these positions.

## (iii) Flux depression effect

There is negligible flux depression within the fuel compact of the Tubular Interacting element according to TNPG studies.

# 1.5 Damage dose distributions

The axial fast neutron flux profile follows very closely the rating shape and, for the purposes of the calculations in this thesis, the fast neutron dose at axial position z, will be given by:

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$$D(z) = \frac{R(z) \overline{D}}{\overline{R}}$$

where R(z) = the axial rating factor at position z

 $\overline{R}$  = channel mean rating factor (normally equal to 1)

 $\overline{D}$  = channel mean dose.

The units of damage dose are usually given as neutrons/cm<sup>2</sup> EDN (equivalent neutron flux in the DIDO reactor).

From Table 3/1 the channel mean dose assumed for the peak rated channel was 2.0 x  $10^{21}$  n/cm<sup>2</sup> EDN.

The dose at any particular moment in time must of course be determined by the integration of the axial profile with time up to the moment of interest since, as can be seen from Fig 3/1, the axial rating shape varies with burn-up.

# 1.6 Refuelling scheme

Up to the time at which this work was carried out there was no refuelling pattern available for an equilibrium core. The Author has therefore devised a scheme which should be typical of a realistic pattern. The method for deriving this scheme was simple. Ten age groups were chosen: one at fuel loading, one at each gag change and one at the mid-point of each gag interval (Fig 3/4). (These ages were chosen to be of most use in the corrosion calculations described in Chapter 4 section 4).

The columns in the sextant of the core considered were then allocated an age such that the following conditions were satisfied:

- (i) The total power in the sextant at this snapshot time is the same as that given by the sum of the life average SNAP rating. This was achieved to within 1%.
- (ii) There were equal numbers of columns in all age groups. With
   51 columns in the sextant age group 10 was allocated the extra

column. (See Table 5/3).

Fig 3/3 shows the distribution of ages in the sextant of the core considered.

# 1.7 Moderator heat generation

Heat is generated within the moderator as a result of neutron and  $\gamma$  irradiations. The axial and time distributions of this heat generation is assumed to follow the fuel heat generation.

The fraction of the total channel heat generated within the moderator is small (8%) and the entire component is assumed to be within the fuel block; the graphite sleeves being only a small fraction of the total graphite volume.

# An introduction to the optimisation of core flow distribution

The Oldbury 'B' design of HTR for which this study was made has 301 columns; containing either seventeen (fuel column) or nine (control rod column) fuel channels (Figs 2/4, 2/5) totalling 4533 fuel channels in all.

As explained in the previous section the power variations between these channels at any particular time can be divided into two components:

- (i) Irradiation
- (ii) Spatial.

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The major limiting phenomena in this design of HTR are fission product release and graphite corrosion both of which are highly sensitive to fuel element temperatures. In order to maintain these limits in a peak channel, without the adjustment of channel flow to offset the power variations, it would be necessary to reduce the core rating or coolant gas outlet temperature, grossly overcooling the rest of the channels. Whereas, with the only major cost arising from higher pumping powers, significantly higher ratings and cycle efficiences can be obtained by judicious adjustment of the core flow distribution.

This section describes the methods developed in a detailed study made on the Oldbury 'B' equilibrium core and gives the thermal and fuel performance repercussions for a range of flow gagging assumptions.

The gagging scheme chosen for the Oldbury 'B' design is described in detail and using the radial power distribution and age factor data presented in section 1 the time and spatial distributions of channel gas outlet temperature are derived.

# 3 <u>Time gagging</u>

## 3.1 General considerations

The reduction in channel power with burn-up, described in section 1 would, with a constant gag setting, produce a corresponding reduction in channel gas outlet temperature and whilst maintaining the desired life average gas outlet temperature, large swings in temperature would occur. An alternative is to periodically adjust the gag so as to progressively reduce the mass flow rate in step with the channel power. In the limit the gag would be continuously changed so as to achieve the minimum (zero) deviation from the desired life mean gas outlet temperature.

Appendix I derives the relationship between the peak gas outlet temperature and the life mean value assuming N gag changes at equal intervals throughout the fuel dwell.

For the peak rated channel case (Table 5/1) the gas and fuel element temperature effects of different numbers of gag changes are given in Fig 3/6 and Tables 3/2, 3/3 derived using the AZIMUSTAP 5 program.

The ideal scheme, with remotely controlled continuous gag changing, as employed in the AGR, has special design problems in the HTR. In the TNPG Oldbury 'B' design the gags are changed by the refuelling machine and because of this time consuming method it is desirable to have as few a number of gag changes as possible.

The following sub-section gives the fuel endurance repercussions of such reductions.

#### 3.2 Fuel element endurance considerations

The incentive to reduce the number of gag changes depends upon the limiting criteria, namely fission product release and graphite

corrosion.

In order to remain within the limits on fission product release it is necessary not to exceed a particular failed particle fraction. The two recognised modes of particle failure during reactor operation, 'amoeba and 'pressure', are both highly temperature sensitive.

As described in Chapter 2 'ámoeba' attack is a corrosion phenomenon of the inner PyC layer and is cumulative over life. 'Pressure' failure is due to gaseous fission products causing the SiC layer to come under tension and is dependent upon the instantaneous particle temperature and burn-up.

It is therefore important, in order to escape 'pressure' failure, to have a sufficiently low fuel temperature at the end of life, when the burn-up is at a maximum. For 'amoeba' failure, however, the integrated fuel temperature over life is the important factor.

To restrict the number of gag changes will result in higher temperatures at the start-of-life, lower at the end-of-life but with approximately the same life average values (Fig 3/6). From the above 'pressure' failure considerations this form of life evolution of fuel temperature would appear beneficial and the fact that the life average temperature is unaffected by reducing the number of gag changes, suggests that 'amoeba' attack would not be increased. There is however some increase, as 'amoeba' attack is an exponential function of fuel temperature, although a linear function of time (days).

Table 3/3, derived using the AZIMUSTAP 5 - PARTICLE FAILURE link applied to the peak rated channel (Table 5/1) shows fuel element temperatures and fuel endurance for the reference four gag change scheme and a scheme where the gag is not changed throughout the dwell.

As a measure of the integrated 'amoeba' attack the factor F is given such that the particle is said to be at risk if  $F^{>}1$ . The extent of the 'failure' is also given in terms of the failed particle fraction in the channel.

From the table it is clear that for this, the most limiting channel, the 'amoeba' failure is increased by reducing the number of gag changes to zero, whereas the possibility of pressure failure is removed.

Although the peak fuel temperature for the no-gag case is  $65^{\circ}$ C above the reference case it can also be seen from this table that by a reduction of only  $20^{\circ}$ C on the mean gas outlet temperature 'amoeba' failure can be reduced to below the four-gag change value.

As far as the corrosion of graphite components is concerned there is no well defined limiting criterion on temperature. If, however, the number of gag changes are reduced, increasing the overall peak graphite temperatures, this is known to significantly increase the graphite removal rates and such factors as a smaller allowable water ingress and the possible replacement of corroded graphite components have to be offset against the advantages of a smaller number of gag changes.

For the Oldbury 'B' tender work and for this thesis a four gag change scheme has been adopted (Fig 3/4, 3/5).

Fig 5/2 shows the life evolution of peak fuel and graphite temperatures for the reference peak rated channel for this scheme.

In this section it has been assumed that in each gagging interval the mean gas temperature is maintained at the life mean value. If there is a large variation in fuel and graphite temperatures over life there is obviously some incentive to gag such that, although the overall mean gas temperature is maintained, the distribution with

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life of gas temperature provides a more propitious distribution of fuel element temperatures. However, since the variation of fuel temperature with life is small and the two graphite sleeve temperature distributions are opposite in form (Fig 5/2) there appears to be little incentive to shape gas temperature distribution with this fuel element design.

#### 4 Spatial gagging

4.1 General spatial gagging philosophy

Spatial gagging can be regarded as providing an 'optimum' distribution of channel gas outlet temperature within certain design limitations.

The radial power variations between channels across the core, which are to be gagged out, are made up of two components:

- (i) dolumn to column variations
- (ii) across column power gradients.

For the Oldbury 'B' design, however, there is one gag per column and therefore only column to column power variations can be gagged out. This design limitation implies that uniform peak channel temperatures cannot be realised. Therefore, the criterion for a successful spatial gagging scheme within these limits would be if all columns, or group of columns, gagged to their own gas outlet temperature, had the same peak temperature; the temperatures assumed in this study being peak channel gas outlet, graphite and fuel temperatures. Ultimately instead of temperatures, fission product release or corrosion could be considered.

In order to realise equal peak channel temperatures between columns it is necessary to gag each column to its own gas outlet temperature because of differing column average powers and gradients (e.g. the higher the gradient the lower the  $\overline{T}_{0}$ ).

By applying the 'grouping' principle, following AGR practice, the columns can be arranged into groups of similar gradient, gagging all the columns within a group to the same  $\overline{T}_2$ . This reduces, to some extent, operational complexities at some cost in performance.

For example, if  $\hat{G}$  is the maximum gradient and N groups are chosen these groups would contain channels of gradient  $0 - \hat{G}/N$ ,  $\hat{G}/N-2\hat{G}/N$ , ....(N-1)  $\hat{G}/N - \hat{G}$ .

The following section itemises the calculation route from obtaining core power maps to the final temperature distributions and gives the resulting thermal performance for different spatial gagging schemes and optimisation criteria. Finally, for the chosen gagging scheme, the core flow -  $T_2$  distribution is determined.

In order to compare different gagging options it has been assumed that there is constant flow axially through all columns i.e. there is no inter-brick leakage of flow.

In reality there will be significant leakage in particular areas of the core and this is discussed, giving the resulting flow distributions in section 5.

# 4.2 General theory of group gagging

Although it is possible to equalise peak fuel and graphite temperatures between groups only the equalisation of peak channel gas outlet temperature will be considered here.

Let  $\overline{R}$  be a column mean channel heat generation and let G be the column gradient where  $G = \frac{\widehat{R}}{\overline{R}}$  and  $\widehat{R}$  = maximum channel heat generation. Rc<sub>ij</sub> is the heat generation (life mean) of the jth column in the ith group. Assuming N gag groups then:

 $\hat{G}_1, \hat{G}_2, \hat{G}_3, \ldots, \hat{G}_N$  are the maximum gradients in each group where the columns are grouped according to gradient i.e. group 1 contains those columns with the lowest gradient and group N those with the largest.

If there are  $M_1$  columns in group 1,  $M_2$  columns in group 2 etc. then the combined heat generation of all columns in the groups is given by:

 $\Sigma_{R_1} = Rc_{11} + Rc_{12} + Rc_{13} \cdots Rc_{1M_1}$ 

$$\Sigma R_2 = Rc_{21} + Rc_{22} + Rc_{23} \cdots Rc_{2M_2}$$
  

$$\vdots$$
  

$$\Sigma R_N = Rc_{N1} + Rc_{N2} + Rc_{N3} \cdots Rc_{NM_N}$$

The heat balance from the core shows:

$$C_{p}W_{F}(\overline{T}_{2c} - T_{1c}) = \Sigma R_{1} + \Sigma R_{2} + \cdots \Sigma R_{N}$$

where  $W_{p}$  = total core flow through fuel channels

 $\overline{T}_{2c}$  = mixed gas outlet temperature from all fuel channels  $\overline{T}_{1c}$  = inlet gas temperature

If  $\overline{T}_{21}$ ,  $\overline{T}_{22}$  - - - are the column mean gas outlet temperatures from each group:

$$\frac{\Sigma R_1 + \Sigma R_2 + \Sigma R_3 - - \Sigma R_N}{(\overline{T}_{2c} - \overline{T}_{1c})} = \frac{\Sigma R_1}{(\overline{T}_{21} - \overline{T}_{1c})} + \frac{\Sigma R_2}{(\overline{T}_{22} - \overline{T}_{1c})} + \frac{\Sigma R_N}{(\overline{T}_{2N} - \overline{T}_{1c})} \cdots \cdots 4$$

The gagging criterion is that the peak channel gas outlet temperatures from each group are equalised i.e.

 $(\overline{T}_{21} - T_{1c}) \ \hat{G}_1 \ F_1^* = (\overline{T}_{22} - T_{1c}) \ \hat{G}_2 \ F_2^* = \cdots \ (\overline{T}_{2N} - T_{1c}) \ G_N F_N^*$ where  $F_1^*, \ F_2^*, \ - - F_N^*$  is the factor which allows for across-block flow variations. (F  $\simeq G^{0.4}$  derived in Appendix II ).

Therefore:

$$(\bar{\mathbf{T}}_{22} - \mathbf{T}_{1c}) = (\bar{\mathbf{T}}_{21} - \mathbf{T}_{1c}) \hat{\mathbf{G}}_{1} \mathbf{F}_{1}^{\prime} \hat{\mathbf{G}}_{2} \mathbf{F}_{2}^{\prime}$$

$$(\bar{\mathbf{T}}_{2N} - \mathbf{T}_{1c}) = (\bar{\mathbf{T}}_{21} - \mathbf{T}_{1c}) \hat{\mathbf{G}}_{1} \mathbf{F}_{1}^{\prime} \hat{\mathbf{G}}_{N} \mathbf{F}_{N}^{\prime}$$

Substituting equations 5 in 4 we have:  

$$(\overline{T}_{21} - T_{1c}) = \frac{(T_{2c} - T_{1c})}{(\Sigma R_1 + \Sigma R_2 + \cdots \Sigma R_N)} (\Sigma R_1 + \frac{\hat{G}_2 F_2}{G_1 F_1} \Sigma R_2 + \cdots + \frac{\hat{G}_N F_N}{G_1 F_1} \Sigma R_N) \cdots 6$$

Having found  $\overline{T}_1^e$  from equation 6  $\overline{T}_2 - - \overline{T}_N$  can be found from equations 5.

The maximum reduction in peak channel gas outlet temperature is obtained, when the number of groups equals the number of columns in the core when individual column  $\overline{T}_2$  gagging is achieved.

# Thermal performance effects of various gagging schemes

Group gagging to the gas outlet temperature criterion can be done explicitly without the need for iteration to ensure conservation of mass flow. Gagging to other criteria such as peak fuel or graphite temperature is, however, a complex iterative calculation requiring computing techniques.

A program, FOIL, has been written, specified by WILLIAMS(10) which incorporates the  $\overline{T}_2$  gagging criterion method developed by the Author as well as the peak fuel and graphite temperature criteria. The program derives the resulting temperature histograms, using the method of deducing channel peak temperature from integral AZIMUSTAP 5 data developed by the Author and described in Chapter 5.

FOIL has been used to investigate the performance repercussions of different gagging schemes and the Author acknowledges the assistance of Mr. L.G. Williams in making this study.

#### 4.3.1 Channel gas outlet temperature criterion

Using the case where all the columns in the core are gagged to the same gas outlet temperature as the datum, Fig 3/7 shows that for the maximum gas outlet temperature the greatest saving occurs when changing from one to two groups and for further increases in the number of groups, the saving diminishes until the limiting value is obtained at around twelve groups. The relationship between the number of groups and the gas outlet temperature appears to follow an exponential curve, but the relationships relating the fuel and surface temperatures are more complex.

The results for fuel and surface temperatures shown in Fig 3/7 indicate that savings in fuel are less than gas temperature savings while savings in surface temperatures are greater. The grouping of columns on cross-column gradient, neglects the effect of rating and columns having high gradients do not necessarily have high ratings. This means that peak fuel temperatures can occur in columns

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which are not necessarily the peak gradient columns in a group. It is this phenomenon that causes the saving in fuel temperature to fall below the saving in gas temperature; the fluctuation of location of peak temperatures from one column to another also causes the discontinuous nature of the curves.

The surface temperature results all show reductions that are greater than the gas temperature reductions as these peak temperatures occur in columns more closely related to the peak channel gas temperature columns. The minimum saving appears to occur for the inner sleeve; the maximum occurring for the channel wall. These savings are consistent with the characteristics of the Tubular Interacting element where the peak inner sleeve temperature occurs further from outlet than the peak outer sleeve and channel wall temperatures and therefore does not benefit to such a great extent from flow increases. An increase in the number of groups results in an increase of flow in the channels having the peak temperatures and this produces a slight modification in the heat and flow splits which also contributes to the effect of the saving in temperature on the inner sleeve surface being less than that on the outer sleeve surface. The channel wall has the greatest reduction in temperature because there is an additional reduction owing to a smaller radiation component heat flux, resulting from the lower outer sleeve temperatures.

The core distribution of life peak fuel and graphite surface temperatures are shown in Figs 3/8-3/11. These results show that the effect of increasing the number of groups on the temperature distributions, is to produce a more weighted histogram at the higher temperature end; at the same time, however, reducing the

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overall peak value.

N.B. These are results produced at the early stages of the research programme and do not include all the work described in Chapter 4 (e.g. corrosion). They are, therefore, only to be used to compare different gagging schemes and cannot be expected to be consistent with the final results presented in Chapter 5.

#### 4.3.2 Fuel and graphite surface temperature criteria

The significant reductions in fuel and graphite temperature by gagging to equalise peak channel gas outlet temperature can be further improved if the fuel and graphite temperatures themselves are equalised.

The gas outlet temperature of each column is chosen so that the peak fuel or particular graphite surface temperature is equal in all columns. The distribution of column  $\overline{T}_2$  values will depend on which temperature is being optimised and so it would not be possible to simultaneously optimise fuel and all graphite surface temperatures. If, however, on-line computing facilities were available a combined fuel and graphite temperature optimisation scheme may be devised.

In order to determine the possible performance advantages of a more complex optimisation procedure the program FOIL has been employed where it is possible to optimise the flow distribution to satisfy the following options:

- Option 1 Equalisation of life peak fuel temperature in all columns
- Option 2 Equalisation of life peak inner graphite surface temperature in all columns

Option 3 - Equalisation of life peak outer graphite surface

temperature in all columns

Table 3/4 gives the corresponding life peak temperatures for the three options together with, for comparison, a 12 group equalised channel gas outlet temperature scheme.

N.B. Once again these temperatures are presented only for comparison and are not consistent with the Chapter 5 figures.

The distribution changes to which these temperature reductions correspond are similar to those experienced by increasing the number of groups given in the previous sub-section i.e. the high temperature 'tail' is forced into the lower temperature bands.

The 20°C to 30°C temperature reduction found by optimising the flow distribution in this way is quite significant particularly for the graphite surfaces. As explained in Chapter 5 it is the changes of distribution where the high temperature tail is removed that has the most beneficial effect on graphite corrosion.

It is conceivable to advance one stage further and optimise to 'equal risk of particle failure' which would provide the maximum performance savings. The lack of understanding on particle failure modes and the uncertainty on local rating and temperature perturbations, however, make such a scheme unjustifiable. <u>The reference three group peak channel gas outlet temperature</u>

## scheme

4.4

For the Oldbury 'B' tender a relatively simple scheme was devised so as not to deviate from previous (AGR) experience. Operation of the reactor is certainly simplified if only three life mean gas outlet temperatures need to be considered at, of course, some cost in reactor performance.

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The object therefore was to determine three values of column overall mean gas outlet temperature  $(\overline{T}_2)$  which, given the radial power distribution, minimises peak channel gas outlet temperature.

The quantities which need to be known are:

(i) column average power for each column,

(ii) power gradient for each column,

(iii) number of channels in each column.

Sextant symmetry has been assumed and the above data for 1/6 th of the core is given in section 1 (Fig 3/3).

The across column flow variation factors (F') also need to be known and these can be found from Appendix. II.

Using the theory developed in section 4.2 the three values of  $\overline{T}_{O}$  can be derived (Appendix III) i.e.

819°C, 782°C, 754°C.

The overall peak value of channel gas outlet temperature found in the largest gradient column of each group is 850°C.

The resultant distributions of column flow,  $\overline{T}_2$  and channel peak gas outlet temperature are shown in Fig 3/12.

The peak rated channel in the core which has been used for the studies of single channel performance in the following chapter is not shown on either the power map (Fig 3/3) or flow map (Fig 3/12) since it includes additional margins. It has been assumed, however, that it has an across column gradient of 7.5% and can therefore be allocated to group 2 (Appendix III) giving its column a  $\overline{T}_2$  of 782°C and a channel gas outlet temperature (life mean) of 833°C.

So far inter-column flow leakage has been neglected. As will be explained it is not possible to gag spatially allowing for leaking columns and the final flow distribution will be off optimum to some degree. The effect on channel flows and temperatures of leakage is

given in section 5 below.

4.5 Gagging sensitivity to the radial power distribution

Variations in column average rating will not affect a peak gas outlet temperature gagging scheme although there will be some effect on fuel element temperatures. Gagging and temperature distributions are, however, most sensitive to across-column gradients - the higher the gradient, the higher the peak temperatures for the same number of gag groups.

A comparison has been made between two radial power maps where, for one case, the maximum gradient was 17% (maximum/average) and for the other 11%.

Power map (Max. gradient)	T <sub>2</sub> (°C)	
	3 groups	12 groups
11%	842	826
17%	858	842

The results are shown in the table below:

It can also be seen from this table that in order to achieve the same peak gas outlet temperature a greater number of groups need be taken for the map with the higher gradients.

It is possible to compensate for the effect of high gradient columns by reducing the rating of those columns by radial enrichment zoning i.e. from equation 6, if  $\Sigma R_N$  is the rating of columns with a peak gradient of  $G_N$ , then by reducing  $\Sigma R_N$  and increasing  $\Sigma R_1$  by  $\delta R$ , the total core power is unchanged and because  $\frac{\widehat{G}_N F_N^*}{\widehat{G}_1 F_1^*} > 1$ ,  $\widehat{T}_{21}$  and  $\widehat{T}_2$  are reduced.

There is obviously a limit to this radial power shaping as, although peak channel gas outlet temperatures are reduced there will

#### Inter-brick leakage

N.B. The information given below in sub-sections 5.1 and 5.2 was obtained from general TNPG design work in which the Author made no significant contribution.

#### 5.1 Cause of leakage

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The gaps between adjacent columns are sealed to coolant flow at the bottom of the core and, therefore, provided there are no gaps between bricks in a stack the flow entering a column at the top of the core is equal to that leaving the column at the bottom.

For a cold unirradiated array of columns this non-leaking situation prevails. Under hot, irradiated conditions however, temperature and fast neutron dose gradients exist across all columns causing them to bow, owing to differential expansion and shrinkage.

This bow causes, through the interaction of the column with its neighbours, gaps to open up between the brick (Fig 3/13). The gradients across some columns can be sufficiently large to produce gaps of such a size as to present a relatively easy flow path to the coolant.

In this way a fraction of the normal column flow by-passes the bricks up-stream of the gaps and flows down the interstitial space, flowing back into column at the gap-opening.

### 5.2 Nature of leakage

# 5.2.1 Distribution of flow within a column

From the wedge shaped nature of the gap it is clear that the channels within a column leak to varying degrees and in fact some channels at the apex will have virtually the design flow. Fig 3/14 shows a typical axial variation of flow for the column and the worst affected channel, given as fraction of the normal non-leaking flow.

## 5.2.2 Leakage as a function of time

#### (a) Thermal gradient bowing

High thermal flux gradients across columns, predominant in the outer region of the core, produce, through the resulting power gradient, a gas and moderator temperature differential across the column.

This temperature gradient will occur immediately the column is loaded but owing to creep effects the thermal gap will reduce to effectively zero during the life of the column.

### (b) Fast neutron dose gradient bowing

As with thermal flux gradient, dose gradients are also a maximum towards the outer region of the core.

The resulting irradiation shrinkage is a time integrated effect which implies a zero gap at the start of a column life and maximum gaps at discharge.

With the combination of these two gap opening effects a situation exists at some time in the dwell of the column that the gaps, and therefore the leakage are a minimum. Fig 3/15 shows a typical time evolution of leaking column flow.

## 5.2.3 Distribution of leaking columns

As stated above the high thermal and fast neutron dose gradients required for significant bow to occur exist in the outer region of the core and in general it is only the peripheral fuel columns which are affected. Fig 3/16 shows these columns together with their modified  $\overline{T}_2$  values, the derivation of which is given in the following sub-section.

#### 5.3 Thermal performance repercussions of inter-brick leakage

#### 5.3.1 Whole core effects

Although only 20% of the columns have appreciable gaps and suffer a flow surplus the surplus is such (approximately 20%) that the non-leaking columns in the core experience a significant flow deficit (3.5%).

This result follows from the basic assumption that the core is gagged ignoring leakage and core flow is fixed rather than the core pressure drop. This latter assumption is valid as the core heat generation and boiler inlet temperature are design limitations. The former assumption, that the core is gagged neglecting leakage, results from within column considerations.

### 5.3.2 Within column effects

As mentioned above there will be some channels in a leaking column which will have the design flow. In addition the bricks up stream of the first gap will suffer flow starvation as can be seen from Fig 3/14.

If, however, effort is made to gag out the effects of leakage by restricting the flow in the column then the non-leaking channels and starved bricks in the leaking column will have even lower cooling flows resulting in higher than design temperatures.

For this reason, in order to maintain the limiting temperatures, leakage can not be compensated for when deciding the core flow distribution and over-cooling must be tolerated.

The core temperature distributions, however, should be calculated taking into account the true core flow distribution.

### 5.3.3 Temperature distribution effects

Models are not sufficiently refined to calculate the fuel element temperature effects of an axially varying flow rate although HEATAX, described in Chapter 5 and Appendix VI could be easily modified to make an initial assessment. It is unjustified at present, therefore, to develop the sophisticated method required to determine the distribution of channel gas outlet temperature within a leaking column.

For the present work it will be pessimistically assumed that leaking columns have the design gas outlet temperatures and the non-leaking column  $\overline{T}_{o}$  values will be based on an overall flow deficit of 3.5%.

Fig 3/16 shows the column and peak channel gas outlet temperatures for this hypothetical leaking core.

The effect on the peak rated channel, referring to sub-section 4.4 above, is to increase the life average channel gas outlet temperature to  $852^{\circ}$ C.

#### CHAPTER 4

## THE FUEL ELEMENT

In the previous chapter the reactor environment was dealt with and the derivation of the axial, radial and time evolutions of heat generation were discussed. Methods were also described for obtaining the coolant mass flow rate and outlet temperature for any fuel channel in the core.

With channel power distribution and flow as the basic starting points, the major part of the work - to develop methods which can evaluate the thermal and hydraulic characteristics of the fuel element can now be described. The objective of this work was to develop methods which would derive:

- (i) important temperatures within the fuel channel, e.g. fuel
   and graphite, at a number of axial positions and times throughout
   the fuel dwell
- (ii) flow distribution and pressure drop within the channel.

As a starting point to this work the program MUSTAP, briefly discussed in Appendix VI, has been utilized. This program has the following limitations:

- thermal and fast neutron irradiation effects on dimensions are neglected (The calculation is made for one instant in time and the interface gap conductance is assumed invariant with temperature and axial position.)
- (ii) material properties are assumed independent of fast neutron dose
- (iii) corrosion induced roughening and changes of dimension have been neglected.

Firstly in this chapter in section 1, there is a critical discussion of the model used in MUSTAP to obtain temperatures within the fuel element, given the element surface temperatures. In section 2 the heat transfer from the fuel element is subject to an original examination.

In section 3 the modifications to MUSTAP (AZIMUSTAP-5) specified by the Author to allow for effects (i) and (ii) above, are described.

Section 4 details the model developed by the Author to cover effect (iii), above, which is incorporated in the HEATAX code.

#### Heat transfer through the fuel element

Presented in this section are the basic equations that are used in the programs MUSTAP and HEATAX for calculating the heat transfer through the fuel, across the interface gaps and through the graphite sleeves. For completeness, the equations used will be derived here, together with a discussion of other effects not included in the equations.

### 1.1 The fuel matrix

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As described in Chapter 2 the fuel bed is made up of coated particles, approximately 1 mm in diameter, set in a matrix of graphite. There are two temperature distributions within the compact which can be considered:

macroscopic distribution derived from smeared values of thermal conductivity, heat generation, etc.

fine structure distribution, superimposed on the macroscopic distribution, arising from the presence of the particles, where the heat transfer through the particle must be considered.

# 1.1.1 Macroscopic temperature distribution within the fuel compact

Firstly the macroscopic distribution is derived, assuming a mean thermal conductivity  $k_f$  (see Chapter 5) and a mean volumetric heat generation  $q_f'''$ . In fact,  $q_f'''$  is not constant throughout the fuel for the following reasons.

(i) The neutron flux depression effect

The fuel at the centre of the compact is shielded from the thermal neutron flux by the fuel towards the outside of the compact. As already explained in Chapter 3 this effect is negligible in the case of the tubular interacting elements.

## (ii) Across-pin flux gradients

As described in Chapter 3 this effect is small for peak rated channels and will be neglected since, in order to allow for them, we would depart from axial symmetry thus making an analytical method intractable.

For cylindrical fuel, with conduction in the radial direction only, the Fourier heat conduction equation can be applied across an element dr i.e.

$$q''(r) = -k_{f} \frac{dT}{dr} \qquad \dots 1$$

Where q"(r) is the heat flux across the element and is given by

$$q_{f}''(r) = q_{f}''' (r^{2} - r_{i}^{2})/2r$$

r is the radius of peak fuel temperature and is termed the 'heat split radius'.

Substituting into Eq. 1 and separating variables we have

$$\frac{q_{f}}{2} \left(r - \frac{r_{i}}{r}\right) dr = -k_{f} dT \qquad \dots 2$$

If k<sub>r</sub> is assumed constant radially, integration gives

$$T = \frac{-q_{f}^{iii}}{4k_{f}} (r^2 - 2r_{i}^2 \ln r) + \text{constant} \qquad \dots 3$$

The boundary conditions are:

$$r = r_{f1}, T = T_{F1}$$
  
 $r = r_{f2}, T = T_{F2}$ 

By substituting these conditions and eliminating the constant of integration and  $r_i$  we obtain

$$T = T_{F1} - \frac{q_{f1}^{iii}}{4k_{f}} \left[ r^{2} - r_{f1}^{2} + \frac{\ln r/r_{f1}}{\ln r_{f2}/r_{f1}} \left( r_{f2}^{2} - r_{f1}^{2} - \frac{4k_{f}}{q_{f1}^{iii}} (T_{F2} - T_{F1}) \right) \right] \cdots 4$$

This distribution has been evaluated for the conditions given in Table 4/1 and is shown in Fig 4/1.

The peak fuel temperature  $T_{\rm FP}$  is given by

$$T_{FP} = T_{F1} - \frac{q_{f}^{m}}{4k_{f}} \left(r_{i}^{2} - r_{f1}^{2} - 2r_{i}^{2}\ln\frac{r_{i}}{r_{f1}}\right) \qquad \dots 5$$

where 
$$r_{i}^{2} = \frac{1}{2\ln^{r} f^{2}/r_{f1}} \left[ \frac{4\kappa_{f}}{q_{f}^{m}} (T_{F2} - T_{F1}) + (r_{f2}^{2} - r_{f1}^{2}) \right] \dots d$$

## 1.1.2 Local temperature variations within a compact

In order to ascertain how the smeared peak fuel temperature derived above relates to the peak  $UO_2$  kernel temperature the heat transfer properties of the kernel, buffer, pyrolytic carbon and silicon carbide shells (Chapter 2) must be examined. This has been done by ROSSITER (<u>11</u>) and RAPIER (<u>12</u>).

As described in Chapter 2 the important temperature values, as far as particle failure is concerned, are the kernel temperature and acrosskernel temperature difference. ROSSITER has shown that the mean kernel temperature is only a fraction above the 'smeared' compact temperature  $(3^{\circ}C$  for the conditions taken). The across-kernel temperature difference can be calculated from the macroscopic temperature gradient (Eq. 2). This gradient for the Table 4/1 conditions has been plotted in Fig 4/1. Across-kernel temperature differences of up to  $18^{\circ}C$  for a kernel diameter of 0.8 mm are seen to occur. RAPIER has shown, however, that an important factor to be considered is the anisotropy of the shell thermal conductivity which can be 100 times greater in the circumferential direction than in the radial direction. This has the effect, according to RAPIER, of shielding the kernel from the macroscopic gradient producing across-kernel temperature difference of nearer  $2^{\circ}C$ . The effects described above depend heavily upon two factors:

- the size and degree of eccentricity of the interface gap between kernel and shells
- (ii) the thermal conductivity of the kernel and shells in the radial and circumferential directions.

Information, both analytical and experimental, relating to these two factors is severely lacking and we will assume for the benefit of this study that the kernel temperature and across-kernel temperature difference can be given by the macroscopic relations derived above.

## 1.2 The fuel/sleeve interface gaps

The heat transfer conductance of narrow gas filled gaps, where there are stagnant gas conditions, consists of three components:

- (i) ) conductance through the gas
- (ii) radiation across the gap
- (iii) in the case of a nominally zero gap, when the surfaces are

in the contact, we have solid conductance.

Let us define an effective gap conductance ki; i.e.

$$k_j = \frac{q''}{T_F - T_I}$$

where q" is the heat flux across the relevant interface gap, which has fuel side and sleeve side temperatures of  $T_F$  and  $T_I$  respectively. q" can be derived from  $q_F^{"}$  and  $r_i^{:}$  (Eq. 6) i.e.

$$q_{1}^{"} = q_{f}^{""} (r_{i}^{2} - r_{f1}^{2})/2r_{f1}$$

$$q_{2}^{"} = q_{f}^{""} (r_{f2}^{2} - r_{i}^{2})/2r_{f2}$$

$$\cdots 7$$

#### 1.2.1 Heat conduction through the filling gas

The gas conductance can be defined as

$$h_{\rm G} = \frac{k_{\rm G}}{g_{\rm eff}} \qquad \dots 8$$

where  $k_{G}$  is the gas conductivity evaluated at  $(T_{F} + T_{I})/2$  and  $g_{eff}$  is the effective gap width. MAIN (B) defines  $g_{eff}$  as

$$g_{eff} = g + g_1 + g_2 + g_1 + g_2 + \dots 9$$

The components of geff are:

- (i) the nominal gap clearance g
- (ii) an allowance for the gas lying between the peaks of the surface asperities - g', g'
- (iii) the 'temperature jump distance'  $-g_1''$ ,  $g_2''$  an additional thermal resistance caused by the imperfections in the transference of kinetic and vibrational energy between the solid and gas molecules.

The calculation of g, which depends upon the irradiation and temperature history of the fuel, is described in section 3 and we will consider items (ii) and (iii) above.

(a) Surface roughness

The equivalent increase in gap width is proportional to the roughness height:

#### g' = C.R

where R is the roughness height in CLA. The constant C, the subject of a literature survey by MAIN  $(\underline{13})$  has been shown to have a value of approximately 2.5, when the surfaces are not in contact. R is more difficult to quantify as there is no known measurement of surface roughness of extruded graphite tubes or pressed compacts. WARBURTON  $(\underline{14})$ has investigated the surface roughness of machined graphite and has shown

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a wide variation  $(4 - 15 \mu \text{m CLA})$ . The effective increase in gap width  $(g_1^* + g_2^*)$  using C = 2.5 and an average value of R (10  $\mu$  m CLA) is 50  $\mu$  m. One would expect, however, that a smoother finish would be possible by extrusion and pressing producing a smaller effect on the HTR fuel gaps.

In the work described here no increase in the effective gap has been allowed and in this respect the interface gaps have been probably underestimated by between 0 and 50  $\mu$ m. The effect is sufficiently significant, therefore, to warrant experimental measurements to be made of compact and tube roughness.

# (b) <u>Temperature jump distance</u>

As reported by MAIN (<u>13</u>) g" is a function of the thermal accommodation coefficient  $\alpha_t$ , which itself depends on the molecular weight of the gas and solid surface, and on the mean free path L of the gas molecules. For any particular gas L is dependent upon the gas temperature and pressure, i.e.

 $L \propto \sqrt{T/P}$  (from MAIN (13))

where T is in K

and

MAIN has calculated g"  $(g_{ref}^{"})$  for helium assuming T = 500°C, P = 1 atmosphere and  $\alpha_t = 0.4$ . This value of g"  $(4.4 \,\mu\text{m})$  can be used to obtain g" for the HTR fuel interface gap.

As reported by MAIN Jeans suggested the following relation for  $\alpha_{\pm}$ :

$$\alpha_{t} = 1 - \left(\frac{M - m}{M + m}\right)^{2}$$

g"  $\propto 2 - \alpha t$ . L

where M and m are the gas and solid molecular weights respectively. For helium and graphite:

$$a_{\pm} = 0.75$$

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Also 
$$P \simeq 50$$
 atmospheres

and 
$$T \approx 1000^{\circ}C$$
  
and since  $g''/g''_{ref} = \frac{2 - \alpha}{\alpha_t} \sqrt{T} P_{ref}$   
 $(\frac{2 - \alpha}{\alpha_t}t) P_{t} \sqrt{T}_{ref}$ 

then  $g''/g''_{ref} = 0.01$ 

Therefore g"≥0.04 µm

Although there is considerable uncertainty on  $\alpha_t$  the high pressures in the HTR fuel gaps ensure small mean free paths and a negligible temperature jump distance.

### 1.2.2 Radiation across the gap

The radiative component of the gap conductance is given by the standard relation

$$h_{r} = \frac{\varepsilon_{f}\varepsilon_{g}\sigma_{s}}{\varepsilon_{f}+\varepsilon_{g}-\varepsilon_{f}}\varepsilon_{g} \quad \left(\frac{T_{F}^{4}-T_{I}^{4}}{T_{F}^{4}-T_{I}^{4}}\right) \qquad \dots \dots 10$$

where  $T_F$ ,  $T_I$  - interface temperatures in  $^{\circ}K$ If we define the mean interface temperature as

$$\overline{T}_{I} = (T_{F} + T_{I})/2$$

and

$$\varepsilon_{\text{eff}} = \frac{\varepsilon_{efg}}{fg} / (\varepsilon_{f} + \varepsilon_{g} - \varepsilon_{fg})$$

then 
$$h_r = \epsilon_{eff} \sigma_s \cdot 2 \overline{T}_I [4 \overline{T}_I^2 - 2 T_F T_I]$$

For moderate gap temperature differences we can assume

$$T_{F}T_{I} = \overline{T}_{I}^{2}$$

(e.g. for  $T_{\rm F} = 1150^{\circ}$ C,  $T_{\rm I} = 1000^{\circ}$ C,  $\overline{T}_{\rm I} = 1075^{\circ}$ C,  $\sqrt{T_{\rm F}T_{\rm I}} = 1073^{\circ}$ C) Therefore

#### 1.2.3 Effective gap conductance

The effective gap conductance,  $k_j$ , is given by a combination of the fluid conductance ( $h_{G}$ , Eq. 8) and the radiative conductance ( $h_r$ , Eq. 10) i.e.

$$k_{j} = \frac{k_{G}}{g_{eff}} + \epsilon_{eff} \sigma_{s} (T_{F} + T_{I}) (T_{F}^{2} + T_{I}^{2}) \qquad \dots 12$$

The simplified form of the equation for  $h_r$  (Eq.11) will be used to demonstrate how  $k_j$  varies with gap width  $(g_{eff})$ . The values of  $\stackrel{\epsilon}{eff}$ and the variation of  $k_{G}$  with temperature are given in Chapter 5. Fig 4/2 shows how  $k_j$  varies with  $g_{eff}$  for different mean temperatures  $(\bar{T}_I)$ . From the log-log scale on which the curves are plotted, it is clear that thermal radiation contributes only 5% to the heat transfer process with gaps of less than approximately  $50_{\mu}$  m. In addition, of course, the higher the mean interface temperature the more significant the radiation component for any particular gap size.

## 1.2.4 Effective interface conductance for nominally zero gap

When the compact and tube are in contact the interface conductance will depend upon the interface pressure. In this work, however, an effective maximum value of  $k_j - k_{jm}$  is assumed - which will apply regardless of how small the gap becomes below a value  $g_{min}$ . This approach is necessary if one wishes to use Eq. 12 to evaluate  $k_j$ , since, from Eq. 12:-

as  $g_{eff} \rightarrow 0, k_j \rightarrow \infty$ 

The value of  $k_{jm}$  is derived from contact resistance experiments noted in Chapter 5, and has been taken to be 2 x 10<sup>4</sup> W/m<sup>2</sup> °C. The corresponding value of  $g_{min}$  can be seen from Fig 4/2 to be approximately 20 µm.

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#### 1.3 Conduction through the fuel sleeves

Again using the Fourier equation:

$$q'/2\pi r = - kg dT/dr \qquad \dots \dots 13$$

Where q' is the linear heat rating across a sleeve given by Eq. 7 i.e.

 $q'_1 = q''_1 2\pi r_{f1}$  $q'_2 = q''_2 2\pi r_{f2}$ 

It is assumed here that a negligible part of the total heat generation is from within the sleeves. This is supported by information given in Chapter 2. The assumption is also made that the thermal conductivity is uniform across the sleeve. Conductivity values used in the work are given in Chapter 5 and section 4 discusses the corrosion effect on sleeve conductivity. Integration of Eq. 13 for the two sleeves gives:

Inner sleeve:

$$\Gamma = T_{W1} + q_1'' \frac{r_{f1}}{kg} \ln r/r_{s1}$$

Outer sleeve:

$$\Gamma = T_{W2} + q_2' \frac{r_{f2}}{kg} \ln r_{s2}/r$$

These temperature distributions are plotted in Fig 4/1 for the conditions given in Table 4/1. The interface temperatures  $T_{I1}$  and  $T_{I2}$  are given by:

$$T_{I1} = T_{W1} + \frac{q_1'' r_{f1}}{kg} \ln r_{f1} / r_{s1}$$
  

$$T_{I2} = T_{W2} + \frac{q_2'' r_{f2}}{kg} \ln r_{s2} / r_{f2}$$
  
.....15

4

....14

#### Heat transfer to the coolant and coolant pressure drop

2

In the previous section relations were derived providing temperatures within the fuel element which required the tube surface temperatures as boundary conditions.

In the case of the tubular element, the graphite surface heat fluxes are also dependent upon the heat transfer from the surfaces as well as on heat transfer within the element.

In this section this surface heat transfer is studied and convective heat transfer coefficients are defined in terms of the surface heat fluxes  $q_a^{"} \cdot q_a^{"}$  can be derived from Eq. 7 i.e.

$$q_{s1}^{"} = q_{1}^{"} r_{f1} / r_{s1}$$
  
 $q_{s2}^{"} = q_{2}^{"} r_{f2} / r_{s2}$ 
....16

For the inner surface, the total of  $q_s^{"}$  is removed by convection. From the outer surface, only a proportion of  $q_s^{"}$  is removed by convection; the remaining fraction being the net thermal radiation to the channel wall  $(q_{RB2}^{"})$ . The heat flux from the channel wall  $q_{RB2}^{"}$ , therefore, is given by:

$$q_{s3}'' = q_{Rs2}'' \frac{r_{s2}}{r_{s3}} + q_{B}'/2\pi r_{s3}$$
 .....17

where  $q_{\rm R}^{*}$  is the liner heat rating of the moderator block.

The three surface convective heat transfer coefficients are therefore defined:

$$h_{s1} = q_{s1}''(T_{W1} - T_{g1})$$

$$h_{s2} = (q_{s2}' - q_{Hs2}'')/T_{W2} - T_{g2})$$

$$\dots \dots 18$$

$$h_{s3} = q_{s3}''(T_{W3} - T_{g2})$$

In order to determine the bore and annulus pressure drop it is also necessary to have expressions for friction factor f which is defined

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(Fanning) as

$$f = \frac{De}{2\rho u^2} \cdot \frac{dp}{dx} \qquad \dots \dots 19$$

where dp/dx - channel pressure gradient (friction).

In the HTR design studies carried out by TNPG it is a requirement for particular sources of certain data, e.g. heat transfer and pressure drop data, to be used.

Those engaged on HTR thermal performance design are kept up to date on recommended heat transfer and friction factor correlations by the Heat Transfer Study Group of the collaborative Reactor Policy Committee. These correlations come, in fact, from experiments and literature survey work carried out by the UKAEA at the Windscale Laboratory under the directorship of Dr. D. Wilkie.

It is these Wilkie correlations which have been used for certain of the convective heat transfer and pressure drop calculations described in this thesis.

It was believed necessary, for this thesis, to justify fully the use of these correlations and to this end an original analytical derivation of heat transfer coefficients and friction factors, applicable to a helium coolant has been made, and then compared with the Wilkie correlations actually used.

## 2.1 Heat transfer and friction factors in smooth tubes

# 2.1.1 Dimensional analysis

The heat transfer coefficient can be assumed to be dependent upon the fluid velocity  $\bar{u}$ , density  $\rho$ , viscosity  $\mu$ , specific heat Cp, thermal conductivity  $k_{G}$  and a linear dimension D which, for confined flows, would be the equivalent diameter De, i.e.

h = C.  $u^{\alpha} C_{p}^{\beta} \rho^{\gamma} \mu^{\varepsilon} k_{\alpha}^{\varepsilon} De^{\psi}$ 

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These variables can be reduced into their basic units of mass, length, time and temperature. By comparing indices, four simultaneous equations containing the six unknown exponents can be obtained. Thus defining  $\Upsilon$ ,  $\delta$ ,  $\varepsilon$  and  $\psi$  in terms of  $\alpha$  and  $\beta$  we obtain

$$h = C \left(\frac{\overline{u} \rho}{\mu \overline{b} e}\right)^{\alpha} \left(\frac{\mu O p}{k_{G}}\right)^{\beta} \frac{k_{G}}{\overline{b} e}$$
$$\underline{h D e} = C \left(\frac{\overline{u} \rho}{\mu \overline{b} e}\right)^{\alpha} \left(\frac{\mu C p}{k_{G}}\right)^{\beta}$$

Thus the heat transfer coefficient can be defined in terms of a dimensionless group  $\frac{hDe}{kG}$  - the Nusselt number (Nu) as a function of the dimensionless groups  $(\frac{u \rho}{\mu De})$  Reynolds number (Re) and  $(\frac{\mu Cp}{kG})$  the Prandtl number (Pr) i.e.

$$Nu = C Re^{\alpha} Pr^{\beta}$$
 .....20

The Reynolds number clearly defines the hydrodynamic conditions (fluid velocity, degree of turbulence, geometry, etc.), whereas the Prandtl number appears to be merely a property of the fluid. Although the form given above is how heat transfer coefficients are normally expressed, in order to obtain some idea of C,  $\alpha$  and  $\beta$  it is necessary to look further into the physical processes involved.

# 2.1.2 <u>Velocity distribution in a tube</u>

The velocity profile of developed turbulent flow in a tube can be divided conveniently into three regions where different physical laws are involved in the momentum transfer process (see Fig 4/3).

(i) <u>Close to the wall - laminar sub-layer</u>

Momentum exchange is by molecular interaction and there is little or no macroscopic movement across the stream of fluid particles. The velocity gradient in this region is high, the velocity at the wall being zero. (ii) Centre region - turbulent core

Here momentum exchange is predominently achieved by the macroscopic movement of fluid across the stream. The velocity gradient in this region is comparatively low.

## (iii) Transition region - buffer layer

This region lies between the above two and obviously there is a mixture of the two momentum exchange processes.

If a fully developed velocity profile is assumed, the velocity can be expected to depend only upon cross-stream distance (y), shear stress at the wall ( $\tau_{o}$ ), fluid kinematic viscosity (v), and density ( $\rho$ ) i.e.

$$a = f(y, \tau_0, v, \rho) \quad \text{where } y \ll r_0$$

applying dimensional analysis

(a)

th

$$\frac{u}{\sqrt{\tau_0/\rho}} = f\left(\frac{y\sqrt{\tau_0/\rho}}{v}\right) \qquad \dots 21$$

 $\sqrt{\tau} \circ \rho$  and  $\sqrt{\tau} \circ \rho / \nu$  have dimensions of velocity and distance respectively and therefore we can write Eq. 21 in terms of dimensionless quantities u<sup>\*</sup>, y<sup>\*</sup>,

where 
$$u^* = \frac{u}{\sqrt{\tau_0/\rho}}$$
  
and  $y^* = \frac{y\sqrt{\tau_0/\rho}}{v}$   
therefore  $u^* = f(y^*)$ 

implying a constant relationship between  $u^*$ ,  $y^*$  for all cases. We will now try to determine  $f(y^*)$  for the three regions described above. Laminar sub-layer

In this very confined region close to a wall the shear stress can be defined simply as

$$\tau / \rho = v \frac{du}{dy} \qquad \dots 22$$
  
erefore  $\int \frac{\tau}{\rho} dy = \int v du$ 

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assuming constant  $\rho$  ,  $\nu$  and assuming  $\tau$  is constant at the wall value  $\tau_{_{\rm O}}$ 

$$\frac{\tau_{0}}{\rho} y = yu + c$$

$$u = 0 \text{ at } y = 0 \text{ therefore } C = 0$$
ucing u, y
$$*$$

Introd

$$\underline{u}^* = \underline{y}^* \qquad \dots 23$$

#### Turbulent core

(b)

One would expect an apparent shear stress to be governed by a similar equation Eq. 22 in the turbulent core. Although in this case  $\mu$  in Eq. 22 would be replaced by a more complicated expression.

To provide this expression the Prandtl Mixing Length theory will be employed giving a clear, if somewhat crude, explanation of the physical process of turbulence.

Consider a particle of fluid of mass  $\delta$  m moving in the x direction with velocity u. If now, due to turbulence, the particle moves in the y direction into a stream of velocity  $u + \delta u$ , the two streams being a distance  $L_m$  apart, a similar particle of fluid must pass from the  $u + \delta u$ stream to the u stream in order for mass to be conserved. Thus there is a fluctuating velocity v' in the cross-stream direction.

If  $\delta\,\text{m}$  does not lose or gain momentum in moving distance  $\text{L}_{_{\text{m}}},$  then  $\text{L}_{_{\text{m}}}$ is defined as the mixing length.

The net exchange of momentum is  $\delta m \, \delta u$  which if occurring in a time  $\delta$  t the apparent shear force is given by

$$F = \frac{\delta m \, \delta u}{\delta t}$$

If A is the area over which the force acts, the apparent shear stress  $\tau$  is

$$\tau = \frac{1}{A} \frac{\delta m \delta u}{\delta t} \qquad \cdots 24$$

If L is small  $\delta u = L_m (du/dy)$ 

 $\underline{smbt} = \overline{v}^{*}\rho$  where  $\overline{v}^{*}$  is a statistically averaged fluctuating

velocity in the y direction.

Eq. 24 becomes, therefore,

$$\frac{\mathbf{I}}{\mathbf{\rho}} = \left(\mathbf{L}_{\mathrm{m}} \mathbf{v}^{\mathrm{T}}\right) \frac{\mathrm{d}\mathbf{u}}{\mathrm{d}\mathbf{y}} \qquad \dots \dots 25$$

The similarity between equations 22 and 25 is obvious and  $(L_m \nabla^{\dagger})$  is the turbulent exchange equivalent of the molecular exchange kinemetic viscosity and is termed the 'momentum eddy diffusivity'  $\varepsilon_{m}$ . Equations 22 and 25 now describe the exchange mechanism in the laminar sub-layer and the turbulent core.

In the buffer layer where both mechanisms play a part, the apparent shear stress will be given by

However, returning to the turbulent core Eq. 25, we can say:

$$\nabla^{\dagger} = \overline{u}^{\dagger} \times \text{CONST.}$$
  
 $\overline{u}^{\dagger} = \text{CONST.} \times \delta u$ 

and, from above,

and

$$\delta u = L_m \frac{du}{dy}$$

Absorbing the constants in  $L_m$  we have, by substitution,

$$\frac{\tau}{\rho} = L_m^2 \left(\frac{du}{dy}\right)^2$$

In Prandtl's argument he also assumed the mixing length was proportional to y. Therefore  $L_m = Ky$ 

nd 
$$\mathbf{I} = K^2 y^2 \left(\frac{du}{dy}\right)^2$$

Away from the centre of the tube it is a fair approximation to say

$$\tau = \tau_{0}$$

the wall value, therefore, in terms of u\* and y\* the equation becomes

$$\frac{\mathrm{du}^*}{\mathrm{dy}^*} = \frac{1}{\mathrm{Ky}^*}$$

Integrating

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(c)

## Buffer layer

Returning to Eq. 26 it can now be implemented in deriving the velocity profile within the transition region.

Again we will use the mixing length theory in deriving an expression for  $\boldsymbol{\varepsilon}_{m}$  i.e.

$$E_{\rm m} = K^2 y^2 \frac{du}{dy} \qquad \dots 28$$

Substituting in Eq. 27

$$\tau/\rho = (v + K^2 y^2 \frac{du}{dy}) \frac{du}{dy} \qquad \dots 29$$

Once again we will assume  $\tau = \tau_0$  and that K is constant within the region of interest.

Eq. 29 becomes, using 
$$u^*$$
 and  $y^*$   
 $du^*/dy^* = (-1 + \sqrt{1 + 4K^2 y^2})/2K^2 y^{*2}$  .....30

This differential equation has been solved with the help of GREEN  $(\underline{15})$  and gives the following profile:

$$u^{*} = \frac{1}{2K^{2}y^{*}} + \frac{1}{K} \left[ \ln \left( 2Ky^{*} + \sqrt{2Ky^{*} + 1} \right) - \sqrt{\frac{1 + 4K^{2}y^{*}}{2Ky^{*}}} \right] + 0$$

Substituting  $x^* = 2Ky^*$ 

$$u^{*} = \frac{1}{K} \left[ \frac{1 - \sqrt{1 + x^{*2}}}{x^{*}} + \ln (x^{*} + \sqrt{1 + x^{*2}}) \right] + C \quad \dots 31$$

This equation tends to Eq. 27 as  $X^* \rightarrow \infty$ . This would be expected because, as  $y^*$  increases,  $\epsilon_m$  becomes dominant over v.

As  $x^*$  tends to zero,  $u^* \rightarrow C$  which implies that Eq. 31 does not apply very close to the wall.

# (d) Velocity profile - Comparison with other work

The experimental work carried out by NIKURADSE (<u>16</u>) has had curves fitted to it for the three regions of the boundary layer by MARTINELLI (<u>17</u>).

From this experimental work the three regions can be defined approximately by:

Laminar sub-layer	0 < y* < 5
Buffer layer	5 < y* < 30
Turbulent core	y* > 30
and the three equations are.	

0 < y* < 5	$u^* = y^*$ (Eq. 23)
5 < y* < 30	$u^* = -3.05 + 5.00 \ln y^*$ $\left\{ .32 \right\}$
y* > 30	$u^* = 5.5 + 2.5 \ln y^* (Eq. 27)$

These three profiles are shown in Fig 4/3.

Eq. 31 derived above is also plotted. With a K value of 0.15 this expression is in good agreement with the NIKURADSE/MARTINELLI data over the range 1 < y < 40 and can therefore be regarded as an adequate description of a large proportion of the laminar sub-layer as well as the buffer layer.

Fig 4/4 shows the variation of velocity gradient (non-dimensional  $du^*/dy^*$ ) with y\* derived from Eq. 30. As expected, the velocity gradient reduces with y\* the further one moves into the turbulent stream whereas  $\frac{du^*}{dv^*}$  tends to the laminar value of 1 as the wall is approached.

The velocity gradient close to the wall given by Eq. 30 obviously has the correct form and also overcomes the problem of the discontinuity at  $y^* = 5$ . This equation has, therefore, an important advantage over the Martinelli representation in deriving the heat transfer properties of the system where it is the velocity gradient only that is used.

It can be seen from Fig 4/3 that above  $y^* = 30$  i.e. in the turbulent core, that Eq. 31 ceases to apply with K = 0.15.

This is entirely due to the constant value of K that has been taken. K should, of course, be made a function of y. VAN DRIEST (<u>18</u>) suggests a  $(1 - \exp(y^*/A^*))$  variation derived from a study of Stokes, oscillating plate experiments. Van Driest's relation simplifies, as does Eq. 31 to

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the form of the universal velocity profile at large y\*, namely Eq. 27.

For the purposes of deriving the heat transfer characteristics of turbulent flow in a smooth tube, we will accept one discontinuity for the sake of mathematical simplicity and use Eq. 31 for  $0 \le y^* \le 30$  and Eq. 27 for  $y^* > 30$  where K = 0.4 and C = 5.5.

## 2.1.3 Friction factor

As a major proportion of the flow is confined between the centre of the pipe and  $y^* = 30$  it is possible to derive the bulk mean velocity using Eq. 27 and the expression

$$\overline{u} = \frac{2}{r_o^2} \int_0^r rudr$$

The shear stress at the wall can be put in terms of the friction factor f from

$$\tau_{o} = \frac{f \rho \bar{u}^2}{2}$$

also, introducing the Reynolds number  $(\frac{2\rho \overline{ur}o}{\mu})$ 

Karman - Nikuradse derived the following expression:

$$\frac{1}{\sqrt{4f}} = -0.8 + 0.87 \ln (\text{Re} \sqrt{4f})$$

(reported by KAYS (19)).

where the constants - 0.8 and 0.87 have been adjusted to fit experimental data.

$$f = 0.046 \text{ Re}^{-0.2}$$
 .....33

and is valid for  $3 \times 10^4 < \text{Re} < 10^6$ 

The wholly experimental BLASIUS equation gives

$$f = 0.079 \text{ Re}^{-0.25}$$
 .....34

which gives better agreement than Eq. 33 for the HTR channel bore according to WILKIE (20).

It is interesting to note from KAYS (<u>19</u>), that Eq. 34 can be reasonably approximated to the following relationship between u\* and y\*  $u^* = 8.7 (y^*)^{1/7}$  .....35

2.1.4 Temperature distribution and heat transfer coefficient

In the derivation of heat transfer coefficients in smooth tubes for developed turbulent flow, the similarity between momentum and heat turbulent exchange is often used.

As a starting point in this present analysis we will use the Karmán-Boelter-Martinelli analogy as described by KAYS (19).

The description of turbulent momentum transfer is by

$$\tau_{0} = (\varepsilon_{m} + v)^{du/dy}$$
 .....36

By analogy, the turbulent heat transfer can also be defined by a modified Fourier law:

$$\frac{Q''}{\rho c_p} = (\epsilon_H + \alpha_h) \frac{dT}{dy} \qquad \dots 37$$

where  $\epsilon_{H}$  is eddy diffusivity of heat and is the turbulent equivalent of the laminar  $\alpha_{h}$  (or  $\frac{k_{G}}{\rho C_{D}}$ ).

For a cylindrical geometry, with just molecular heat diffusion in the radial direction we have

$$\frac{1}{r} \frac{\partial}{\partial r} (r k_{G} \frac{\partial T}{\partial r}) = u \rho C_{p} \frac{\partial T}{\partial x}$$

By analogy, we can replace  $k_{G}$  by the combined turbulent and molecular equivalent:

$$\rho^{Cp} \left( \varepsilon_{H}^{c} + \alpha_{h}^{c} \right)$$
  
i.e.  $\frac{1}{r} \frac{\partial}{\partial r} \left( \rho^{rCp} \left( \varepsilon_{H}^{c} + \alpha_{h}^{c} \right) \frac{\partial T}{\partial r} \right) = u \rho^{Cp} \frac{\partial T}{\partial x}$  .....38

transforming, such that

$$y = r_0 - r$$
$$dy = -dr$$

and assuming

$$\frac{\partial T}{\partial x} \simeq \frac{\partial Tg}{\partial x}$$

also

$$T_{W} - T = \frac{Q''}{\rho C_{p}} \int_{0}^{y} \frac{1 - y/r}{(\varepsilon_{H} + \alpha_{h})} dy \qquad \dots 39$$

where

$$Q'' = \frac{\rho}{2} r_0 \overline{u} C p \frac{dTg}{dx}$$

In order to solve Eq. 39 it remains to obtain a relationship between  $\boldsymbol{\varepsilon}_{_{\mathrm{H}}}$  and y.

Again, by the similarity between momentum diffusion and heat diffusion we will assume

 $\varepsilon_{\rm H} = \varepsilon_{\rm m}$ 

This is a good approximation for fluids of Prandtl number close to unity which is the case for gases.

From Eq. 36 and the fact that  $\tau$  is linear with radius and also introducing the non-dimensional velocity gradient du\*/dy\* we obtain

$$\varepsilon_{m/y} = \frac{1 - (y/r_{\alpha})}{du^*/dy^*} - 1$$

and therefore

$$\varepsilon_{\rm H/y} = \frac{1 - (y/r_{\rm o})}{du^*/dy^*} - 1 \qquad \dots 40$$

By using the expressions derived above for du\*/dy\* the temperature profile can be derived.

As already stated the channel can be divided into two regions: one close to the wall  $(y^{*}$  30) described by Eq. 31 and the turbulent core

where the universal velocity profile is said to apply (Eq. 27).

(a) <u>y\* < 30</u>

Eq. 39 becomes

$$T_{W} - T_{30} = \rho \frac{Q''}{c_{p}} \int_{0}^{\frac{1 - y/r}{(\varepsilon_{H} + \alpha_{h})}} dy \qquad \dots 41$$

close to wall

 $y \ll r_{0} \qquad \therefore y/r_{0} \neq 0$  $\therefore \frac{\varepsilon_{H}}{v} \neq \frac{1}{du^{*}/dy^{*}} = 1 \qquad \qquad \dots 42$ 

Introducing y\* we have

$$T_{W} T_{30} = \frac{Q''}{\rho C_{p}} \sqrt{\tau_{o/p}} \int_{0}^{1} \frac{dy^{*}}{\varepsilon_{H/} + \alpha_{h/}} \cdots 43$$
  
$$\alpha_{h/v} = 1/Pr \cdots 44$$

and from Eq. 42 and Eq. 30 we have

$$\mathbf{\underline{s}}_{H} = \underbrace{\frac{2K^{2}y^{*2}}{\sqrt{1+4K^{2}y^{*2}-1}}}_{\mathbf{1}+4K^{2}y^{*2}-1} - 1 \qquad \dots 45$$

Combining equations 45 and 44 in Eq. 43 we obtain

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Eq. 46 has been solved with the help of GREEN (15) to give

$$T_{W} - T_{30} = \frac{Q''}{K_{\rho}C_{p}} \sqrt{\frac{1}{\tau_{o}/\rho}} \int_{0}^{50} \ln(2Ky^{*} + \sqrt{4K^{2}y^{*2} + 1}) - \frac{a^{*}}{b^{*}} \left[\frac{2Ky^{*} + \sqrt{4K^{2}y^{*2} + 1} + a^{*} - b^{*}}{2Ky^{*} + \sqrt{4K^{2}y^{*2} + 1} + a^{*} + b^{*}}\right]$$

where

$$a^* = \frac{2}{P_r} - 1$$
;  $b^* = 2\sqrt{(\frac{1}{P_r} - 1)^2 + (\frac{1}{P_r} - 1)^2}$   
Let  $Z^*_{30} = 2K \cdot 30 + \sqrt{4K^2 30^2 + 1}$ 

Therefore

$$T_{W} - T_{30} = \frac{Q''}{K\rho C_{p}} \sqrt{\frac{1}{\tau_{o}/\rho}} \left\{ \ln \frac{Z_{30}^{*} - \frac{a^{*}}{b^{*}} \ln \left[ \frac{(Z_{30}^{*} + a^{*} - b^{*})(1 + a^{*} + b^{*})}{(Z_{30}^{*} + a^{*} + b^{*})(1 + a^{*} - b^{*})} \right] \right\} \cdots 47$$

## (b) y\*> 30

The velocity gradient for the turbulent core is given by

$$\frac{du^*}{dy^*} = \frac{1}{k_m y^*}$$

 $(K_{T} \text{ refers to the turbulent core})$ 

Substituting in Eq. 40 we obtain

$$\frac{\varepsilon_{\rm H}}{v} = (1 - y/r_{\rm o}) K_{\rm T} y^* - 1$$

Substituting into Eq. 39

η

$$T_{30} - T_{C} = \frac{Q''}{\rho C_{P} \sqrt{t_{0}} / \rho} \int_{30}^{y} \frac{(1 - y/r_{0})}{(1 - y/r_{0})K_{T} y^{*} - 1 + \frac{1}{P_{T}}} dy^{*}$$

For the turbulent core  $\epsilon_{\rm H}^{>>}$  1

and for gases where the Prandtl number is close to unity

$$(1 - y/r_{o}) K_{T}y^{*} - 1 + \frac{1}{P_{r}} \simeq (1 - y/r_{o}) K_{T}y^{*}$$

(The approximation made by KAYS (<u>19</u>)) Thus we obtain

$$T_{30} - T_{C} = \frac{Q''}{\rho c_{p} / \tau_{0} / \rho} \int_{30}^{3} \frac{dy^{*}}{K_{T} y^{*}}$$

Thus

$$T_{30} - T_{c} = \frac{Q''}{K_{T} \rho c_{p}} \sqrt{\frac{\rho}{\tau_{o}}} \ln \frac{y_{c}}{30}^{*} \dots 48$$

Combining equations 47 and 48 we have

$$T_{W}-T_{C} = \frac{Q''}{\rho C_{p}} \sqrt{\frac{\rho}{\tau_{o}}} \left\{ \frac{1}{K_{T}} \frac{\ln \frac{r_{o}}{30} \sqrt{\frac{\tau_{o}}{\rho}} + \frac{1}{K} \left[ \frac{\ln Z_{30}^{*} - \frac{a^{*}}{b^{*}} \ln \left[ \frac{(Z_{30}^{*} + a^{*} - b^{*})(1 + a^{*} + b^{*})}{(Z_{30}^{*} + a^{*} + b^{*})(1 + a^{*} - b^{*})} \right] \right\} \cdot 49$$

Introducing the friction factor which is defined as

$$f = \frac{2}{\overline{u}}2 \frac{\tau_0}{\rho}$$

also the Reynolds number is defined as

$$Re = \frac{2\overline{u} r}{v} \circ \frac{1}{\sqrt{\rho}} = \sqrt{\frac{f}{2}} \frac{(v Re)}{2ro}$$

Eq. 49 becomes

$$T_{W}-T_{C} = \frac{Q''}{\bar{u}\rho C_{p}/f/2} \left\{ \frac{1}{K_{T}} \frac{\ln (\underline{Re\sqrt{f/2}}) + \frac{1}{K} \left[ \ln Z_{30}^{*} - \underline{a^{*}} \ln \left[ (\underline{Z_{30}^{*} + \underline{a^{*} - b^{*}})(1 + \underline{a^{*} + b^{*}})}_{(Z_{30}^{*} + \underline{a^{*} + b^{*}})(1 + \underline{a^{*} - b^{*}})} \right] \right\}, 50$$

In order to define a heat transfer coefficient in terms of the bulk mean fluid temperature we must obtain a relationship between  $T_{C}$  and  $T_{g}$ .

Following KAYS  $(\underline{19})$  we use the 1/7 power law given by Eq. 35 and assume a similar variation over the bulk of the fluid for temperature. Thus

$$\frac{\mathbf{T} - \mathbf{T}}{\mathbf{T}_{\mathrm{C}} - \mathbf{T}_{\mathrm{W}}^{\mathrm{W}}} = \left(\frac{\mathbf{y}}{\mathbf{r}_{\mathrm{o}}}\right)^{1/7}$$

hence

$$\frac{T}{T} \frac{g - T}{c - T} W = 0.833 \qquad \dots 5$$

The Stanton number is given by

$$St. = \frac{h}{\overline{u}\rho C_p}$$
 .....52

and

$$h = \frac{Q''}{T_W - T_g}$$
 .....53

Using equations 51, 52, 53 and the relation

Nu = St.Re.Pr

Eq. 50 becomes

$$N_{u} = \frac{\text{Re Pr}\sqrt{f/2}}{0.833 \left\{ \frac{1}{K_{T}} \ln(\frac{\text{Re}\sqrt{f/2}}{60}) + \frac{1}{K} \left[ \ln Z_{30}^{*} - \frac{a^{*}}{b^{*}} \ln\left[ \frac{(Z_{30}^{*} + a^{*} - b^{*})(1 + a^{*} + b^{*})}{(Z_{30}^{*} + a^{*} + b^{*})(1 + a^{*} - b^{*})} \right] \right\}} \dots 54$$

Using Eq. 34 to provide an expression for the friction factor (which, of course, is dependent chiefly on the turbulent core velocity profile) we can obtain an expression for the Nusselt number as a function of the Reynolds number. Fig 4/5 shows this variation for Pr = 0.7, a typical value for helium under HTR conditions. The Reynold number range has been chosen to cover the variation between channels in an HTR at full power.

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#### 2.1.5 Comparison of derived Nusselt number correlation with other data

Shown in Fig 4/5 is that data derived from KAYS (21) which is a theoretical approach including a more refined eddy diffusivity relationship close to the wall (Diessler) and the 'Jenkins' momentum/thermal diffusivity ratio. The resulting equations have been solved numerically on a digital computer. They can be seen to agree very well with the present analysis over this Reynolds number range, the maximum error being 5% at a Reynolds number of  $3 \times 10^4$ .

Also shown in Fig 4/5 is that data recommended by WILKIE (20) with the term allowing for the temperature dependence of coolant properties ignored, since that is the assumption made in this analysis. The 'simplified' WILKIE recommendation is

 $Nu = 0.023 \text{ Re}^{0.8} \text{ Pr}^{0.4}$ 

This is essentially the Dittus - Boelter equation and can be shown in Fig4/5 to give reasonably good agreement with Eq. 54, the maximum difference being about 11% at a Reynolds number of 3 x  $10^5$ .

It is believed that this justifies fully the use of the basic WILKIE correlation for developed turbulent flow in the smooth bore of the HTR fuel channel.

It now remains to discuss the necessary modifications to Eq. 55 to allow for temperature dependent properties and to justify (not so rigorously) the correlation used for heat transfer calculations in a smooth HTR channel annulus.

## 2.1.6 Temperature dependence of coolant properties correction

In the previous analysis it has been assumed that the fluid properties are invariant with temperature. In fact, for helium, the density varies inversely with temperature and viscosity and thermal conductivity to approximately a 0.8 power law (Chapter 5). Specific heat and Prandtl number are essentially constant.

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The normal way of allowing for this effect is to evaluate the properties at the axially local bulk mean coolant temperature and apply a correction to the Nusselt number and friction factor calculated from, say, equations 34 and 55.

This correction takes the form of  $(\frac{T_W(^{\circ}K)}{T_g(^{\circ}K)})^M$  where M is evaluated from experiments.

There is considerable uncertainty associated with the value of M as it depends upon the temperature range, the value of  $T_W/T_g$  and the properties of the particular gas.

BARNES (22) has investigated the effect on Nusselt number for helium and proposes M = -0.185. Whereas Deissler, reported by KAYS (19) suggests M = -0.34. In this work a value of M = -0.15 is taken, as this is the value recommended by WILKIE (20).

It is interesting to note that with a value of -0.34 for M as opposed to -0.15 and with the maximum surface-to-bulk ratio encountered in the HTR channel (1.5) this reduces the Nusselt number by 8%, giving some indication of the uncertainty in heat transfer coefficient arising from possible errors in this correction factor.

The effect is much less significant on friction factor and WILKIE (20) suggests M = -0.05.

## 2.1.7 Thermal entry effects

The assumption of a fully developed turbulent boundary layer does not apply just after entry to the bore or annulus where the thermal boundary layer, at least, is still developing. The Nusselt number in this region is, in general, higher than the developed value, and KAYS (<u>19</u>) suggests that for a tube it would take approximately 30 equivalent diameters before the Nusselt number is within 1% of the developed value, which for the HTR fuel channel bore is 1m (one brick length). For the annulus,

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development can be expected to be much sooner. As, in general, it is peak temperatures which govern thermal performance, one can feel justified in neglecting these entry effects and for the purposes of this thesis fully developed conditions are assumed throughout.

The velocity and temperature profiles are once again disturbed at discontinuities in the channel and once again these effects will be ignored.

2.2

## Annulus heat transfer and pressure drop

The presence of two walls, at first sight, would seem to complicate significantly the derivation of the velocity and temperature profiles and consequently the friction factors and heat transfer coefficients in the annulus. However, a number of simple observations can be made. If  $r_1$ ,  $r_2$  are the inner and outer radii respectively of an annulus:

- (i) there is a position of zero velocity gradient at some radial position between the two walls radius of no-shear  $(r_s)$  which generally coincides with the position of maximum velocity. (This only applies for high values of radius ratio  $\bar{r}$   $({}^{r_1}/r_2)$  according to LAWN (23)).
- (ii) it is possible to find the radius of no-shear by assuming dp/dz is constant with r and also that the mean velocity within this radius is equal to that outside it
- (iii) by considering the flow area inside and outside the radius of no-shear separately (i.e. reducing to one relevant surface) data already derived for tubes can be applied to an annulus. (This 'transformation' was first proposed by HALL (24), who developed the method so that data for passages with different geometries, friction and heat transfer characteristics could be compared.)

## 2.2.1 Friction factor

The pressure gradient, assumed uniform across the channel, can be defined in the inner and outer flow regions by

$$\frac{\mathrm{d}\mathbf{p}}{\mathrm{d}\mathbf{z}} = \frac{2\mathbf{f}_1}{\mathrm{D}\mathbf{e}_1} \stackrel{\mathbf{p}}{=} \overline{\mathbf{u}}_1^2 = \frac{2\mathbf{f}_2}{\mathrm{D}\mathbf{e}_2} \stackrel{\mathbf{u}_2^2}{=}$$

where  $f_1$ ,  $\bar{u}_1$ ,  $De_1$  and  $f_2$ ,  $\bar{u}_2$ ,  $De_2$  refer to the inner and outer regions, respectively. With common peak velocities and with smooth surfaces it is reasonable to assume

$$u_1 = u_2$$
  
therefore  $f_1/f_2 = De_1/De_2$  .....56

If we now assume

$$f_{1} = 0.079 \text{ Re}_{1}^{-0.25}$$

$$f_{2} = 0.079 \text{ Re}_{2}^{-0.25}$$

$$f_{1/f_{2}} = (\frac{de_{1}}{de_{2}})^{-0.25}$$

$$\dots 56(a)$$

Therefore, for equations 56(a) and 56 to hold simultaneously

 $de_1 = de_2$ 

Defining the hydraulic diameter as (4xflow area)/wetted perimeter then

$$De_{1} = 2(r_{s}^{2} - r_{1}^{2})/r_{1}$$

$$De_{2} = 2(r_{2}^{2} - r_{s}^{2})/r_{2}$$

$$\cdot r_{s}^{2} = \frac{r_{1}De_{1}}{2} + r_{1}^{2} \qquad \dots 57$$

Since  $De_1 = De_2$ 

$$De_1 = 2(r_2 - r_1)$$

which is equal to the hydraulic diameter of the whole channel as would be expected.

Substituting for De, into Eq. 57 we have

and if

$$r_{s}^{2} = r_{1}r_{2}$$

$$\overline{r}_{s} = r_{s}/r_{2}$$

$$\overline{r}_{s} = \sqrt{\overline{r}}$$

KAYS (21) quotes an experimentally derived relationship between the radius of no-shear and the radius ratio. The equation is:

$$\bar{r}_{s} = \frac{\bar{r} \cdot 343}{1 + \bar{r} \cdot 343} \cdots 59$$

This is plotted in Fig 4/6 together with Eq. 58. As can be seen they are virtually identical at high radius ratios.(Difference at  $\overline{r} = 0.9$ is less than 0.1%)

From the above analysis it is clear that the tube friction factor correlation should apply equally to the annulus for high radius ratios.

The experimental results given by LAWN (23) certainly shows that as the radius ratio approaches unity the tube friction factor correlation is also approached. From the limited number of results quoted in this reference, however, the conclusion drawn is that even for parallel plates ( $\overline{r} = 1$ ), the friction factor is 5% above that of the tube. This would indicate limitations in the hydraulic diameter concept used in Hall's method.

The correlation recommended by WILKIE (20) for the HTR fuel channel ( $\overline{r} = 0.866$ ) annulus gives a value of friction factor 10% above the tube value, i.e.

$$f = 0.087 \text{ Re}^{-0.25}$$

#### 2.2.2 Heat transfer coefficient

The heat transfer coefficient for both surfaces of a smooth annulus can also be expected to be similar to the tube value providing the position of peak temperature in the fluid coincides with the position of no-shear

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and the bulk mean gas temperature within the radius of no shear is equal to that outside it. This condition can be met if the heat fluxes from the two surfaces are equal.

In the HTR annulus, however, there is a much higher heat flux from the inner surface than from the outer, and clearly the heat transfer correlation for the two surfaces should include a heat flux ratio function ( $\psi$ ).

WILKIE (20) suggests for the two surfaces:

$$\begin{aligned} \Psi &= 1/1 + 0.25(1 - q_0''/q_1'') & \text{for the inner surface} \\ \Psi &= 1/1 + 0.125(1 - q_1''/q_0'') & \text{for the outer surface} \end{aligned}$$

As expected, if  $q_i^{"} = q_o^{"}$ ,  $\Psi$  becomes unity and the tube value is obtained.

The work by KAYS (21) is again used to give a comparison with the WILKIE correlation.

The results quoted by KAYS are for two cases:

A range of radius ratio values were considered. Fig 4/7 shows Nusselt number versus  $\overline{r}$  for Reynold numbers of  $10^4$ ,  $10^5$  and  $10^6$  for Pr = 0.7. The interpolated Nusselt numbers for  $\overline{r} = 0.866$  are plotted against Reynold number in Fig 4/8.

The WILKIE correlation for HTR annulus inner surface is:

$$Nu = \frac{0.023 \text{ Re}^{0.8} \text{Pr}^{0.4}}{1+0.25(1-q_0'/q_1'')} \left(\frac{T_W}{T_B}\right)$$
 .....61

For the HTR annulus  $q_0^{"} \ll q_1^{"}$  and for the purposes of comparison we assume  $q_0^{"}/q_1^{"} = 0$  and compare with (i) above.

In addition, the  $T_W/T_g$  term is ignored since KAYS assumes constant fluid properties.

Eq. 61 becomes:

$$N_{\rm H} = 0.0184 \ {\rm Re}^{0.8} \ {\rm Pr}^{0.4}$$

For Pr = 0.7 Eq. 62 is plotted in Fig 4/8. There is good agreement with KAYS over this Reynolds number range, the error being generally less than 5%.

#### 2.2.3 Annulus hydraulic diameter

The equivalent diameter for the annulus is calculated from the basic relationship

De =  $\frac{4 \times flow area}{wetted perimeter}$ 

The calculation of the flow area and wetted perimeter must make full allowance for the presence of the ribs i.e.

flow area = 
$$\pi (r_o^2 - r_i^2) - Ndl$$

Since  $1 \approx r_0 - r_1$  the wetted perimeter on the rib end is neglected as well as the adjacent perimeter in the channel wall, as recommended by WILKIE (20)

Wetted perimeter = 
$$2\pi (r_0 + r_1) + 2NI - 2Nd$$
  

$$De = \frac{2 \left[\pi (r_0^2 - r_1^2) - Nd1\right]}{\pi (r_0 + r_1) + N(1-d)}$$
.....63

2.3 <u>Summary of convective heat transfer and pressure drop in a</u> HTR fuel channel

## 2.3.1 Convective heat transfer

The standard correlations used in the bulk of the work described in the thesis are based on three major assumptions:

(i) fully developed turbulent flow

(ii) azimuthal symmetry

(iii) smooth channels.

(The effects of roughness will be discussed in section 4.)

The correlations (WILKIE (20)) used are as follows: Channel bore:

$$Nu = 0.023 \text{ Re}^{0.8} \text{ Pr}^{0.4} (T_{W1}/T_{g1})^{-0.15} \dots 64$$

Annulus inner surface:

$$Nu = \frac{0.023 \text{ Re}^{0.8} \text{ Pr}^{0.4}}{1 + 0.25(1 - q_0^{"}/q_1^")} \qquad (T_{W2}^{"}/T_{g2}^{"})^{-0.15} \qquad \dots 65$$

Annulus outer surface:

$$Nu = \frac{0.023 \text{ Re}^{0.8} \text{ Pr}^{0.4}}{1+0.125 (1-q_1''/q_0'')} (T_{W3}/T_{g2})^{-0.15} \dots 66$$

#### 2.3.2 Pressure drop

The Guggenheim equation is the basic relation giving the axial pressure distribution within a channel. The equation, derived from force balance and mass conservation considerations is:

$$\Delta P = \frac{\rho}{2} \overline{u}^{2} \left[ \frac{4f \Delta z}{De} + \frac{2\Delta T}{Tg} + \frac{2\Delta P}{\overline{P}} + K_{D} \right] \qquad \dots 67$$

Buoyancy effects are small compared with the other terms.

 $\Delta P$  is the pressure drop over axial element  $\Delta z$ 

 $\Delta T$  is the temperature rise over axial element  $\Delta_{\rm Z}$ 

Tg is the mean gas temperature in axial element  $\Delta_z$ 

 $\overline{P}$  is the mean pressure in axial element  $\Delta_z$ 

 $K_D$  is the pressure loss due to discontinuities (e.g. brick joints). This equation can be further simplified by noting that for the HTR under operating pressure  $\Delta P << \overline{P}$  s.  $2 \Delta P \simeq 0$ 

The friction factors used (WILKIE (20)) are given by: Bore:

$$f = 0.079 \text{ Re}^{-0.25} (T_{W1}/T_{g1})^{-0.05}$$
 .....68

Annulus:

$$f = 0.087 \text{ Re}^{-0.25} (T_{W2}/T_{g2})^{-0.05} \dots 69$$

# 2.4 Radiative heat transfer in the HTR channel annulus

If one assumes the annulus to be represented by two infinitely long concentric cylinders, both being 'grey bodies' i.e. they emit and absorb all wavelengths to the same degree, then the net heat flux emitted by the inner surface is given by (JACOB (25)):

$$q_{Rs2}'' = \frac{\sigma_{s} (T_{W2}^{4} - T_{W3}^{4})}{\frac{1}{R}_{1} + \frac{r_{s2}}{r_{s3}} (\frac{1}{\epsilon} - 1)}$$
 .....70

where  $\varepsilon_1$  and  $\varepsilon_2$  are the emmissivities of the inner and outer surfaces respectively and  $\sigma_s$  is Stefans constant (5.67 x 10<sup>-8</sup> W/m<sup>20</sup>C).

The radiative heat flux removed by convection from the channel wall is given by:

The small effect of the ribs has been neglected.

## 3 Thermal and irradiation induced dimensional change

3.1 Description of the phenomena

The fuel pin, as described in Chapter 2, consists of a number of compacts placed one on top of another, between a pair of nominally concentric graphite tubes. From the point-of-view of heat transfer, it would be desirable to have zero clearance between the compacts and the sleeves. However, the manufacturing tolerances on the dimensions of the pin components immediately introduce interface gaps which, from a thermal resistance standpoint, are highly significant. These gaps, of about 100 µm and filled with helium under stagnant conditions, present a resistance to heat transfer of the same order as the convective heat transfer resistance at the pin surface. Thus any change in the size of the gaps, although dimensionally small, needs to be predicted with some accuracy.

The precise size of the gaps before the fuel enters the reactor is immediately subject to uncertainty. By matching compact size with tube size it is believed possible to reduce the radial gap to between zero and 80  $\mu$ m for a concentric system. With a fully eccentric compact the maximum gap is 160  $\mu$ m.

For the purposes of the analysis below a concentric system will be assumed.

As soon as the fuel is loaded into the core the temperatures of compact and tube are increased, perhaps by  $1200^{\circ}$ C and  $1000^{\circ}$ C respectively. This difference in temperature rise - combined with the inherently large difference in thermal expansion coefficient CTE - produces, by differential thermal expansion, large changes in the gap sizes. The net effect produces an increase in the radial outer gap of about 100  $\mu$ m and a similar decrease for the inner gap - there being only small strains in the fuel and large strains in the tubes.

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As the irradiation proceeds, the effect of fast neutron damage produces significant changes in the CTE (Chapter 5). These changes, together with any temperature variation, again modify the interface gaps.

Fast neutron dislocation of atoms from the crystal lattice of the compact and sleeves also produces large dimensional changes which are negative until high fast neutron doses are reached (>  $3 \times 10^{21} n/cm^2$  EDN). The graphite crystal structure consists of hexagonal arrays of carbon atoms lying in planes; of separation  $3.35 A^{\circ}$ . The energy required to displace one carbon atom is 25 ev. Under elastic bombardment of neutrons in excess of this energy atoms are displaced from the arrays and, subsequently, are trapped in defects, crystallite edges or return to a vacancy. After some dose, lines of vacancies are formed which collapse producing the 'shrinkage' effect. When high doses are reached, porosity within the crystal becomes 'filled' and 'growth' occurs.

With the graphite form encountered in the compact these so-called "Wigner' strains are highly significant, and can attain well over 0.5 mm radially, if unrestrained. Wigner shrinkage is highly temperature dependent (Chapter 5) and the radial temperature distribution through the fuel element produces not only thermal stresses, but stresses arising from the shrinkage effect. These stresses are relieved slightly by the third important phenomenon - creep.

So far we have assumed that the compact and tube are free to expand or shrink at will. This certainly applies in the non-interacting, or hollow-rod, designs of element (see Chapter 2). In the former, the interface gap between inner tube and compact is made sufficiently large to ensure there is no interaction. In the latter, there is no inner tube. (On present data it is not thought possible for the compact and outer tube to interact with the foreseeable fast neutron doses.) As mentioned above, this condition produces larger outer gaps and consequently worse

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heat transfer characteristics (see section 1 of this chapter.)

With the interacting 'tubular' design, the compact and inner tube are allowed to interfere and a nominal inner gap is chosen to give a satisfactory compromise between high stresses and low heat transfer. Interaction is not allowed to occur at the start of a fuel dwell as creep will have no time to relieve the high stresses produced. Thus a nominal radial gap is chosen (say,  $150 \mu$  m) which ensures that interaction occurs only after some irradiation period.

The axial variation of interface gap is as highly significant as the time variation and arises from the axial distributions of temperature and fast neutron dose (see Chapters 3 and 5). The axial variation of interface gap is more important in the tubular design. This is because the temperatures at an axial position are affected by the upstream partition of heat between inner and outer coolant passages. This partition is greatly affected by the upstream interface gaps. Therefore, in order to assess the endurance of the fuel and graphite at a point in the channel, an accurate estimate of the axial and time variation of the interface gaps is essential.

The first attempts to allow for these effects were made by the Author (<u>26</u>, <u>27</u>); the final method, described below, is included in the AZIMUSTAP program and used these references as a starting point. This final version of AZIMUSTAP, AZIMUSTAP 5, has been used to provide the predictions of interface gap development described in sub-section 3.4.

3.2 Basic theory

#### 3.2.1 Unirradiated conditions - thermal expansions

Consider an axial section of the fuel pin  $\Delta z$ . For any hollow cylinder of inner/outer radii  $r_1/r_2$  with no end restraints and with a temperature distribution being a function of radius r only, the three stresses a point given in cylindrical co-ordinates (Pr, P0 and Pz)

4

are given by TIMOSHENKO (28):

$$Pr = \frac{\Upsilon \alpha}{(1-\sigma)r^{2}} \left\{ \frac{r^{2}-r}{r_{2}^{2}-r_{1}^{2}} \int_{r_{1}}^{r_{2}^{2}} rT^{*} dr - \int_{r_{1}}^{r} rT^{*} dr \right\}$$

$$P\theta = \frac{\Upsilon \alpha}{(1-\sigma)r^{2}} \left\{ \frac{r^{2}+r}{r_{2}^{2}-r_{1}^{2}} \int_{r_{1}}^{r_{2}^{2}} rT^{*} dr + \int_{r_{1}}^{r} rT^{*} dr - r^{2}T^{*} \right\}$$

$$Pz = \frac{\Upsilon \alpha}{(1-\sigma)r^{2}} \left\{ \frac{2}{r_{2}^{2}-r_{1}^{2}} \int_{r_{1}}^{r_{2}^{2}} rT^{*} dr - T^{*} \right\}$$

and Hooke's law gives:

$$Y\left(\frac{u}{r}-\alpha T^{*}\right) = P\theta - \sigma (Pr + Px)$$
 ....73

Young's modulus, Y. is assumed constant with radius.

These equations can be closely applied to the compact which is unrestrained. They apply less accurately to the tubes which are connected at one end.

For the fuel inner radius displacements,  $r_1 = r_{f1}$ ,  $r_2 = r_{f2}$ ,  $r = r_{f1}$ Substituting for the radii in equations 72 and 73 we have

Substituting Eq. 74 in Eq. 73 we derive the expression for the fuel displacement given as:

$$u_{f1} = \frac{2\alpha_{f} r_{f1}}{r_{f2}^{2} - r_{f1}^{2}} \int_{r_{f1}}^{r_{f2}} r T * dr \qquad \dots 75$$

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)

Similar expressions can be obtained for the other surfaces

$$u_{f2} = \frac{2\alpha_{f} r_{f2}}{r_{f2}^{2} - r_{f1}^{2}} \int_{r_{f1}}^{r_{f2}} rT * dr \qquad \dots 76$$

$$u_{S1}^{i} = \frac{2\alpha r_{S1}^{i}}{r_{S1}^{i^{2}} - r_{S1}^{2}} \int_{r_{S1}}^{r_{S1}^{i}} rT^{*} dr \qquad \dots 77$$

$$u_{s2}' = \frac{2\alpha}{r_{s2}^2 - r_{s2}^2} \int_{r_{s2}}^{r_{s2}} rT * dr$$
 .....78

Now  $T^* = T - T_o$  where  $T_o$  is room temperature (~20°C)

therefore 
$$\frac{2}{r_2^2 - r_1^2} \int_{r_1}^{r_2} rT^* dr$$
 becomes  
 $\frac{2}{r_2^2 - r_1^2} \int_{r_1}^{r_2} rT dr - \frac{2}{r_2^2 - r_1^2} \int_{r_1}^{r_2} rT dr$ 

and

$$\frac{\frac{2}{r_2^2 - r_1^2}}{r_2 - r_1^2} \int_{r_1}^2 r T dr - T_0$$

Now  $\frac{2}{r_2^2 - r_1^2} \int_{r_1}^{r_2} rTdr$  is the volumetric mean temperature  $\overline{T}$  and

equations 75 - 78 can be rewritten:

- $U_{f1} = \alpha_{f_{f1}} [\overline{T}_{f} T_{o}]$ .....79
- $U_{f2} = \alpha_{f} r_{f2} [\overline{T}_{f} T_{o}]$ .....80

$$U_{s_2} = \alpha_{g} r_{s_2}^{(1)} [\bar{T}_{s_1} - T_{o}]$$
 .....81

$$U_{s1} = \alpha_{g} r_{s1} [\overline{T}_{s2} - T_{o}] \qquad \dots 82$$

These displacements can be combined to give the net change in the inner and outer interface gaps. Also, if  $g_1(o)^{<<} r_{f1}$  and  $g_2(o)^{<<} r_{f2}$  $r_{s1}^{\prime} \simeq r_{f1}$  and  $r_{s2}^{\prime} \simeq r_{f2}$ 

Thus

$$g_{1}(o) = g_{c1} + r_{f1} \left[ \alpha_{f} \left( \overline{T}_{f} - T_{o} \right) - \alpha_{g} \left( \overline{T}_{g} - T_{o} \right) \right] \dots .83$$

$$g_{2}(o) = g_{c2} + r_{f2} \left[ \alpha_{g} \left( \overline{T}_{g} - T_{o} \right) - \alpha_{f} \left( \overline{T}_{f} - T_{o} \right) \right] \dots .84$$
The CTE,  $\alpha$ , has been assumed constant. In fact both  $\alpha_{f}$  and  $\alpha_{g}$  vary with

temperature, as can be seen in Chapter 5.

The temperature difference across the graphite sleeves can be as large as 100°C and the constant CTE assumption could produce significant errors in the thermal gap. Correctly,  $\alpha$  should be included in the integral term of Eq.72, and a function of temperature substituted; whereas a more convenient method would be to use a value of  $\alpha$  evaluated at  $\overline{T}_{g1}$  or  $\overline{T}_{g2}$ . Appendix IV shows that, assuming  $\alpha$  is a linear function of graphite temperature, which in turn is a linear function of radius r, the differences in approach lead to errors in the strain of less than 0.02%. Similar errors in fuel strain can be expected but, as these strains are very much less significant than the graphite displacements, the thermal gap is less affected.

Arising from this error study, therefore, good accuracy can be expected for the thermal gaps if  $\alpha_f$  and  $\alpha_g$  given in equations 83 and 84 are evaluated at  $\overline{T}_f$ ,  $\overline{T}_{s1}$  and  $\overline{T}_{s2}$ .

## 3.2.2 Conditions under irradiation

## (a) Thermal strain

If  $\overline{T}_{f}(d)$ ,  $\overline{T}_{s1}(d)$  and  $\overline{T}_{s2}(d)$  are the mean fuel and graphite temperatures which exist after a dose d, then the CTE values are given by  $\alpha_{f}(d, \overline{T}_{f}(d))$ ,

 $\alpha_{g}(d,\overline{T}_{s1}(d)) \text{ and } \alpha_{g}(d,\overline{T}_{s2}(d)) \text{ and the expressions for the thermal gaps}$ at dose d are:  $g_{1t}(d) = g_{c1} + r_{f1} \left[ \alpha_{f}(d,\overline{T}_{f}(d))(\overline{T}_{f}(d) - T_{o}) - \alpha_{g}(d,\overline{T}_{s1}(d))(\overline{T}_{s1}(d) - T_{o}) \right] \dots 85$   $g_{2t}(d) = g_{c2} + r_{f2} \left[ \alpha_{g}(d,\overline{T}_{s2}(d))(\overline{T}_{s2}(d) - T_{o}) - \alpha_{f}(d,\overline{T}_{f}(d))(\overline{T}_{f}(d) - T_{o}) \right] \dots 86$ where  $g_{1t}(d)$  and  $g_{2t}(d)$  are the interface gaps at dose d due to thermal.
strains only.

# (b) Wigner shrinkage

After a dose, d, it is assumed that there is a small additional dose  $\Delta$  d. If at d the rate of change of Wigner strain with dose is  $\S(d)$  the strain at d +  $\Delta$ d is  $\S(d)\Delta d$ . Now consider Eq. 75 written in a general form

$$Sr_1 = \frac{2}{r_2^2 - r_1^2} \int_{r_1}^{r_2} r Sr dr$$

where Sr, is the strain at radius r, and Sr, is the strain at radius r.

This equation is valid regardless of the origin of the strain Sr if it obeys the same elastic laws. Therefore, assuming Wigner shrinkage can be treated in this way, Sr can be replaced by  $(d) \Delta d$  i.e.

$$\Delta Wr_{1}(d) = \frac{2}{r_{2}^{2} r_{1}^{2}} \int_{r_{1}}^{r_{2}} r \, \mathfrak{s}(d) \, \Delta \, d \, dr \qquad \dots 87$$

 $\Delta Wr_1(d)$  is the increment of Wigner strain after a dose  $\Delta d$  at dose d at radius  $r_1$ .

For both the fuel and graphite it is a good approximation to assume that dose is independent of radius. However, as can be seen from Ref.  $(\underline{43})$ § (d) is dependent on temperature which is, of course, a function of radius. Fig 4/9 shows the variation of §(d) with temperature for the fuel and graphite where d = 2.0 x 10<sup>20</sup> n/cm<sup>2</sup> EDN. It can be seen that for the expected temperature variations (less than  $100^{\circ}$ C) linearity, is a reason-

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able approximation i.e.

$$(d) = M(d)T + N(d)$$

Thus, substituting in Eq. 87 we have:

$$\Delta Wr_{1}(d) = \frac{2\Delta d}{r_{2}^{2} - r_{1}^{2}} \int_{r_{1}}^{r_{2}} r (M(d)T + N(d)) dr$$
$$= \Delta d \left[ 2 M(d) \int_{r_{1}}^{r_{2}} rTdr + N(d) \right]$$

and  $\Delta Wr_1(d) = \Delta d(M(d)\overline{T} + N(d))$  $\therefore \Delta Wr_1(d) = \Delta d\$ (d,\overline{T})$ 

Therefore, as with CTE, shrinkage is evaluated at mean fuel or graphite temperature conditions.

The Wigner shrinkage gaps can be written as follows

$$g_{1W}(a + \Delta a) = g_{1W}(a) + r_{f1} [\$_{f}(a, \overline{T}_{f}) - \$_{g}(a, \overline{T}_{g1})]\Delta a \dots 89$$
  
$$g_{2W}(a + \Delta a) = g_{2W}(a) + r_{f2} [\$_{g}(a, \overline{T}_{g2}) - \$_{f}(a, \overline{T}_{f})]\Delta a \dots 90$$

Although in equations 89 and 90 no distinction is made between the doses in the three annuli, in principle there is no reason why different doses can not be assumed.

If  $\Delta d$  ceases to become small compared with d, it then becomes necessary to evaluate § at some mean dose, say  $(d + \frac{\Delta d}{2})$ .

A treatment by HAIG  $(\underline{29})$  which includes creep in the analysis shows that, providing the creep constant is invariant with radius r, similar expressions for the strain to those derived above are obtained.

N.B. It is also assumed that r<sub>f1</sub>, r<sub>f2</sub> are independent of temperature and dose i.e. thermal and Wigner strains are very much less than 1.

# (c) An interacting fuel element

The equations given above only apply if tubes and compact are unrestrained as with the hollow rod element or tubular non-interacting designs. With the tubular interacting (T.I.) element, however, the inner gap is made sufficiently small so as to ensure interference between compact and inner tube after some accumulation of dose. The compact so restrained has a lower strain rate at its outer surface resulting in a smaller gap. The precise size of the gap at any dose is highly dependent upon the inner interface pressure and creep, involving highly specialised analysis. A series of equations were developed to deal with the interacting condition by a stress analysis specialist (ROBINSON (<u>30</u>)) and although the Author had no hand in their derivation they are given here for completeness.

In the use of the equations, however, some modifications were made by the Author, and these are described in sub-section 3.3.

The outer gap at dose  $d + \Delta d$  is given by

$$g_2(d + \Delta d) = g_2(d) + r_{f2} (V_g - V_f) - Rr_{f1}\Delta X \dots 91$$

where  $V_g$  and  $V_f$  are the combined Wigner and thermal strains derived in equations 86 and 90. The term  $\operatorname{Rr}_{f1}\Delta X$  is the reduction in displacement due to the interacting effect. Where

$$R = 2r_{f1}^{2} / [(1 - \sigma_{f}) r_{f1}^{2} + (1 + \sigma_{f}) r_{f2}^{2}]$$

and  $\Delta X$  is given by  $\Delta X = P(d)L\mu(1-\lambda) + (V_g - V_f) + \frac{L}{\mu} (V_f - V_g) \left\{ Y_g K_g + \frac{\mu(1-\lambda)}{\Delta d} \right\} \dots 92$ L,  $\mu$ ,  $\lambda$ ,  $Y_g$  and  $K_g$  are evaluated at dose d +  $\Delta d$ . The interface pressure P(d) is evaluated at dose d, and

$$P(d + \Delta d) = P(d) \lambda (d + \Delta d) - \frac{(1 - \lambda (d + \Delta d))}{\mu \Delta d} (V_{f} - V_{g}) \qquad \dots 93$$

$$\lambda (d + \Delta d) = \exp[-\phi \ \Delta d]$$

$$L = \frac{1 - \alpha g}{Y_g}, \quad \mu = 1 - \frac{Y_g K_g}{\phi}$$

$$\phi = \frac{\mu}{\theta}, \quad \theta = \frac{m + \sigma f}{Y_f} + \frac{k - \sigma}{Y_g}$$

$$m = \frac{r_{f2}^2 + r_{f1}^2}{r_{f2}^2 - r_{f1}^2}, \quad k = \frac{r_{f1}^2 + r_{g1}^2}{r_{f1}^2 - r_{g1}^2}$$

$$u = K_f (m + \sigma_f) + K_g (k - \sigma_g)$$

In order to treat the unusual occurrance of interaction at zero irradiation owing to thermal effects only, the following simplified expression gives the resulting interface stress

where  $\Delta X = (\overline{T}_{g1} - T_0) \stackrel{\alpha}{g} (\overline{T}_{g1}) - (\overline{T}_f - T_0) \stackrel{\alpha}{f} (\overline{T}_f) - \frac{g_{c1}}{r_{f1}}$ The outer gap is assumed unaffected by interaction and is given by Eq. 84.

# 3.3 Description of method as incorporated in AZIMUSTAP

#### 3.3.1 General

Material properties and temperatures are complicated functions of axial position and dose, and it is therefore not feasable to determine analytically the interface gaps at any point in space and time. The program AZIMUSTAP was employed therefore, to carry out step-wise calculations both axially and with irradiation dose. The axial calculation method is described in Appendix VI and only one axial position, z, will be considered here.

The gaps at any dose are dependent upon the gaps at previous doses and hence on the whole preceding irradiation history. It is therefore necessary to start the calculation by analysing fresh fuel and, at discrete dose intervals, repeat the calculations, passing on calculated gaps and

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other necessary data to the next dose step. At each dose step the relevant operating conditions (channel power and gas outlet temperature) and material properties are used, having been derived from arrays input as data.

TRG  $1000(R)(\underline{43})$  (Ch. 5) shows the fuel and graphite thermal conductivity as a function of temperature and fast neutron dose (EDN) and Fig 3/4 shows typical time evolutions of channel power and gas outlet temperature.

As described in Appendix VI there are two main iterative loops in the AZIMUSTAP calculation.

(i) Axial mesh point iteration

At each axial step the gas temperatures, calculated at the previous step are the boundary conditions for the calculation. The fuel and graphite temperatures are then derived by calculating the temperature dependent conductances and then iterating until consistancy is achieved.

### (ii) Flow iteration

For the tubular designs where there are two flow passages there is an iteration on flow split in order to achieve an equal pressure at outlet, since flow resistances are temperature dependent.

Using the axial mesh point iteration as a framework, the temperature dependent interface gap can be incorporated as an additional dependent variable.

Let us now consider the axial mesh point calculation at the start of the fuel dwell where the interface gaps are influenced by thermal effects only.

#### 3.3.2 Thermal gap at zero irradiation

For the first axial calculation step the first guess for the interface gap is taken as  $g_c$ , the cold unirradiated radial interface gap, assumed constant axially. Because the only temperatures known at this stage are the inlet gas temperatures, Eq. 12, which gives the gap conductances, is approximated to

$$k_{j} = \frac{k_{g}(T_{1})}{g_{c}} \qquad \dots 96$$

where  $k_{G}(T_{1})$  is helium conductivity evaluated at  $T_{1}$ . The thermal radiation term can, in any case, be assumed small since at the inlet temperatures are low. For example  $k_{j}$  would typically have a value at outlet of ~ 0.26 W/cm<sup>2</sup> °C where the madiation term contributes only 3.6%. The conductance given by Eq. 96 is therefore included in the calculation of the temperatures for that axial position. The bulk mean temperatures are calculated(SINCLAIR (51)) and gaps calculated from equations 83 and 84. New gap conductances are calculated from Eq. 12 and the procedure repeated until fuel temperatures have converged to a specific criterion.

 $\alpha_{f}$  and  $\alpha_{g}$  are input as arrays of  $\alpha$  versus temperature. The value of  $\alpha$  required for a particular temperature is then found by linear interpolation.

For subsequent axial steps the procedure is identical, except that as a first guess the previous axial step converged gap conductances are taken.

The maximum value of  $k_j$ ,  $k_{jm}$ , is derived experimentally (see subsection 1.2.4) and is prescribed in the program so that  $k_j$  is set equal to it should its value be greater when derived from Eq. 12.

If, from Eq. 83,  $g_1(o)$  is found to be negative, interaction is said to have occurred and as well as setting  $k_{j1}$  equal to  $k_{jm}$  and  $g_1(o)$  equal to zero, the interface pressure is calculated from Eq. 95. Young's

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modulus is given as an array with temperature which is interpolated linearly. Poisson's ratio for the fuel and graphite are taken as constant with temperature.

# 3.3.3 Gap calculation under irradiation

The irradiation calculation is carried out in step-wise fashion through the irradiation period of the fuel channel. At each step the full axial calculation is carried out, together with he flow iteration, after which interface gaps and other necessary information are passed onto the next step. The size of the step is chosen to give the desired accuracy.

The thermal conductivity, dimensional change and mechanical property data are given as functions of fast neutron dose (EDN) and it is therefore convenient to divide the irradiation period into dose steps and specify channel operating conditions, power, flow, also as functions of dose.

When calculating an interface gap at axial position z and dose  $d_n$  the new gap is dependent upon the previous gap at dose  $d_{n-1}$  at that axial position. It is therefore necessary to store the complete axial distribution of interface gaps for use in the next dose step. This also applies to other calculated quantities.

For the dose calculation it is necessary to be able to specify property data as two-dimensional arrays, dose as well as temperature, and the value of any property is found using the temperature and dose which apply to a particular axial position for a particular dose step.

The irradiation period of the channel is divided into steps of channel mean dose and the dose at any axial position is found from the relation:

$$\Delta d(z) = \frac{\overline{\Delta}d}{\overline{R}(z)} R(z)$$

where  $\Delta d(z)$  is the increment of dose accumulated by an axial position z;  $\Delta \overline{d}$  is the specified channel mean dose;  $\frac{R(z)}{R(z)}$  is the normalised axial rating factor. The justification for using the axial rating

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shape as opposed to an axial dose shape is given in Chapter 3.

The axial rating shape is not a constant with irradiation and it is therefore necessary to pass on to the next dose step the accumulated dose. Therefore if  $d(z)_{n-1}$  is the accumulated dose up to step n-1 for axial position z, the dose at step n for axial position z is

$$d(z)_{n} = d(z)_{n-1} + \Delta \overline{d}_{n} \quad \left(\frac{R(z)}{R(z)}\right)_{n} \qquad \dots 97$$

where  $\Delta \overline{d}_n = \overline{d}_n - \overline{d}_{(n-1)}$  specified as data.

Consider dose step n and z = 0. As with the start-of-life calculation Eq. 96 is used for a first guess but now  $g_{(z=0)(n-1)}$  is taken instead of the cold unirradiated gap. For other axial positions the converged interface conductances of the previous axial step is taken - as before.

Let us consider an axial position z at the start of the calculation at dose step n. A test is first made to find if, at n-1, interaction has occurred. If not, the non-interacting equations are used.

#### (a) The non-interaction method

The inner and outer gaps are given by:

$$\begin{split} g_{1n} &= g_{1(n-1)} + r_{f1} \left( \mathbb{V}_{f}(d_{n},\overline{T}_{fn}) - \mathbb{V}_{g}(d_{n},\overline{T}_{s1n}) \right) & \dots 98 \\ g_{2n} &= g_{2(n-1)} + r_{f2} \left( \left( \mathbb{V}_{g}(d_{n},\overline{T}_{s2n}) - \mathbb{V}_{f}(d_{n},\overline{T}_{fn}) \right) & \dots 99 \right) \\ \mathbb{V}_{g} \text{ and } \mathbb{V}_{f} \text{ are combined thermal and Wigner strains and are derived from a combination of equations 85, 86, 89 and 90 thus:} \\ \mathbb{V}_{f}(d_{n},\overline{T}_{fn}) &= \$_{f}(d_{n},\overline{T}_{fn}) \Delta d_{n} + \left(\overline{T}_{fn} - \overline{T}_{o}\right) \alpha_{f}(d_{n},\overline{T}_{fn}) - \left\{ \left(\overline{T}_{f} - \overline{T}_{o}\right) \alpha_{f} \right\}_{n-1} & \dots 100 \\ \mathbb{V}_{g}(d_{n},\overline{T}_{s1n}) &= \$_{g}(d_{n},\overline{T}_{s1n}) \Delta d_{n} + \left(\overline{T}_{s1n} - \overline{T}_{o}\right) \alpha_{g}(d_{n},\overline{T}_{s1n}) - \left\{ \left(\overline{T}_{s1} - \overline{T}_{o}\right) \alpha_{g} \right\}_{n-1} & \dots 101 \\ \mathbb{V}_{g}(d_{n},\overline{T}_{s2n}) &= \$_{g}(d_{n},\overline{T}_{s2n}) \Delta d_{n} + \left(\overline{T}_{s2n} - \overline{T}_{o}\right) \alpha_{g}(d_{n},\overline{T}_{s2n}) - \left\{ \left(\overline{T}_{s2} - \overline{T}_{o}\right) \alpha_{g} \right\}_{n-1} & \dots 102 \\ \mathbb{V}_{g}(d_{n},\overline{T}_{s2n}) &= \$_{g}(d_{n},\overline{T}_{s2n}) \Delta d_{n} + \left(\overline{T}_{s2n} - \overline{T}_{o}\right) \alpha_{g}(d_{n},\overline{T}_{s2n}) - \left\{ \left(\overline{T}_{s2} - \overline{T}_{o}\right) \alpha_{g} \right\}_{n-1} & \dots 102 \\ \mathbb{V}_{g}(d_{n},\overline{T}_{s2n}) &= \$_{g}(d_{n},\overline{T}_{s2n}) \Delta d_{n} + \left(\overline{T}_{s2n} - \overline{T}_{o}\right) \alpha_{g}(d_{n},\overline{T}_{s2n}) - \left\{ \left(\overline{T}_{s2} - \overline{T}_{o}\right) \alpha_{g} \right\}_{n-1} & \dots 102 \\ \mathbb{V}_{g}(d_{n},\overline{T}_{s2n}) &= \$_{g}(d_{n},\overline{T}_{s2n}) \Delta d_{n} + \left(\overline{T}_{s2n} - \overline{T}_{o}\right) \alpha_{g}(d_{n},\overline{T}_{s2n}) - \left\{ \left(\overline{T}_{s2} - \overline{T}_{o}\right) \alpha_{g} \right\}_{n-1} & \dots 102 \\ \mathbb{V}_{g}(d_{n},\overline{T}_{s2n}) &= \$_{n-1} \text{ terms are the thermal strains which apply to the previous dose step (n - 1). \end{split}$$

 $\$(d_n, \overline{T}_n)$  terms are mean gradients of shrinkage for the dose step and  $\$(d_n, \overline{T}_n)$  is taken as the difference between the shrinkage ordinate at dose  $d_n$  and dose  $d_{n-1}$  of the shrinkage versus dose curve applying at temperature  $\overline{T}_n$ . It would be more consistent if an average temperature between  $\overline{T}_n$  and  $\overline{T}_{n-1}$  were taken. However this would necessitate passing on large numbers of temperatures which would be cumbersome and, providing small enough dose steps are taken (which, in any case, is necessary for an average  $\$(d_n, \overline{T}_n)$  to apply) errors can be made acceptably small.

If it is found on convergence that Eq. 98 leads to a negative gap i.e. if the accumulated strain over an irradiation period is greater than  $g_{1(n-1)}/r_{f1}$ , then the axial step calculation is repeated using the interacting method.

## (b) Interacting method

We now use the equations 91 - 95 for evaluating the outer gap and interface pressure at dose step n. The equations assume, however, that there has been interaction throughout  $\Delta dn$ , whereas in general the onset of interaction would have occurred between steps n - 1 and n.

This discrepancy is not very significant in calculating the outer gap as only the correction term  $\operatorname{Rr}_{f1} \Delta X$ , in equation 91, is in error and providing the dose steps are not too large the effects can be ignored.

With the interface pressure, however, its value at n - and therefore the accumulated peak value - is highly dependent upon the precise time at which interaction occurs. Therefore, in order to avoid uneconomically small dose steps a correction term is necessary to allow for this effect.

If  $g_{1(n-1)}$  is the inner gap calculated at dose step n-1 and  $g_{1n}$  is negative, the problem is to find the dose increment  $\Delta d$  after dose step (n-1) when  $g_1$  becomes zero and interaction is said to begin (see Fig 4/10).

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We have

$$g_{1n} = g_{1(n-1)} + r_{f1} (V_f(d_n, \overline{T}_{fn}) - V_g(d_n, \overline{T}_{g1n}))$$

The mean strain rates over the dose increment  $d_n - d_{(n-1)}$ , ( $\Delta d_n$ ) for the fuel and graphite are given by

Thus  $\Delta d'$  is calculated from

$$g_1 (d_{(n-1)} + \Delta d^*) = 0$$

and therefore

$$-g_{1} (n-1) = \Delta d^{*}r_{f1} (V_{f}' - V_{g}')$$
  
$$\Delta d^{*} = \frac{-g_{1}(n-1)}{r_{f1}(V_{f} - V_{g}')} \dots \dots 103$$

and

Therefore the stress is applied for a dose increment given by  $\Delta d_n - \Delta d'$  and since P(n-1) = 0

from Eq. 93

$$Pn = -\mu (1-\lambda n) (V_{f'} - V_{g'})$$

 $\lambda_n$  which gives the creep effect on pressure is an inverse function of  $\Delta d$ , the period over which the pressure is maintained.

i.e. 
$$\lambda_n = \exp \left[-\frac{\phi}{(n-1)}\Delta d\right]$$

where, in this case,  $\Delta d = \Delta dn - \Delta d'$ 

Therefore substituting in for  $\Delta d$  from Eq. 103 we have

$$\lambda_{n} = \exp \left[ -\phi_{(n-1)} \left( \Delta d_{n} + \frac{g_{1(n-1)}}{r_{f1} (V_{f}^{\circ} - V_{g}^{\circ})} \right) \right]$$
  
$$\lambda_{n} = \exp \left[ -\phi_{(n-1)} \Delta d_{n} \left( 1 + \frac{g_{1(n-1)}}{r_{f1} (V_{f} (d_{n}, \overline{T}_{fn}) - V_{g} (d_{n}, \overline{T}_{sn}))} \right) \right] \cdots 104$$

Thus the complete expression for the pressure is given by

$$P_n = P_{(n-1)}\lambda_n - \left(\frac{1-\lambda n}{\mu\Delta d_n}\right) \left( \nabla_f (d_n, \overline{T}_{fn}) - \nabla_g (d_n, \overline{T}_{sn}) \right) \qquad \dots 105$$
  
where  $\lambda_n$  is given by Eq. 104.

This expression now applies at any dose step, for if there is no interaction at n-1, then P(n-1) = 0. Conversely, if there were interaction at n-1,  $g_{(n-1)} = 0$  and the equation reverts to Eq. 93.

The effect this correction has on interface pressure is shown schematically in Fig 4/10.

# (c) Correction for the termination of interaction between dose steps

If the test which was made to find out if there was interaction at the previous dose step, is found to be positive then the interacting equations (equations 91 - 95) are used for the first round of iterations.

It is possible, however, particularly at high doses for the fuel and graphite strain rates to change such that  $\nabla'_f - \nabla_g$  is no longer negative i.e. when  $\$_f$  becomes less negative than  $\$_g$ . If  $\nabla'_f - \nabla'_g$ is sufficiently positive, the interface pressure will be relieved (calculated to be negative) and the inner gap will begin to grow. This can be shown from Eq. 93 i.e.

$$P_n = P_{(n-1)} n - (1 - \lambda_n) (\forall f - \forall g)/\mu$$

For  $P_n = 0$ 

 $P_{(n-1)} \lambda_n = (1 - \lambda_n) (\nabla'_f - \nabla'_g)/\mu$ 

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From Eq. 94 0< λ<sub>n</sub> <1

 $\therefore v_{f}^{i} - v_{g}^{i} > 0$ 

In order to allow for the fact that interaction ceases between doses, the expression for the inner gap (Eq. 98), for use in the second round of iterations, must be modified so that accuracy as well as consistency are maintained.

Again the problem is to find the dose increment  $\Delta d$  necessary to achieve a zero interface pressure, i.e. from Eq. 106.

$$\lambda_{n}(\Delta d^{\prime}) (P_{(n-1)} + \frac{1}{\mu} (V_{f}^{\prime} - V_{g}^{\prime})) = \frac{1}{\mu} (V_{f}^{\prime} - V_{g}^{\prime})$$

$$\exp \left[-\phi_{(n-1)} \Delta d^{\prime}\right] = \frac{1}{\mu} (V_{f}^{\prime} - V_{g}^{\prime})/(P_{(n-1)} + \frac{1}{\mu} (V_{f}^{\prime} - V_{g}^{\prime}))$$

$$\Delta d^{\prime} = \frac{1}{\phi_{(n-1)}} \ln \left[\frac{P_{(n-1)} + \frac{1}{\mu}(V_{f}^{\prime} - V_{g}^{\prime})}{\frac{1}{\mu} (V_{f}^{\prime} - V_{g}^{\prime})}\right] \dots 107$$

Thus Eq. 98 can be rewritten

$$g_n = g_{(n-1)} + r_{f1} (V_f - V_g)(\Delta d_n - \Delta d')$$

where, in this case,  $g_{(n-1)} = 0$ , and  $\Delta d_n - \Delta d^*$  is the dose increment over which the strain rate differential is contributing to the inner gap. Therefore, in terms of calculated quantities:

$$g_n = r_{f1} \left[ V_f(d_n, \overline{T}_{fn}) - V_g(d_n, \overline{T}_{Sn}) \right] \left( 1 - \frac{\Delta d'}{\Delta d_n} \right) \dots 108$$

Consistency is achieved since, when P = 0 at  $d_n$ ,  $\Delta d' = \Delta d_n$  and therefore  $g_n$ , from Eq. 108, is also zero and if P = 0 at  $d_{(n-1)}$ , the equation for  $g_n$  reverts to Eq. 98.

#### 3.4 Typical gap and stress evolution for a fuel channel

The mechanical and dimensional change and conductivity data given in Chapter 5 have been used in AZIMUSTAP-5 to produce the axial and time variations of interface gaps and pressures for a peak rated channel. The parameters and operating conditions of this channel are given in Tables 4/1 and 5/1.

#### 3.4.1 Time evolution

The time variation of the interface gaps and pressures at the 2m (from top reflector) level are given in Fig 4/11.

On loading the column the inner gap is reduced by thermal effects on reaching the steady state operating temperatures.

(The dwell of the channel is divided into 20 equal dose steps, the end of life, channel average, dose being  $2 \ge 10^{21} \text{ n/cm}^2 \text{ EDN.}$ )

At 1 x  $10^{20}$  n/cm<sup>2</sup> EDN channel average dose the inner gap has decreased still further and a\*2 x  $10^{20}$  n/cm<sup>2</sup> EDN interaction has occurred. By extrapolating the straight line drawn between the zero and 1 x  $10^{20}$ n/cm<sup>2</sup> EDN dose points it was found it passed through the 2 x  $10^{20}$  n/cm<sup>2</sup> EDN/ zero gap point. However, interaction must have occurred slightly before this dose since a finite interface pressure has been calculated. Therefore in order to obtain the precise time of interaction, which is needed for compact stressing calculations, extrapolation should not be used for accuracy and more dose steps at these low doses should be taken.

At dose step 3 x  $10^{20}$  n/cm<sup>2</sup> EDN the stress had increased markedly. The rapid increase being due to the large values of  $\$_{f}$  at these doses.

As is noted in Chapter 3 (also see Fig 4/32) gags are changed at doses  $4 \ge 10^{20}$ ,  $8 \ge 10^{20}$ ,  $12 \ge 10^{20}$  and  $16 \ge 10^{20}$  n/cm<sup>2</sup> EDN. In order to represent the step change in temperatures which occur at each gag change extra dose steps have been introduced into the calculation at  $3.9999 \ge 10^{20}$ ,  $7.9999 \ge 10^{20}$ ,  $11.9999 \ge 10^{20}$  and  $15.9999 \ge 10^{20}$  n/cm<sup>2</sup> EDN.

Therefore the next dose step after  $3.0 \ge 10^{20} \text{ n/cm}^2 \text{ EDN}$  is 3.9999  $\ge 10^{20} \text{ n/cm}^2 \text{ EDN}$ . Here it is found that the stress has reduced since creep and reduced thermal effects have begun to counteract the shrinkage part.

Once the gag is changed there is an abrupt increase in fuel and graphite temperatures. It is found therefore at dose step 4 x  $10^{20}$  n/cm<sup>2</sup> EDN that there is an increase in interface pressure owing to

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the increased thermal contribution. There is clearly a transient effect of changing the gag which has not been allowed for.

Beyond 4 x  $10^{20}$  n/cm<sup>2</sup> EDN the interface pressure generally decreases owing to the reduction of  $s_r$ .

This reduction proceeds until, at  $1.9 \ge 10^{21} \text{ n/cm}^2 \text{ EDN}$ , an inner gap has formed again. At the next dose step,  $2 \ge 10^{20} \text{ n/cm}^2 \text{ EDN}$  the channel has come to the end of its dwell and is discharged.

The outer gap varies monotonically as it is unaffected by gag changes, the thermal strain making only a small contribution to the total strain.

It can be seen from the figure that the rate of change of gap size is greater at low doses than at high doses and is therefore consistent with the fuel shrinkage/dose curve (

#### 3.4.2 Axial distribution

Fig 4/12 shows the axial variation of interface gaps and pressures for a channel average dose of 2.0 x  $10^{20}$  n/cm<sup>2</sup> EDN.

The fuel region in the column is 5m in length and has been divided into twenty axial slabs. Therefore each slab is  $\frac{1}{4}$  of a brick and  $\frac{1}{2}$  of a pin, there being two pins per brick.

At the top of the first pin where the fuel is at inlet conditions the temperatures and doses are low (see Chapters 3 and 5). The thermal and Wigner strains are, therefore, small and gaps have changed little from their cold unirradiated values. Further down the stack the inner and outer gaps are decreasing and increasing respectively resulting from the increased temperatures (thermal strains) and doses (Wigner strains).

At the 2m level it is found that interaction has occurred, initially at approximately 1.9m (found by extrapolation).

From the top of the third brick downwards the enrichment is lower.

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Therefore, just below the 2m level, the doses and temperatures are also lower and it is found that there is no interaction and the outer gap has reduced.

Further down the column, temperatures and doses are increasing again until at 2.88m interaction has occurred, causing the corresponding outer gap to be smaller. With the increasing doses and temperatures both the outer gap and interface pressure increase until 4.44m where, with a reduced dose, there is no interaction.

# 3.5 Thermal expansion and irradiation effects on channel dimensions

In the calculations described so far the core and annulus dimensions have been assumed invariant. The thermal expansion and Wigner shrinkage effects, however, cause the dimensions of the flow passages to have an axial and time distribution.

#### 3.5.1 Thermal effects

Let us first consider the start-of-life where only thermal expansion effects are relevant. There are three radial dimensions which need to be considered:  $r_{g1}$ ,  $r_{g2}$ ,  $r_{g3}$ . It is assumed that the expansion of the channel wall dimension is controlled by the channel wall temperature. In fact, the whole temperature and stress field within the block decides the channel dimensions.

From equations similar to Eq. 79 the displacements of the three surfaces at an axial position z are given by:

$$\Delta r_{g;1}(z) = \alpha_{g}(\overline{T}_{g1}(z)) \cdot r_{g1} \cdot (\overline{T}_{g1}(z) - T_{o})$$
  

$$\Delta r_{g;2}(z) = \alpha_{g}(\overline{T}_{g2}(z)) \cdot r_{g2} \cdot (\overline{T}_{g2}(z) - T_{o}) \qquad \dots 109$$
  

$$\Delta r_{g3}(z) = \alpha_{g}(T_{W3}(z) \cdot r_{W} \cdot (\overline{T}_{W3}(z) - T_{o})$$

The varying temperature axially ensures an axial variation of passage geometry. The change in dimension, however, is sufficiently small to cause minimal effects on boundary layer development.

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The changes in passage geometry do have an effect on heat transfer and pressure drop. The latter effect in turn changes the flow division between the hore and annulus. To allow for all these factors the HEATAX program has been modified (HEATAX-II).Appendix VII includes a description of the HEATAX series of codes.

Fig 5/1, derived from HEATAX, shows the axial variation of graphite surface temperature for the channel operating conditions given in Table 5/1.

The corresponding axial distribution of dimensional change ( $\Delta r$ ) for the three surfaces is shown in Fig 4/13. This has also been derived from HEATAX which has used Eq. 109.

As can be seen from Fig 4/13 the bore dimension experiences a maximum expansion of 140 µm. In the annulus, at the inlet region, the pin surface has a larger value of  $\Delta r$  than the wall since the temperature difference offsets the differences in radius. As the wall temperature increases  $\Delta r_{s3}$  increases until outlet is reached; at which point  $\Delta r_{s3}$  is greater than  $\Delta r_{s2}$ . The result of this axial distribution is an increase in annulus pressure drop down to about 3.5m from inlet and a reduction from there to outlet. The net result, as shown by HEATAX, is only a slight increase in annulus pressure drop (less than 0.5%). There is, of course, a reduction in bore pressure drop and the program shows this to be 1.5%.

The heat transfer effect on surface temperature is small and HEATAX shows maximum changes of 1 or 2°C for the same flow split. The change in flow split arising from the resulting imbalance in outlet pressure has the following effect on the axial peak surface temperatures:

$$\Delta \hat{T}_{W1} = -2^{\circ}C$$

$$\Delta \hat{T}_{W2} = +6^{\circ}C$$

$$\Delta \hat{T}_{W3} = +8^{\circ}C$$

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## 3.5.2 Irradiation effects

The small temperature changes arising from the thermal effects tend to be reduced by Wigner shrinkage as this is an opposite effect. As the maximum shrinkage that can occur, for the maximum dose, is about 0.5%, the changes in graphite dimensions are not more than about 150  $\mu$ m. Wigner shrinkage has not, however, been included in HEATAX since this would be a difficult development and the thermal calculations, already described, suggest a small effect.

#### Corrosion within the HTR fuel channel

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One of the main reasons helium was chosen as a coolant is its inability, unlike CO<sub>2</sub>, to react with the core components and so reduce core integrity. It is particularly important in the HTR to have an inert coolant because of the high temperatures that will be experienced.

Steam which can leak into the core from, say, a faulty boiler tube weld can cause significant damage to core components because of these high operating temperatures.

The form this corrosion can take and its effect on fuel performance and endurance is highly important as it is these factors which will determine the limits on water ingress. It is the aim of this section to describe the models that have been developed by the Author to analyse the phenomenon. Using these models the effects of corrosion are predicted. The first work published on this subject was by the Author in September 1969 (<u>31</u>) which, in an analytical way, dealt with the removal of graphite from the pin surface assuming a smooth Hollow-rod element. In November 1970, the Author studied a smooth tubular interacting element (<u>32</u>).

The present work is a further extension on the references above so as to include:

 a model to describe the form and development of corrosion induced roughness

(ii) a study of the heat transfer and fluid flow effects of roughness(iii) specially written computer codes to analyse the problem.

This present work is a new step forward in analysing the corrosion phenomenon since, by one method, the degree and form of corrosion is determined, the heat transfer and fluid flow effects of the change of geometry and degree of roughness are found (making allowance for the

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temperature feed-back effect), and the resulting fuel channel performance is determined for the whole channel and throughout the fuel dwell.

#### 4.1 The corrosion phenomenon

4.1.1 Corrosion mechanism

There are three corrosion regimes which apply to the case of chemical attack by a gaseous medium (water vapour) of a porous solid (graphite). These three regimes operate over three temperature ranges (Fig 4/14). Reactor pressures (approximately 53 bars) are assumed.

#### (i) The chemical regime

Below temperatures of about 800°C the water vapour diffuses through the medium and because of the low temperatures an even concentration occurs, equal to that of the gaseous environment. The corrosion rate K1 is given by the Arrhenius relation:

$$K1 = K_0 - \frac{E}{RT}$$
 .....110

where E is the activation energy and R is the gas constant.

(ii) <u>The in-pore diffusion regime</u> (between approximately 800 and 1200°C) At these higher temperatures a water vapour concentration gradient exists where, at equilibrium, the rate of depletion of corrodant is balanced by the rate of diffusion. The corrosion rate K2 is given by

Where D<sub>eff</sub> is the effective diffusion coefficient and is itself dependent upon the level of corrosion.

The corrosion is a surface effect - the rate determined by diffusion through the gaseous boundary layer  $\delta$  .

K3 = Kc (Co - Cs)

where

Kc = mass transfer coefficient

Co = concentration of reactant in main gas stream

Cs = concentration of reactant at graphite surface

In order to determine the effects of changes in geometry and for realistic graphite temperatures, the in-pore diffusion regime is of interest and is now investigated further.

As stated above, the in-pore diffusion mechanism is controlled by diffusion through the graphite pores. As the graphite becomes corroded, the pores widen, increasing the diffusion coefficient and thus the corrosion rate.

As described by BIRCH (33) the concentration,  $\gamma$ , of corrodant within the porous solid is given by

where  $\boldsymbol{\gamma}$  is the mole fraction of corrodant relative to the gaseous environment.

and 
$$\frac{\$}{t} = \frac{\text{distance from surface}}{\text{wall thickness } (d_{+})}$$

and  $\phi_{,}$  the catalyst number is given by

$$\phi_{o} = \frac{d_{t} \sqrt{\frac{k_{mo} \rho_{g}}{D_{eff}}}}{D_{eff}}$$

where

 $\rho_{g}$  = density of graphite

$$k_{mo} = \text{ chemical reaction rate at } T^{\circ}K$$
$$D_{eff} = Do\lambda \left(\frac{T}{273.2}\right)^{1.75} \left(\frac{1}{p}\right)$$

and

where

Do = free gas diffusion coefficient at  $0^{\circ}C$  and 1 atm T = temperature of graphite

.....113

P = total gas pressure

 $\lambda$  = a variable defining pore shape and size.

Therefore, since the pore size is burn-off dependent the diffusion coefficient and the corrodant concentration are also burn-off dependent.

If equations 110 and 111 are now combined, we obtain

where  $k_{eff(T)}$  is defined as the effective burn-off rate at surface temperature T, B is assumed constant and A, which includes the diffusion coefficient, is dependent upon burn-off.

# 4.1.2 Data used

#### (a) Burn-off rate - temperature correlation

Effective burn-off  $k_{eff(T)}$ , at one atmosphere pressure, is shown as a function of temperature in Fig 4/15 derived from HELSBY (<u>34</u>) where he has assumed that the Arrhenius form (Eq. 114) applies and a burn-off of 50 mg/cm<sup>2</sup>.

From Fig 4/15

$$A = 1.563 \times 10^4 \text{ mg.cm}^{-2} \text{h}^{-1} \mu \text{at.H}_{0}$$

$$B = 2.0174 \times 10^4$$

The experimental work of HELSBY shows that  $k_{eff(T)}$  at 100 mg/cm<sup>2</sup> burn-off is approximately eight times that at zero burn-off. It is assumed, in this work, that  $k_{eff(T)}$  at 50 mg/cm<sup>2</sup> represents a mean burn-off rate. (N.B. Beyond about 100 mg/cm<sup>2</sup>  $k_{eff(T)}$  is constant.)

Assuming an average value of  $k_{eff(T)}$  given by the 50 mg/cm<sup>2</sup> burn-off value, is reasonable because:

 (i) at the temperatures and pressures of interest, 1000°C and 53 bars respectively, corrosion is chiefly concentrated at or near the graphite surface and therefore k<sub>eff</sub> will tend to be less dependent on burn-off

 (ii) there is sufficient doubt on corrosion data to make factors of two or three on k<sub>eff</sub>, unfortunately, the level of irreducible error.

## (b) Pressure effects

HELSBY (<u>34</u>) recommends a factor of  $\sqrt{P_2/P_1}$  (equations 111 and 113) to convert  $k_{eff}$  at pressure  $P_1$  to a pressure of  $P_2$ , however, BIRCH (<u>33</u>) suggests this is only true at zero burn-off or when the steady-state has been reached (i.e. when  $k_{eff}$  becomes constant with burn-off). Fig 4/16 derived from BIRCH (<u>33</u>), shows how the factor Cp (= $k_{eff}$  (P<sub>2</sub>)/  $k_{eff}$ (P<sub>1</sub>)) varies with burn-off and graphite temperature.

For the work described in sub-section 4.2, on the Hollow-rod element, some allowance is made for the variation of Cp with burn-off and temperature and for the temperatures  $1000^{\circ}$ C,  $1050^{\circ}$ C and  $1100^{\circ}$ C Cp is taken as 0.2, 0.154 and 0.143 respectively. (Reactor pressure is assumed to be 53 atm.)

In later work, (sub-section 4.6), where burn-offs are less, a constant value of  $C_p$  of 0.25 has been taken since a variation is not just-ified when considering basic data uncertainties.

# (c) Moderator block data

The data derived above can be applied to the pin graphtie. There is evidence quoted by MERRETT ( $\underline{35}$ ) that the moderator block, being made of different graphite, has a much higher chemical reactivity, the level of which is very uncertain. It is assumed, for the purposes of this work, that

 $k_{eff}$  (block) = 10 x  $k_{eff}$  (Pin)

 $k_{eff} (block) = 1.563 \times 10^5 \exp\left(\frac{-2.0174 \times 10^4}{T^0 K}\right) \text{mgcm}^{-2} \text{h}^{-1} \mu \text{ atm } \text{H}_20$ where  $k_{eff}$  (block) applies at one atmosphere pressure.

#### (d) Water vapour concentration

The concentration of water vapour present basically depends upon:

(i) the amount of leakage from the boilers

(ii) the net reactivity of the core.

In fact, there is a maximum continuous tolerable concentration (MCTC) which is defined by considering the corrosion to the most limiting reactor component. That is, a study is made of the corrosion effect (thermal, mechanical etc) of a range of concentration levels on certain key reactor components and the MCTC is chosen that just meets the severest limit. The work described below on the channel performance effects would be one important factor that is considered in setting the MCTC.

The lowest MCTC that can be measured is approximately 0.1 vpm and for the purpose of obtaining realistic answers to the thermal performance questions this concentration is assumed in the work to follow.

0.1 vpm water concentration for a reactor at 53 atm gas pressure is equivalent to 5.3  $\mu$  atm H\_O concentration.

# (e) Summary of corrosion data

Combining the above factors together, the following expressions are obtained for the effective burn-off rates  $(k_{eff})$  for the pin and block: Pin:

$$k_{eff} = 8.282 \times 10^4$$
. Cp.e  $\frac{-2.0174 \times 10^4}{T^0 K} mgcm^{-2}h^{-1}$ 

Block:

 $k_{eff} = 8.282 \text{ x } 10^5 \text{. Cp.e} \frac{-2.0174 \text{ x } 10^4}{\text{T}^{\circ}\text{K}} \text{ mgcm}^{-2}\text{h}^{-1}$ 

At the temperatures of interest it is reasonable to assume that all the graphite is removed at the surface.

N.B. from corrosion profiles shown by BIRCH  $(\underline{33})$ , at  $1030^{\circ}$ C, less than 1% of the graphite is removed below a depth of  $250\mu$  m - half the grist particle diameter (see sub-section 4.3)

The rate of removal in mm  $(k_d)$  is obtained, therefore, by dividing the equations above by the density (1800 mg/cm<sup>3</sup>) i.e.

Pin:

$$k_d = 460.1 C_p e \frac{-2.0174 \times 10^4}{T^0 K} mm/h$$
 ....115

Block:

$$k_d = 4601 C_p e \frac{2.0174 \times 10^4}{T'k} mm/h$$
 .....116

#### 4.2 Planar removal

The early work in this field, by the Author  $(\underline{31}, \underline{32})$ , deals with the effect on thermal performance of corrosion induced changes of graphite section.

#### 4.2.1 Hollow-rod element

The Hollow-rod element, described in Chapter 2 is the subject of the 1969 work (31). Below is shown, diagrammatically, a section through the element.

The increased reactivity of the block graphite was not known when this work was done, and with the lower temperatures of the hollow rod moderator block (850°C maximum) it was assumed that the block would remain unscathed. The outer surface of the graphite sheath, however, was attacked and it was the effect on the temperatures of removal of that surface which was considered. This work is now related here.

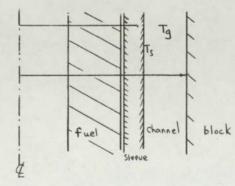


Table 4/2 lists the operating conditions assumed for the analysis. To determine the effect of different surface temperatures three bulk gas temperatures have been assumed (Table 4/2). One axial position has been taken.

As described in Chapter 2 the Hollow-rod, with a continuous gagging scheme experiences approximately constant surface temperatures - in the absence of corrosion. If, therefore, the surface temperature at any time is given by

then the ratio of convection linear heat rating  $q_c^*$  to heat transfer coefficient(h) is approximately a constant. This is because the channel flow (W) is reduced at the same rate as  $q_c^*$  to maintain  $T_g$  constant and  $h \propto W^{0.8}$ .

The equation for h assumed is

If  $({}^{T}S/T_{g})^{-0.3}$  is assumed to remain constant then

$$T = T_g + \frac{G}{r} (r_c^2 - r^2)^{0.8} (r_c - r)^{0.2}$$
 ....119

Since  $De = 2(r_c - r)$  and  $A = \pi (r_c^2 - r^2)$ and  $G = q_c^* ({}^{T}S/T_c)^{0.3}/0.0416 k_c P_r^{0.4} ({}^{W}/\mu)^{0.8}$ 

where  $q_C^i = q_T^i - q_R^i$  and  $q_R^i$ , the radiative linear heat rating, is assumed constant.  $q_T^i$  is the total linear heat rating.

If  $r = r_0 - \Delta r(t)$  where  $r_0$  is the uncorroded dimension and  $\Delta r(t)$ the removal up to time t, then if one assumed  $\frac{\Delta r}{r_0} <<1$  Eq. 119 can be reduced to

where

and

 $C_{o} = (r_{c}^{2} - r_{o}^{2})^{0.8} (r_{c} - r_{o})^{0.2}$  $C_{1} = \frac{1.6r_{o}}{r_{c}^{2} - r_{o}^{2}} + \frac{0.2}{r_{c}^{-} - r_{o}} + \frac{1}{r_{o}}$ 

From Eq. 115

$$\frac{d}{dr} (\Delta r) = 460.1.Cp.e \frac{-2.0174 \times 10^4}{T_S(^{\circ}K)} \qquad \dots \dots 121$$

and set a = 460.1, b =  $2.0174 \times 10^4$ Differentiating Eq. 120 w.r.t. time t we have

$$\frac{\mathrm{d}^{\mathrm{T}}\mathbf{S}}{\mathrm{i}(\Delta \mathbf{r})} = \frac{\mathrm{GC_{0}C_{1}}}{\mathrm{r_{0}}} \qquad \cdots 122$$

Combining equations 121 and 122

$$\frac{dT}{dt} = \frac{aGC_0 C_1 C_p}{r_0} e^{-\frac{b}{T_s}}$$
....123

Let  $H = \frac{aGC_0C_1C_p}{r_0}$  then, separating variables and integrating:  $Ht = \int_{T}^{T_s} b/T_s dT_s$ 

where  $T_o$  is the surface temperature at start-of-life (t-0). We can substitute  $y = \frac{-b}{t}$ :

$$\int_{T_o}^{T_S} \frac{b}{T_S} dT_S = b \qquad \int_{\frac{b}{T_o}}^{\frac{b}{T_s}} e^{-y} \frac{d}{dy} \left(-\frac{1}{y}\right) dy$$

Integrating by parts:

Integral = 
$$\begin{bmatrix} -\frac{b}{y}e^{-y} \end{bmatrix} \begin{bmatrix} -\frac{b}{T_{S}} & -\frac{b}{T_{S}} \\ -\frac{b}{T_{O}} & -b \end{bmatrix} \int_{-\frac{b}{T_{O}}}^{\frac{T}{T_{S}}} \frac{1}{y}e^{-y} dy$$
$$-\frac{b}{T_{O}} \int_{-\frac{b}{T_{O}}}^{\infty} \frac{1}{y}e^{-y} dy = \int_{-\frac{b}{T_{O}}}^{\infty} \frac{1}{y}e^{-y} dy - \int_{-\frac{b}{T_{S}}}^{\infty} \frac{1}{y}e^{-y} dy$$

The integrals on the R.H.S. are E functions of the first kind and can be evaluated using tables calculated by SINCLAIR (36)

and 
$$\int_{x}^{\infty} \frac{1}{y} e^{-y} dy = E_{1}(-x) = \overline{E}_{1}(x)$$
  
Thus: Ht =  $T_{S} e^{y} b/T_{S} - T_{O} e^{b/T_{O}} - b\overline{E}_{1}(\frac{b}{T_{O}}) + b \overline{E}_{1}(\frac{b}{T_{O}}) \dots 124$ 

Eq. 124 is evaluated by substituting increasing values of  $T_S$ , starting with  $T_o$ , until a value of t is reached that exceeds the dwell of the fuel. Table 4/3 shows values of  $\overline{E}_1 ({}^{b}/T_S)$ ,  $T_S * {}^{b}/T_S$  and t over a range of Tg. Three starting temperatures  $(T_o)$  were assumed to investigate the effect of temperature level. These temperatures were chosen to cover the range of interest for the Hollow-rod design considered, but the precise values were chosen for convenience in reading the tables of  $\overline{E}_1({}^{b}/T_S)$  i.e. the three values of  $T_o$  chosen were: 1099°C, 1054°C and 989°C. Other data used (e.g.  $C_p$  values) are given in subjection 4.1.2.

The removal  $\Delta$  r associated with each temperature  $T_{\rm S}$  is found from Eq. 120.

Figs 4/17 and 4/18 show surface. temperature T<sub>S</sub> and removal respectively, versus fuel dwell. With the long life times of the Hollow-rod fuel (2000 days) quite large removals are experienced. At normal operating peak surface temperatures of say 1050°C, more than 1 mm of the 5 mm thick sleeve is removed, producing increases in surface temperatures of about 40°C. At hot spots, say 1100°C, even larger effects are noticed. In this early work no allowance had been made for roughening, which would tend to offset these increases in temperature. This serious problem, however, was eventually alleviated by changing the design to the tubular interacting element which, because of its shorter dwell times (800 days), experienced much less, although still

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significant, corrosion attack.

The special corrosion analysis problems introduced by the T.I. element are now discussed.

# 4.2.2 Tubular interacting element

The T.I. element, as described previously, has cooling gas passing both inside and outside the pin and because of interface gap growth the surface temperatures, heat fluxes, etc., cannot be assumed constant with irradiation. The method of calculation derived for the hollow rod element is, therefore, no longer applicable.

The method developed by the Author  $(\underline{32})$ , to deal with the T.I. element, was to divide the dwell into finite steps and, assuming constant conditions over that step, calculate the removal  $\Delta$  r and change of temperatures according to the above equations. Once again this work does not consider removal from the channel wall, nor the effect of roughness. It assumes also no change in the flow division between bore and annulus. With these limitations, which have now all been overcome, it is not proposed to describe that early work here, but to begin the description, immediately, of the final method that has been developed for analysing corrosion in the T.I. element and incorporated in the HEATAX program.

# 4.3 The form and hydrodynamic definition of roughness.

# 4.3.1 A model to describe roughness development

So far in the analysis of the thermal performance repercussions of graphite corrosion, only changes in geometry have been considered the planar removal effects. Throughout smooth channel heat transfer coefficients and friction factors have been assumed - which is reasonable if the corrosion is uniform over the graphite surface. Owing to the lack of homogeneity of the graphite tubes and moderator, however, this assumption is far from valid.

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Arising from the manufacturing process the graphite consists of 'grist' particles set in a matrix of pitch binder and from experiments by HELSBY (<u>34</u>) it is clear that the binder has a much higher chemical reactivity than the particles. This leads to preferential attack, pitting, and a generally rough surface.

The longer the dwell in the corrosive environment the deeper the pitting and more pronounced the **roughness** until a grist particle is exposed to such an extent it can be eroded away, resulting in the planar removal already described.

This roughening of the graphite surfaces leads to a general improvement in heat transfer and a corresponding increase in frictional drag.

There is very little experimental information on the form and degree of corrosion induced roughening, although it is known to be highly dependent on the type of graphite and the presence of small quantities of impurity. Even one sample of graphite is corroded unevenly owing to property variations within the sample. Any model, developed, therefore, to describe the form of the roughness and which determines the characteristic roughness height can only be highly speculative. The following is such an attempt to relate measured bulk graphite removal rates to a characteristic roughness height.

Fig 4/19 shows an idealised section through a graphite sample where the average 'grist' particle diameter is 'd'.

If  $k_{eff}$  is the measured effective corrosion rate of the sample this will include graphite removal from the particles and binder. If  $k_p$ and  $k_B$  are the respective components of  $k_{eff}$  after a dwell  $\delta$  t with a water concentration H the corrosion depths of binder and particle are

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respectively,

$$\delta h_{B} = \frac{k_{B H} \delta t}{\rho}$$
$$\delta h_{p} = \frac{k_{p H} \delta t}{\rho}$$

where  $\overline{\rho}$  is the mean graphite density. (Assume equal areas of binder and particle exposed.)

The net roughness height after time  $\delta$  t is

$$\varepsilon = \frac{1}{\rho} (^{n}B - ^{n}p) H \circ t$$

$$K_{p}/k_{B} = x$$

$$\varepsilon = \frac{k_{B}}{\rho} (1 - x) H \delta t \qquad \dots 125$$

Now:

Let

$$k_{eff} = \frac{k_{B} + k_{p}}{2} = \frac{k_{B}}{2} (1 + x)$$

Therefore we can substitute for  $k_B^2$  in Eq. 125

$$\varepsilon = \frac{2k_{eff}}{(1+x)_{o}} (1-x) H \delta t \qquad \dots 126$$

From this equation it can be seen that if the grist particle did not corrode (x = 0) the roughness height would be that given by  $2k_{eff}$  since  $k_{eff}$  is defined in terms of the total surface area when in fact only half is being corroded. The other extreme of  $\varepsilon$  is zero when the binder and particle corrode equally.

As the dwell  $(\delta t)$  increases,  $\epsilon$  increases until sufficient of the particle is exposed so that it becomes dislodged. From this time on  $(t_{crit})$  the roughness height will be assumed to remain constant. (Fig 4/19(a)).

One would expect the mean depth of particle still embedded before dislodgment to be d/2, although with sticking the probability distribution of dislodgment could become skewed (Fig 4/19(b)). The amount of sticking is a complete unknown and the maximum roughness height is assumed to be d/2.

The value of x is unknown and we will arbitarily assume that the roughness height fisgiven by the effective burn-off  $k_{eff}$  i.e.

This is equivalent to assuming the binder reactivity is three times higher than the particles i.e. x = 0.333.

# 4.3.2 Hydrodynamic definition of roughness

As already described in section 2 the turbulent flow velocity profile has, adjacent to the wall, a laminar sub-layer in the region  $0 < y^* < 5$ where  $y^* = \frac{y}{\sqrt[3]{7}\sqrt{\tau_0/\rho}}$  .....128

According to NIKURADSE (37) a surface is hydrodynamically rough when the protruberences extend beyond the laminar sub-layer. The limiting roughness height will depend upon the Reynolds number since, as has already been shown, the laminar sub-layer thickness decreases as the Reynolds number increases.

Let us first establish the limiting roughness height/Reynolds number range, applying to the current design of fuel element.

For a rough channel  $\varepsilon > y_T$ 

where 
$$y_{\rm L} = \sqrt{\frac{5y}{\tau \, 0/\rho}}$$

the wall shear stress can be defined in terms of the friction factor f, i.e.

$$\tau_{o} = \overline{\rho} \cdot \frac{\overline{u}^{2}}{2} f$$

Therefore

$$y_{\rm L} = \frac{5\sqrt{u}}{\sqrt{u}} \frac{f}{2}$$

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Now

$$Re = \overline{u} \frac{\partial}{\partial t} / x$$

Therefore

$$y_{\rm L} = \frac{5 {\rm De}}{{\rm Re} \int f/2}$$

That is

$$\epsilon_{D_e} > \frac{5}{Re\sqrt{f/2}}$$
 .....129

As can be seen from Eq. 129 the critical value of the dimensionless roughness height  $\varepsilon$  is Reynolds number dependent – the larger the Reynolds number becomes, the smaller  $\varepsilon/D_{\rm e}$ .

For a smooth tube:

$$f = 0.079 \text{ Re}^{-0.25}$$

Therefore

$$(\varepsilon/D_{\rm p}) = 25.2 \ {\rm Re}^{-0.875}$$
 .....130

Fig 4/20 shows the critical values of  $\varepsilon/D_{2}$ , plotted against Reynolds number.

Under mormal operation the Reynolds numbers for the fuel core and annulus are of the order  $10^5$  and  $10^4$  respectively, resulting in critical  $\epsilon_{D_e}$  values of  $10^{-3}$  and  $8 \ge 10^{-3}$  respectively. For the bore and annulus this gives corresponding critical  $\epsilon$  sizes of 30 and 80 µm. With graphite grain sizes of the order 500 µm it is clear there is every likelihood the coolant channels will behave as rough surfaces after some period in the core. In fact it has been shown by WARBURTON (14) that even the originally machined graphite surfaces can approach these critical roughness heights.

#### 4.4 Friction in rough channels

#### 4.4.1 Friction in rough tubes

Initially the data available are investigated which can be applied to the bore of the fuel element.

The majority of work carried out in this field can be divided into two classes:

- (i) that applied to manufactured regular roughness in connection with studies into the improvement of heat transfer from reactor fuel elements and heat exchangers
- (ii) random roughness or sand grain roughness more applicable to the natural state of surfaces and ducts.

The latter category would seem to apply to a corroded graphite surface since, as with sand grains, we have grist particles of nominally uniform size exposed in a somewhat random manner.

WARBURTON (<u>14</u>) has shown, by comparing friction factors; that naturally rough graphite surfaces have similar characteristics as sand grain.Foughness.

In the absence of experimental results specifically applicable to corroded graphite surfaces, it would therefore seem reasonable to use the results of sand grain roughness work.

The most authoratiative work on velocity distributions and friction factors for sand grain roughened tubes is that published by NIKURADSE (37) in 1933 and forms the basis of the following treatment.

NIKURADSE used water as the working fluid and achieved a Reynolds number range of  $10^3 - 10^6$  and a  $\epsilon/D_e$  range of 0 - 0.03, which encompasses very well the range of interest in the present work.

NIKURADSE defines the roughness height  $\varepsilon$  as the average sand grain diameter which, because, of the thinness of adhesive, is effectively the average 'peak to valley' height. As applied to this particular case, this is equivalent to the average depth of grist particle exposed, or  $\varepsilon$  as defined by Eq. 127. In the reference work D<sub>e</sub> is defined as the diameter of the pipe and is therefore the roughness root diameter which, for this work, is the average binder diameter.

At low Reynolds numbers (< 2000) where the flow is laminar, the friction factor is independent of  $\epsilon/D_{\rm e}$ .

There is then a range of Reynolds number (transition range) where the friction factor increases with Reynolds number for a particular  $\varepsilon/D_e$ . In this region NIKURADSE suggests that the projections are of the same order as the laminar sub-layer and individual.projections extend beyond the layer causing vortices and a resulting loss of energy. As the Reynolds number increases an increasing number of projections extend through the layer producing larger energy losses.

In the third range (fully rough region) the sub-layer is sufficiently thin for all the projections to extend beyond it and the energy losses – and thus frictional drag – become independent of Reynolds number. These characteristics can be observed in Fig 4/23.

In the analysis of the smooth tube velocity distribution it was found that, except for radial positions close to the wall, the Universal Velocity Profile applied (see Fig 4/3).

u*	=	$A + B \ln y^*$	•••••131
u*	=	u/to/p	

and

where

are dimensionless quantities and A = 5.5 and B = 2.5.

 $y^* = \frac{y}{v} \sqrt{\tau o} / \frac{1}{v}$ 

NIKURADSE has shown that a similar equation to Eq. 131 can be applied to rough tubes and, in fact, B ( $\delta u * / \delta y *$ ) is unchanged. The value of A, however, is dependent upon the relative roughness  $\varepsilon / D_e$  and Reynolds number, i.e.

$$u^* = A(\epsilon/D_s, Re) + 2.5 \ln y^*$$
 .....132

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Fig 4/21, derived from NIKURADSE (<u>37</u>) shows by comparison with the smooth wall velocity profile the equivalent rough wall profiles for a range of  $\varepsilon/D_{\rm a}$  and Reynolds numbers.

Let us define a dimensionless roughness height  $\varepsilon$  \* such that

$$\varepsilon^* = \frac{\varepsilon}{v} \sqrt{\tau o/\rho} \qquad \dots 133$$

Combining Eq. 133 with Eq. 132 and the definition of y\*, we obtain

$$u^* = A(\varepsilon/D_e, Re) + 2.5 \ln s/\epsilon + 2.5 \ln \varepsilon^*$$

which becomes

$$u^* = A^* + 2.5 \ln \frac{y}{\epsilon}$$
 .....134

where A\* is still a function of  $\epsilon/D_e$  and Reynolds number and, in fact, NIKURADSE found that A\* was purely a function of  $\epsilon$ \*. Also:

$$\varepsilon^* = \operatorname{Re}\sqrt{f \tilde{D}_e}$$
 .....135

When NIKURADSE plotted u\* -2.5  $\ln \frac{y}{\varepsilon}$  versus  $\varepsilon$ \* he found the experimental points could be represented by five straight lines over the  $\varepsilon$ \* range covered (Fig 4/22).

The five lines are:

(i) Smooth region:

 $0 \le \varepsilon^{*} 3.04$   $A^* = 5.5 + 2.5 \ln \varepsilon^*$ 

(ii) Transition region:

(a)	3.04 ≤ ε* ≤ 7.2	$A^* = 6.59 + 1.52 \ln \varepsilon^*$	
		A* = 9.59	••••136
(c)	15.0 ≤ ε * ≤ 73.0	$A^* = 11.5 - 0.705 \ln \varepsilon^*$	

(iii) Fully rough region:

By integration of the velocity profiles to obtain  $\overline{u}$ , the mean velocity, NIKURADSE obtained an expression for the peak velocity  $\hat{u}$  in terms of  $\overline{u}$ , i.e.

$$\frac{\hat{u} - \bar{u}}{\sqrt{\tau o/\rho}} = 3.75 \qquad \dots 137$$

also  $\tau_{0/\rho} = \frac{1}{2} \overline{u}^{2} f$ when  $u^{*} = \sqrt{\frac{u}{\tau_{0/\rho}}}$   $y = D_{0/2}$ ..... 138

and substituting into Eq. 134 we have

$$\frac{a}{\sqrt{\tau o/\rho}} = A^* + 2.5 \ln \frac{D}{2}$$

Substituting for  $\hat{u}$ ,  $\tau_0/\rho$  from equations 137 and 138 we have

$$\sqrt{2/f} = A^* - 2.5 \ln 2 / D_e - 3.75$$
  
and  $f = \frac{2}{(A^* - 2.5 \ln \frac{2\epsilon}{D_e} - 3.75)^2}$  .....139

The friction factor, f, can now be found from equations 135, 136 and 139, although it is clear that an iterative method is required since  $\hat{\boldsymbol{\varepsilon}}$  \* is friction factor dependent.

The method of iteratively solving the equations is as follows:

(i) the smooth value of f is taken from the expression  $f = 0.079 \text{ Re}^{-0.25}$ 

(ii) E \* is calculated from 135.

(iii) depending upon the value of 
$$\varepsilon^*$$
 the relevant equation from  
Eq. 136 is used to calculate A\*. (N.B. If  $\varepsilon^* \leq 3.04$  the  
initial smooth value of f is valid.)

(iv) f is calculated from Eq. 139

The procedure is then repeated from step (ii) until convergence.

Fig 4/23 shows friction factor as a function of Reynolds number for various values of  $\varepsilon/D_e$  derived from the above equations using a simple FORTRAN program. Typical relative positions of the HTR channel bore and annulus are shown. The c value is 0.25 mm (the maximum roughness height for a grist particle diameter of 0.5 mm.)

# 4.4.2 Friction in a rough annulus

# (a) The theoretical method

In sub-section 2.2 the Hall transformation method was applied to friction in a smooth annulus to show the validity of smooth tube correlations when applied to an annulus. We will use the same method to deal with an annulus with walls of varying degrees of roughness.

From force balance considerations the following relation has been derived:

$$\frac{f_{1}p_{1}u_{1}^{2}}{De_{1}} = \frac{f_{2}p_{2}u_{2}^{2}}{De_{2}} \dots \dots 140$$

where the suffixes 1 and 2 apply to inside and outside the no-shear boundary, respectively.

In order to separate the heat transfer and momentum transfer phenomena it is assumed, for simplicity, that  $\bar{\rho}_1 = \bar{\rho}_2$ As before:

$$De_{1} = 2 (r_{s}^{2} - r_{1}^{2})/r_{1} \qquad \dots 141$$
$$De_{2} = 2 (r_{2}^{2} - r_{s}^{2})/r_{2}$$

Therefore

Eq. 140 becomes:

From Hall's work it is obviously reasonable to determine  $f_1$  and  $f_2$  from tube results using transformed values of Reynolds number and hydraulic diameter. If Re<sub>1</sub> and Re<sub>2</sub> are the transformed Reynolds numbers for inside and outside the plane of no shear then:

Where, as before, we have assumed

 $\vec{\rho}_1 = \vec{\rho}_2 = \vec{\rho}$  $\vec{\mu}_1 = \vec{\mu}_2 = \vec{\mu}$ 

and

From NIKURADSE (37) for a tube: (Eq. 139)

$$f = \left(\frac{2}{A*(\epsilon^*) - 2.5 \ln \frac{2\epsilon}{De} - 3.75}\right)^2$$

Now for the transformed annulus:

$$f_{1} = \left(\frac{2}{A_{1}^{*}(\varepsilon_{1}^{*}) - 2.5 \ln \frac{2\varepsilon_{1}}{D\varepsilon_{1}} - 3.75}\right)^{2} \dots 145$$

$$f_{2} = \left(\frac{2}{A_{2}^{*}(\varepsilon_{2}^{*}) - 2.5 \ln \frac{2\varepsilon_{2}}{D\varepsilon_{2}} - 3.75}\right)^{2}$$

where

$$\varepsilon_1^* = \operatorname{Re}_1 \sqrt{\frac{f_1}{2}} \frac{\varepsilon_1}{\operatorname{De}_1}$$

$$\varepsilon_2^* = \operatorname{Re}_2 \sqrt{\frac{f_2}{2}} \frac{\varepsilon_2}{\operatorname{De}_2}$$
....146

From Eq. 143 and 145 it is possible by iteration to evaluate  $f_1$  and  $f_2$  providing  $\overline{u}_2/\overline{u}_1$  the mean velocity ratio can be determined.

WHITE (<u>38</u>) who has also used NIKURADSE'S tube results for annuli implies  $\overline{u}_2/\overline{u}_1$  should be made equal to unity. This only applies if the shear stress, and therefore the roughness at the two walls, is not very different.

The case that is investigated by WHITE is one where the inner surface is very rough, and the outer smooth. Such a case is bound to produce significant differences in mean velocity between the two regions.

This limitation can be avoided by deriving velocity profiles in roughened annuli from the transformation of NIKURADSE'S tube results.

....144

These profiles can then be compared with some experimental results for rough annuli with the hope of justifying Hall's transformation theory as applied to this particular case. It will then be possible, using these profiles, to determine the mean velocity ratio and show how friction factors in rough annuli are modified by a consideration of velocity distribution.

In order to determine the mean velocity ratio NIKURADSE'S expression for the velocity profile in a rough or smooth tube is used:

$$u^* = A + 2.5 \ln y$$
 .....147

where, for a rough tube, A is roughness dependent. Substituting the expression for u\* we have

$$\sqrt{\frac{u}{\tau_{0/0}}} = A + 2.5 \ln y$$
 .....148

Eq. 148 should now be transformed to apply to an annulus and in the same way as we define a transformed hydraulic diameter for the annulus we must define a transformed y in Eq. 148:

- (i) for a tube:
  - y = R r

where r is the radial distance from the tube centreline and R is the tube radius.

(ii) for an annulus:

$$y_{T} = R_{T} - r_{T}$$
where  $R_{T} = \frac{De_{1}}{2} = \frac{r_{s}^{2} - r_{1}^{2}}{r_{1}}$  (or  $\frac{De_{2}}{2} = \frac{r_{2}^{2} - r_{s}^{2}}{r_{2}}$  for outer ) surface

and therefore, as suggested by NICOL  $(\underline{39})$  it is reasonable to make the analogy:

$$r_{T} = \frac{r_{s}^{2} - r^{2}}{r}$$
 (or  $\frac{r^{2} - r_{s}^{2}}{r}$  for outer surface)

Therefore

$$\frac{u}{\tau_{o/p}} = A + 2.5 \ln (R_{T} - r_{T}) \qquad \dots 149$$

for the plane of no shear (  $\mathbf{r}_{\mathrm{T}}$  = 0)

$$\sqrt{\frac{\hat{u}}{\tau_{o/p}}} = A + 2.5 \ln R_{T} \qquad \dots 150$$

where Q is the peak velocity.

By combining Eq. 149 and Eq. 150 we have

$$\frac{u-\hat{u}}{\sqrt{\tau_{o}/\rho}} = 2.5 \ln\left(\frac{R_{T}-r_{T}}{R_{T}}\right) \qquad \dots 151$$

The mean velocity within the plane of no shear  $\overline{u}_1$  is given by:

$$\overline{u}_{1} = \frac{2}{R_{T}^{2}} \int_{R_{T}} r_{T} u dr_{T}$$

and substituting Eq. 151 for within the plane of no shear we have

$$\overline{u}_{1} = \frac{2}{R_{T}^{2}} \int_{R_{T}}^{0} r_{T} \left(2.5 / \frac{\overline{To}}{\rho} \right) \ln \left(\frac{R_{T} - r_{T}}{R_{T}}\right) + \hat{u} dr_{T}$$

which gives

$$\bar{u}_1 = \hat{u} - 3.75 \sqrt{\frac{\tau_0}{\rho}} 1$$
 ....152

For the outer region:

$$\bar{u}_2 = \hat{u} - 3.75 \sqrt{\frac{\tau_0}{\rho}^2}$$
 ....153

As expected similar expressions to those for a tube are obtained. Now

$$\sqrt{\frac{\tau_0}{\rho}} 1 = \overline{u}_1 \sqrt{\frac{f}{2}}$$

and

$$\sqrt{\frac{\tau_o}{\rho}^2} = \bar{u}_2 \sqrt{\frac{f_2}{2}}$$

Substituting in Eq. 152 and Eq. 153 we have

$$\bar{u}_1 (1 + 3.75 \sqrt{f_1/2}) = \hat{u}$$
 ....154  
 $\bar{u}_2 (1 + 3.75 \sqrt{f_2/2}) = \hat{u}$  ....155  
120

and therefore

$$\bar{u}_2/\bar{u}_1 = \frac{1+3.75\sqrt{f_{1/2}}}{1+3.75\sqrt{f_{2/2}}}$$
 ....156

a further relation between  $\overline{u}_2$  and  $\overline{u}_1$  can be derived. If  $\overline{u}$  is the mean velocity for the channel then

$$\bar{a} = \left(\frac{2}{r_2^2 - r_1^2}\right) \int_{r_1}^{r_2} rudr = \rho\left(\frac{W}{r_2^2 - r_1^2}\right)$$

Where W is the channel mass flow rate. Therefore, since

$$\overline{u}_{1} = \left(\frac{2}{(r_{s}^{2} - r_{1}^{2})} \int_{r_{1}}^{r_{s}} rudr$$
$$\overline{u}_{2} = \frac{2}{(r_{2}^{2} - r_{s}^{2})} \int_{r_{s}}^{r_{2}} rudr$$

and

Also

$$\int_{r_{s}}^{r_{2}} \operatorname{rud} r + \int_{r_{1}}^{r_{s}} \operatorname{rud} r = \int_{r_{1}}^{r_{2}} \operatorname{rud} r$$

Therefore

$$(r_{s}^{2} - r_{1}^{2})\overline{u}_{1} + (r_{2}^{2} - r_{s}^{2})\overline{u}_{2} = \frac{W}{\rho}$$
 ....157

By the simultaneous solution of equations 141, 142, 144, 145, 146, 156 and 157, it is possible to obtain mutually consistent mean velocity, Reynolds number, hydraulic diameter and friction factor for the two regions of the annulus. The solution of these equations, together with other dependent relations requires digital methods and a simple FORTRAN IV program RUSTAN (Appendix V) has been developed by the Author for this purpose. Table 4/4 shows a typical RUSTAN output for a range of annulus flow rates and for various degrees of roughness on the two surfaces. This case applies to the HTR channel annulus where the effects of the ribs have been ignored. The radius ratio is 0.866 and, therefore, one would expect the assumption made in the foregoing - that the peak velocity occurs at the radius of no-shear - to be valid.

As a check upon the programming, the transformed values of friction factor for the particular values of transformed  $\varepsilon$ /De and Re can be compared with the NIKURADSE results and, as one would expect, they agree within acceptable calculation approximation and convergence limits.

Fig 4/24 shows how the mean velocity within the surface of no-shear  $\bar{u}_1$  varies with roughness height and channel Reynolds number. As can be seen,  $\bar{u}_1$  increases above the channel mean value ( and  $\bar{u}_2$  decreases below it) as the roughness on the outer surface increases. The opposite effect is seen with a smooth outer surface and with the roughness on the inner surface increasing.

As one would expect, the greater the Reynolds number the greater the effective roughness and consequently the further  $\overline{u}_1$  deviates from  $\overline{u}_2$ .

Since we have assumed similar velocity profiles in the two regions the mechanism by which  $\bar{u}_1$  and  $\bar{u}_2$  change is by a movement of the radius of no-shear.

From Eq. 140 it is clear that if the outer channel roughness increases and  $f_2/f_1$  increases then this must be met by a corresponding change in De<sub>1</sub>/De<sub>2</sub> and, or  $\bar{u}_2/\bar{u}_1$ .

A change in both these ratios is achieved by a movement of the radius of no-shear <u>away</u> from the surface of increasing relative shear stress.

Fig 4/25 demonstrates this phenomenon and also shows how this movement is not so great if the approximation of equal mean velocities is assumed .

To show the deviation from the situation of two smooth surfaces  $\bar{r}_{c}$  has been plotted in Fig 4/25 where:

$$\overline{\mathbf{r}}_{\mathbf{s}} = \sqrt{\frac{\mathbf{r}_{\mathbf{s}} - \mathbf{r}_{\mathbf{1}}}{\sqrt{\mathbf{r}_{\mathbf{1}}\mathbf{r}_{2} - \mathbf{r}_{\mathbf{1}}}}}$$

 $f_{2/F} = \frac{De_2 \bar{u}^2}{De \bar{u}_2^2}$ 

In Figs 4/26 and 4/27 the transformed friction factors for the two surfaces are plotted against channel Reynolds number for a smooth inner surface and varying degrees of roughness on the outer surface.

Once again the effect of assuming equal mean velocities inside and outside the surface of no-shear is indicated.

The transformed friction factors are normalised to the effective channel friction factor (F) where:

$$f_{1/F} = \frac{De_1 \bar{u}^2}{De \bar{u}_1^2}$$
 .....158

and

Although the approximation of assuming equal mean velocities introduces calculable errors in transformed friction factors (up to about 5%), the effect on F and therefore  $\Delta P$ , the channel pressure drop, is virtually negligible. This is because the change in f<sub>1</sub> is almost entirely offset by the changes in De<sub>1</sub> and  $\overline{u}_1$ . There is very little experimental work carried out on sand-grain type rough annuli, although the work of NICOL (39) can be applied to this case. It is clear from the results quoted in that work that the artificially formed rough surfaces described can be assumed to follow the sand-grain characteristics. They have also shown that transforming the data according to Hall results in a favourable comparison with NIKURADSE'S work .

As predicted by the present theory NICOL shows a movement of the radius of no-shear away from the surface of increasing roughness. However, he states that no appreciable change in  $r_s$  was seen with varying Reynolds number, contrary to the present theory and as shown in Fig 4/25.

As the Reynolds number increases the smooth surface friction factor decreases (Fig 4/23) and the effect on rough friction factor depends on the degree of roughness. For the surface of no-shear to remain unchanged it is necessary for  $f_1/f_2$  to remain unchanged, and although this is conceivable over a limited range of Reynolds numbers and roughness heights, it cannot generally be true.

Alternatively it is possible that with varying Reynolds number the velocity profile could alter, compensating for the change of friction factor.

In conclusion one can say that the method described here, applying Hall's transformation theory, adequately predicts the trends and certainly provides, to a good approximation, friction factors in an annulus assuming sand-grain roughness. Any limitations which may be indicated from Nicol's work are probably overshadowed by the assumptions made on the actual form of the roughness.

The final method that calculates the fuel performance throughout life, allowing for corrosion, is considerably simplified if the channel mean velocity can be assumed to apply inside and outside the plane of

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no shear. It has been shown that the effects of this refinement are small and therefore this simplification has been incorporated in the complete performance code HEATAX III.

# 4.5 Heat transfer in rough channels

#### 4.5.1 Heat transfer in rough tubes

It has been seen above how surface roughness tends to increase the frictional drag in tubes owing to a destruction of the laminar sub-layer. This increase in turbulence at the surface can also produce large increases in heat transfer. There is very little published data on heat transfer in rough tubes that can be applied to the sand-grain type and probably the most respected is that by DIPPREY and SABERSKY ( $\underline{40}$ ). WHITE ( $\underline{38}$ ) uses this source in his analysis of heat transfer coefficients in the roughened HTR channel and in the absence of specific experimental data we will follow the example of his limited case and extend to a more general case.

#### (a) The Dipprey and Sabersky results

DIPPREY (40) has used water as the working fluid and adjusted the bulk temperature to obtain a Prandtl number range of 1.2 to 5.94.

Because of the difficulty in defining the sand-grain roughness height and in order to achieve consistency with the respected NIKURADSE work, DIPPREY defines effective  $^{\varepsilon}/D_{e}$  values. These were such that his measured friction factors were identical with the NIKURADSE results over the 'hydraulically fully rough region'. In this way the effective  $^{\varepsilon}/D_{e}$ values were calculated to be 0.0488, 0.0138 and 0.0024 respectively.

This normalisation carried out by DIPPREY very conveniently ensures consistancy between the heat transfer coefficients and the  $\epsilon/D_e$  relations already derived from NIKURADSE in the previous section.

DIPPREY then considers the similarity between momentum and heat diffusivities and using the Universal Velocity Profile derives a

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relationship between Stanton number  $(h/\bar{\rho} \ \bar{u} \ C_p)$  and friction factor:

$$\frac{(f/2St) - 1}{\sqrt{f/2}} + A = g(\varepsilon^*, Pr) \qquad \dots \dots 159$$

where A is the fully rough value of A\* (8.48) and g is dimensionless roughness height and Prandtl number dependent. The Prandtl number dependence was found to be  $Pr^{0.44}$  in the fully rough region and Fig 4/28 shows how  $gPr^{-0.44}$  (B\*) varies with  $\varepsilon$ \* over the Prandtl number range covered. As the lwest Prandtl number in these results is 1.2 it is necessary to extrapolate to 0.64 the helium value at HTR temperatures.

DIPPREY does make an extrapolation of Prandtl number to 0.72 and it is this  $B^*-\varepsilon^*$  relation used by WHITE (<u>38</u>) to deal with the HTR channel.

In following suit, however, it was found that if the limiting value of B\* for Pr = 0.72, that is 6.66, was substituted into Eq. 159, then a value of Stanton number was found which was appreciably <u>greater</u> (4%) than the value calculated for some small values of  $\varepsilon$ \* (e.g. 3.9). Since one would expect the Stanton number to be always increased by roughening, the DIPPREY extrapolation becomes suspect.

This was checked by first plotting the smooth tube values of g derived from Fig 4/28 (see Fig 4/29) and plotting on the same curve the smooth tube value of NUNNER at Pr = 0.72 (air) quoted by DIPPREY. As can be seen, a smooth curve relates well the results of NUNNER and DIPPREY which suggests a value of  $B_{smooth}^*$  (Pr = 0.72) of 7.5 not 6.66.

With this smooth value of B\* it was found that St (smooth) was always less than St(rough) for Pr = 0.72 and for  $\varepsilon$ \* greater than 3.5.

It only remained, therefore, to extrapolate further to Pr = 0.64. This was achieved by plotting  $B^*(Pr=0.72)$  versus  $\varepsilon *$  (from DIPPREY) on a logarithmic scale (Fig 4/30). It was found that two straight lines could be fitted:

 $\epsilon *>60$  fully rough region  $B^* = 5.58 (\epsilon^*)^{0.1865}$  ....160  $3.5 \le \epsilon \le 60$  transition region  $B^* = 6.61 (\epsilon^*)^{0.1410}$  ....161 From Fig 4/29 the smooth value of  $B^*$ ,  $B^*_s$ , for Pr = 0.64 was found to be 6.64. Therefore:

 $B_{\alpha}^{*}$  (Pr = 0.72) -  $B_{\alpha}^{*}$  (Pr = 0.64) = 0.86

This difference was assumed to exist at  $\mathbf{c}^* = 3.5$  and a corresponding line to Eq. 161 could be drawn (Fig 4/30). Therefore at Pr = 0.64 for the transition region B\* = 5.54 ( $\mathbf{c}^*$ )<sup>0.1885</sup>. .....162

Eq. 160 and 162 are very similar and to a very close approximation (less than 1% error) Eq. 160 can be assumed to apply over the whole roughness range.

Fig 4/31 shows how Nusselt number varies with Reynolds number for different  $\hat{\mathbf{c}}$ /De values for a Prandtl number of 0.64 derived using the program mentioned in sub-section 4.4.1 where the equations 159 and 160 have been incorporated.

It is clear that factors of two on the smooth Nusselt number can be easily obtained in roughened tubes.

#### Variations in the coolant - property correction

(b)

As described in sub-section 2.1.6 for smooth surfaces, a correction must be applied to the heat transfer coefficient to allow for variations in the coolant properties with radial distance from the surface. This correction would be expected to be different for roughened surfaces.

There is little experimental evidence related to roughened surfaces, but WALKER (41) has carried out comparative studies between rough and smooth rods in smooth channels for  $CO_2$  and  $N_2$  coolants. The rod was roughened by transverse ribs where  $\frac{1}{2}$ /De was 0.006.

Although the results quoted cannot be directly applied to a helium cooled corrosion induced rough surface any major effects can be determined.

WALKER shows, for  $N_2$ , that there is very little difference in the  $({}^{T}W/T_{B})$  index. For  $CO_2$ , however, the rough index is a large factor down on the smooth case. By noting the standard deviations, that are also quoted for the  $CO_2$  rough case the difference can be largely explained by the greater experimental error in the rough test.

For the purpose of this work we will assume an unchanged index from the smooth value i.e. -0.15.

#### 4.5.2 Heat transfer in rough annuli

To obtain the heat transfer coefficient on the two surfaces of the annulus, the concept of transformation can again be implemented. The expression derived for a tube describing the effect of roughness on Stanton number (Eq. 159) can be used therefore, providing transformed values are taken.

For the pin surface:

$$St_1 = \frac{1}{2(\sqrt{\frac{f_1}{2}}(g_1 - A))}$$

For the channel wall:

$$St_2 = \frac{t_2}{2(\sqrt{\frac{f_2}{2}} (g_2 - A))}$$

 $f_1$ ,  $f_2$  are obtained from the equations given in sub-section 4.4.2(a) and  $g_1$  and  $g_2$  are given by

$$g_1 = 5.58 (f_1)^{0.1865} Pr^{0.44}$$
  
 $g_2 = 5.58 (f_2)^{0.1865} Pr^{0.44}$ 

where Et and Et refer to the inner and outer annulus surfaces respectively.

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..... 163

In deriving consistent values of  $f_1 e_1^*$ ,  $De_1$  etc, as described in sub-section 4.4.2, it was necessary to consider the mean velocity ratio  $\bar{u}_1/\bar{u}_2$ . Having determined in sub-section 4.4.2(b), however, that this ratio has a small effect on channel pressure drop the effect on surface heat transfer must now be examined.

In Table 4/4 derived from RUSTAN one case is shown where there is a roughness height of 0.4 mm on the pin outer surface and a smooth channel wall. The annulus flow is 0.25 kg/s.

This case has been repeated also using RUSTAN where  $\overline{u}_1/\overline{u}_2 = 1$ . The table below gives the important parameters for the two cases

	r <sub>s</sub> (mm)	$\overline{u}_1/\overline{u}_2$	ε*	f <sub>1</sub>	St <sub>1</sub>
'real'	36.15	0.908	222.34	0.01376	0.005198
$\bar{u}_1/\bar{u}_2 = 1$	36.31	1.0	228.01	0.01350	0.005093

where equations 163 and 164 were used to derive the Stanton numbers. Now St. =  $h_1$  and St! =  $h_1'$ 

$$p_{w} \quad \text{St}_{1} = \frac{1}{\rho \overline{u}_{1} C_{p}} \quad \text{and} \quad \text{St}_{1} = \frac{1}{\rho \overline{u}_{1} C_{p}}$$

where St<sub>1</sub>, h<sub>1</sub> and  $\overline{u}_1$  are derived for the  $\overline{u}_1/\overline{u}_2 = 1$  case Also  $\overline{u}_1 = \overline{u}$  which can be derived from Eq. 157, i.e.  $\overline{u}_1/\overline{u} = 0.966$ .

We obtain therefore:

$$\frac{h_1}{h_1} = \frac{st_1}{st_1} \frac{u_1}{u}$$

and by substitution:

$$\frac{h_1}{h_1} = 0.986$$

If one remembers that this 1.4% difference applies to a fairly extreme roughness difference across the annulus (0.4 mm/smooth) it is a reasonable approximation to neglect this velocity ratio correction in the determination of heat transfer coefficients in the HEATAX code as has been done in the derivation of friction factors.

So far it has been assumed that the no-heat transfer boundary corresponds to the no-momentum transfer (or no-shear) boundary which can only apply if there are equal heat fluxes from the two surfaces (as described in section 2). Ideally the temperature profile in the annulus should be considered and a radius chosen that gives  $\frac{\delta T}{\delta^r} = 0$ . In the absence of any reliable information on temperature profiles in a rough annulus, for the purposes of this work the heat flux ratio correction term recommended by WILKIE (20) for a smooth annulus are employed here i.e.

Outer pin surface:

$$h_{1} = \frac{\text{St}_{1} \text{Re}_{1} \text{Pr k}}{\text{De}_{1}(1 + 0.25(1 - q_{0}^{"}/q_{1}^{"}))} \begin{pmatrix} T_{W2} \\ T_{g2} \end{pmatrix}}$$

Channel wall:

$$h_{2} = \frac{\text{St}_{2} \text{Re}_{2} \text{Pr k}}{\text{De}_{2}(1 + 0.125(1 - q_{1}''/q_{0}''))} (\frac{T_{W3}}{T_{g2}})$$

# 4.6 Graphite corrosion effects on channel performance

4.6.1 General approach

It will now be shown how the corrosion mechanisms described in the previous sub-sections affect temperatures, flow, pressure drop and general fuel element endurance.

As before, the method will be applied to the final concept of cylindrical element - the tubular interacting design.

In Sub-section 4.1 the basic mechanisms and the corrosion data used were described. Sub-section 4.2 used this data to investigate the planar removal phenomenon and sub-section 4.3 proposed a model to investigate corrosion induced roughening. In 4.4 and 4.5 theory was developed to estimate roughening effects on friction and heat

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transfer. It now remains to combine the methods developed into a single routine so that the total effect on fuel element performance can be determined.

Corrosion is highly temperature dependent and in a tubular element the flow division between the two passages will, in addition, be corrosion dependent. It is clear therefore that a computer method is required where the effects of the interdependent variables of temperature, flow rate and corrosion can be allowed for simultaneously.

The program HEATAX - II, already used to calculate the effect of thermal expansion on channel performance (section 3), has been further developed (HEATAX - III) to include the relevant corrosion equations given in the sub-sections above. Appendix VII gives a detailed description of the HEATAX series of codes.

In order to assess the effect of corrosion on the peak temperatures in the core, the model will be applied to a peak rated channel. The operating conditions of this channel are given in Table 5/1. The gas conditions are based upon the gagging scheme described in Chapter 3.

As described in Appendix VII HEATAX calculates only the thermal expansion component of the fuel/can interface gap and therefore it is necessary to determine the shrinkage component using AZIMUSTAP (see section 3) for the peak rated channel at each dose step to be considered, and then to assume that this shrinkage component will remain unchanged. As only small changes in fuel temperatures are envisaged within the HEATAX calculation this assumption causes negligible errors.

The fuel channel flow rate is gagged down four times during the fuel dwell after equal intervals of time. The saw-toothed evolution of gas outlet temperature that results is shown in Fig 4/32. In

order to determine the precise corrosion effect throughout the dwell it would be necessary to have a large number of steps (24) in the HEATAX calculation, as in the AZIMUSTAP calculation, to describe this evolution. As demonstrated in Appendix VII, however, HEATAX requires a large amount of data, e.g. shrinkage gaps, fuel and graphite conductivity, to be input at each calculation dose step and it is therefore impractical to have 24 dose steps. To keep the data preparation within reason, seven time steps are taken: one at the start-of-life, one to represent the mean conditions within each gag interval i.e. at the mean temperature point and one at the end-of-life (Fig 4/32).

# 4.6.2 Data input

The data input to the AZIMUSTAP run is described in Chapter 5 since it is common to more than this section.

The data input to HEATAX-III is shown in Appendix VII . The origins of the property data used both in the AZIMUSTAP and HEATAX runs are also described in Chapter 5.

For the case studied here, as described above, a calculation is made at the end-of-life. Data at this time is very little different from that at the previous step ( $^9/10$  life) and the same data has been assumed to apply.

As described in Chapter 3 the dwell for the peak rated channel for this design is 770 days. Table 4/5 shows how this dwell has been sub-divided into seven steps and gives the equivalent fast neutron doses and the associated operating conditions.

# 4.6.3 <u>Peak rated channel graphite corrosion - Results</u> (a) <u>Previous work</u>

There are only two pieces of work known to the author that have been applied to channel performance effects of corrosion, and both of these studies are highly limited. WHITE  $(\underline{38})$ , already quoted in connection with the roughness effects on heat transfer and friction factor, goes on to estimate the approximate effects on

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channel pressure drop and graphite temperatures. However, no attempt is made to allow for the following effects:

- (i) corrosion does occur as a progressive phenomenon over the fuel dwell and it is extremely unlikely that the entire quota of water ingress occurs at the start-of-life, as assumed by WHITE.
- (ii) planar removal is a parallel and inter-related phenomenon
- (iii) there is a redistribution of heat flow within the fuel element
- (iv) the channel wall does corrode at probably a faster rate than the sleeve surfaces and cannot, therefore, be assumed to be smooth

HOUGH (42) allows for items (i) and (iii) but neglects items (ii) and (iv). In addition HOUGH, who uses friction factor and heat transfer data derived from WHITE (38), assumes St(rough)/St(smooth)and f(rough)/f(smooth) relations are dependent upon temperature only, for particular roughness heights. In fact, they will also be dependent upon Reynolds number and hydraulic diameter which change because of roughening. Changes in flow division between bore and annulus have also been neglected by HOUGH.

With such fundamental differences between the present and previous work comparison is difficult, particularly as HOUGH does not quote the channel operating conditions which have been assumed. Present work

As described in sub-se

(b)

As described in sub-section 4.1, the allowable water ingress is assumed to occur evenly throughout the fuel dwell so that there is a constant 0.1 vpm. In addition, the abrupt changes in temperature caused by gagging are neglected. The resulting fuel element

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roughnesses, **planar** removal and temperatures are, therefore, smooth functions of time. In order to estimate the effect on a realistic, gagged, fuel channel these results are adjusted.

So as to obtain the time effect of corrosion two sets of HEATAX runs have been carried out on a peak rated channel:

- (i) data as shown in Appendix VIII
- (ii) data as shown in Appendix VIII but the time intervals ∆t set of zero.

Case (ii) simulates an uncorroded channel.

The HEATAX results for cases (i) and (ii) are shown in Appendix IX. Figs 4/33-4/37 summarise the tabulated results.

# (c) Discussions of results

Fig 4/33(a) and (b)

These figures show how planar removal and roughness height vary with axial position and dwell. The high block graphite reactivity explains the 1mm peak removal from the channel wall and it can be seen that the maximum roughness height (0.25 mm) only occurs on the channel wall. The axial distribution of planar removal follows the axial temperature distributions (Fig 4/36) and it is the peak in the inner surface temperature at the 20% height position (enrichment boundary), that is responsible for the small peak in the planar removal.

# Fig 4/34 (a)

This figure shows the effect on channel pressure drop. Here we have two compensating effects:

(i) increasing roughness - increasing pressure drop
 (ii) increasing planar removal - decreasing pressure drop.

This results in the almost constant increase (approximately 4%) on pressure drop over a large proportion of the dwell.

N.B. On this basis there would be no increase in pumping power, owing to corrosion, as that depends upon peak or start-of-life pressure drop. An increase in pumping power could only occur if a boiler tube started to leak badly just as a peak rated channel was being loaded.

# Fig 4/34 (b)

The growth in the outer fuel/can interface gaps relative to the inner gaps (Fig 4/11) results in progressively more heat being forced into the bore. This leads to higher temperatures, lower densities and therefore a higher bore flow resistance. The flow split ratio W(bore)/W(annulus) can be expected to decrease with dwell. This is demonstrated by Fig 4/34(b).

With corrosion there is a general increase of resistance owing to roughening and a decrease arising from planar removal. However, with the significantly larger removals from the channel wall (Fig 4/33) the net effect is a relative increase in bore resistance and at the end of life the flow split ratio has been reduced by 10.0%. This reduction is made up of a 4.5% reduction in bore flow and a 5.5% increase in annulus flow.

# Fig 4/35 (a)

In order to determine the corrosion effect, only, on friction factor the initial pressure loop results of cases (i) and (ii) have been compared i.e. the values of W(bore)/W(annulus) are the same for the corroded and uncorroded cases. There are, of course, two friction factors to consider for the annulus in the corroded case arrived at by the transformation - and Fig 4/35(a) shows a maximum

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of 37% increase in pin surface friction factor and 54% for the channel wall.

N.B. The maximum friction factor for the channel wall does not occur at the peak corroded position owing to the influence of the outer pin surface.

# Fig 4/35 (b)

As with the friction factors, flow split changes are not included in the heat transfer coefficient effects shown. The effect on channel wall heat transfer coefficient is interesting.

At axial heights of about 60% the roughness heights are small enough (  $30 \ \mu$ m) to have a negligible effect. However, the combined planar removal in the annulus (60 µm) produces a 2% reduction in the coefficient. As the roughness increases the coefficient increases until the maximum roughness is attained at 80% axial position. At this level the maximum increase in coefficient is obtained (20%). Above this level the roughness height remains constant but the planar removal increases sharply (Fig 4/33(a)) decreasing the coefficient until the 100% position is reached when it is 3% below the uncorroded value. A similar effect is noticed on the pin outer surface heat transfer coefficient, although the reduction in coefficient at the 100% position is due to the large amount of planar removal from the channel wall.

# Fig 4/36 (a)

As one would expect there is a general decrease in graphite surface temperature due to corrosion. The decrease in annulus temperatures is due to flow split changes as well as heat transfer coefficient increases. It is the flow split effect that causes the increase in inner pin surface temperature at the low axial position levels (less than 55%).

# Fig 4/36 (b)

There is an expected decrease in fuel temperatures above the 55% axial position.

# Fig 4/37

The temperature effects with life are shown for the peak temperature axial position(%). The maximum temperature reductions occur at the end of life and are as follows:

peak fuel (80%)	31°C
peak pin inner surface (90%)	35°C
peak pin outer surface (90%)	28°C
peak channel wall (100%)	29 <sup>°</sup> C

#### (d) Application of results

It is now necessary to convert these results, derived from a seven step calculation, to a gagged channel. The starting point is an AZIMUSTAP calculation of the peak rated channel (Chapter 5) which will be termed the reference case.

Table 4/6 gives the temperature reductions, for the peak temperature positions, applying to each of the seven time steps. These results are now interpolated to find the intermediate points. For instance, in the peak inner pin surface temperature case, there is a  $14^{\circ}$ C reduction at 30% dwell and a  $24^{\circ}$ C reduction at 50% dwell. It is assumed, therefore, at  $19^{\circ}$ C reduction at 40% dwell at the second gag change. In such a way Figs 4/38(a), (b) and (c) have been drawn showing the corrosion effect on the gagged peak rated channel graphite surface temperatures and Fig 4/3% similarly, for the peak fuel temperature.

#### (e) Fuel element endurance

With the assumptions made it is clear that substantial reductions in temperatures can be expected from corrosion, without any penalty on pumping power. This would be encouraging were it not for the uncertainty surrounding the form and development of roughness and planar removal. It has been assumed that the binder has a reactivity three times that of the particle. If the difference is not so large the roughness is reduced, together with the temperature savings. With smooth surfaces the effect of panar removal would produce only small increases in temperature and, as some roughness is inevitable, it is most probable that there will be a net temperature reduction.

With the temperature distributions calculated the effect on endurance can be summarised as follows.

There is a mean reduction in fuel temperature of 19°C over life, which would reduce the likelihood of both 'Amoeba' and 'Pressure' failure of the particle. According to the rules set out in Chapter 2 a 19°C reduction in fuel temperature would lengthen the life of the peak temperature particle by approximately 19%.

A 1 mm removal from the channel wall has a number of effects:

- (i) reducing the integrity of the block (There is a 9 mm ligament and therefore a 1 mm loss could have an effect on the mechanical strength.)
- (ii) widening the channel by 1 mm increases the amplitude of vibrations of the fuel element
- (iii) the pin can bow to a greater extent leading to higher assymetry and higher peak temperatures.

Quantitative answers to (i), (ii) and (iii) will not be given in in this work.

#### 4.7 Additional corrosion effects

So far, we have only considered the effect of corrosion on heat transfer from the graphite surfaces. There are two further corrosion phenomena which need consideration:

- (i) reduction in graphite conductivity arising from corrosion induced density changes
- (ii) changes to the interface gap conductance owing to compact corrosion.

We will consider each of these effects in turn.

#### 4.7.1 Graphite thermal conductivity effects

At the temperatures which are important from a fuel endurance view-point, i.e. the peak or near peak graphite temperatures ( $1030^{\circ}C$ ), corrosion takes place very close to the surface. BIRCH (<u>33</u>) shows a corrosion profile for a graphite temperature of  $1050^{\circ}C$  and 53 atmospheres total pressure and it is observed that less than 1% of corrosion takes place below  $250\,\mu$  m. It can be assumed therefore that weight losses are sufficiently small for this effect to be neglected.

#### 4.7.2 Compact corrosion

Water vapour can gain access to the compact by two routes:

- diffusion through the sleeves. (This mechanism only applies if the sleeve temperatures are low enough for the water to escape reaction (less than about 800°C).)
- access through the pin end. (By design, the open pin end is at the downstream or low pressure end of the pin and, therefore in this configuration no water can enter.)

In conclusion, therefore, for the purposes of peak temperature and fuel endurance calculations the compact corrosion effect can be neglected.

#### CHAPTER 5

#### TIME AND SPATIAL DISTRIBUTIONS OF FUEL ELEMENT TEMPERATURES

The methods derived in Chapters 3 and 4 can now be employed to derive complete time and spatial distributions of fuel channel temperatures. From Chapter 3 the channel power, axial rating profile and channel gas outlet temperature of each and every channel in the core can be obtained. Chapter 4 using this basic information, presents methods that can be used to obtain the axial and time distributions of fuel channel temperatures for any desired channel.

In this chapter we will first summarise the basic data that has been used in all this work (section 1). In section 2 the computer codes which have been developed to, collectively, include the analytical methods derived in Chapter 4 will be presented together with axial and time evolutions of fuel channel temperatures for a typical channel. Section 3 discusses further systematic effects previously not considered. A method, developed by the Author, to determine whole core temperature distributions from a limited number of single channel calculations will then be described in section 4.

So far we have only considered Best Estimate property, heat transfer, corrosion data etc., and because of the statistical variation of these values precise distributions cannot be evaluated and the final results must be expressed in terms of an Expected Frequency Distribution of Temperature. These aspects will be discussed in Section 5.

In conclusion section 6 gives an indication of what these temperatures actually mean in terms of fuel element endurance.

#### A summary of data used

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Most of the material property data used has been taken from TRG 1000 (R) ( $\underline{43}$ ) i.e. 'Data and Conventions for Mk. III calculation' compiled by the UKAEA from recommendations made by the relevant collaborative working party. Where property data has not been taken from this reference, for example in the corrosion work, this has been referenced separately in the relevant section. Fuel element data; geometry, particle failure criteria etc., are given in Chapter 2 and operating conditions, e.g. channel powers and gas outlet temperatures are given in Chapter 3. Heat transfer and friction factor data can be found in Chapter 4 section 2. A summary of data assumed for the peak rated channel is given in Table 5/1 and includes additional items (e.g. brick and pressure drop losses) not mentioned elsewhere.

As revised data becomes available, from in-pile experiments for example, the relevant section of TRG 1000 (R) (<u>43</u>) becomes re-issued. Table 5/2 lists all these properties together with the issue number at the time of use. Errors associated with this data are discussed in section 5.

#### Axial and time evolutions of fuel channel temperatures

2

The two programs employed in determining single channel temperatures are AZIMUSTAP 5 and HEATAX III. The former code calculates axial temperature distributions at discrete times in the fuel dwell. The time dependent calculation is described in Chapter 4 sub-section 3.3 and the axial calculation is given in Appendix VI. This final version of AZIMUSTAP, as already noted in Chapter 4, does not include the thermal expansion effect on channel dimensions or the corrosion phenomenon which are discussed in Chapter 4. HEATAX II and III have been written to take account of these two effects respectively. Appendix VII describes the HEATAX series of codes and also gives a listing as programed by the Author.

As HEATAX III only calculates the thermal expansion component of the fuel/can interface gap AZIMUSTAP is needed to produce shrinkage gaps at each axial position and time in life required by the HEATAX run.

In addition, HEATAX only makes a limited number of calculations with time and therefore AZIMUSTAP is also required to describe the saw toothed time evolution caused by gagging.

Chapter 4 sub-section 4.6 describes the general approach.

As an example of axial and time temperature distributions the peak rated channel will be taken, the operating conditions of which are given in Tables 4/1, 5/1.

The axial rating distributions for this channel are shown in Chapter 3. The data input to HEATAX is given in Appendix VIII.

#### 2.1 Axial distributions of temperature

Fig 5/1 shows plots of the important fuel channel temperatures for the start of life of a peak rated channel and have been taken from the HEATAX III output listed in Appendix IX. The reader is referred to the nomenclature (Appendix VII).

The heat split radius  $(r_i)$  versus axial position is also shown in Fig 5/1. The initial value of  $r_i$  at channel inlet is 23.8 mm indicating 54% of fuel heat generation is passing into the bore of the channel. This percentage increases down the channel since the annulus gas temperature rises at a faster rate than the gas temperature in the bore resulting from the mass flow deficiency in the annulus (Fig 4/34). After the 2m level, the enrichment boundary,  $-\frac{\partial r}{i}/\partial_z$ increases sharply, the reason for which is obvious from Chapter 4 equation 6. From this equation it can be seen that  $r_1^2$  is inversely proportional to the heat generation rate  $q_T^{m}$  which of course, decreases immediately below the enrichment boundary. The increase of  $\partial r_i/\partial_z$  towards channel outlet is explained by the reduction in rating resulting from thermal neutron flux shape effects (Chapter 3).

The partition of heat in favour of the bore shows itself in the resulting temperature distributions. Those temperatures within the radius of peak fuel temperature follow more closely the axial flux shape than those outside this radius. Consequently the inner tube graphite temperatures  $(T_{W1}, T_{I1})$  exhibit the 'twin peak' effect at the 2m and 4m positions more strongly than the outer tube temperature  $(T_{W2}, T_{I2})$ .

Only ten axial slabs were represented in the HEATAX run and consequently in the sharply changing areas between the 2m and 2.5m levels the shape has been drawn by interpolation. There is, however,

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little justification for decreasing the step length since axial conduction effects at this position will play a significant part. Time evolutions of temperature

2.2

The distributions of temperature with time were generated in a similar way to that described in Chapter 4 sub-section 4.6 i.e. differences between the HEATAX and AZIMUSTAP temperatures were found for each HEATAX time step, and differences at the intermediate AZIMUSTAP dose step obtained by linear interpolation. In this way a complete time evolution of temperature was obtained which was consistent with the HEATAX method.

Fig 5/2 shows the time evolutions for peak fuel and graphite wetted surface temperature. The relevant axial positions were chosen so that the peak temperature overall was represented. It is interesting to note that the peak temperature occurs at different axial positions at different times i.e. the overall peak values of  $\hat{T}_{FP}$  and  $\hat{T}_{W1}$  occur just after the first gag change (154 days) at the 4m and 4.5m positions respectively, whereas the peak values of  $\hat{T}_{W2}$  and  $\hat{T}_{W3}$  occur immediately after loading at the 4.5m and 5.0m positions respectively.

The time evolutions of temperature shown in Fig 5/2 follow in quite a predictable fashion the evolution of channel gas outlet temperature controlled by a four change gag scheme (Chapter 3). The corrosion effect, as already explained in Chapter 4, depresses the distribution towards the end-of-life. (This will have a beneficial effect on particle failure,) The distributions are rather more complicated over the period 0-154 days. As described in Chapter 4 section 3 this period is one of rapid development of the interface gaps. Between 0 and 77 days the inner gap decreases and the

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outer gap increases forcing more heat into the bore of the channel. This explains the high level of  $\hat{T}_{W1}$  and the steep fall of  $\hat{T}_{W2}$  and  $\hat{T}_{W3}$ . Interaction between inner sleeve and fuel occurs towards the end of this period,  $(1-2 \times 10^{20} \text{ n/cm}^2 \text{ EDN})$  slowing down the rate of outer gap growth and hence heat re-distribution. This explains the fall in  $\hat{T}_{W1}$  between 77 and 154 days. The minimum (39 days) and maximum (80 days) in the  $\hat{T}_{FP}$  distribution can also be explained by the gap development. Initially the growth of the outer gap is offset by the reduction in the inner gap producing a net decrease in  $\hat{T}_{FP}$ . Once interaction has occurred the outer gap growth begins to take effect by increasing  $\hat{T}_{FP}$  until the rate of gap growth reduces and corrosion starts to play a part towards the end of the first gag interval.

#### 'Best Estimate' temperatures and other systematic effects

As part of the analysis of the fuel element described in this thesis certain assumptions have been made. The major assumptions are:

- (i) One dimensional (radial) heat conduction within the fuel and graphite
- (ii) Axial development and symmetry of velocity and temperature profiles in the coolant

Strictly, therefore, in order to obtain the so called 'Best Estimate' temperature allowance should be made for any effects which lay outside these basic assumptions. The most important of these factors are now discussed.

#### 3.1 Fuel pin bowing

3

Arising from damage dose gradients across the fuel pin differential shrinkage occurs which causes pin bow. The bow is limited by the anti-bowing ribs which interact with the channel wall. The bow causes the annulus flow passage and compact/tube gaps to become eccentric resulting in azimuthal temperature variations within the element and a three dimensional velocity temperature field within the coolant. The calculations of the fuel performance under such conditions becomes highly complex and for the purpose of thesis we will use the results of a simplified case investigated by CONWAY-JONES (44).

This work showed a  $25^{\circ}$ C increase in overall peak fuel temperature and although there will be a corresponding reduction elsewhere in the pin and the net effect on particle failure will be less than an overall  $25^{\circ}$ C increase implies we will assume a full  $25^{\circ}$ C increment.

As far as graphite temperatures are concerned we will assume no net increase due to bowing which is approximately equivalent

to taking the azimuthal mean values.

#### 3.2. Across-pin rating gradients

Across-pin gradients are caused by two factors:

- (a) Macroscopic radial neutron flux gradient
- (b) Fine structure effects of control rods.

The former effect is only really significant towards the edge of the core (Chapter 3) where, in any case, the rating tends to be lower. Close to control rods gradients can be large but again channel ratings will be low.

It is a fair approximation to say that peak rated channels will have low gradients and for the purposes of this work the effect will be neglected.

#### 3.3 Heavy metal density variations

Owing to systematic manufacturing defects the HMD varies axially within a compact by, as quoted by GUILD (45),  $\pm 3\%$ . The resulting perturbations to the axial rating shape cause peaks in temperature which are smoothed to some extent by axial conduction. The net effect on fuel and graphite temperatures is as follows:

$$\hat{T}_{FP}$$
 - 7°C  
 $\hat{T}_{W1}$  - 9°C  
 $\hat{T}_{W2}$  - 3°C

#### 3.4 Total systematic increments

The net systematic increments on the peak temperatures are

therefore:

TFP	-	32°C
Îrw1	-	9°c
Î <sub>W2</sub>	-	3°C
Î.W3	-	o°c

## 3.5 Peak 'Best Estimate' temperatures

The 'Best Estimate' peak temperatures for the peak rated channel are therefore defined as the HEATAX III/AZIMUSTAP 5 values (Fig 5/2) <u>plus</u> the increments given above i.e. the peak 'Best Estimate' temperatures over life are:

$\mathbf{\hat{T}}_{\mathrm{FP}}(\mathrm{BE})$	=	1237°C
T <sub>W1</sub> (BE)	=	1014 <sup>0</sup> C
T <sub>W2</sub> (BE)	=	1048 <sup>0</sup> C
T <sub>W3</sub> (BE)	=	1008 <sup>0</sup> C

#### Channel to channel distributions of temperature

Having obtained complete distributions, both axially and with time, of temperatures for one channel and also determined how the axial peak temperatures must be modified to allow for other systematic effects, the spatial distribution of channel peak temperature will now be evaluated.

We will concern ourselves only with the spatial distribution at one moment in time ('snapshot') of axial peak 'Best Estimate' fuel  $(\hat{T}_{FP})$  inner sleeve surface  $(\hat{T}_{W1})$ , outer sleeve surface  $(\hat{T}_{W2})$  and channel wall  $(\hat{T}_{W3})$ .

The method that has been developed by the Author to evaluate these spatial distributions from single channel calculations will now be described.

#### 4.1 Integral data method

4

From Chapter 3 the methods for obtaining channel power and gas outlet temperature distributions are discussed and in theory, at least, it is now possible to run single channel temperature calculation programs (e.g. AZIMUSTAP) for each channel to obtain whole core distributions. The expense, however, in terms of computer running times would be prodigious.

The object, therefore, was to derive a correlation between the important fuel element temperatures and channel power and gas outlet temperature. This correlation could then be applied to each channel in turn given its operating conditions.

In order to derive this correlation a number of AZIMUSTAP cases were run covering the range of start-of-life channel power ( $Q_{CHS}$ ) and channel life mean gas outlet temperature ( $\overline{T}_{c2}$ ) values experienced in an HTR core. From the results, for any desired dose step the values

of  $\hat{T}_{FP}$ ,  $\hat{T}_{W1}$ ,  $\hat{T}_{W2}$  and  $\hat{T}_{W3}$  can be plotted against  $Q_{CHS}$  for each value of  $\bar{T}_{c2}$  in turn. Fig 5/3 (a) is such a plot for  $\hat{T}_{FP}$  at the start-of-life and end-of-life times.

As can be seen the curves are linear to within 5°C. Fig 5/3 (b) shows plots of  $\hat{T}_{FP}$  (500 kW) and  $\partial \hat{T}_{FP}/\partial Q_{CHS}$  versus  $\overline{T}_{c2}$ . Linearity is again evident in the former case, whereas in the latter a stright line drawn between the two extreme points results in an accpetable error of 1-1.5% in  $\partial \hat{T}_{FP}/\partial Q_{CHS}$  at a  $\overline{T}_{c2}$  of 775°C. This analysis suggests the following correlation between  $\hat{T}_{FP}$  and  $Q_{CHS}$  and  $\overline{T}_{c2}$ :

$$\hat{T}_{FP} = (A\bar{T}_{c2} + B)Q_{CHS} + C\bar{T}_{c2} + D$$
 ....1

In the case of the graphite surface temperatures these are only weakly dependent on channel power. Fig 5/4 illustrates this point where the grahite surface temperatures are plotted against  $\overline{T}_{c2}$  for different values of  $Q_{CHS}$  i.e.

$$\tilde{I}_{W} = C\bar{T}_{c2} + D + f(Q_{CHS})$$

 $f(Q_{CHS})$  will be small but to make some allowance for this the relationship given in equation 1 will be assumed, i.e. if  $\hat{T}$  is any desired fuel channel temperature then:

 $\hat{T} = (A\bar{T}_{c2} + B) Q_{CHS} + C\bar{T}_{c2} + D$  ....2

Where the constants A, B, C and D will depend upon the temperature and time considered.

In order to evaluate the constant A, B, C and D only four AZIMUSTAP cases need to be run. For each time step the four peak values of the desired temperature can be plotted against  $Q_{CHS}$  for the two values of  $\overline{T}_{c2}$  (Fig 5/5). The expression for the constants are therefore seen to be:

$$A = (T_4 - T_3 - T_2 + T_1) / (Q_{CHS}'' - Q_{CHS}') (\overline{T}_{c2}'' - \overline{T}_{c2}')$$

$$B = (T_2 - T_1) / (Q_{CHS}^{"} - Q_{CHS}^{"}) - A\overline{T}_2^{"}$$
  

$$C = (T_2 - T_1) / (\overline{T}_{C2}^{"} - \overline{T}_{C2}^{"}) - AQ_{CHS}^{"}$$
  

$$D = T_1 - (A\overline{T}_{C2}^{"} + B)Q_{CHS}^{"} - C\overline{T}_{C2}^{"}$$

A computer program - BATTLEAXE - was written which evaluated the equations, given  $T_1$ ,  $T_2$ ,  $T_3$ ,  $T_4$ ,  $\overline{T}_{c2}^*$ ,  $\overline{T}_{c2}^*$ ,  $Q_{CHS}^*$  and  $Q_{CHS}^*$ . The constants A, B, C and D so determined are then used by BATTLEAXE to evaluate equation 2 given the values of  $Q_{CHS}$  and  $\overline{T}_{c2}$  for each channel.

Having determined the relevant peak temperatures for each channel the numbers of channels within a  $10^{\circ}$  interval are summed and the resulting histogram printed out.

BATTLEAXE was programmed in Functional Language to the Author's specifications by LUXMOORE (46).

#### 4.2 BATTLEAXE input data

The information required is as follows:

- (a) Spatial channel power (start-of-life) distribution
- (b) Refuelling pattern
- (c) Distribution of leaking columns
- (d) Gagging pattern
- (e) Integral temperature data.

Items (a)  $\rightarrow$  (d) can be obtained from Chapter 3 and are summarised in Table 5/3. We will now discuss the derivation of the integral temperature data.

A set of AZIMUSTAP runs was available which could be applied to the fuel element under consideration. However, owing to data and program changes there were differences between these runs and the current AZIMUSTAP 5/HEATAX III results and although the differences were small it was felt necessary to correct them so as to remain consistent with the rest of the work in this thesis. The four runs covered the channel power range: 300 - 600 kW and the channel  $\overline{T}_{c2}$  range  $700 - 850^{\circ}$ C. Table 5/4 shows these 'nominal' temperatures for each of the ten age groups together with the derived 'Best Estimate' temperatures which, as well as being normalised to the HEATAX III/ AZIMUSTAP results also include the additional systematic mentioned in section 4 above. Two assumptions have been made in normalising the integral data:

- (i) The deviations from the 'Best Estimate' can be divided into two categories - power dependent, flow dependent - the correction factors scaled accordingly.
- (ii) Corrosion is negligible in all the four AZIMUSTAP cases except 600 kW/850°C when it is as given in Chapter 4 and varies linearly between these two extremes. (This is a major approximation and given more time it would have been desirable to have applied the HEATAX III/AZIMUSTAP 5 model to channels operating over a range of conditions).

a thomas denotes as its standard to an the

#### 4.3 Snapshot temperature histograms

Figs 5/6 - 5/9 show the snapshot distributions of  $\hat{T}_{FP}$ ,  $\hat{T}_{W1}$ ,  $\hat{T}_{W2}$  and  $\hat{T}_{W3}$ . It will be noticed that the peak 'Beat Estimate' fuel temperature over life of  $1237^{\circ}C$  (sub-section 4.5) is not achieved. This is because the peak channel power of 607 kW includes margins to cover the effects of fuel management.

The histograms of peak outer pin surface and channel wall temperature (Figs 5/8, 5/9) show that there are channels with higher temperatures

than the peak rated channel temperatures (sub-section 4.5).

This is because  $\hat{T}_{W2}$  and  $\hat{T}_{W3}$  are more dependent upon  $T_2$  than channel rating and there are of course channels with higher gas outlet temperatures than that in the peak rated channel.

It will be noticed that the high temperature 'tail' of the histograms is shorter than the tail at the low temperature range. This phenomenon results from a gagging scheme where those columns with high across column gradients are gagged to lower temperatures than those with low gradients. It follows, therefore, that since the lowest, as well as the highest, temperatures occur in the high gradient columns there will be a larger number of low temperature channels.

#### 5 Statistical aspects

#### 5.1 Variations in data input parameters

So far in the analysis only the Best Estimte values of parameters have been considered. In practice, around the most probable value there will be a statistical distribution which will be decided by, for example, manufacturing tolerances or experimental error.

The object of this section is to assess the probability of a temperature occurring in the reactor to replace the 'rigid' histograms: presented in the foregoing.

A distinction must be made, initially, between 'within core' and 'whole core' statistical variations.

The within core variations will be termed 'randoms' and originate from statistical variations between points in the reactor. An example would be manufacturing tolerances of the fuel element.

In the 'whole core' case we are thinking in terms of variations which affect the whole core equally. Such variations are defined as 'uncertainties' and would include reactor operating variations.

The purpose of this distinction is so that the 'randoms' can be combined statistically to obtain a modified histogram of temperature within the core, the Expected Frequency Distribution, whereas the 'uncertainties' provide maximum and minimum envelopes to this histogram.

It is not always straightforward, to allocate a factor to one category or the other. Material property variations are an example. They arise from:

(i) the property measurement errors of a material sample(ii) sample-to-sample differences within the core.

The latter is clearly a 'random' factor and is usually the dominant component. A certain experimental measurement error,

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however, is constant over the whole core i.e. suggesting it to be an 'uncertainty' factor. This uncertainty will, of course, lead to different increments of temperature within the core arising from, say local rating differences.

Data variations quoted by references (e.g. TRG 1000(R)) are not usually divided into components in this way and only recently have the relevant working parties of the RPC begun to think in these terms.

For material property variations we will use TRG 1000 (R) (43)and assume the whole of the quoted standard deviations to be allocated to the 'random' category.

Variations also occur in channel power and point rating but these can be quite easily defined as 'random' since an overestimation of rating at one point in the core must, necessarily, be associated with a corresponding underestimation elsewhere. This argument equally applies to the estimation of coolant flow rate in various parts of the core for, as with reactor thermal power, total core flow is a design constant. There will, of course, be fluctuations in these constants owing to perturbations in the reactor operation but these will come under the category of 'uncertainty' as mentioned above. The study here will be confined to obtaining the Expected Frequency Distribution of channel peak temperature in an equilibrium core at a particular moment in time ('snapshot') and Table 5/5 lists all the random factors assumed. The standard deviations have been taken from:

- (i) GRUNDY (47)
- (ii) TRG 1000 (R) (<u>43</u>)

(iii) general TNPG design work (unreported)

The noteworthy omission from Table 5/5 is the variation in corrosion data. According to MERRETT (<u>35</u>) chemical reactivities of gilsocarbon graphite can vary by as much as a factor 10 from sample to sample

owing to, for example, the presence of differing quantities of impurity. Such a large variation would dominate other variations to such an extent as to make the statistical analysis highly speculative. The random variations in corrosion rate will therefore be excluded from the temperature standard deviation calculations.

Once the Expected Frequency Distribution has been evaluated, neglecting corrosion randoms, the effect of this distribution on the corrosion of critical components, for the range of graphite reactivities, can be found.

#### Combination of 'randoms' 5.2

ABERNATHY (48) has shown that if  $\sigma_m$  is the standard deviation on temperature T arising from random deviations in variables u1, u2 ....un then if the variables are independent:

$$\sigma_{\rm T}^2 = a_1^2 \sigma_{\rm u_1}^2 + a_2^2 \sigma_{\rm u_2}^2 + - - a_n^2 \sigma_{\rm u_n}^2$$
$$a_1 = \overline{a_{\rm T}} / \overline{a_{\rm u_1}} \quad \text{etc.}$$

where

We can define  $\sigma_{n}(u_{1})$  which is the contribution to  $q_{n}$  from variable u, and :

$$\sigma_{T}(u_{1}) = a_{1} \sigma_{u_{1}}$$
  

$$\sigma_{T} = \sqrt{\sigma_{T}(u_{1})^{2} + \sigma_{T}(u_{2})^{2} + - - \sigma_{T}(u_{n})^{2}}$$
....4

As well as knowing the standard deviation of temperature T it is equally important to know the form of its probability distribution. The distributions of the component variables will not all be the same; some will be rectangular, e.g. pin dimensions whereas others will be closer to a Gaussian distribution e.g. channel power. The only precise way of determining the temperature T probability distribution is to perform a 'Monte-Carlo' calculation. This is where values of each variable are chosen from its distribution in a random fashion and

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the temperature T calculated. If this is done many thousands of times the distribution of T and its standard deviation can be found accurately.

If one considers, however, the number of variables on which T is dependent and the complexity of the basic calculations this Monte-Carlo method is seen to be a difficult proposition. It has been applied in a limited way by GRUNDY (49) who has determined the probability distribution of various fuel element temperatures resulting from the rectangular distributions of pin dimensions. These temperature distributions are similar to the Gaussian form with, of course, upper and lower cut-offs. These calculations were for just one axial position and if the probability distribution of a temperature T were required which included a combination of all the variables given in Table 5/5 then a whole channel temperature calculation would be necessary. GRUNDY (49) suggests that, assuming 1000 runs, the routine for choosing the values of the variables and performing once the channel temperature calculation should take no longer than 10 secs; the 3 hours total running time being acceptable for a generic study. HEATAX III takes 2.4 secs per time step and therefore lends itself for use in the Monte-Carlo method. Future development of the work in this thesis could, therefore, usefully include such a study.

N.B. By using a Monte-Carlo method which incorporates HEATAX III the large variation in corrosion data could be allowed for correctly.

For the purposes of this work the standard deviation of temperature T will be obtained from equation 4 and its distribution from the Central Limit Theorem described by ABERNATHY (<u>48</u>). This theorem states: The distribution of the sum of n independent random variables asymptotically approaches the normal distribution as n approaches infinity. (It also assumes that no one factor is dominant over the others and if,

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$$f_{T}(T) = \frac{1}{\sigma_{T} 2 \pi} \exp \left[-\frac{\left(\frac{T}{2} - \overline{T}\right)^{2}}{2 \sigma_{T}^{2}}\right] \qquad \cdots$$

where  $\overline{T}$  is the mean value of T. The probability of a temperature occurring between  $T_1$  and  $T_2$  is given by:

temperature T then from the theorem it can be assumed:

$$P(T_1 \leq T \leq T_2) = \frac{1}{\sigma_T \int 2\pi} \int_{T_1}^{T_2} e^{-\left[\left(\frac{T}{2} - \frac{T}{T}\right)^2\right]} dT \qquad \cdots \qquad 6$$

If in a reactor there are N fuel pins with identical frequency functions  $f_{T}(T)$  as given by equation 5 then the expected number of fuel pins with a temperature between  $T_1$  and  $T_2$  is given by NP  $(T_1 \leq T \leq T_2)$ .

In general there will be different values of  $\overline{T}$  and  $\mathbf{q}$  for each fuel pin and the Expected Frequency Distribution of temperature within the reactor can be found by the summation of the probability function (equation 6) for each pin.

Let  $\overline{T}_i$  be the mean temperature of Pin i and  $\begin{array}{c} \sigma \\ T_i \end{array}$  the standard deviation then the expected number of fuel pins within the temperature range  $T_1 - T_2$  is:

$$n(T_{1} - T_{2}) = \frac{1}{2\pi} \sum_{i=1}^{i=N} \frac{1}{q_{T_{i}}} \int_{T_{1}}^{T_{2}} e^{-\frac{(T_{1} - \overline{T}_{i})^{2}}{2\sigma_{T_{i}}^{2}}} dT \cdots 7$$

### 5.3 Expected Frequency Distributions of fuel channel temperatures

In order to obtain the component variances  $(\sigma_T(u_i)^2)$  of the temperature T variance  $(\sigma_T^2)$  the derivatives,  $a_i$ , must be derived. Take for example the standard deviation on column power  $(\sigma_{QS})$ .

If the column power is different from design the gag will be adjusted and the only major effect on the fuel temperature will arise

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from the local rating changing the fuel - gas temperature difference. If Z is the axial position of peak fuel temperature then to a close approximation:

$$a_{QS} = \hat{T}_{FP} - \frac{1}{2} (T_{W1}(Z) + T_{W2}(Z))$$

since the film drops  $(T_{W1} - T_{g1}, T_{W2} - T_{g2})$  are only slightly affected if the column gas outlet temperature is maintained by gagging. (From Chapter 4 equations 64, 65, 66,  $T_W - T_g \propto flow^{0.2}$ ). Therefore:

$$\sigma_{\widehat{T}_{\text{FP}}}(u_{\text{QS}}) = \sigma_{\text{QS}} \left( \widehat{T}_{\text{FP}} - \frac{1}{2} \left( T_{\text{W1}}(Z) + T_{\text{W2}}(Z) \right) \right)$$

Similarly, values of  $a_i$  can be determined for the other random factors and for the other temperatures of interest (i.e.  $T_{W1}$ ,  $T_{W2}$  and  $T_{W3}$ ). The values of  $a_i$  will of course change for a different axial position, irradiation and fuel pin. The component values of  $\sigma_T(u_i)$  quoted in Table 5/5 have been derived assuming the peak temperature axial positions and peak temperature times in life for a peak rated channel (Table 5/1). Also given in Table 5/5 are the standard deviations for  $T_{FP}$ ,  $T_{W1}$ ,  $T_{W2}$ ,  $T_{W3}$ calculated using Eq. 4.

To demonstrate the dependence of  $\sigma_{\rm T}$  on axial position and irradiation values of standard deviations for the peak fuel temperature in a peak rated channel have been derived for different axial positions (Fig 5/10) and irradiation times (Fig 5/11). As would be expected the value of sigma ( $\sigma_{\rm T}$ ) follows closely the axial rating profile (see Chapter 3). There is little variation of sigma with time as would be predicted by observing the time evolution of peak fuel temperature shown in Fig 5/2.

The Expected Frequency Distribution of channel peak temperatures at one moment in time will be considered and, for simplicity, a value of sigma will be assumed for each of the temperatures (the Table 5/5 values) and

assumed constant for all the fuel channels. A program, HISTRAND, has been written by VANDER STEEN ( $\underline{50}$ ) which accepts histograms together with the standard deviations and calculates the expected frequency distributions according to the theory given in the previous sub-section. This program has been used, together with the Best Estimate histograms given in Figs 5/6 - 5/9 and the values of sigma given in Table 5/5, to derive Expected Frequency Distributions of fuel channel temperatures in an equilibrium HTR core at one moment in time. These distributions are shown in Figs 5/12 - 5/15 in the form of a number of channels having a peak temperature between T and T +  $10^{\circ}$ C.

In all these distributions, there has been a shift of 10°C in the 'most common' temperature when compared with the Best Estimate distributions. This shift downwards is caused by the skewed nature of the Best Estimate histograms where, as already pointed out, there are a greater number of channels at temperatures below the 'most common' than there are above it.

The length of the high temperature 'tails' of the Expected Frequency Distributions are highly important in assessing core integrity and safety and this will be discussed in the following section. So as to determine accurately the number of channels within the 'tail' it will be necessary to refer to the tabulated distribution given by the program HISTRAND and listed in Appendix X.

#### Fuel element endurance and integrity

#### 6.1 Temperature limiting criteria

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Traditionally, in reactor design calculations the '2 $\sigma$  peak temperature' has been taken as the limiting criterion. This criterion is the peak 'Best Estimate' temperature plus two standard deviations and has been chosen in a more or less arbitrary fashion. Normally, the statistical distributions of temperature have been assumed Gaussian in form and the 2 $\sigma$  limit corresponds to 2.3% of the number exceeding this limit.

For the AGR the limiting temperature is on the stainless steel fuel can gas swept surface, where  $825^{\circ}C$  is taken as the  $2\sigma$  temperature criterion. If 2.3% of all channels in the core experience peak temperatures above this temperature the actual proportion of total can surface above the limit is, of course, less since only approximately  $1\frac{1}{2}$  pins out of 288 within the cluster are at, or near, the peak value. The  $2\sigma$ criterion, applied in this way, corresponds therefore to 1 in  $10^4$  pins at risk which is regarded as acceptable.

It should be noted that an acceptable risk is a purely subjective concept and is merely a compromise between reactor safety and conflicting economic factors.

#### 6.1.1 $2\sigma$ random temperature limits in the HTR

The  $2\sigma$  concept is still in use in HTR design work e.g. the specification for the Oldbury B tender requires that, given the most limiting channel from 'amoeba' failure considerations, its peak  $2\sigma$  random fuel temperature should be such that at the end of its dwell the maximum 'amoeba' failure factor is 1.0 i.e. 'failure' to have just occurred.

Frequency Distribution of temperature which would just meet, with, of course, the necessary uncertainty margins, the activity release and corrosion criteria.

This procedure requires iteration between the temperature calculation and the calculation of the dependent phenomena. The first step in this iteration loop would be to determine the Expected Frequency Distributions of temperature similar to those given in Figs 5/12 - 5/15. From these distributions and other necessary information important parameters could be determined e.g. failed fuel particle fraction and water concentration. The final step would be to calculated the limiting parameters such as rate of release of fission products, local graphite removal etc. Reactor design, or operation, changes can then be made, revising the temperature distributions, so as to approach more closely the limiting criteria.

#### CHAPTER 6

#### CONCLUSION

Methods were developed which optimised the core coolant flow distributions. Using these techniques the flow and channel gas outlet temperature distributions were found for the reference core design: for the two cases of leaking and non-leaking columns. The channel flow rate and gas outlet temperature evolutions with time were also determined for the peak rated channel.

A single channel was then considered and the temperature distributions were determined within the fuel, can and interface gap.

Derivations of the temperature and velocity profiles were then made within the bore and annulus of the channel and the heat transfer coefficients were determined for developed turbulent flow. These coefficients were then compared with other theoretical and experimental work; in particular with the WILKIE correlations which were used in the thermal performance assessments.

Thermal and irradiation effects on the fuel and can geometry were then dealt with and the mathematical model incorporated in the AZIMUSTAP program. This model made it possible to determine the fuel/sleeve interface gaps at any axial position and at a finite number of time steps throughout the fuel dwell. This method also allowed for the effects of changing channel operating conditions (e.g. gagging) and material properties. Typical results were presented.

The other important phenomenon considered was graphite corrosion which necessitated the specification and writing of a major new computer code, HEATAX. Models were derived to describe the form and development of corrosion attack. The effects on local heat transfer and friction factor within the bore and annulus were assessed chiefly using the experimental results of NIKURADSE (37) and DIPPREY (40). Finally, these models were incorporated within a single channel performance code so that the interplay between corrosion and temperature could be properly determined. The resulting AZIMUSTAP/HEATAX model calculated the complete axial and time dependence of corrosion and temperature within a fuel channel.

Methods were also developed which applied single channel temperature calculations to the whole core. As a result complete spatial distributions of channel peak temperatures at a 'snapshot' time were determined and presented in histogram form. These histograms were further modified to allow for statistical variations in the contributory factors, and Expected Frequency Distributions of peak temperatures were the final result.

#### NOMENCLATURE

The diversity of subjects tackled in this thesis has necessitated the repetition of certain symbols. In general, the symbols have been defined where they occur, but, in those cases where they have not, their definition will be given here.

d	rib width
De	hydraulic diameter
F	channel friction factor
f <sub>1</sub> ,f <sub>2</sub>	transformed inner, outer annulus friction factor
fa	failed particle volume fraction from 'Amoeba'
fp	failed particle volume fraction from 'Pressure'
f <sub>T</sub>	total failed particle volume fraction
g <sub>c1</sub> ,g <sub>c2</sub>	cold inner, outer radial interface gaps
k <sub>c</sub>	can thermal conductivity (Hollow-rod work)
k <sub>f</sub>	fuel thermal conductivity
kg	graphite thermal conductivity
k <sub>j</sub>	interface gap thermal conductance
1	rib height
N	number of ribs
P	gas pressure
q"1,q"o	annulus inner, outer surface heat fluxes
R	gas constant
r	heat split radius
r <sub>f1</sub> ,r <sub>f2</sub> ) r <sub>s1</sub> ,r <sub>s2</sub> ) r <sub>s3</sub> )	See Fig AVI-1
	outer radius of inner can
r <sub>s1</sub> '	
r <sub>s2</sub> '	inner radius of outer can
T <sub>C</sub>	gas temperature at centre of tube

$ \begin{array}{c} {}^{\mathrm{T}}_{\mathrm{W1}}, {}^{\mathrm{T}}_{\mathrm{W2}}, {}^{\mathrm{T}}_{\mathrm{W3}} \\ {}^{\mathrm{T}}_{\mathrm{F1}}, {}^{\mathrm{T}}_{\mathrm{F2}} \end{array} \right) $	See Fig AVI-1
T <sub>FP</sub>	radial peak fuel temperature
$\hat{T}_{W1}, \hat{T}_{FP}, etc$	axial peak temperatures
Τ2	channel, column gas outlet temperature
T <sub>c2</sub>	channel gas outlet temperature
T*	temperature rise; $(T - T_0)$
To	ambient or 'room' temperature
Z	axial distance from channel inlet
af, ag	fuel, graphite coefficients of thermal expansion

Subscript

ç

channel value

#### TABLES

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Chapter 3	
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3/3	Peak fuel element temperatures and particle failure factors for four and no-gag change schemes (peak rated channel)
3/4	Peak fuel and graphite temperature reductions for various spatial gagging options
Chapter 4	
4/1	Fuel element parameters and boundary conditions. Tubular interacting element
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5/4	Integral fuel element temperatures required for BATTLEAXE
5/5	Life peak values of standard deviation for the peak fuel and graphite temperatures

# TABLE 3/1

### REACTOR CORE DATA AND OPERATING PARAMETERS

Station electrical output, gross	MW	765
net	MW	734
Reactor thermal output	MW	1803
Fuel channel coolant inlet temperature	°c	300
Fuel channel coolant outlet temperature (core mean)	°c	800
Core power density	MW/m <sup>3</sup>	8.43
Diameter over active core	m	7.378
Diameter overall across flats	m	9.315
Length of active core	m	5.00
Across flats dimension of fuel brick	mm	400
Lattice pitch of hexagonal bricks	mm	405
Number of fuel channels		4533
Number of columns containing 17 fuel channels		228
Number of columns containing 9 fuel and 3 absorber channels		73
Total number of: black rods		91
grey rods		91
SSD units		48
Control rod diameter (both types)	mm	87
Uranium density in compact	gm/cc	0.8
Peak channel average dose	$n/cm^2$ EDN	2x10 <sup>21</sup>
Peak channel residence time (75% load factor)	days	770

# TABLE 3/2

#### CHANNEL GAS OUTLET AND FUEL TEMPERATURE DEPENDENCE ON THE NUMBER OF GAG CHANGES

Peak rated channel life mean gas outlet temperature 852°C.

Peak gas outlet temperature (°C)	Peak (AZIMUSTAP) fuel temperature (°C)
951	1269
898	1230
882	1216
874	1207
869	1204
	temperature (°C) 951 898 882 874

## TABLE 3/3

No. of gag changes	T g oC	T <sub>FP</sub> oo	T <sub>W1</sub> °C	T <sub>W2</sub> °C	T <sub>W3</sub> °C	F	f <sub>a</sub> (%)	f (%)	f (%)
4	852	1204	1009	1035	995	1.011	0.031	1.289	1.320
0	852	1269	1093	1130	1095	1.184	5.016	0	5.016
0	832	1249	1070	1107	1070	0.997	0	0	0

PEAK FUEL ELEMENT TEMPERATURES AND PARTICLE FAILURE FACTORS FOR FOUR AND NO GAG CHANGE SCHEMES (PEAK RATED CHANNEL)

(see Nomenclature)

## TABLE 3/4

PEAK FUEL AND GRAPHITE TEMPERATURE EFFECTS OF VARIOUS SPATIAL GAGGING OPTIONS

Gagging option	Î <sub>FP</sub> °C	T <sub>W1</sub> °C	Tw2 C	T <sub>W3</sub> °C
12 group	1189	1010	1035	998
.1	1151	1017	1044	1017
2	1171	992	1019	990
3	1172	994	1017	988

(See Nomenclature)

# TABLE 4/1

#### FUEL ELEMENT PARAMETERS AND BOUNDARY CONDITIONS TUBULAR INTERACTING ELEMENT

Peak rated channel (start-of-life) Peak rated position (2 m from inlet)

Operating conditions:			
Channel power	Q <sub>CHS</sub>	607	kW
Mixed gas outlet temperature	T <sub>C2</sub>	869	°c
Active core height	L	5.0	m
Volumetric rating	q‴'f	0.1396	W/mm <sup>3</sup>
Dimensions:			
Bore radius	r <sub>s1</sub>	15.05	mm
Fuel inner radius	r <sub>f1</sub>	20.15	mm
Fuel outer radius	r <sub>f2</sub>	27.50	mm
Annulus inner radius	r <sub>s2</sub>	32.60	mm
Channel radius	r <sub>W</sub>	37.90	mm
Thermal conductivities:			
Fuel	k <sub>f</sub>	28.5	W/m°C
Inner graphite sleeve	I kg	41.0	W/m°C
Outer graphite sleeve	kg	43.1	W/m°C
Typical AZIMUSTAP results:			
Heat split radius	r	24.46	mm
	r <sub>i</sub>	-4.40	
Temperatures:			0
Inner gas	T <sub>g1</sub>	485	°c
Outer gas	Tg2	605	°c
Inner sleeve surface	T <sub>W1</sub>	855	°c
Outer sleeve surface	T <sub>W2</sub>	835	°c
Inner interface surface	T <sub>I1</sub>	945	°c
Outer interface surface	T <sub>I2</sub>	882	°c
Inner fuel surface	T <sub>F1</sub>	1041	°c
Outer fuel surface	T <sub>F2</sub>	1060	°c
Peak fuel	TFP	1085	°c
Interface gaps:			
Inner radial gap	g1(0)	68.8	μm
Outer radial gap	g2(0)	202.5	μ <sub>m</sub>

# TABLE 4/2

## 'HOLLOW ROD' DATA FOR PLANAR REMOVAL ASSESSMENT

Reactor pressure		53	bars
Linear rating	q" <sub>T</sub>	805.5	W/cm
Channel flow rate	W	0.159	kg/s
Channel radius	r <sub>C</sub>	66.5	mm
Fuel sleeve outer radius	ro	52.0	mm
Bulk gas temperature $(T_0 = 1099^{\circ}C)$	Tg	866	°c
Bulk gas temperature $(T_0 = 1054^{\circ}C)$	Tg	815	°c
Bulk gas temperature ( $T_0 = 988^{\circ}C$ )	Tg	744	°c

# TABLE 4/3

VALUES IN THE EVALUATION OF PLANAR REMOVAL EFFECTS

		0		
b∕⊕	(°°)	Ē <sub>1</sub> (b/T) x 10 <sup>-5</sup>	$e^{b}/T$ x 10 <sup>-6</sup>	t (days)
15.2	1054	2.829	3.993	0
15.1	1063	2.578	3.613	533
15.0	1072	2.350	3.269	1021
14.9	1081	2.142	2.958	1471
14.8	1090	1.952	2.676	1885
14.7	1099	1.779	2.422	2257

 $T_{0} = 1054^{\circ}C$ 

(See Chapter 4 sub-section 4.2.1 for nomenclature)

### TABLE 4/4 RUSTAN RESULTS

								-					
RC 1 0.0326	RC 2 0 • 0 379	(M)										• .	
FL OW	EH1	EH2	RE1	RE2	RE	[ E ]	DE2	RM	UR.	E*1	<u>E≠2</u>	E1	F2
0.0500	0.0010	0,0010	14707	14706	14707	10-60	10. 60.	25,15	1.000	0.08	0.08	0.00654	0.2005.0
0.0500	0.0010	0 . 1000	_14022	15295	14707	_10*04	11.08	35.02	1.011	.0.08	8.69	0.00703	C. 0075
0.0500	0.0010	0.2000	12877	16280	14707	9.10	11.89	34,80	1.023	0.08	19.37	0.00718	0.010.0
J. 0500	0.0010	0.4000	11435	17521	147.07	7.90	12.92	34.52	1.068	0.09	45.11	0.00741	(.0):8
0.0500	0=1000	0.2000	13590		14707_	9.68	11.29	34.94	1. 021.	9.04		.00.0.8.29	0.0101
0.0500	0.1000	0.4000	12160	16897	14707	8.48	12.43	34+65	1.055	.9.43	45.66	0.00864	C.CJ41
0.2500	0.0010	0.0010		73532	73535	10.60	10.60	35+15	1.000	0.34	0.34	0.00475	0.0047
0.2500	0.0010	0.1000	58783			8.23	12.64	34.60	1,047_	0.36	44.18	0.00458	0.0083
0.2500	0.0010	0.2000	52825	91344	73535	7.26	13,48	34.37	1.074.	0:27	100.25	0.00511	0.0109
0.2500	0.0010	0.4000	47727	95729	72525	6.42	14,20	34,17	1.103	0.28	226.22	0.00523	C.0140
0.2500	0,1000	0.2000	67453	78762	7:5:5	9,59	11.47	34,91	1.025	47.86	104.69	0.00926	C.0116
0.2500	0.1000	0.4000	62091	82374	73535	8.68	12.25	34,70	1.051	49.59	225.68	0.00561	0.0149
1.2000	0.0010	0.0010	352956	352956	352967	10.60	10.60	35.15	1.000	1.28	1.38	0.00245	0.0024
1.2000	0.0010	0.1000	240938	449310	252967	6.90	12.78	34.28	1.072	1.51	212.89	0.00372	C. COE:
1.2000	0.0010	0,2000	218530	468583	352967	6,15	14,43	34-10	1,095	1.55	474.29	0.00379	0.0100
1.2000	0.0010	0.4000	196093	487883	252967	£ .39	15+08	22,92	1,125	1.60	1071.77	0.00:87	C.0157
1.2000	0.1000	0,2000	328049	374380	352967	9,73	11.34	34,95	1.021	233.42	503.96	0.00560	C.0110
1.2000	0.1000	0 4000	301672	397069	352967	8,80	12.15	34.73	1,048	241.42	1124.37	0.00592	0.0150
0.2500	0.1000	0.0010	88610	60564	7 25 25	13:03		35.21	0:956	.43.81	0.35	0.00830	C. CC4 9
0.2500	0,2000	0.0010	94997	5507(	72525	14,08	7.61	35.95	0.932	99.02	0.36	0.01077	(.005)
0.2500	0,4000	0,0010	100472	50360	7:5:55	14,99	6,82	36,15	0.908	222.34	0.38	0.01376	0.005
0.2500	0,2000	0.1000	79687	68239	73535	11,63	9.72	35.39	0.976	104.24	47.65	0.01156	0.009
0.2500	0.4000	0.1000	85224	63476	72525	12,57	8,91	35,60	0.951	233.57	49.15	0.01483	0.009

(See Appendix V for nomenclature)

% dwell	Dose n/cm <sup>2</sup> x 10 <sup>-20</sup>	QCH (kW)	(°C)	W <sub>1</sub> g/s	W2 g/s	Δt days
0	0	607	869	117.0	88.58	0
10	2.0	589	852	115.7	89.66	77
30	6.0	551	852	107.9	84.62	154
50	10.0	514	852	100.4	79.15	154
70	14.0	477	852	93.03	73.59	154
90	18.0	440	852	85.79	67.91	154
100	20.0	422	835	84.73	67.18	77

			TABLE	4/	5	
TIME	DEPENDENT	DATA	USED	IN	CORROSION	ASSESSMENT

Q <sub>CH</sub>	Channel power
T <sub>2</sub>	Mean channel gas outlet temperature
W	Bore flow rate
W2	Annulus flow rate
Δt	Time increments

%	Corrosion temperature reductions °C								
dwell	∆ T <sub>FP</sub>		Δ T <sub>W2</sub>	ΔÎ <sub>W3</sub>					
0	0	0	0	0					
10	0	0	0	2					
30	14	14	8	9					
50	22	24	18	18					
70	28	31	23	24					
90	30	35	28	27					
100	31	35	28	29					

TABLE 4/6

# A SUMMARY OF DATA RELATING TO THE PEAK RATED CHANNEL (also see TABLE 4/1)

Channel flow: life mean/life peak	kg/s	0.180/0.205
Channel gas outlet temperature: life mean/life peak	°c	852/869
Fraction of active core height containing fuel		0.94
Cold inirradiated radial fuel sleeve interface gaps inner/outer	μm	150/100
Coolant inlet pressure	bars	55•2
Fraction of channel power generated in moderator		0.08
Velocity head losses owing to discontinuities etc: bore/annulus		1•4/4•5
Fuel/sleeve interface conductance (nominal zero gap) (TRG 1000(R) $(43)$ )	W/m <sup>20</sup> C	2 x 10 <sup>4</sup>

MATERIAL 1	PROPERTY	DATA (	DERIVED	FROM	TRG	1000(	R	) (	43)	))	
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Property		Issue
Coefficient of thermal expansion:	compact	2
	graphite	2
Creep constant:	compact	1
	graphite	1
Thermal conductivity:	compact	3
	graphite	1
Wigner shrinkage:	compact	3
	graphite	1
Young's modulus:	compact	1
	graphite	1
Helium thermodynamic properties:		
Density		1
Specific heat (constant pressure)		1
Thermal conductivity		1
Viscosity (dynamic)		1

## COLUMN RATING AND COOLANT TEMPERATURE DATA REQUIRED FOR BATTLEAXE

(See Chapter 3-4.2 for nomenclature)

Age group	Column No.	R	Q	L	F	<b>T</b> 2	Age group	Column. No.	R	G	L	F	Ŧ2
1	41	909	1.0932	1	2	782		45	936	1.0689	1.035	2	782
	75	994	1.0248	1.035	1	819	6	132	1104	1.0153	1.035	1	819
	94	1059	1.0125	1.035	1	819		46	1028	1.0162	1.035	1	819
	77	1022	1.0223	1.035	1	819		8	1069	1.1019	. 1	1	754
-	30	926	1.0357	1.035	1	819		80	1100	1.0101	1.035	2	819
2	114	1033	1.0638	1.035	2	782		48	1022	1.0294	1.035	1	819
	31	983	1.028	1.035	1	819	7	42	1009	1.055	1.035	1	782
	115	1124	1.012	1.035	1	819	1. 1.	59	993	1.023	1.035	1	819
1.1	63	1074	1.0126	1.035	1	819		44	945	1.0306	1.035	1	819
	33	989	1.0375	1.035	1	819		6	936	1.0662	1	1	782
3	3	1034	1.0937	1	1	782		78	991	1.0655	1.035	2	782
	57	991	1.0627	1.035	1	782	8	7	1047	1.1327	1	1	754
	28	1048	1.0993	1	1	782		79	1083	1.0142	1.035	1	819
	16	1005	1.1433	1	1	754		32	1008	1.0224	1.035	1	819
	95	1048	1.0265	1.035	1	819		9	1009	1.0626	1.035	1	782
4	61	1015	1.0191	1.035	1	819		10	1021	1.042	1	1	819
	151	1064	1.0552	1.035	3	782	9	58 -	937	1.0404	1.035	1	819
	62	1057	1.0139	1.035	1	819		76	1032	1.0107	1.035	2	819
	19	1.118	1.0414	1.035	2	819		60	994	1.028	1.035	1	819
	1	1020	1.119	1	1	754		17	934	1.0889	1.035	2	782
5	2	947	1.1474	1	2	754		96	1065	1.0176	1.035	1	819
	27	1015	1.1042	1	1	754	10	18	1073	1.05	1.035	1	782
	43	1099	1.0422	1.035	2	319		97	1105	1.0126	1.035	1	819
	29	1037	1.0598	1.035	1	782	1815	47	1048	1.0136	1.035	2	819
	113	1069	1.0209	1.035	1	819		20	933	1.05	1.035	1	782
			flow def					21	895	1.0648	1.035	2	782

L = Leakage flow deficit F = 1, 17 fuel channels F = 2, 9 fuel channels F = 3, 3 fuel channels (centre channel in sextant representation)

Ext         0 <sup>2</sup> /c         Infantation         Normati and state           0000         000         01010         1004         1003         906         904         905         904         905         904         905         904         905         904         905         901         901         901         901         901         901         901         901         902         902         902         903         903         903         903         903         903         903         903	Left         Optimulation         Incomtation         Incomtation         Incomtation         Incomtation           000         700         11180         1233         1003         1103         1003         1033         1034         1033         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1035         1034         1035         1034         1035         1035         1035         1035         1035         1035         1035         1035         1035         1035         1035         1035         1035         1036         1034         1035         1035         1035         1035         1035         1035         1035         1035         1035         1035         1035         1035         1035         1035         1035         1035         1035	Age	Channel	Channel T	CEL.	T <sub>FP</sub> (°c)	EN .	T <sub>W1</sub> (°c)	M	T <sub>W2</sub> (°c)		T <sub>W3</sub> (°c)
600         870         1180         1213         1003         1004         1032         1039         1034         1035         1034         1035         1034         1035         1034         1035         1034         1035         1	600         630         1180         1213         1003         1004         1022         1039           300         700         1004         1004         1004         1004         1031         972         1039           300         700         1004         1004         1004         1004         1035         944         956           300         700         1002         1004         1005         966         964         953         964         954         954         954         954         954         954         954         954         954         956         954         956         954         955         954         955         954         955         954         955         954         955         956	-	kW	0 <sup>2</sup> C	Nominal	Normalised	Nominal.	Normalised	Nominal	Normalised	Nominal	7
300         700         700         704 <td>000         1/00</td> <td></td> <td>600</td> <td>850</td> <td>1180</td> <td>1213</td> <td>1003</td> <td>1004</td> <td>1032</td> <td>1039</td> <td>991</td> <td></td>	000         1/00		600	850	1180	1213	1003	1004	1032	1039	991	
300         700         897         916         793         796         827         833           300         700         890         1168         1202         998         1001         994         995           300         700         880         1004         1039         821         824         826         834         994         995           300         700         1004         1001         766         7193         716         811         811         811         811         813         814         994         994         995         994         995         996         994         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         995         995         996         995         996         995         995         996         995         996         995         996         995         996         995         995         996         995         996         995         996         995         995 </td <td>joc         joc         joc<td>1</td><td>300</td><td>850</td><td>1063</td><td>1080</td><td>620</td><td>977</td><td>1006</td><td>856 1014</td><td>804</td><td></td></td>	joc         joc <td>1</td> <td>300</td> <td>850</td> <td>1063</td> <td>1080</td> <td>620</td> <td>977</td> <td>1006</td> <td>856 1014</td> <td>804</td> <td></td>	1	300	850	1063	1080	620	977	1006	856 1014	804	
600         850         1168         1202         996         1001         994         995           300         700         1004         1039         821         821         824         985           300         800         906         766         1199         1231         1014         1015         818         81	600         870         1168         1202         996         1001         994         995           3000         700         1044         1003         962         964         982         985		300	700	899	. 916	661	798	827	833	800	
600         700         1004         1039         821         821         824         826           300         700         700         1034         1061         962         766         766         764         811         813         824         826         826         856         964         813         913         915         913         915         913         913         914         1014         1015         962         964         813         814	600         700         1004         1039         821         821         824         825         826         825         825         826         825         825         826         825         826         825         826         825         826         826         825         826         825         826 </td <td>1</td> <td>600</td> <td>850</td> <td>1168</td> <td>1202</td> <td>998</td> <td>1001</td> <td>994</td> <td>995</td> <td>950</td> <td></td>	1	600	850	1168	1202	998	1001	994	995	950	
300         650         1044         1061         962         764         982         984           300         700         700         786         164         1014         1014         1015         163           300         700         700         1179         1231         1014         1014         1015         163           300         700         1070         1096         980         986         986         905         998           300         700         1019         1015         1065         982         986         905         993           300         700         1019         1015         10165         982         986         905         993 <t< td=""><td>300         700         1044         1061         962         796         993         994           500         700         1199         1121         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1015         995         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         996         995         996</td></t<> <td>0</td> <td>600</td> <td>100</td> <td>1004</td> <td>1039</td> <td>821</td> <td>821</td> <td>824</td> <td>826</td> <td>776</td> <td></td>	300         700         1044         1061         962         796         993         994           500         700         1199         1121         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1014         1015         995         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         995         996         996         995         996	0	600	100	1004	1039	821	821	824	826	776	
300         700         889         906         786         786         811         813           500         700         850         1199         1231         1014         1015         1005           500         850         1027         10967         841         813         833         839           300         700         1027         10967         982         804         825         825           500         850         1183         1212         993         987         995         978           500         850         1019         1015         7165         789         802         825         827         993         974         995         978           500         850         1053         1055         789         791         806         992         803         8	300         700         899         906         786         786         811         813           300         700         899         906         786         1014         1014         1015         813           300         700         890         1070         1090         928         802         866         822         823           300         700         1013         11212         993         867         995         978           500         850         1013         11212         993         827         995         978           500         850         1033         1175         799         996         996         993           500         850         1036         1033         9175         799         998         974         993           500         850         1183         1210         980         917         916         993         917           500         850         1183         1210         980         917         916         917           500         1006         917         919         917         919         917         912           500         891 <td></td> <td>300</td> <td>850</td> <td>1044</td> <td>1061</td> <td>962</td> <td>964</td> <td>982</td> <td>984</td> <td>958</td> <td></td>		300	850	1044	1061	962	964	982	984	958	
600         890         1199         1231         1014         1015         1005         1	600         890         1199         1231         1014         1014         1015         1005           3000         8700         1027         1096         980         987         933         939           3000         8700         1037         1096         980         987         933         939           3000         8700         1033         1212         993         9915         789         987         983         939           3000         8700         1033         1015         1220         1039         915         789         987         983         987         983         983         984         984         984		300	700	889	906	.786	786	811	813	784	
600         700         1027         1067         841         843         844         843         844         843         844         843         844         844         843         844         843         844         843         844         843         844         843         844         843         844         843         844         844         843         844         843         844         843         844         843         844         844         843         844         844         843         844         844         843         844         843         844         843         844         843         844         843         844         843         844         843         844         843         844         843         843 </td <td>500         700         1027         1067         841         843         813         819         813         813         813         813         813         813         813         813         813         813         813         813         813         813         813         813         814         813         814         813         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813<!--</td--><td></td><td>600</td><td>850</td><td>1199</td><td>1231</td><td>1014</td><td>1014</td><td>1015</td><td>1006</td><td>971</td><td></td></td>	500         700         1027         1067         841         843         813         819         813         813         813         813         813         813         813         813         813         813         813         813         813         813         813         813         814         813         814         813         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813         814         813 </td <td></td> <td>600</td> <td>850</td> <td>1199</td> <td>1231</td> <td>1014</td> <td>1014</td> <td>1015</td> <td>1006</td> <td>971</td> <td></td>		600	850	1199	1231	1014	1014	1015	1006	971	
300         850         1070         1090         980         986         1002         998           300         700         1019         1212         993         987         995         978           600         850         1033         1212         993         987         995         978           300         700         1019         1055         959         966         983         974           300         850         1201         1230         1075         959         966         983         974           300         850         1201         1230         1008         837         844         832         893           300         700         1036         1084         837         844         832         823           300         700         1013         1084         837         844         832         814           300         700         1013         1013         8103         812         911           400         1013         1013         8104         837         844         832         814           300         700         10133         1017         9103 <t< td=""><td>300         850         1070         1090         926         926         1022         929         928         1022         939         931         932         932         932         932         932         932         932         932         932         932         932         932         932         933         931         933         931         933         931         933</td><td>2</td><td>600</td><td>100</td><td>1027</td><td>1067</td><td>841</td><td>843</td><td>833</td><td>830</td><td>785</td><td></td></t<>	300         850         1070         1090         926         926         1022         929         928         1022         939         931         932         932         932         932         932         932         932         932         932         932         932         932         932         933         931         933         931         933         931         933	2	600	100	1027	1067	841	843	833	830	785	
300         700         908         928         802         804         825         822           600         850         1183         1212         993         987         995         978           600         850         1013         1212         993         827         815         825           300         700         1013         1212         993         987         995         978           300         700         1035         1075         959         966         982         803         874           300         700         1036         1036         1036         932         817         808         803           300         700         1036         1034         1033         817         844         832         823           300         700         1034         1073         819         826         816         995           300         850         1043         1210         813         823         823         814         993           300         850         1043         9107         910         905         916         916           300         850         1043 <td>300         700         908         928         802         804         825         822           500         870         1013         11212         993         995         978         995         978           500         870         1013         1015         1015         915         719         995         978           300         870         1053         1015         993         966         985         915         914           300         870         1054         930         937         937         932         933           300         870         1036         1034         1083         937         937         932         933           300         870         1036         1033         1193         1210         981         932         933         934         933           300         700         1003         9103         917         905         914         934         933           300         700         1003         9103         913         913         913         914         934         934         934         934         934         934         934         934         934</td> <td>,</td> <td>300</td> <td>850</td> <td>1070</td> <td>1090</td> <td>980</td> <td>986</td> <td>1002</td> <td>998</td> <td>116</td> <td></td>	300         700         908         928         802         804         825         822           500         870         1013         11212         993         995         978         995         978           500         870         1013         1015         1015         915         719         995         978           300         870         1053         1015         993         966         985         915         914           300         870         1054         930         937         937         932         933           300         870         1036         1034         1083         937         937         932         933           300         870         1036         1033         1193         1210         981         932         933         934         933           300         700         1003         9103         917         905         914         934         933           300         700         1003         9103         913         913         913         914         934         934         934         934         934         934         934         934         934	,	300	850	1070	1090	980	986	1002	998	116	
600         850         1183         1212         993         967         995         978           500         700         1019         1063         825         825         827         895         978           500         700         1019         1053         915         789         789         915         809           500         700         1035         1053         915         789         916         915         804           500         700         1036         1230         1038         844         837         809         993         814         893         814         993         814         993         814         993         814         993         814         993         814         993         993         993         993         993         993         993         993         993         993         993         994         993         914         993         914         993         914         993         914         993         914         993         914         993         914         993         914         916         916         916         916         916         916         916         916<	600         850         1183         1212         993         867         995         978         995         978           300         700         1019         1063         825         887         895         987         895         993           300         700         1019         1063         1019         1063         802         803         803           300         700         1036         1024         1230         1003         9103         995         961         803         803           300         700         1036         1034         1023         9103         995         913         913         813         813         813         813         813         813         813         813         814         933         914         914         914         914         913         914         913         914         914         913         914         913         914         913         914         914         914         914         914         914         914         914         914         914         914         914         914         914         914         914         914         914         914 <t< td=""><td></td><td>300</td><td>100</td><td>908</td><td>928</td><td>802</td><td>804</td><td>825</td><td>822</td><td>16L</td><td></td></t<>		300	100	908	928	802	804	825	822	16L	
600         700         1019         1063         B25         B27         B15         B19         B09           300         700         1053         1075         795         795         91         80         91         80           300         700         1053         1075         795         795         91         80         91         80         91         80         91         80         93         81         80         93         81 <t< td=""><td>600         700         1019         1063         825         827         815         809           300         700         700         1013         1075         793         915         992         821         815         823         823         823         823         893         824         832         832         832         832         833         832         832         833<!--</td--><td></td><td>600</td><td>850</td><td>1183</td><td>1212</td><td>993</td><td>987</td><td>995</td><td>978</td><td>950</td><td></td></td></t<>	600         700         1019         1063         825         827         815         809           300         700         700         1013         1075         793         915         992         821         815         823         823         823         823         893         824         832         832         832         832         833         832         832         833 </td <td></td> <td>600</td> <td>850</td> <td>1183</td> <td>1212</td> <td>993</td> <td>987</td> <td>995</td> <td>978</td> <td>950</td> <td></td>		600	850	1183	1212	993	987	995	978	950	
300         850         1053         1075         959         966         982         974           300         850         1201         1230         1075         975         789         766         982         974           600         850         1230         1034         8131         844         833         805         993         993           300         850         1069         930         987         844         833         844         833         844         933         980         992         993         993         993         993         993         994         993         991         993         991         993         991         996         796         996         796         996         796         996         796         796         796         796         796         796         796         796         796         796         796         796         796         796<	300         750         1073         1075         759         966         982         974           500         700         700         893         1075         789         966         982         974           600         700         1056         1084         837         844         832         993         993           300         700         1066         1023         1073         845         946         992         803         993 </td <td>4</td> <td>600</td> <td>100</td> <td>1019</td> <td>1063</td> <td>825</td> <td>827</td> <td>815</td> <td>809</td> <td>768</td> <td></td>	4	600	100	1019	1063	825	827	815	809	768	
300 $700$ $893$ $915$ $789$ $791$ $808$ $802$ $600$ $850$ $1201$ $1230$ $1008$ $837$ $844$ $832$ $823$ $823$ $823$ $823$ $823$ $823$ $823$ $823$ $823$ $823$ $823$ $823$ $823$ $823$ $823$ $823$ $823$ $817$ $824$ $832$ $823$ $817$ $824$ $832$ $823$ $814$ $832$ $823$ $817$ $811$ $812$ $811$ $812$ $811$ $812$ $811$ $812$ <td< td=""><td>300         700         993         915         789         791         808         902           500         700         1036         1036         1036         1036         1036         932         823         823         823         823         823         823         823         814         932         932         932         932         932         932         932         932         933         844         933         823         914         932         932         932         932         932         932         932         932         932         933         934         933         934         932         934         932         934         933         934         933         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         935         935         935         935         935         935         935         935         935         935         935&lt;</td><td></td><td>300</td><td>850</td><td>1053</td><td>1075</td><td>959</td><td>996</td><td>982</td><td>974</td><td>956</td><td></td></td<>	300         700         993         915         789         791         808         902           500         700         1036         1036         1036         1036         1036         932         823         823         823         823         823         823         823         814         932         932         932         932         932         932         932         932         933         844         933         823         914         932         932         932         932         932         932         932         932         932         933         934         933         934         932         934         932         934         933         934         933         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         934         935         935         935         935         935         935         935         935         935         935         935         935<		300	850	1053	1075	959	996	982	974	956	
600         870         1201         1230         1008         837         844         933         823<	600         870         1201         1230         1008         803<		300	100	893	915	789	161	808	802	611	
600         700         1036         1084         837         844         832         823           300         850         1069         1993         980         992         1004         992           300         700         1069         1993         980         992         1004         992           600         700         1065         1093         816         975         973         914         992           600         700         1023         1073         817         975         975         975         971         995           300         850         1049         916         776         905         776         975         971         976         975         971         995         776           300         850         1034         1063         813         813         821         821         821         976           300         700         1034         1023         817         978         910         966         796           300         700         1034         1023         813         818         821         976         976           300         700         903 <td>600         700         1036         1084         837         844         832         823         814         932         823         814         932         823         814         932         823         814         932         823         814         932         823         814         932         823         814         932         933         931         932         932         931         932         931         932         931         932         931         932         931         931         932         931<!--</td--><td></td><td>600</td><td>850</td><td>1201</td><td>1230</td><td>1008</td><td>1002</td><td>1019</td><td>993</td><td>974</td><td></td></td>	600         700         1036         1084         837         844         832         823         814         932         823         814         932         823         814         932         823         814         932         823         814         932         823         814         932         823         814         932         933         931         932         932         931         932         931         932         931         932         931         932         931         931         932         931 </td <td></td> <td>600</td> <td>850</td> <td>1201</td> <td>1230</td> <td>1008</td> <td>1002</td> <td>1019</td> <td>993</td> <td>974</td> <td></td>		600	850	1201	1230	1008	1002	1019	993	974	
300         850         1069         1093         980         992         1004         992           300         700         906         930         805         812         823         814         992           600         850         1183         1210         987         979         1004         967         975           300         700         1023         10713         819         828         816         866         975           300         850         1049         916         776         801         966         776           300         850         1195         1220         1005         813         823         816         976           300         850         1034         1065         832         843         833         986         796           300         850         1034         1065         832         843         821         996           300         850         1034         1063         878         906         796           300         850         1068         832         843         823         821           300         850         1074         987 <td>300         850         1069         1093         980         992         1004         992           300         700         906         910         910         812         823         814         992           600         850         1183         1210         981         919         916         916         966           300         850         1195         1220         916         776         916         796           300         850         1195         1220         1005         916         796         966         796           300         850         1174         1194         960         977         803         823         866         796           300         700         1034         1095         877         807         813         823         876           300         700         1018         1053         976         976         971         991         991           300         700         9807         818         976         1007         962         991           300         700         9807         818         976         907         992         792</td> <td>5</td> <td>600</td> <td>100</td> <td>1036</td> <td>1084</td> <td>837</td> <td>844</td> <td>832</td> <td>823</td> <td>785</td> <td></td>	300         850         1069         1093         980         992         1004         992           300         700         906         910         910         812         823         814         992           600         850         1183         1210         981         919         916         916         966           300         850         1195         1220         916         776         916         796           300         850         1195         1220         1005         916         796         966         796           300         850         1174         1194         960         977         803         823         866         796           300         700         1034         1095         877         807         813         823         876           300         700         1018         1053         976         976         971         991         991           300         700         9807         818         976         1007         962         991           300         700         9807         818         976         907         992         792	5	600	100	1036	1084	837	844	832	823	785	
300         700         906         930         805         812         823         814           600         850         1183         1210         987         979         1000         967           700         700         1023         1073         819         828         816         805           300         850         1049         1064         792         807         905         771           300         850         1195         1220         1005         843         813         828         816         771           300         700         1034         1025         832         843         833         986         771           300         700         1034         1085         832         843         833         821         996         771           300         700         1034         1093         978         933         821         996         791           300         700         937         871         978         971         971           300         700         1073         817         984         821         810           300         700         979	300         700         906         930         805         812         823         814           600         850         1183         1210         987         979         1000         967           300         700         1023         1073         819         828         816         806           300         850         1195         1220         1064         702         8017         965         796           300         850         1195         1220         1005         813         813         816         916           300         850         1034         1085         812         813         813         814           300         850         1034         1085         837         843         831         816           300         850         1013         1066         837         813         831         811           300         850         1174         1194         987         813         813         811         804           300         850         10168         1035         827         813         811         804           300         700         807         913<		300	850	1069	1093	980	992	1004	992	616	
600         850         1183         1210         987         979         1000         967           500         700         1023         1073         819         828         816         806         971           300         700         1023         1073         819         960         975         975         975         975         971         876         976         971         876         976         971         876         976         971         876         976         971         876         976         7071         796	600         850         1183         1210         967         979         1000         967         979         1000         967         971         965         971         965         971         965         971         965         971         965         971         965         971         965         971         965         971         965         971         965         971         965         971         965         971         965         971         965         971         965         971         995         972         995         971         995         971         995         975         995         975         995         975         971         975         975		300	200	906	930	805	812	823	814	794	- 9
600         700         1023         1073         819         828         816         806           300         850         1049         1064         960         975         985         971           300         850         1049         1064         960         975         985         971           300         850         1195         1220         1005         891         906         796           600         850         1195         1220         1005         832         843         821         996           300         850         1034         1095         977         807         818         821         996           300         850         1174         1194         987         818         826         811         991           300         850         1018         1095         976         987         916         962           300         850         1078         960         976         960         962         961           300         850         1078         807         818         960         962         961           300         850         1078         960 <td>600         700         1023         1073         819         828         816         806         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         995         971         995         971         995         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         971         971         971         971         971         971         971         971         971         971         971         971         972         971         972         971         972         971         972         972         972         972<!--</td--><td></td><td>600</td><td>850</td><td>1183</td><td>1210</td><td>786</td><td>616</td><td>1000</td><td>196</td><td>953</td><td></td></td>	600         700         1023         1073         819         828         816         806         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         905         971         995         971         995         971         995         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         991         971         971         971         971         971         971         971         971         971         971         971         971         971         972         971         972         971         972         971         972         972         972         972 </td <td></td> <td>600</td> <td>850</td> <td>1183</td> <td>1210</td> <td>786</td> <td>616</td> <td>1000</td> <td>196</td> <td>953</td> <td></td>		600	850	1183	1210	786	616	1000	196	953	
300         850         1049         1064         960         975         985         971           300         700         891         916         7792         801         906         776           300         850         1195         1220         1005         997         1023         986         776           600         850         1195         1220         1005         937         803         821         821           300         850         1034         1093         978         996         1007         991           300         700         902         927         807         818         821         821           300         700         902         927         807         818         828         811           300         700         918         807         818         807         966         962           300         850         1078         920         876         976         967         962           300         850         1078         950         976         977         969         969	300         850         1049         1064         960         975         965         971           300         700         891         916         792         801         905         796           600         850         1195         1220         1005         832         843         821         996           300         850         1174         1194         987         976         1003         996           300         850         1174         1194         987         976         1001         991           300         850         1018         1067         820         832         811         821         996           300         850         1174         1194         987         976         1003         962         971           300         850         1018         1067         820         832         810         962         991           300         850         1186         1203         1076         827         807         962         992           300         850         1186         1203         1006         995         995         995         996         996         9	9	600	100	1023	1073	819	828	816	806	768	
300         700         891         916         792         801         806         796           600         850         1195         1220         1005         997         1023         986           600         700         1034         1085         832         843         833         821           300         850         1078         927         807         996         796           300         700         1003         978         978         996         991           300         700         1068         1093         978         987         996         991           300         700         1074         987         987         976         1007         991           300         700         1018         1067         822         810         962           300         850         1078         950         976         962         963	300         700         891         916         792         801         806         796           600         850         1195         1220         1005         997         1023         986         796           300         870         1034         1085         8132         843         813         821         821           300         850         1174         1194         987         976         1007         991           300         850         1174         1194         987         818         822         810         966           300         850         1018         1067         820         832         817         961         962           300         850         1018         1067         820         832         817         962         962           300         850         1018         1067         826         832         817         962         962           300         850         1186         1203         960         979         967         962           300         850         1074         987         966         966         966         966         962 <t< td=""><td>1</td><td>300</td><td>850</td><td>1049</td><td>1064</td><td>960</td><td>516.</td><td>985</td><td>971</td><td>958</td><td></td></t<>	1	300	850	1049	1064	960	516.	985	971	958	
600         850         1195         1220         1005         997         1023         986           600         700         1034         1085         832         843         833         883         821         991         960         960         960         960         960         960         969	600         850         1195         1220         1005         832         843         803         833         843         833         843         833         843         833         843         823         843         823         843         823         823         824         823         823         824         823         824         823         824         823         824         823         824<		300	100	891	916	.792	801	806	796	2175	
600         700         1034         1085         832         843         833         821           300         850         1068         1093         978         996         1007         991           300         700         7002         1093         987         878         823         821           300         700         902         1093         887         987         996         1007         991           600         700         1074         987         987         976         1004         962           300         850         1078         960         976         987         969	600         700         1034         1085         832         843         833         821         821           300         850         1068         1093         978         996         1007         991         992         991         992         991         992         991         992         991         992         991         992         991         992         991         992         991         992         991         992         991         992         991         992         991         992         991         992         991         992         991         991         991         991         991         991         991         991         991         991         991         991<		600	850	1195	1220	1005	166	. 1023	986	975	
300         850         1068         1093         978         996         1007         991           300         700         902         927         807         818         822         810           600         850         1174         1194         987         976         1004         962           600         700         1018         1067         820         832         810         962           300         850         1074         987         987         976         1004         962           300         850         1053         1067         820         832         817         804	300         850         1068         1093         978         996         1007         991           300         700         902         927         807         818         822         810         991           600         850         1174         1194         987         987         976         1007         991           300         850         1078         1078         960         979         877         962           300         850         1078         1076         820         832         817         962           300         850         1076         818         913         795         807         917         962           300         850         1076         813         913         795         807         917         962           300         850         1074         1075         833         834         822         913         929           300         700         903         927         809         922         821         809           300         850         1074         908         933         922         821         809           3000         850	L.	009	200	1034	1085	832	843	833	821	783	
300         700         902         927         807         318         822         810           600         850         1174         1194         987         976         1004         962           600         850         1018         1067         820         832         811           300         1018         1067         820         832         817         962           300         850         1078         960         977         967         967	300         700         902         927         807         818         822         810           600         850         1174         1194         987         976         1004         962         810           600         850         1174         1194         987         976         1004         962         804           300         700         1053         1067         820         879         967         962         792           300         700         1053         1078         976         807         967         792         804         965           300         700         1053         1078         975         807         967         792         804         965           500         850         1078         1205         813         814         822         813         834         823           300         700         903         927         809         927         809         922         809         922         803           300         7000         809         922         831         834         823         809         922         804         923         903         922	-	300	850	1068	1093	: 978	966	T001 -	991	978	
600         850         1174         1194         987         976         1004         962           600         700         1018         1067         820         832         817         962           300         850         1053         1078         960         9779         987         969	600         850         1174         1194         987         967         1004         962           600         700         1018         1067         820         832         817         804         965           300         850         1078         905         950         967         965         792         804         965         792         804         965         792         804         965         792         804         965         995         969         992         992         792         804         992         992         992         992         992         993         992         993         992         993         992         993         993         992         993         993         993         993         993         993         993         993         993         993         993         993         993         993         993         993 </td <td></td> <td>300</td> <td>100</td> <td>902</td> <td>927</td> <td>807</td> <td>: 818</td> <td>822</td> <td>810</td> <td>788</td> <td></td>		300	100	902	927	807	: 818	822	810	788	
600         700         1018         1067         820         832         817         804           300         850         1053         1078         960         979         987         969	600         700         1018         1067         820         832         817         804           300         700         1053         1078         950         932         817         950           300         700         700         1053         1078         950         957         795         967         955           600         700         1086         1203         1006         995         1026         982           500         850         1074         1095         815         844         822           300         850         1074         1096         973         993         993         992           300         850         1074         1096         973         821         894         922           300         850         1074         1096         979         993         922         809           300         850         1064         817         809         922         809           300         850         1054         809         922         809         922           300         850         1054         810         971         809         922		600	850	1174	1194	987	976	1004	962	954	
696 1.86 6.26 966 9201 650 058 0000 0000 0000 0000 0000 0000 0	300         850         1053         1078         960         979         987         969           300         700         888         913         7795         807         967         969           300         700         886         913         7795         807         805         792           600         850         1186         1203         1006         995         1026         982           300         700         1028         1074         1098         979         999         1009         993           300         700         1074         1098         979         989         821         809           600         700         1008         1179         989         821         809         923           300         850         1164         1179         989         971         804         904           300         850         1054         824         831         910         904         904           300         700         899         912         791         804         904         904           300         1006         912         707         810         971 <td>8</td> <td>600</td> <td>. 700</td> <td>1018</td> <td>1067</td> <td>820</td> <td>832</td> <td>. 817</td> <td>804</td> <td>767</td> <td></td>	8	600	. 700	1018	1067	820	832	. 817	804	767	
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LIFE PEAK VALUES OF STANDARD DEVIATION FOR THE PEAK FUEL AND GRAPHITE TEMPERATURES

Prime mover	ø	110.00	σ <sub>T</sub> (u)	°C	oC		
	1.1.1.1.1.1.1	TFP	T <sub>W1</sub>	Tw2	₽ <sup>₩3</sup>		
Physics uncertainties:				1	-		
<ul> <li>(i) Column power</li> <li>(ii) Across column rating gradient</li> <li>(iii) Axial power distribution</li> <li>(iv) Fraction of heat generated in moderator</li> </ul>	0.045 0.02 0.04 0.01	9 18 17 4	2 14 11 3	2 15 3 1	0 14 1 0		
(v) Control rod position (vi) Across pin rating gradient (vii) Fast neutron dose	( <u>47</u> ) 0.01 0.19	10 4 8	7 3 7	7 1 7	2 0 0		
Flow uncertàinties		1 america	-	1	1.100		
<ul> <li>(i) Flow division between channels</li> <li>(ii) Flow division between sub channels</li> </ul>	0.02 0.02	14 14	14 14	15 15	14 14		
(iii) Flow leakage	0.01	7	11	11	10		
Material property uncertainties:			-				
<ul> <li>(i) Compact CTE</li> <li>(ii) Tube CTE</li> <li>(iii) Compact shrinkage</li> <li>(iv) Tube shrinkage</li> <li>(v) Compact conductivity</li> <li>(vi) Tube conductivity</li> <li>(vii) Compact emmissivity</li> <li>(viii) Tube emmissivity</li> </ul>	0.10 0.10 0.13 0.15 0.19 0.10 0.04 0.04	2 3 6 1 10 7 2 2	2 2 5 1 0 0 1	2 2 5 1 0 0 1	0 0 0 0 0 0 0 0		
dditional uncertainties:			1				
Heat leakage Column mean T <sub>2</sub> Pin end effects Column mean T <sub>1</sub> Bowing Anti-bowing ribs Fuel/sleeve interface resistance Dimension tolerances Fuel enrichment Fuel heavy metal density	0.005 . (47) (47) (47) (47) (47) (47) 0.3 (49) 0.01 0.02	1 10 5 2 10 3 2 10 4 9	0 10 5 2 10 3 0 7 3 6	0 10 5 2 10 3 0 7 1 2	0 10 0 2 0 0 0 1 1		
	σ <sub>p</sub>	44.5	36.3	35.2	28.3		

.

<u>Note</u>: Where  $\sigma$  components not given see given references

#### FIGURES

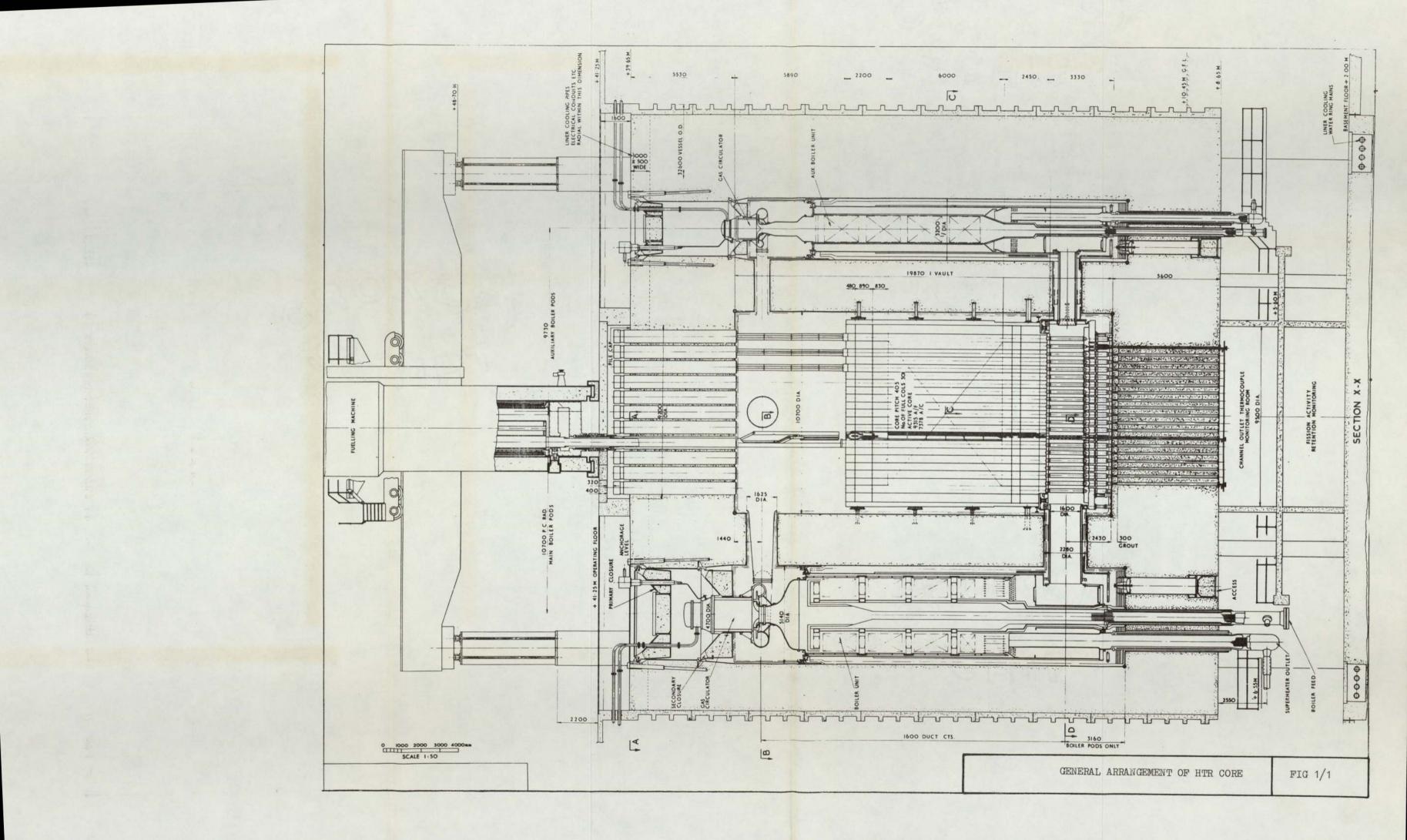
Fig	Title
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1/1	General arrangement of HTR core
Chapter 2	
2/1	The coated particle
2/2	Fuel pin design concepts
2/3	The tubular interacting fuel element
2/4	Oldbury 'B' fuel brick
2/5	Oldbury 'B° control brick
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3/11	Histogram of peak channel wall temperature for one and twelve group schemes
3/12	Sextant of core showing column flows, mean and peak channel gas outlet temperatures
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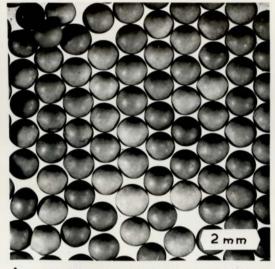
Fig	Title
3/13	Diagrammatic sketch of an irradiated column showing typical gap openings and their effect on flow distribution
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4/6	The dependence of dimensionless radius of no shear $(\bar{r}_{s})$ on radius ratio $(\bar{r})$
4/7	Developed Nusselt numbers in smooth concentric annuli - radius ratio dependence
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4/11	Time evolution of interface gaps and pressures at the peak rated axial position (2m from inlet)
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Fig	Title
4/13	Axial distribution of thermal expansion increments on
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4/15	Burn-off rate (k <sub>eff</sub> ) versus graphite temperature
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4/17	Hollow rod surface temperature versus fuel dwell for various start-of-life values
4/18	Graphite removal versus fuel dwell for various start-of-life surface temperatures
4/19	Development of surface roughness
4/20	Critical values of roughness parameter, $(\epsilon/D_e)_c$ : Reynolds number dependence
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4/22	A* versus E* showing roughness regimes
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4/25	Dimensionless radius of no-shear $(\bar{r}_s)$ against $\epsilon/D$ and Reynolds number in an annulus
4/26	$f_{\rm 1/F}$ versus Reynolds number for various values of $\epsilon^{\rm 2/D}_{\rm e}$
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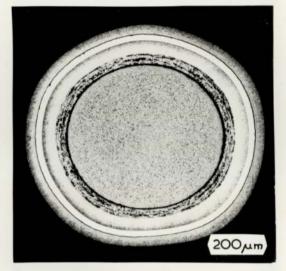
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5/3	Integral data method - Peak fuel temperature
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5/6	Spatial distribution of channel peak Best Estimate fuel temperature
5/7	Spatial distribution of channel peak Best Estimate inner pin surface temperature
5/8	Spatial distribution of channel peak Best Estimate outer pin surface temperature
5/9	Spatial distribution of channel peak Best Estimate channel wall temperature
5/10	Axial distribution of peak fuel temperature standard deviation
5/11	Time evolution of peak fuel temperature standard deviation
5/12	Expected frequency distribution of channel peak fuel
	temperature 184

Fig	Title
5/13	Expected frequency distribution of channel peak inner pin surface temperature
5/14	Expected frequency distribution of channel peak outer pin surface temperature
5/15	Expected frequency distribution of channel peak channel wall temperature

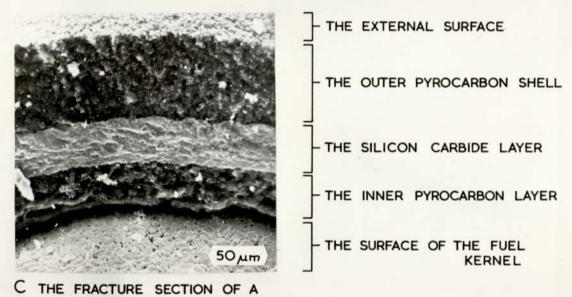




A THE SUPERFICIAL APPEARANCE

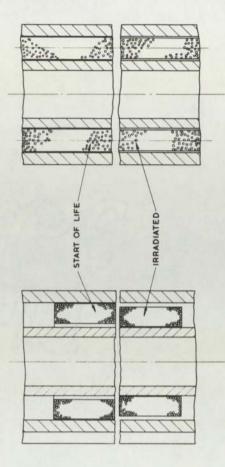


B A POLISHED SECTION



COATING BY "STEREOSCAN"

THE COATINGS ON A DRAGON FUEL PARTICLE



10 196

0000 g

5.A.

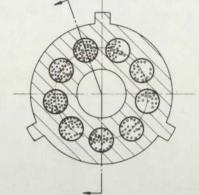
- START OF LIFE

W80

IRRADIATED

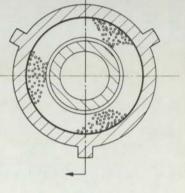
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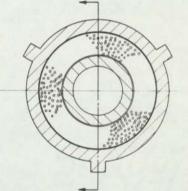


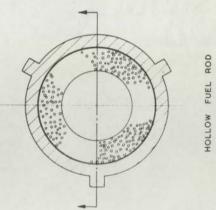
TUBULAR FUEL ROD TELEDIAL DESIGN

TUBULAR FUEL ROD NON - INTERACTING DESIGN





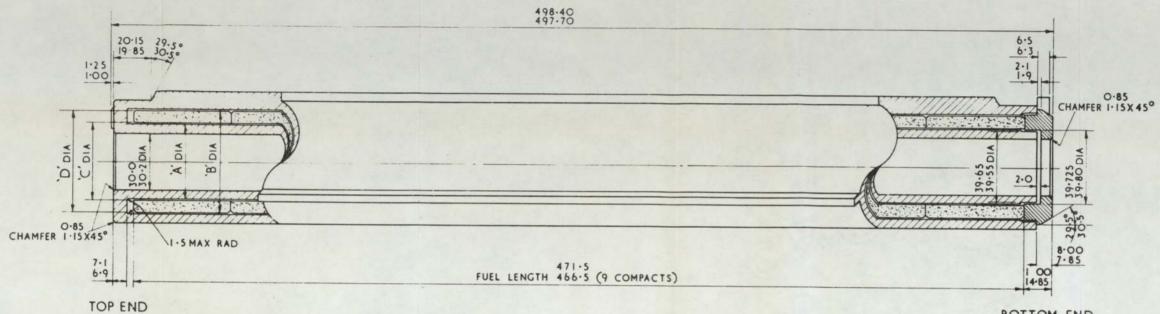




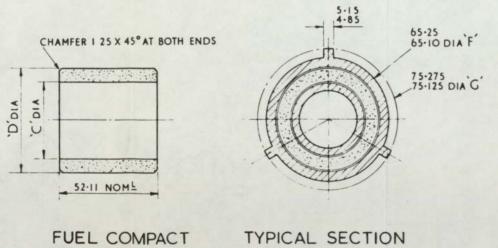
FUEL PIN DESIGN CONCEPTS

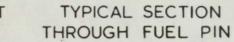
FIG 2/2

DESIGN

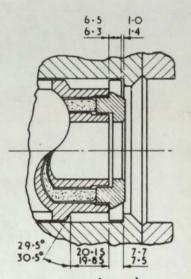


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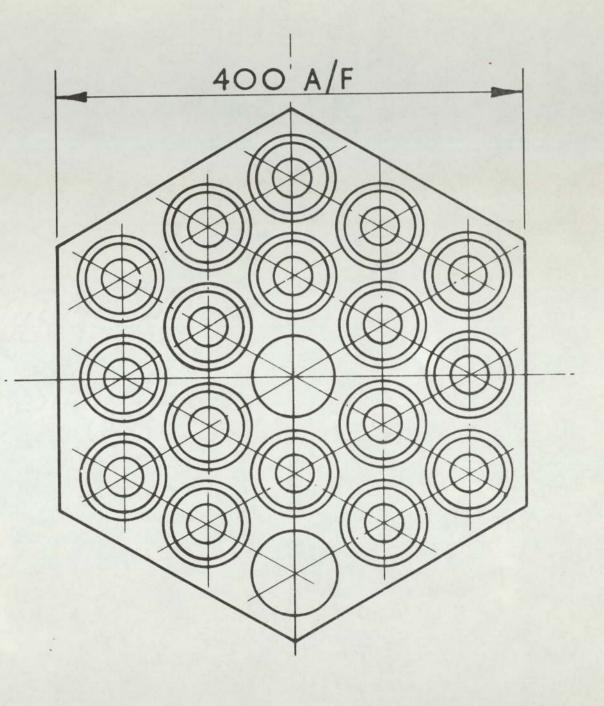
BOTTOM END

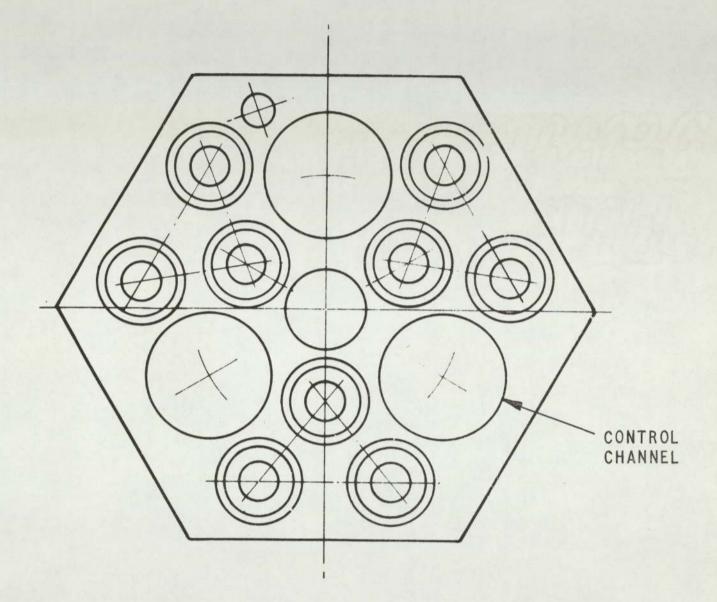


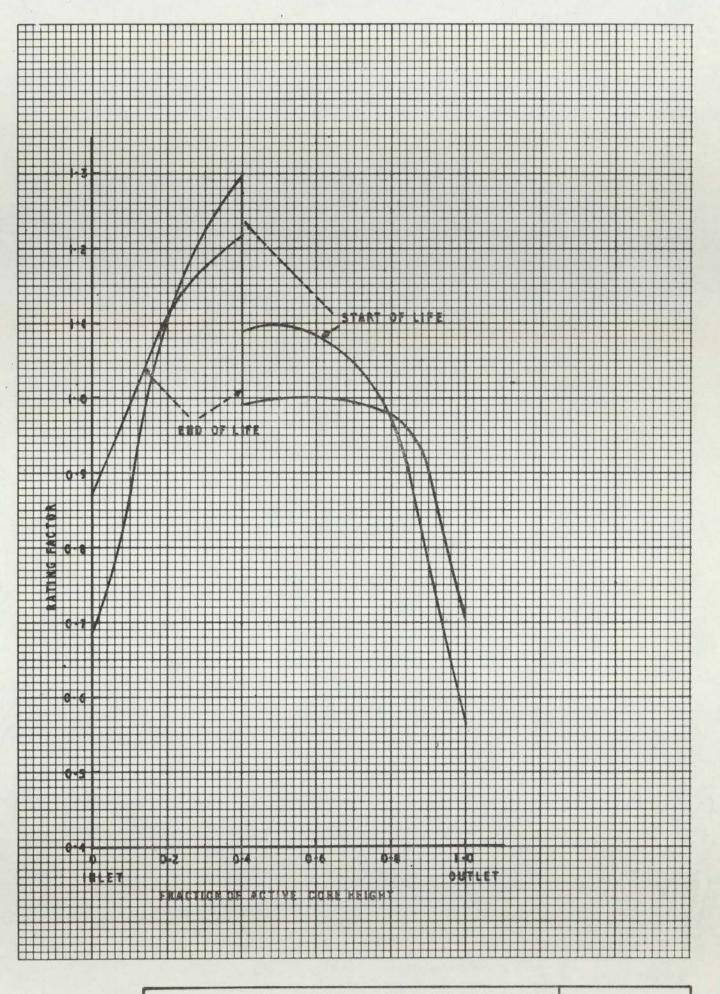
SECTION 'X-Y'SHOWING FUEL PIN IN CHANNEL

THE TUBULAR INTERACTING FUEL ELEMENT

FIG 2/3







AXIAL RATING PROFILES AT THE START AND END OF LIFE OF A PEAK RATED CHANNEL

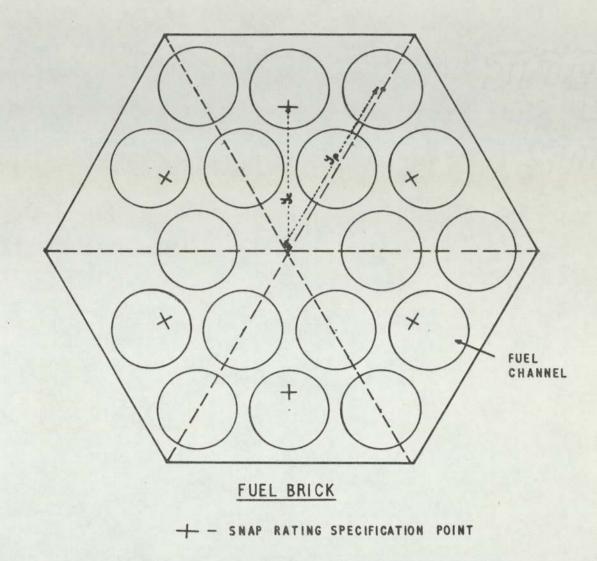
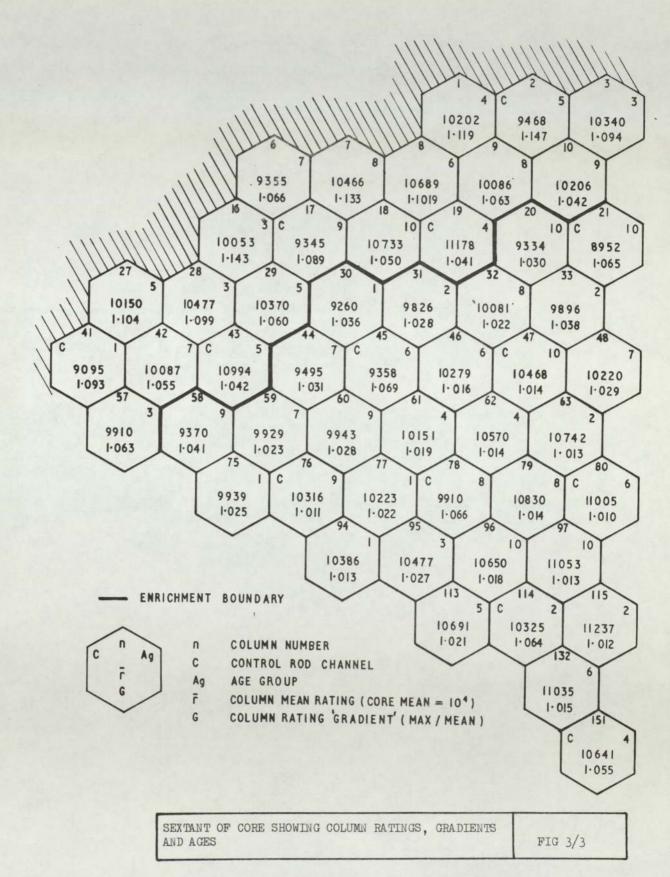
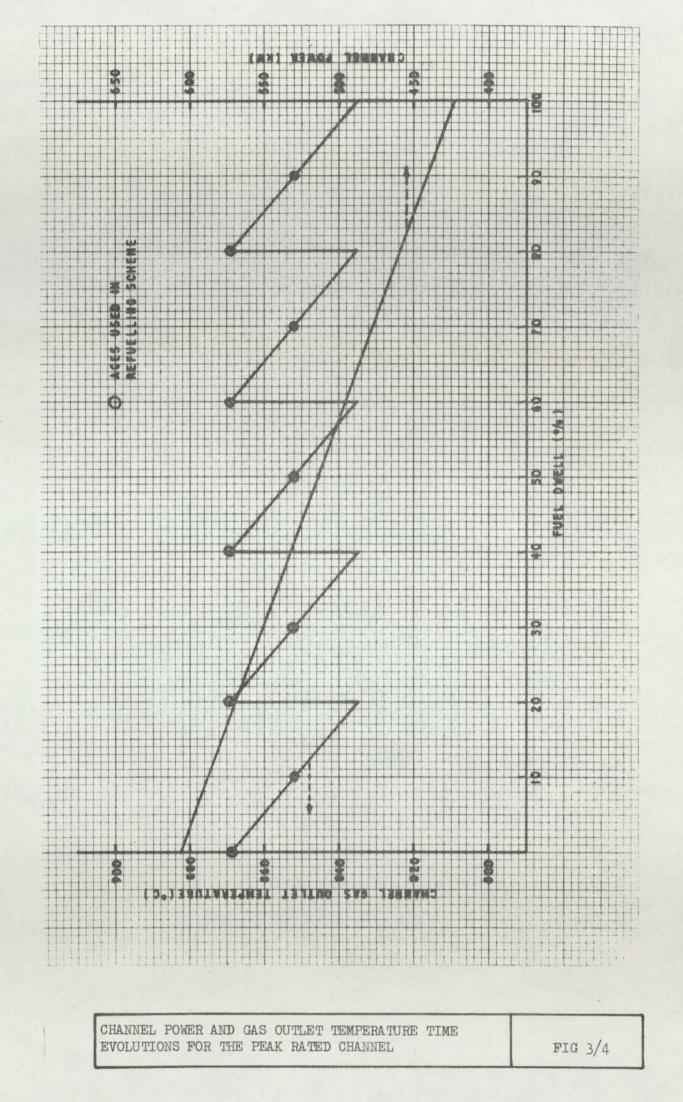
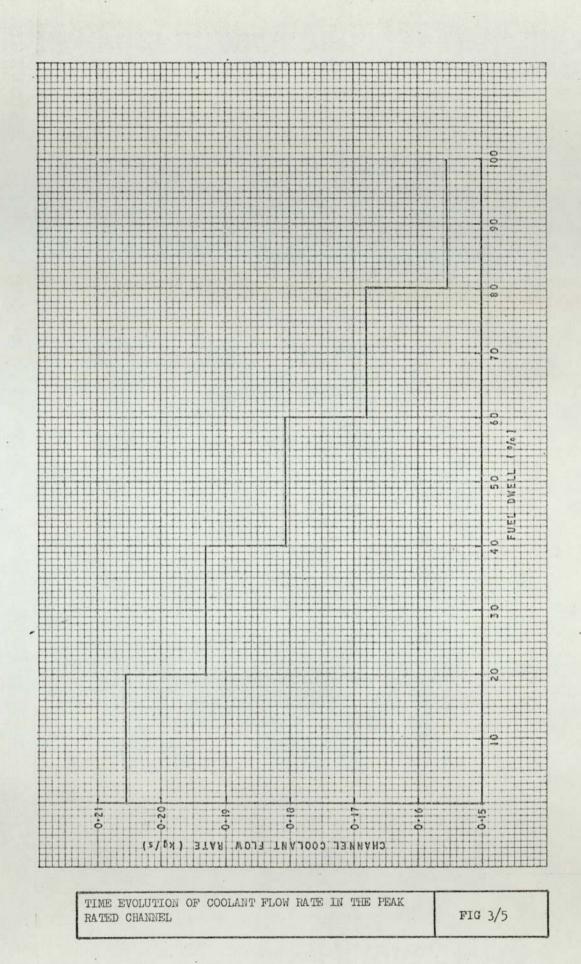
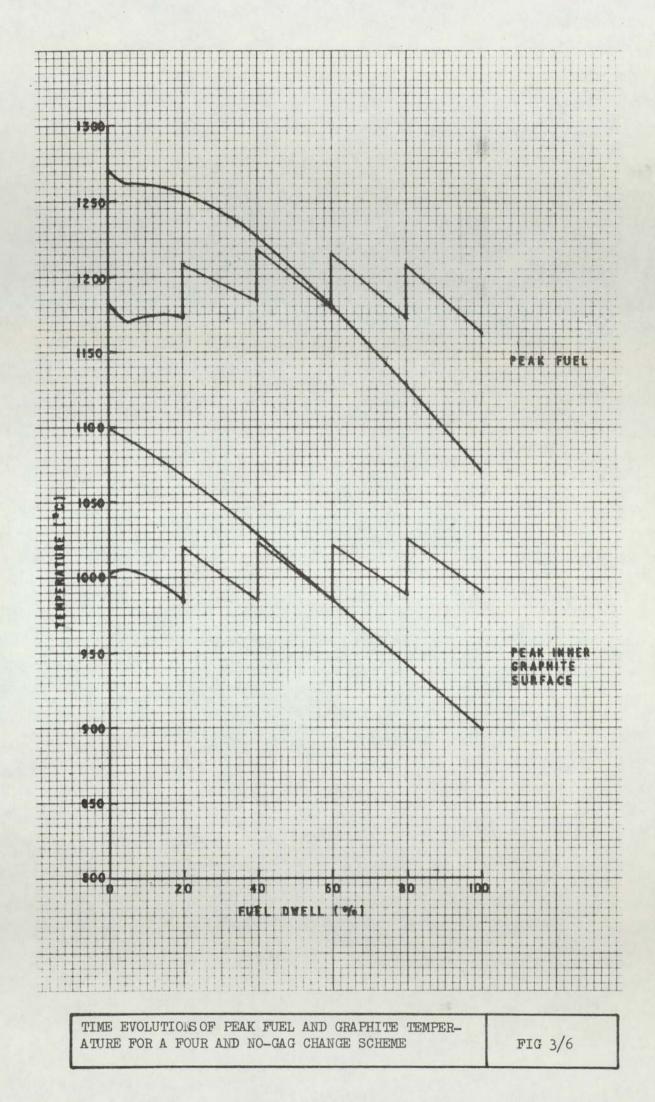


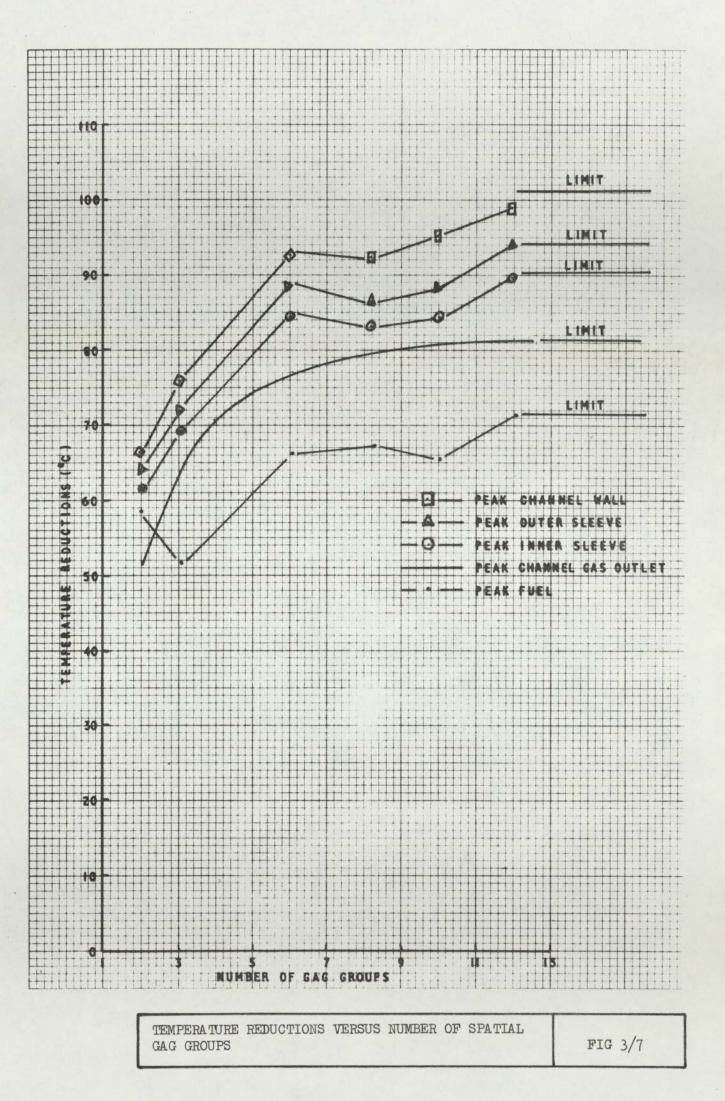
FIG 3/2

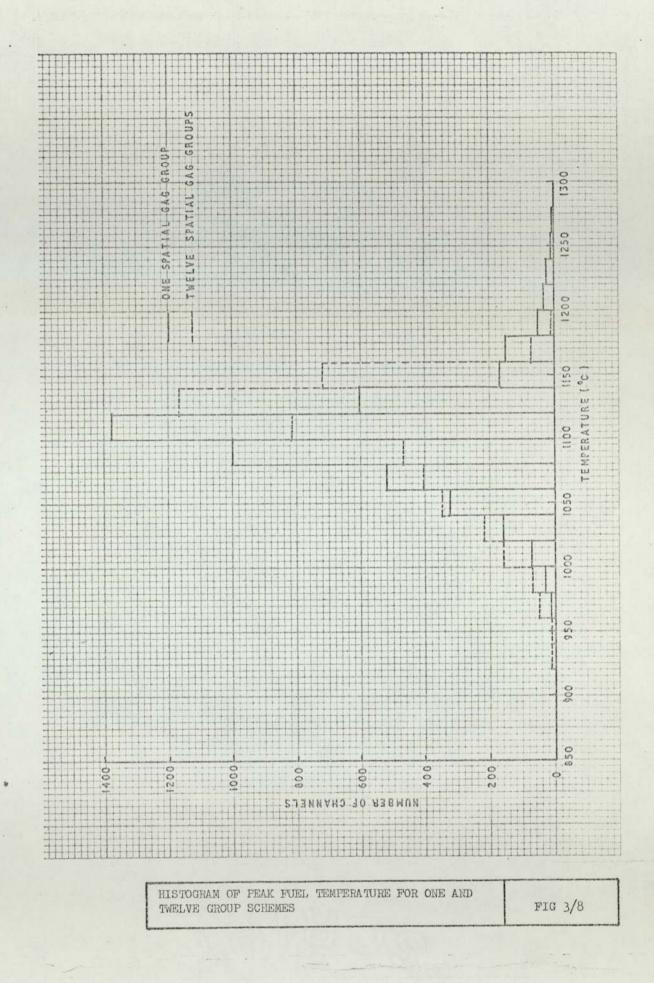


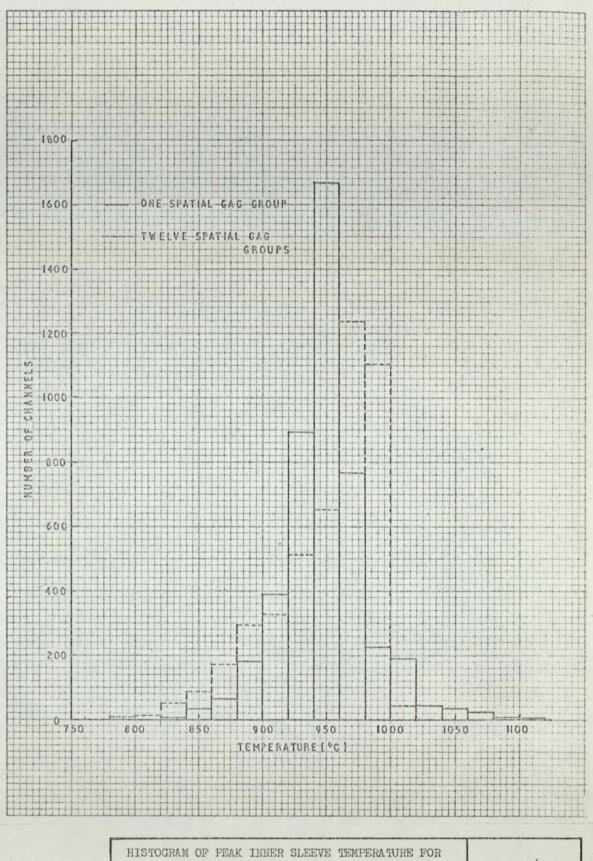






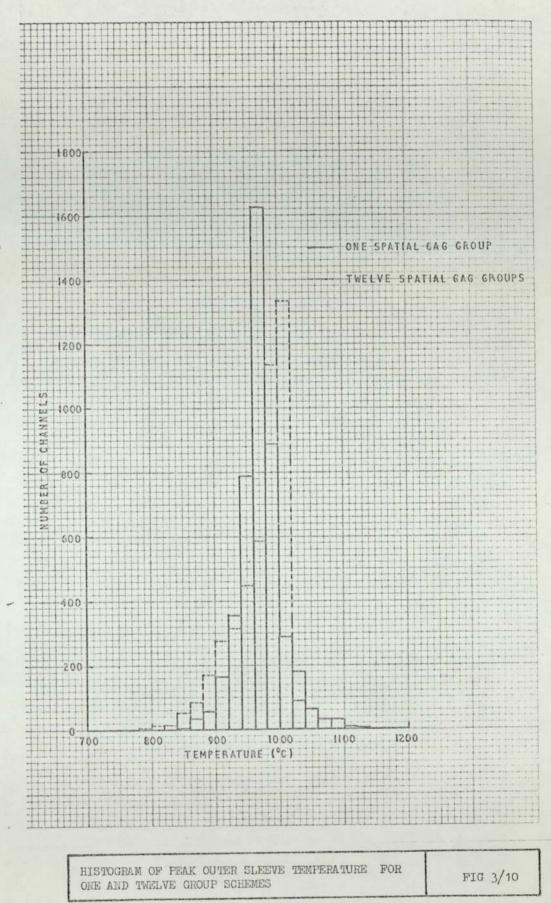


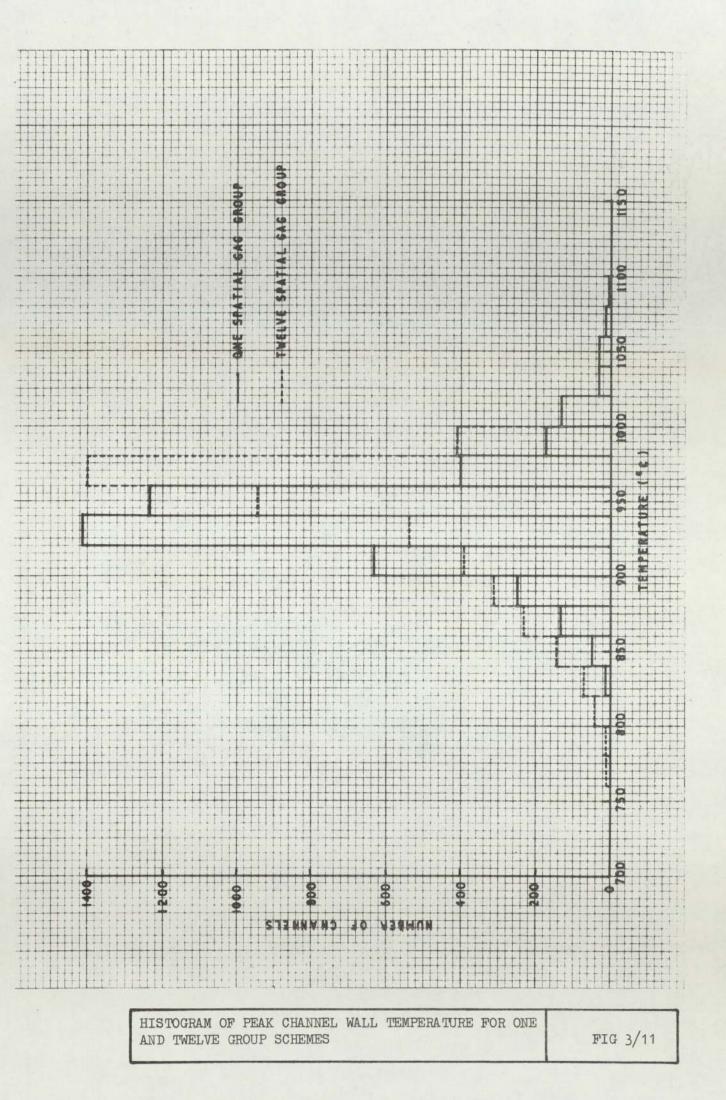


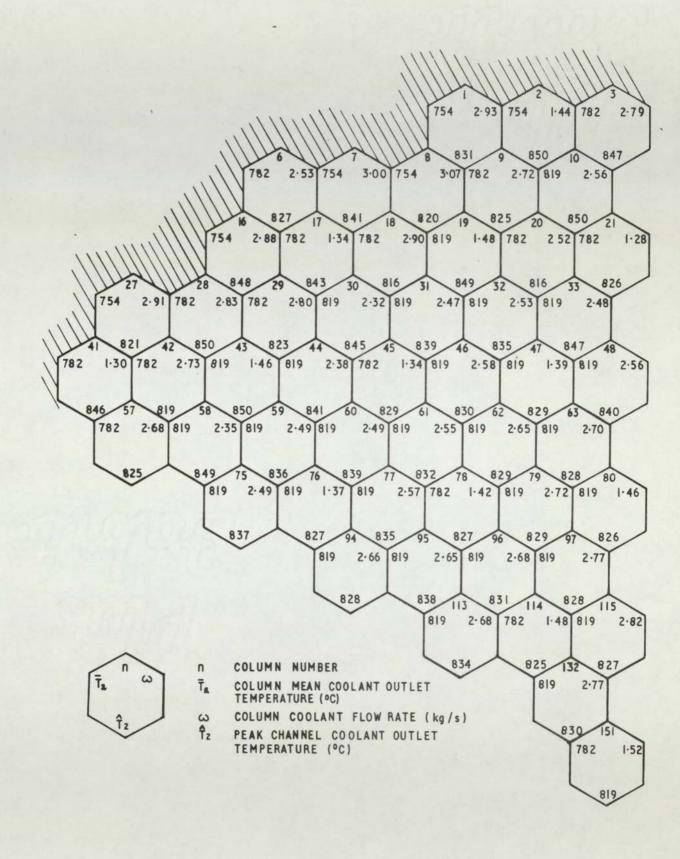


ONE AND TWELVE GROUP SCHEMES

FIG 3/9







SEXTANT OF CORE SHOWING COLUMN FLOWS, MEAN AND PEAK CHANNEL GAS OUTLET TEMPERATURES

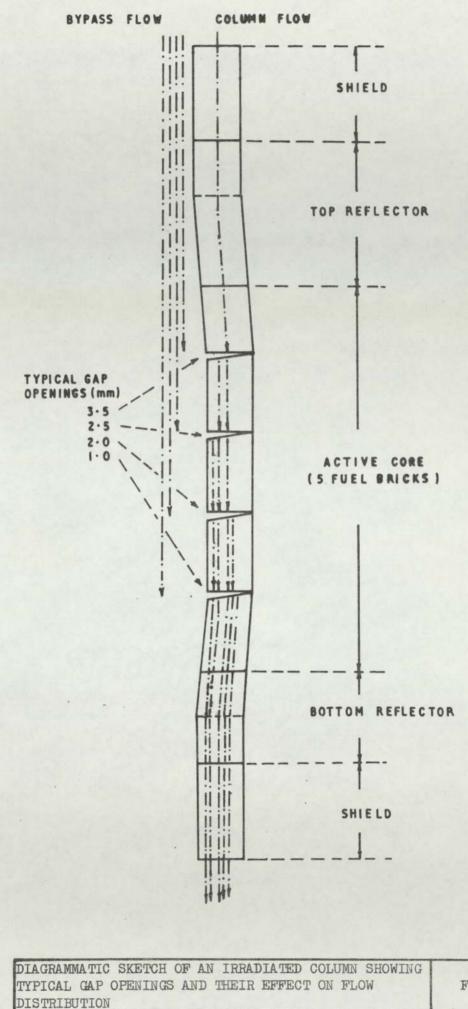
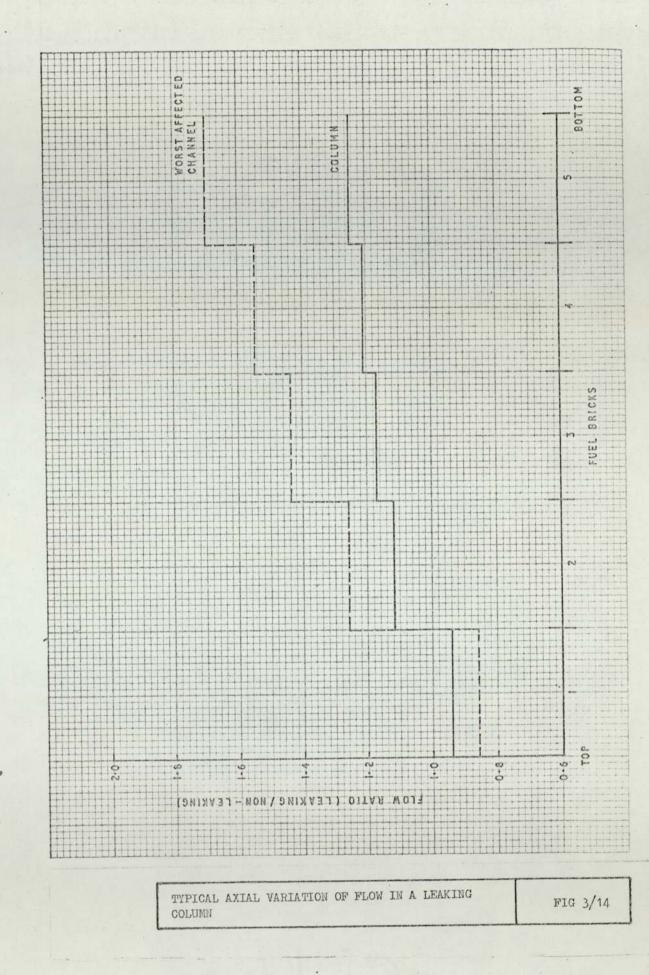
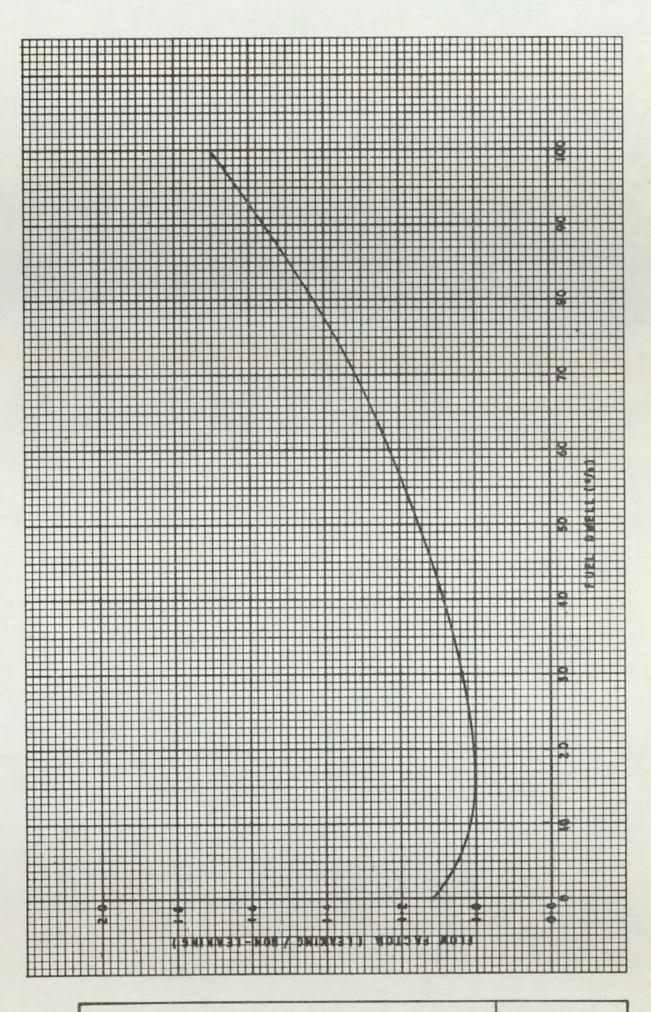
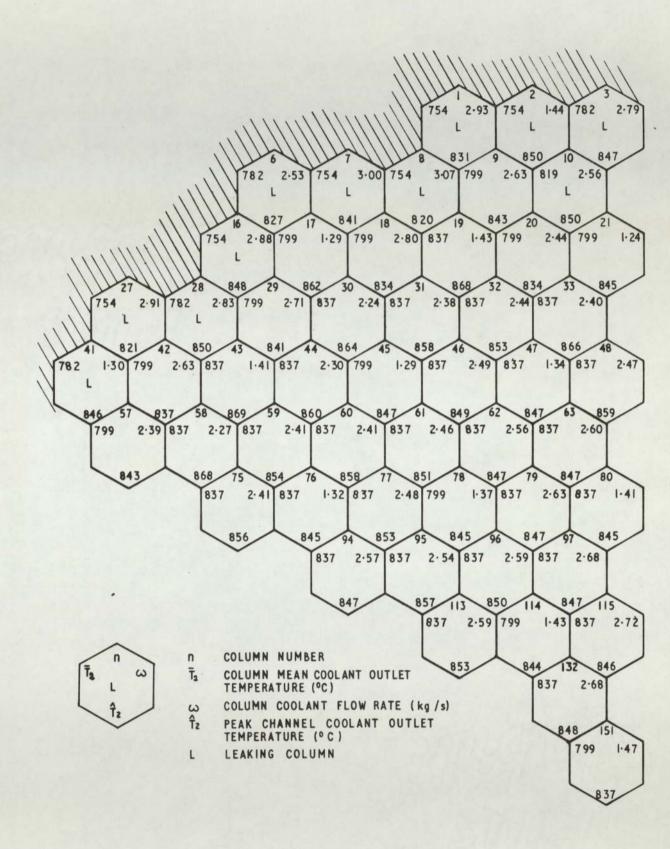


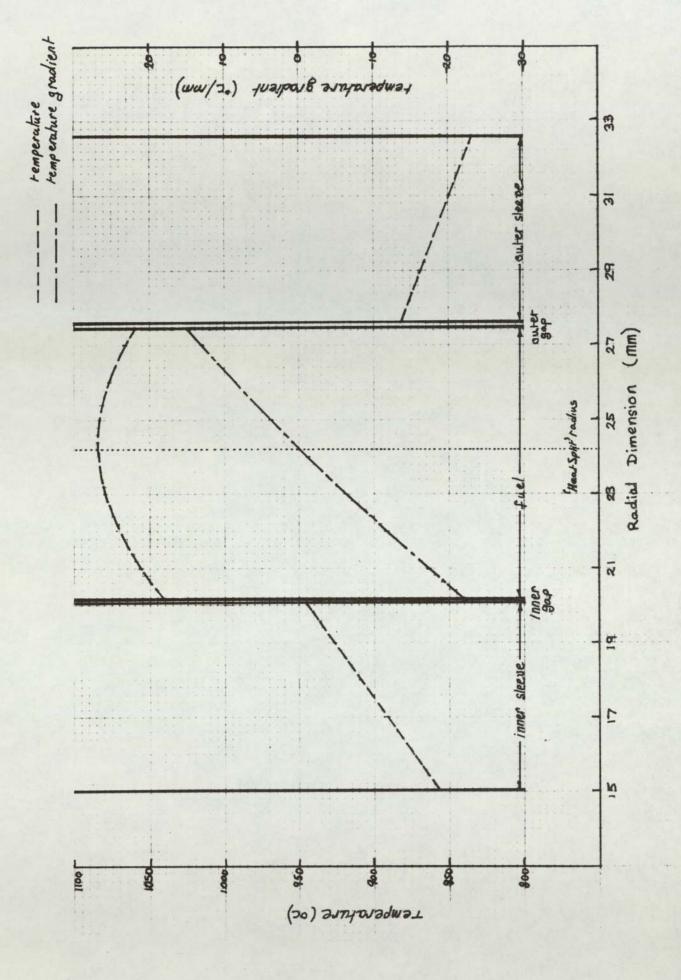
FIG 3/13





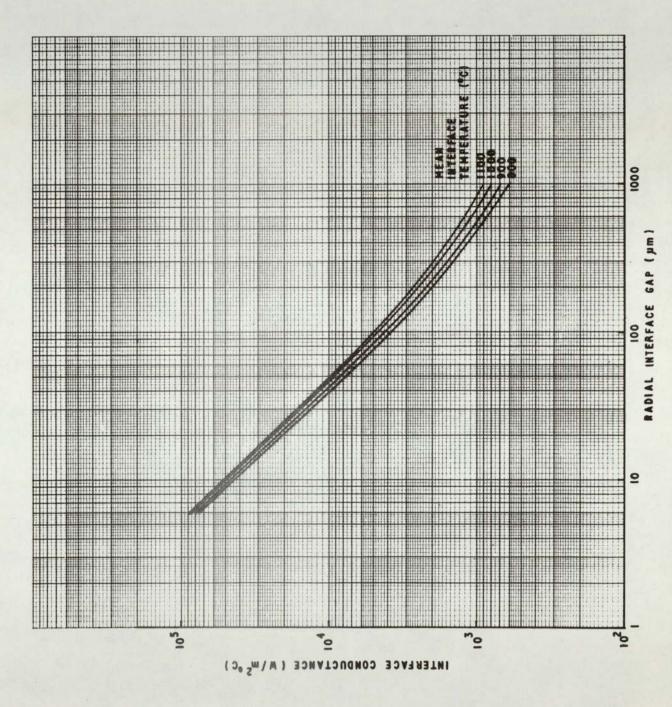
TYPICAL TIME EVOLUTION OF CHANNEL FLOW IN A LEAKING COLUMN

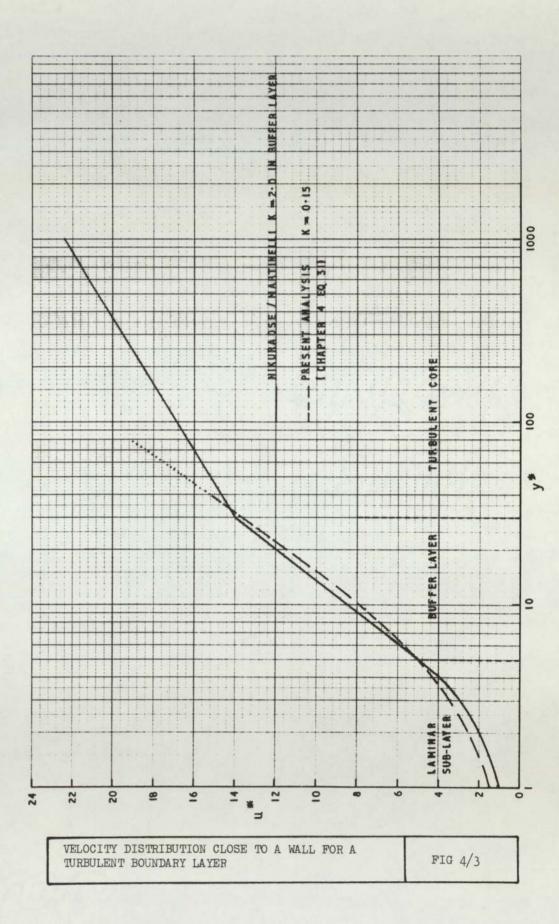


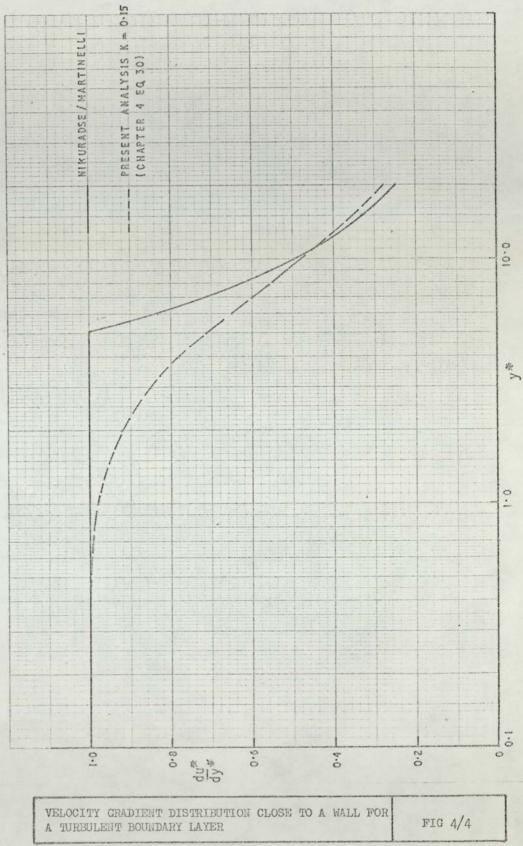


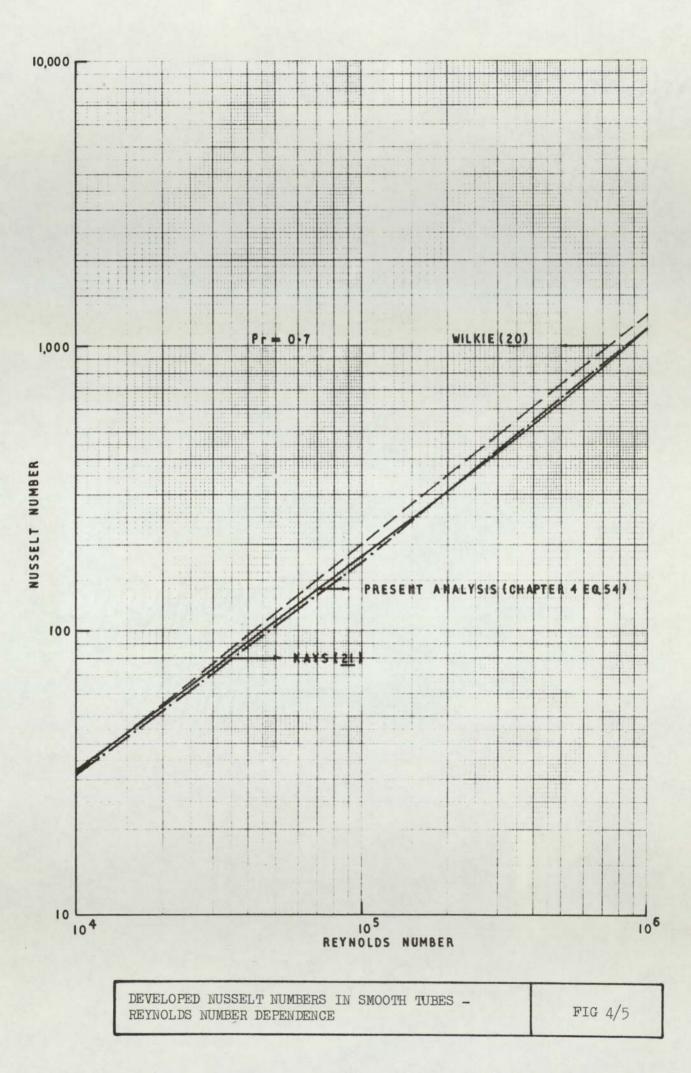
TYPICAL RADIAL TEMPERATURE DISTRIBUTION THROUGH A TUBULAR FUEL ELEMENT

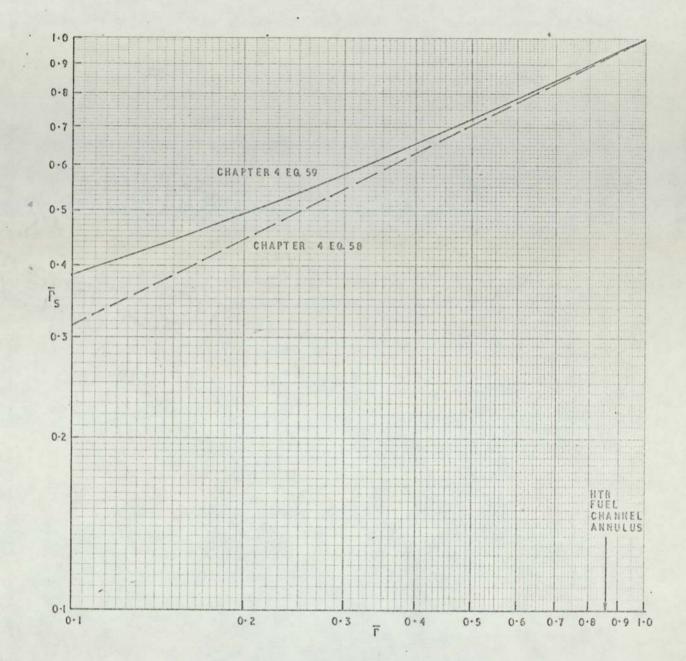
FIG 4/1



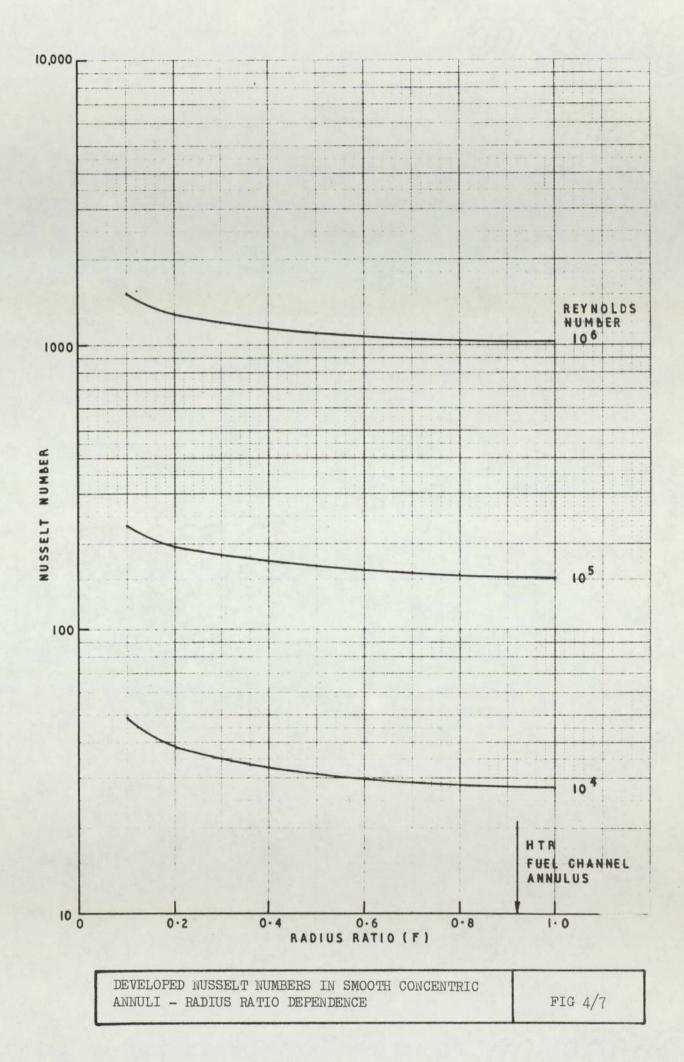




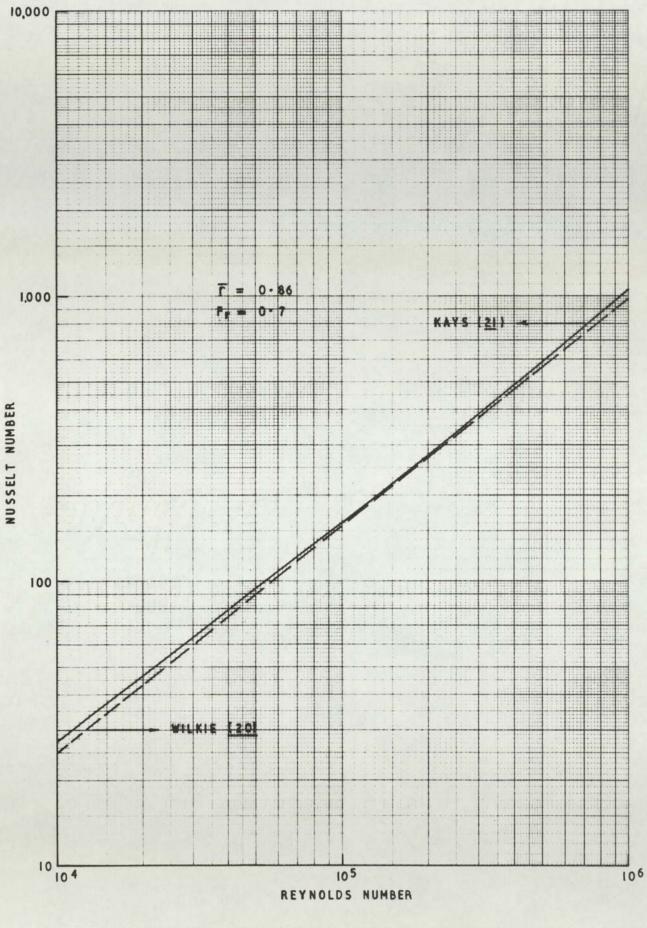


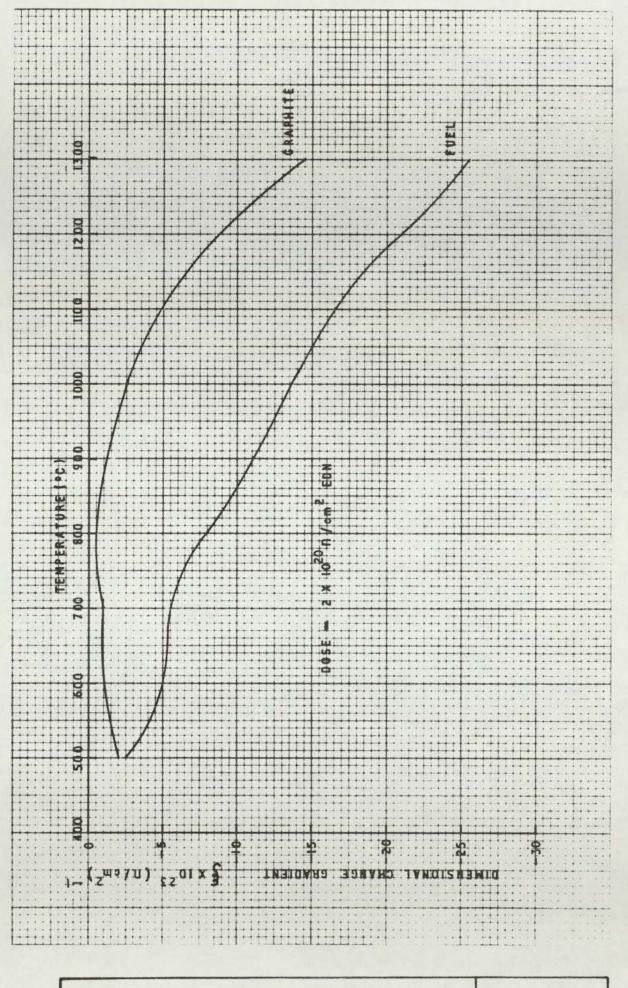


	THE DEPENDENCE (r <sub>s</sub> ) ON RADIUS	OF DIMENSIONLESS RATIO (구)	RADIUS OF N	IO SHEAR	FIG 4/6
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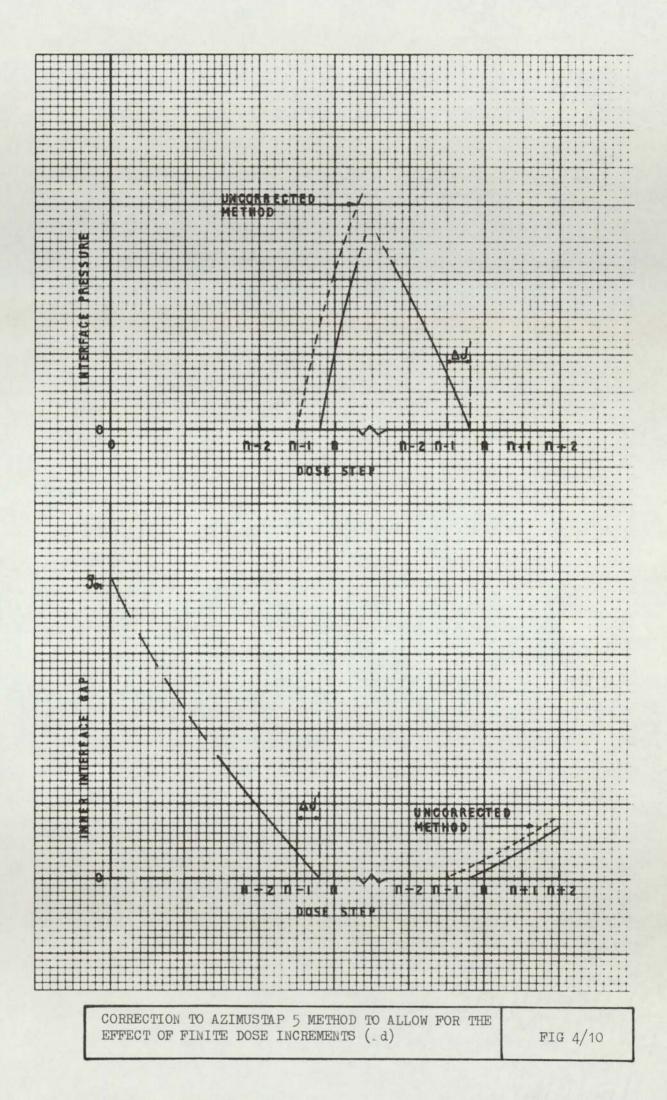


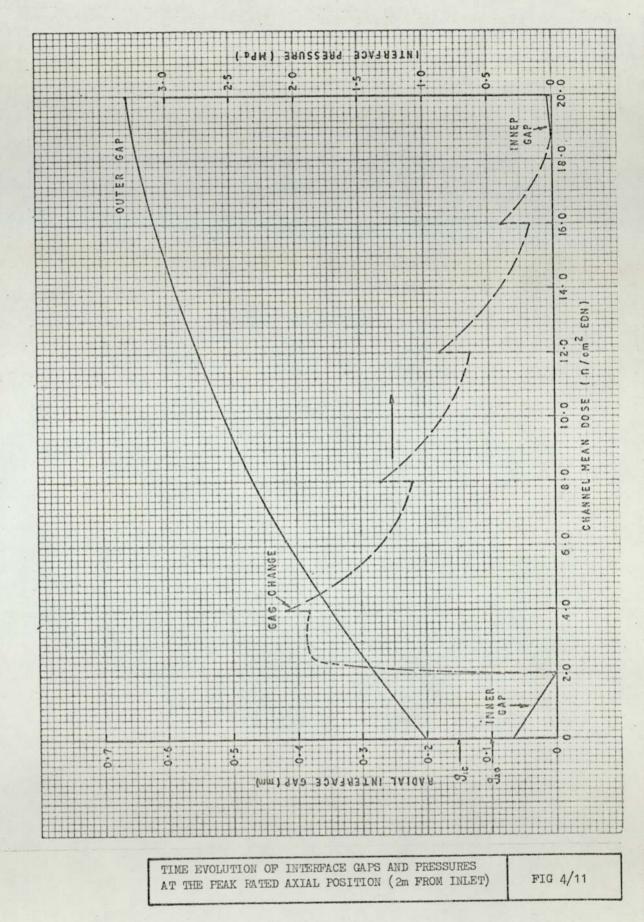
	NUMBERS IN SMOOTH CONCENTRIC	
ANNULI - REYNOLDS	NUMBER DEPENDENCE ( $\overline{r} = 0.86$ )	FIG 4/8

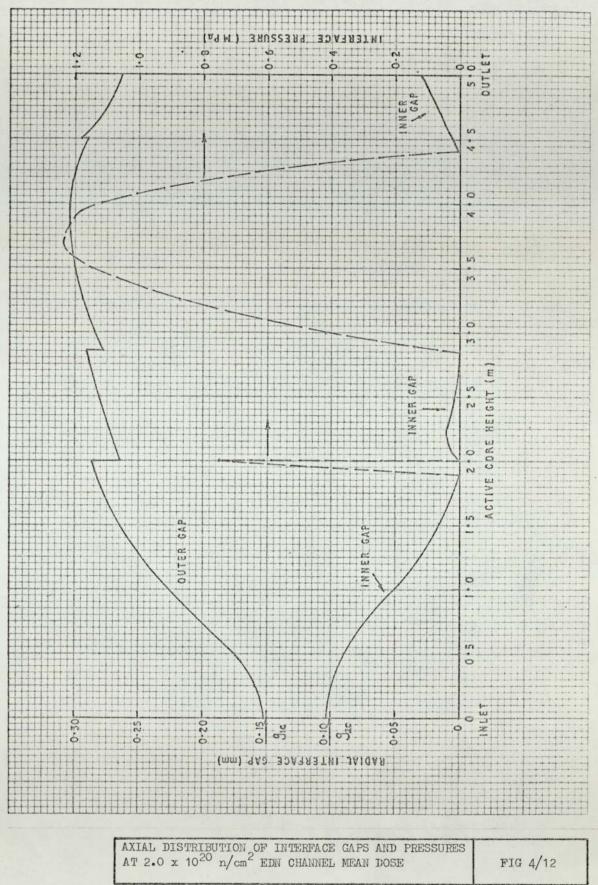


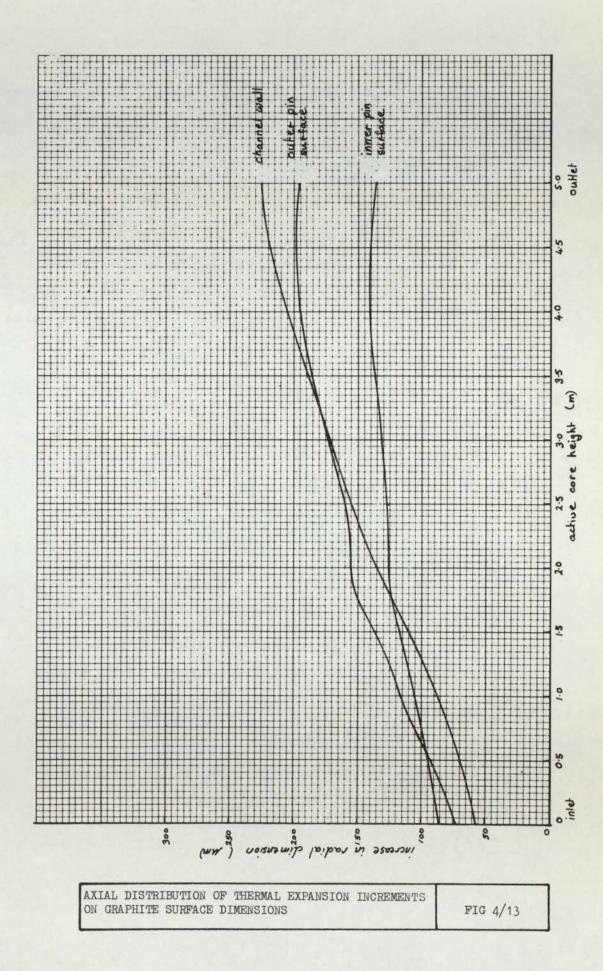


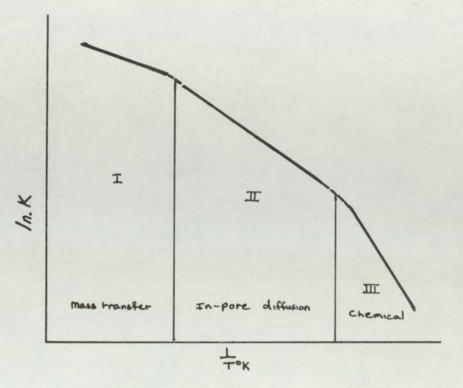
DEPENDENCE	OF	SHRINKAGE	GRADIENT	()	ON	TEMPERA-		
TURE							FIG 4	/9

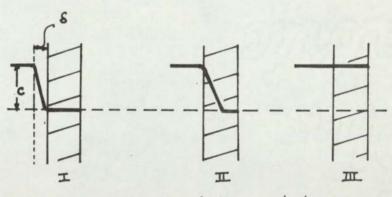


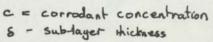


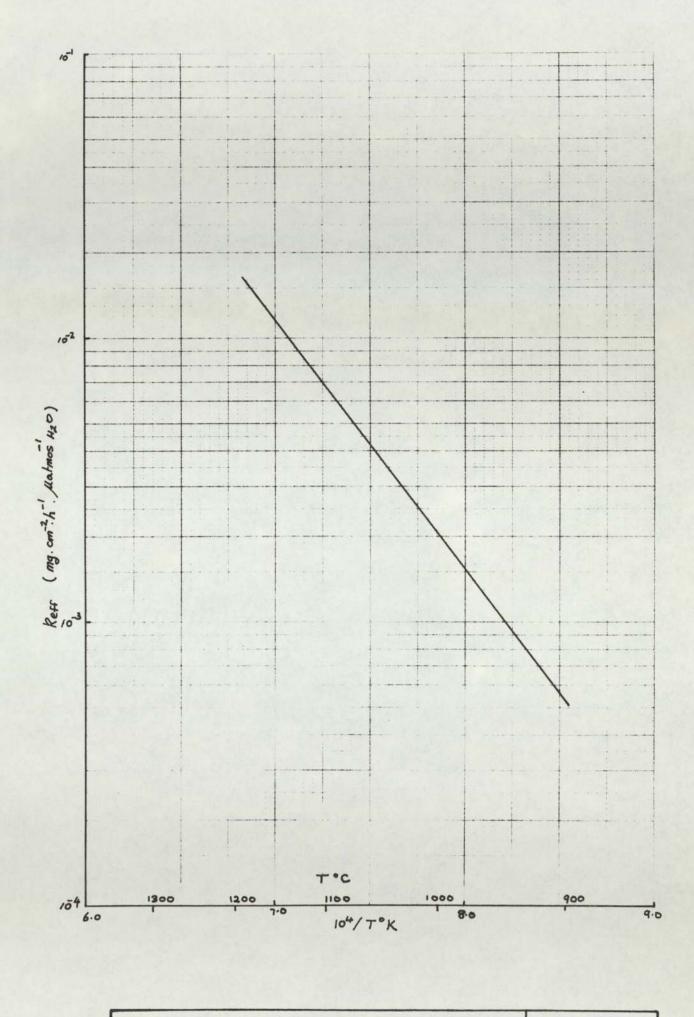


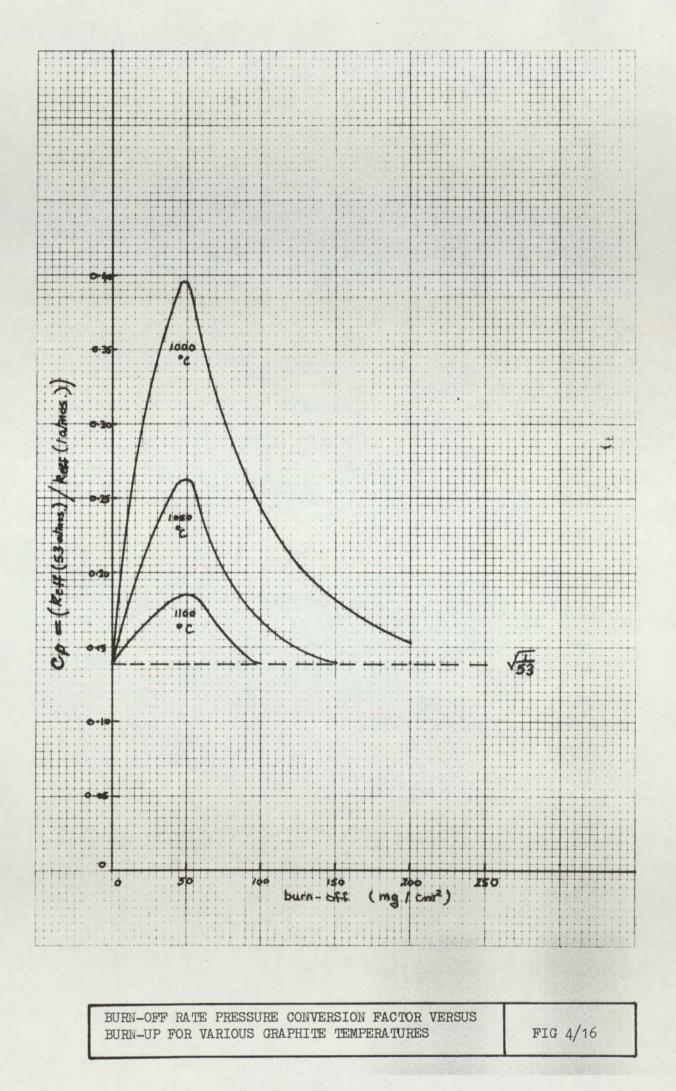


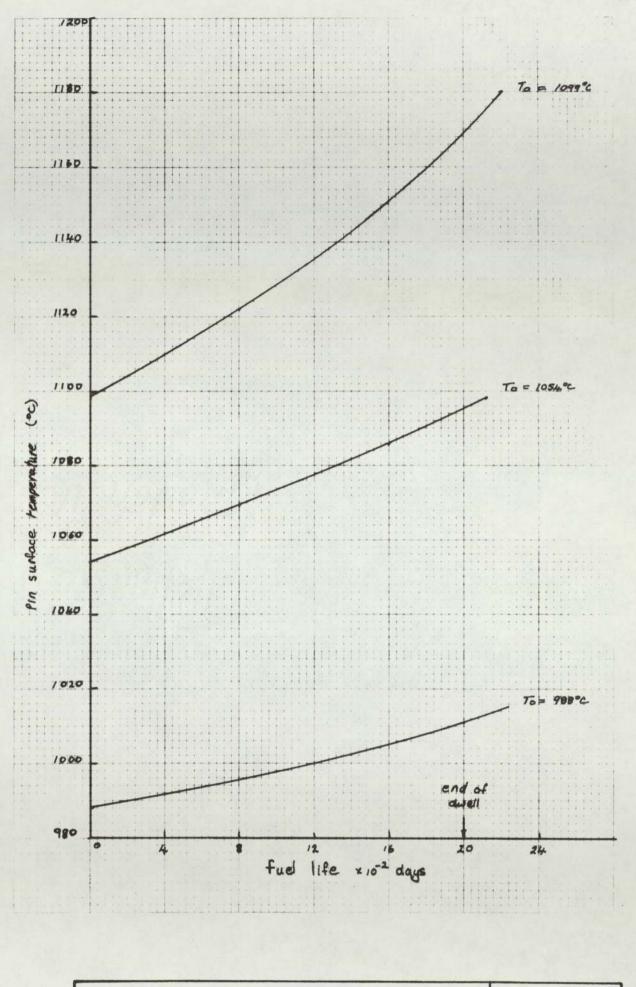




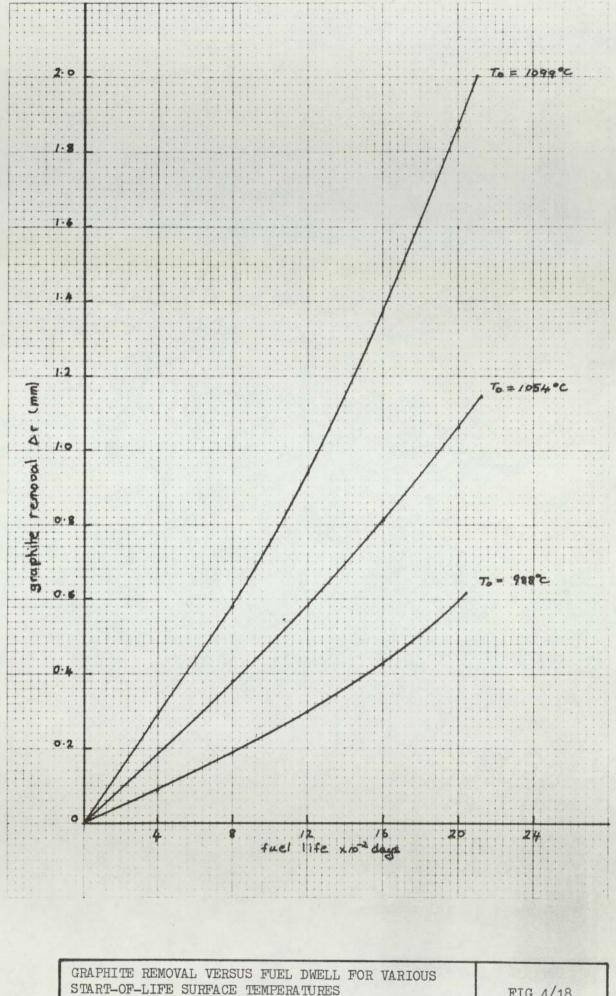


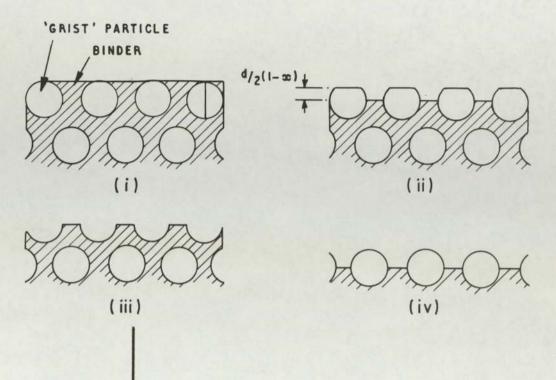


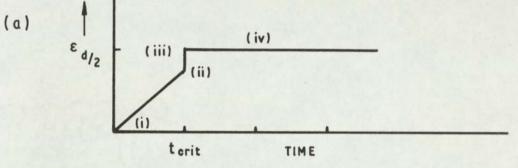




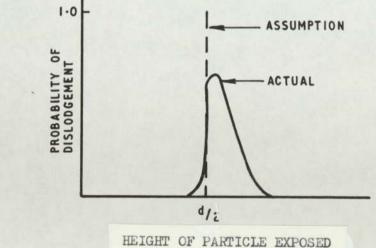
HOLLOW ROD SURFACE TEMPERATURE VERSUS FUEL DWELL FOR VARIOUS START-OF-LIFE VALUES (7)



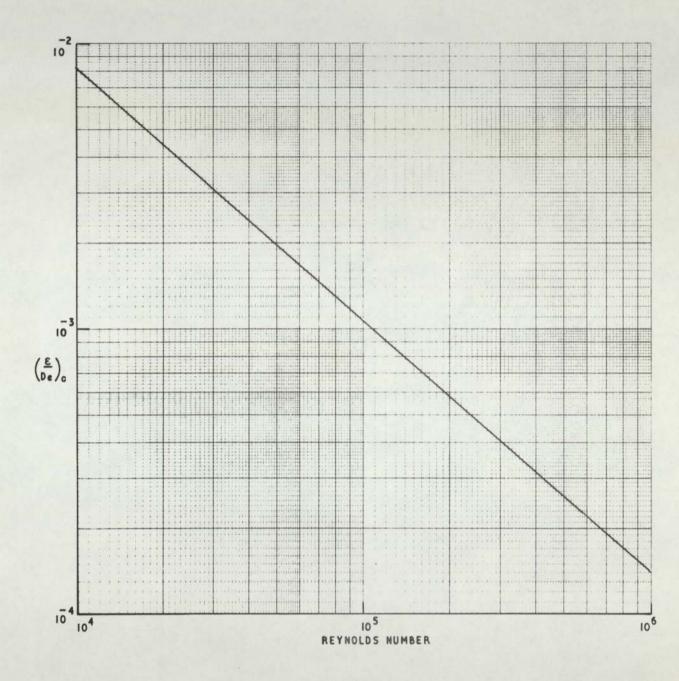




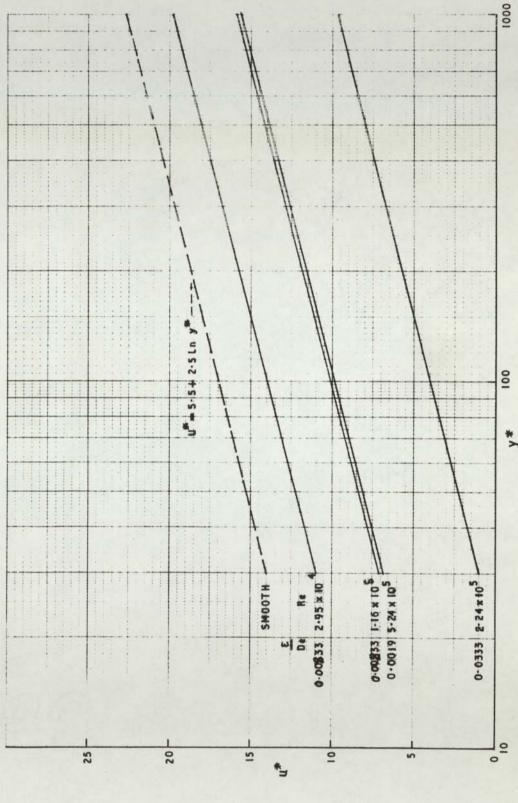
(b)

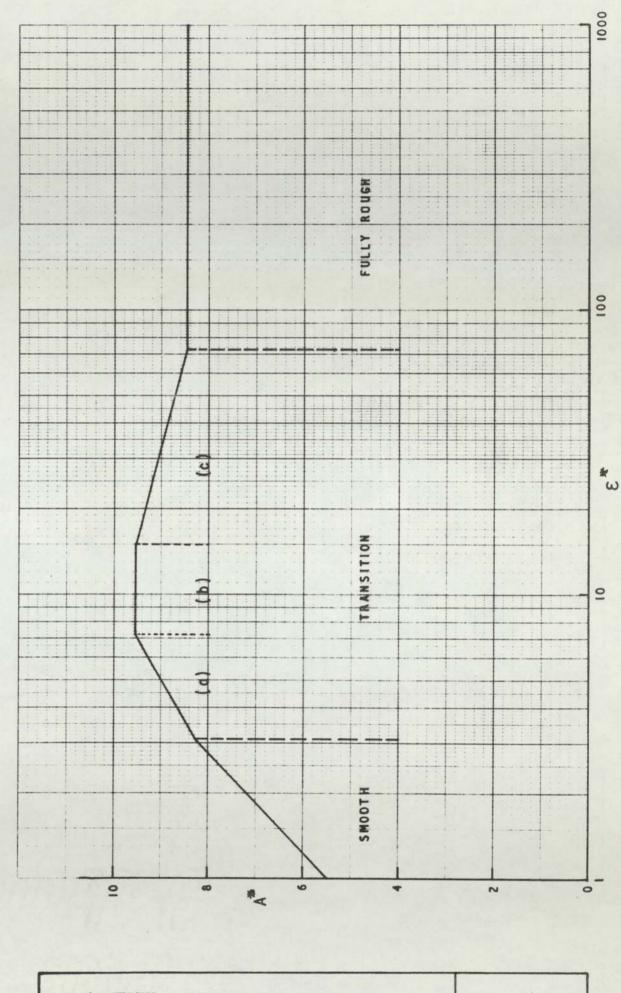


DEVELOPMENT OF SURFACE ROUGHNESS

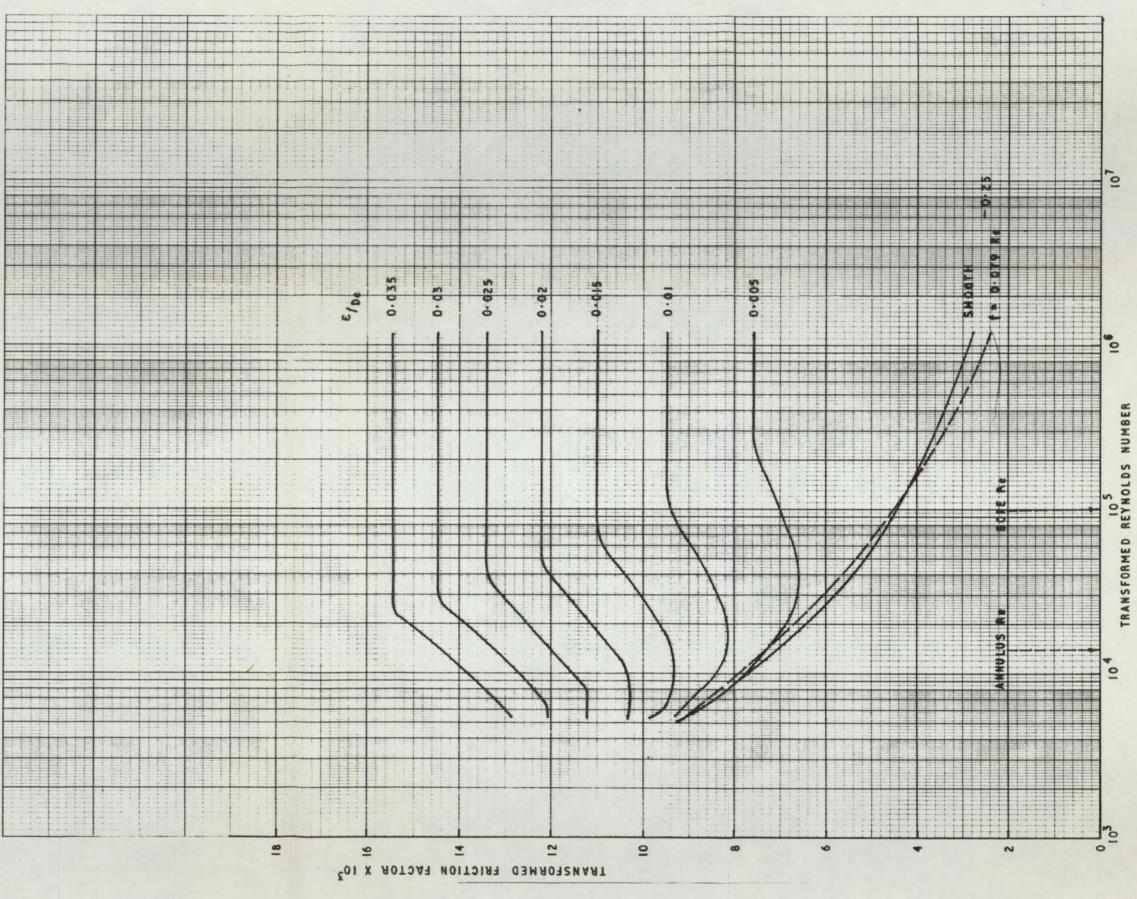


DIMENSIONLESS VELOCITY PROFILES FOR SMOOTH AND ROUGH TUBES

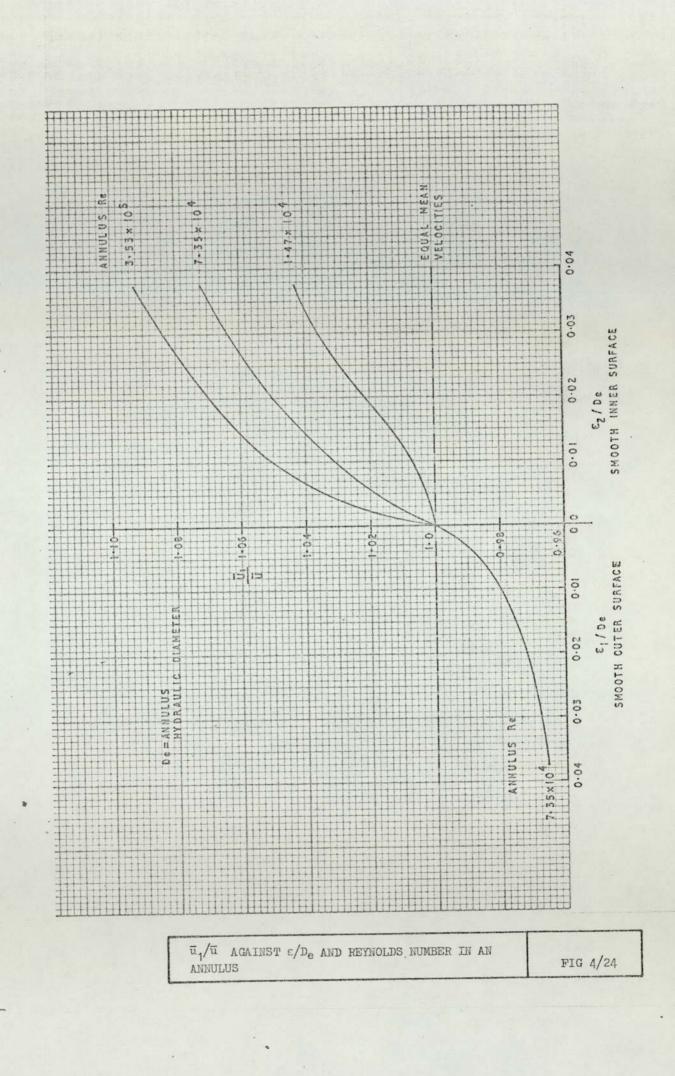


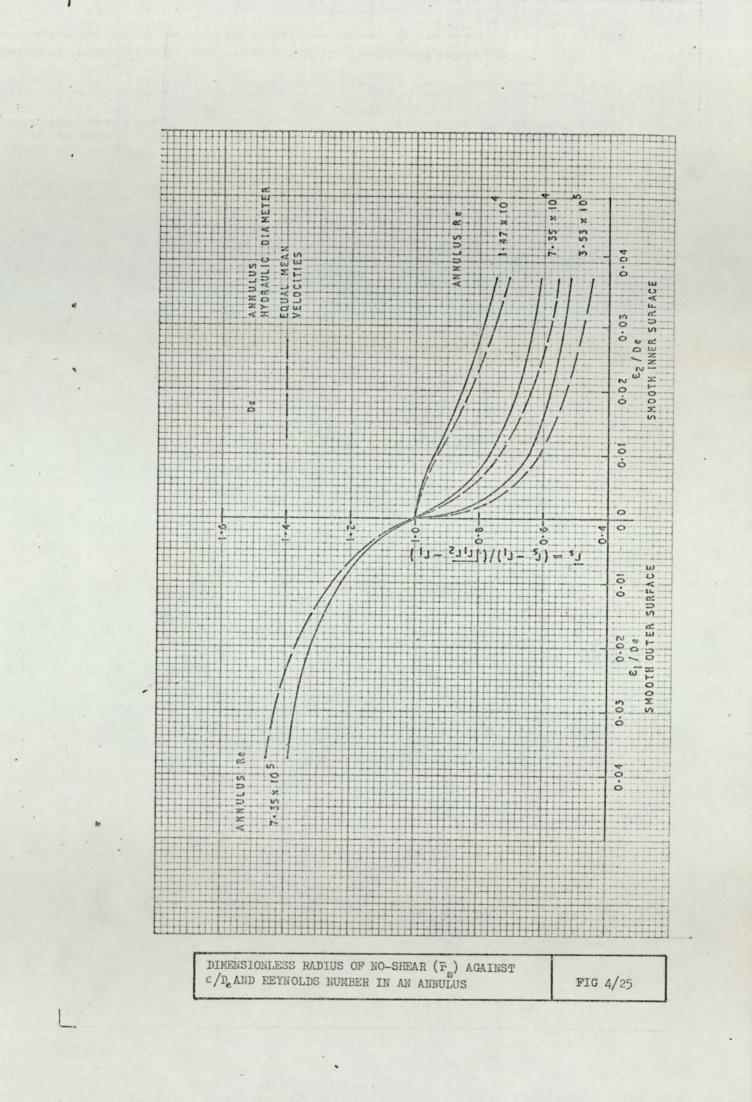


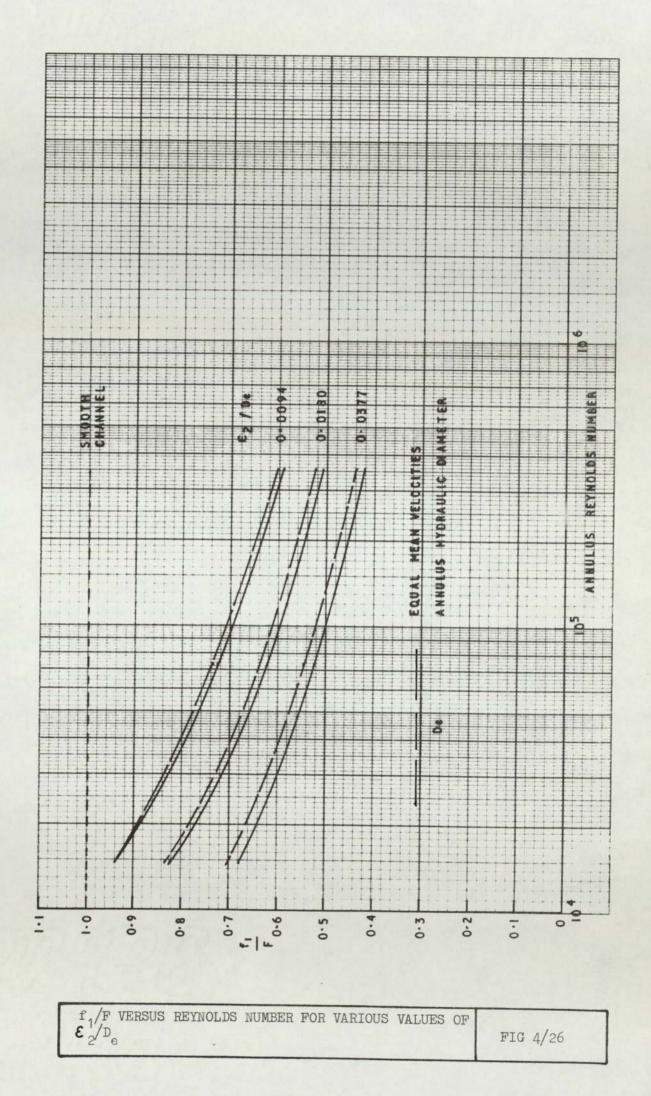
A\* VERSUS C\* SHOWING ROUGHNESS REGIMES

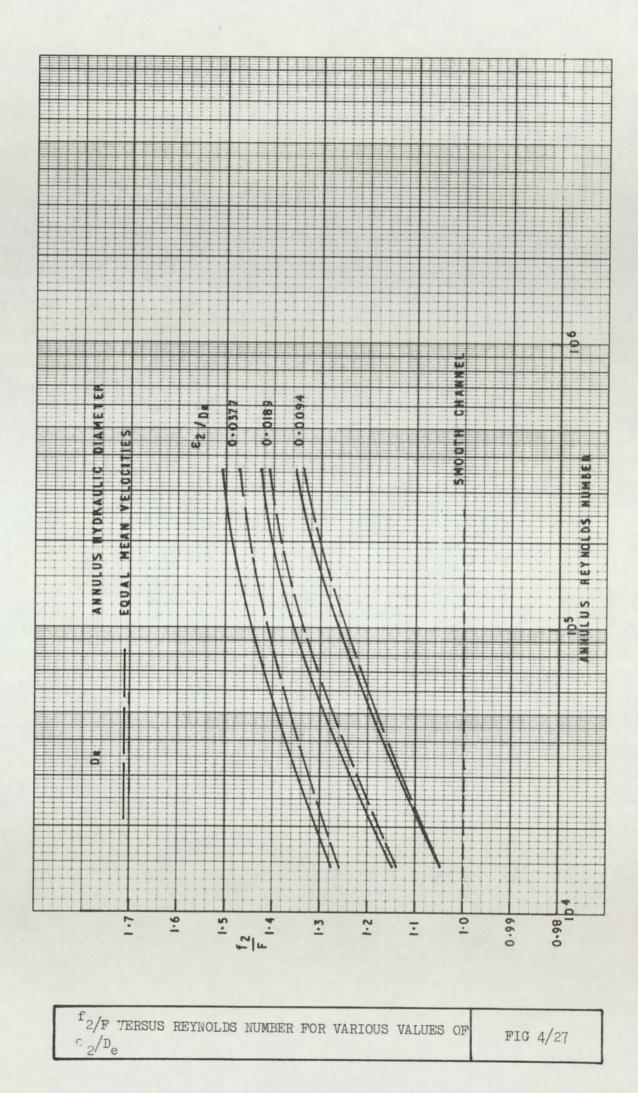


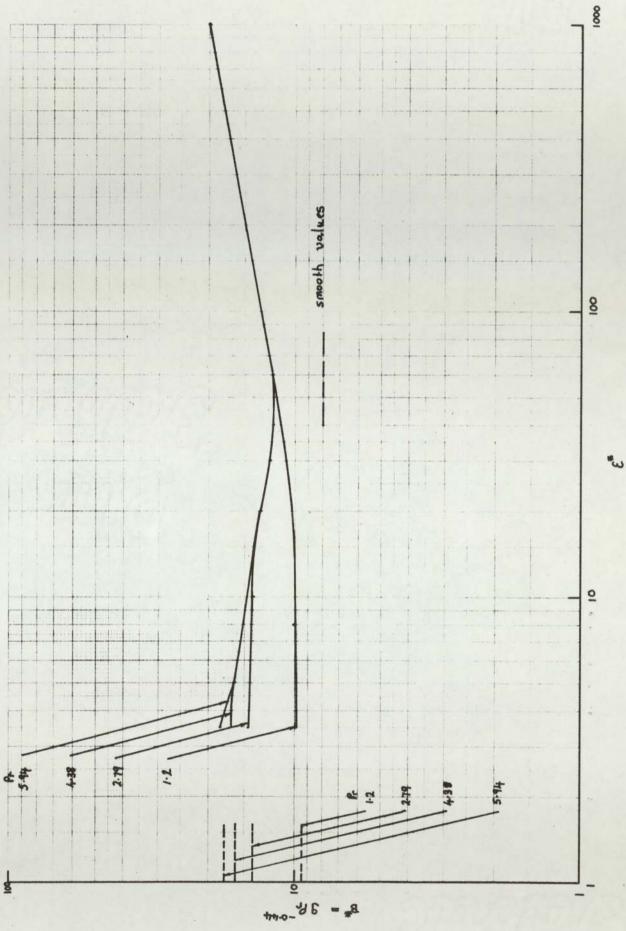
FRICTION FACTOR VERSUS REYNOLDS NUMBER FOR VARIOUS VALUES OF THE ROUGHNESS PARAMETER  $^{\circ}/D_{e}$ 



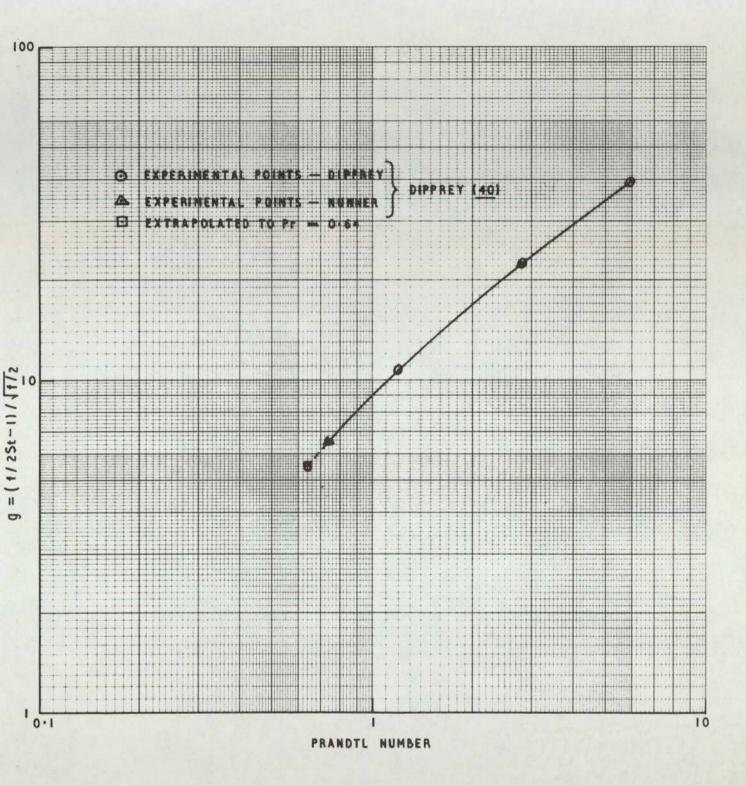


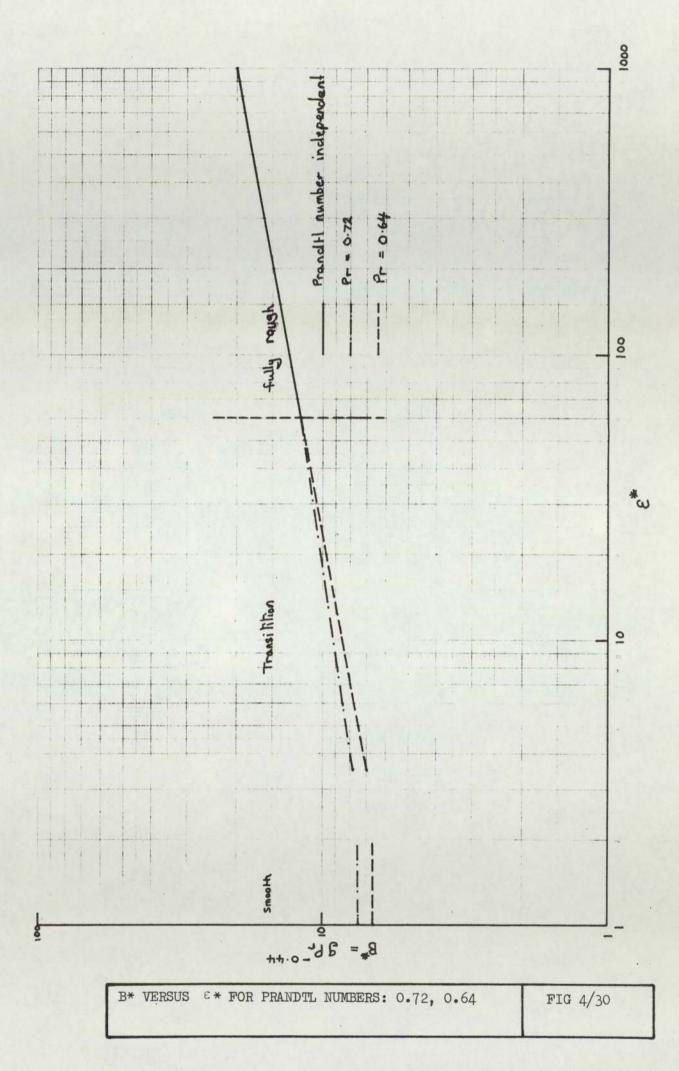


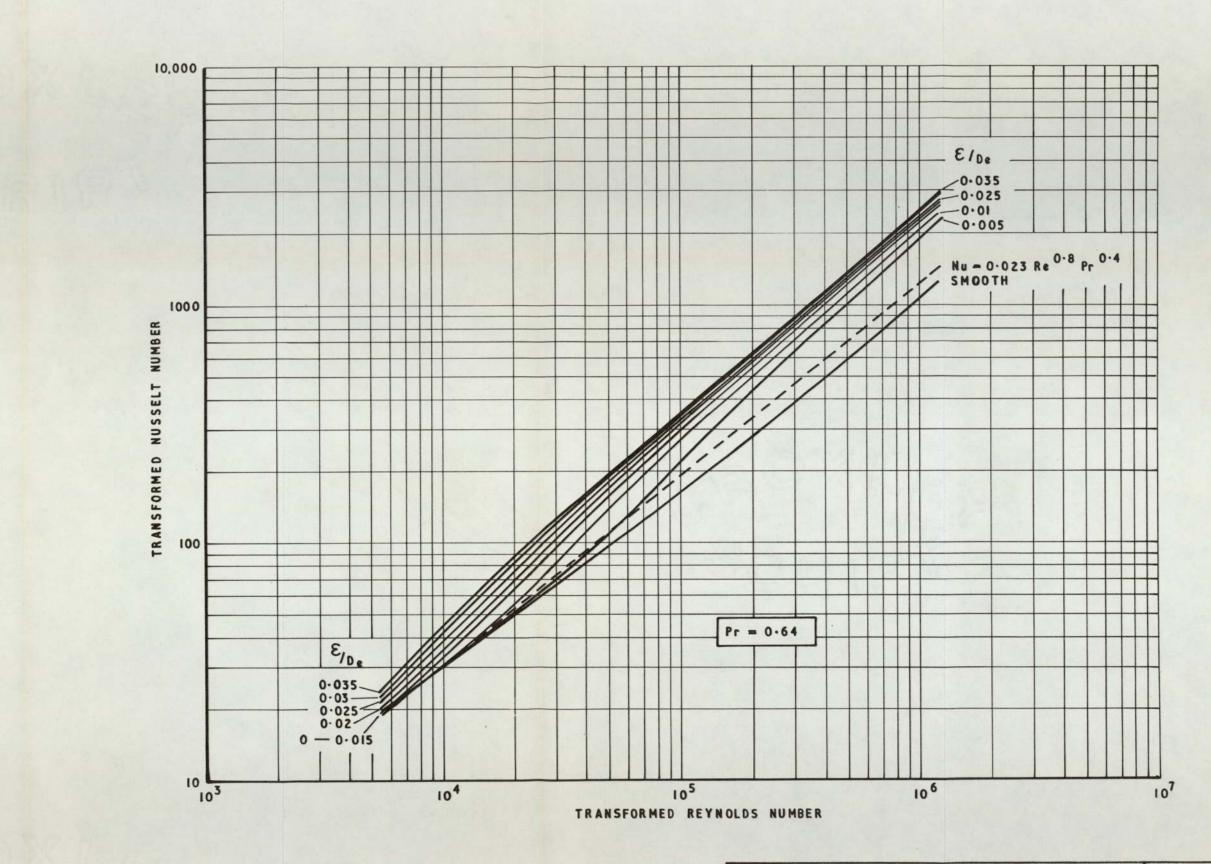




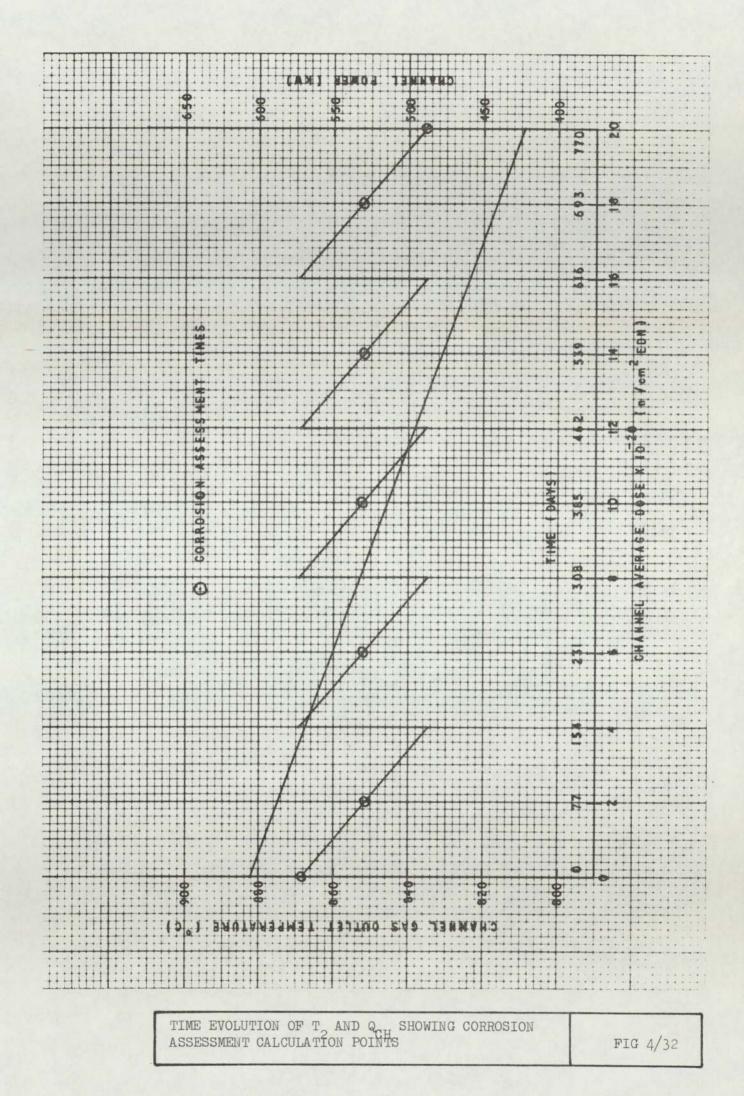
B\* VERSUS C\* FOR PRANDTL NUMBERS: 5.94, 4.38, 2.79, 1.2

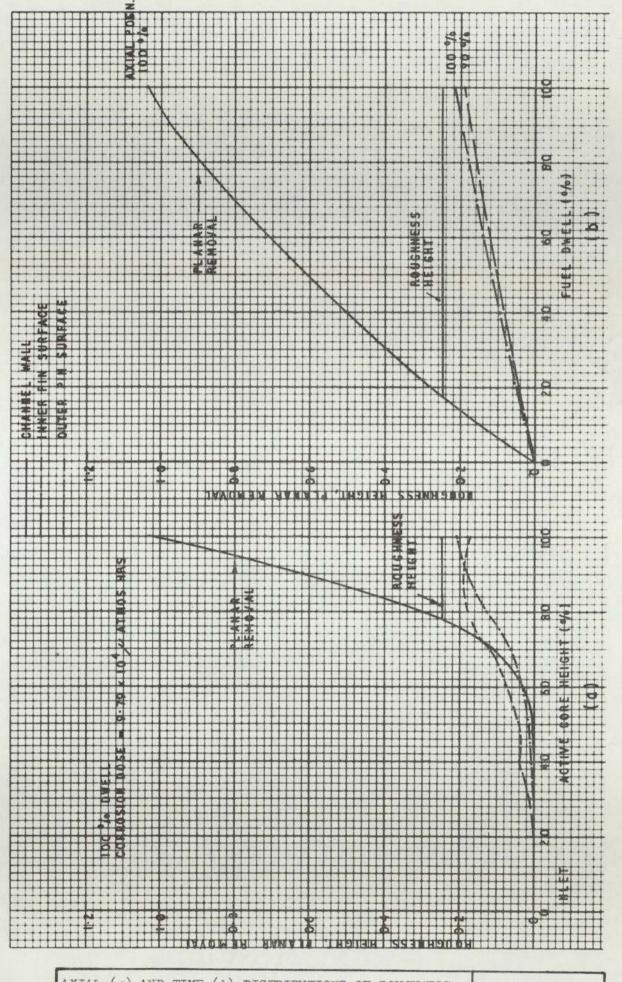




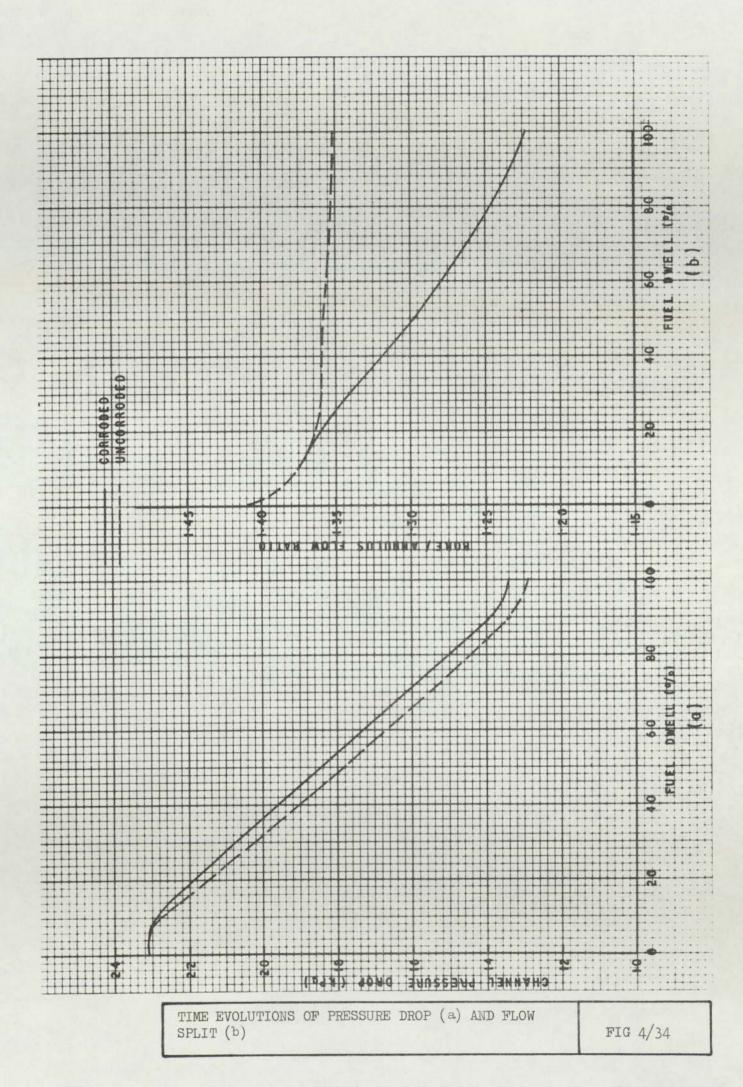


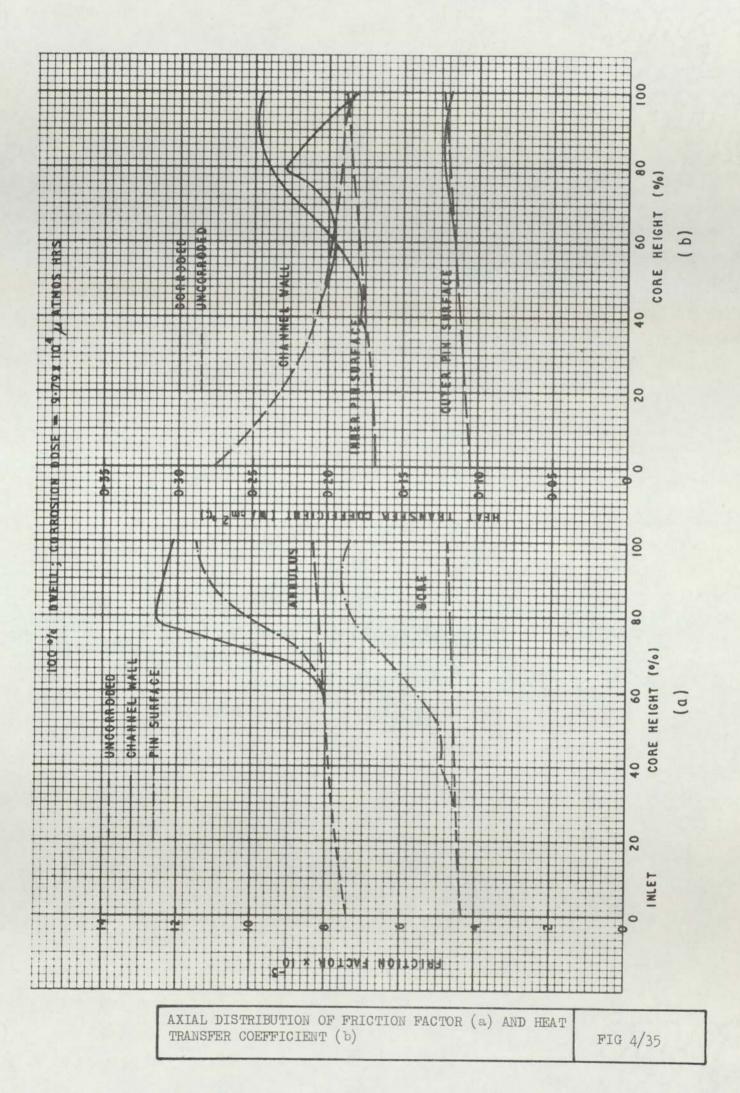
Nu VERSUS REYNOLDS NUMBER FOR VARIOUS VALUES OF /D<sub>e</sub> FIG 4/31

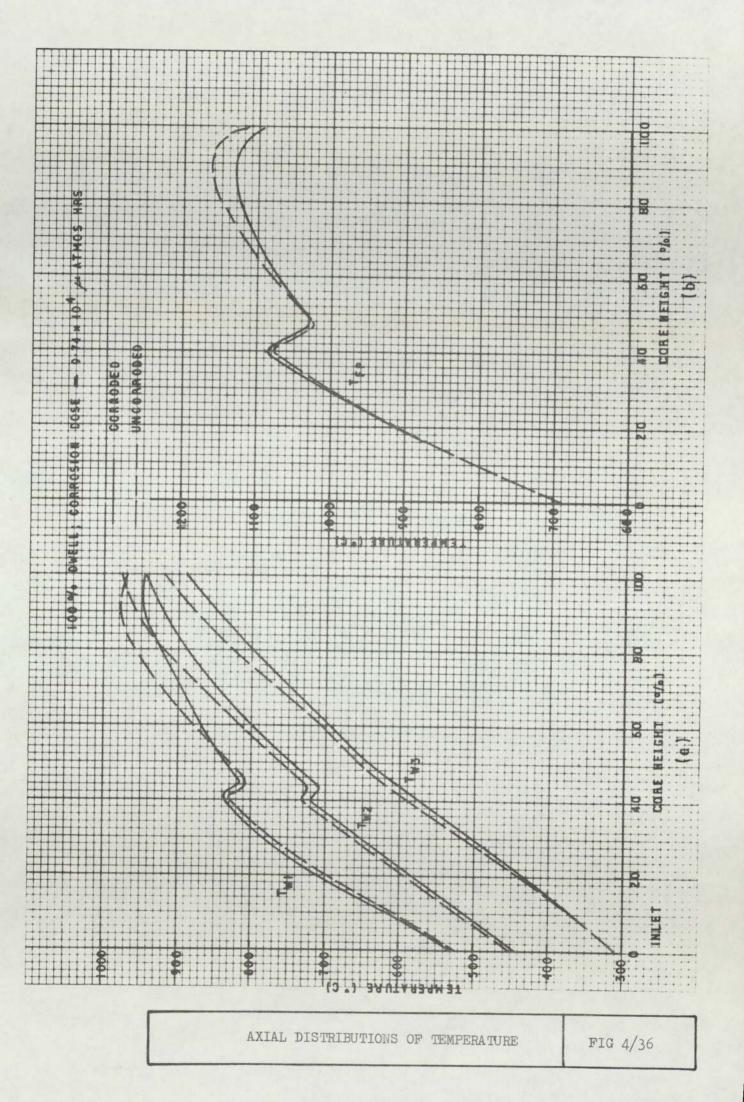


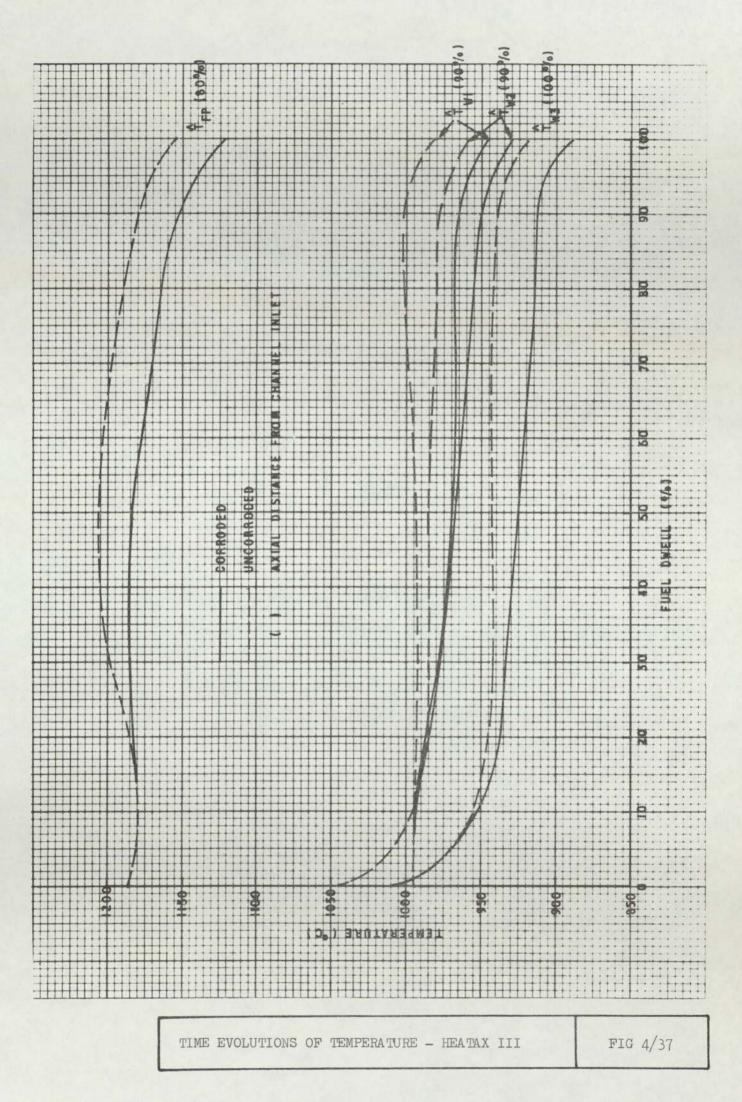


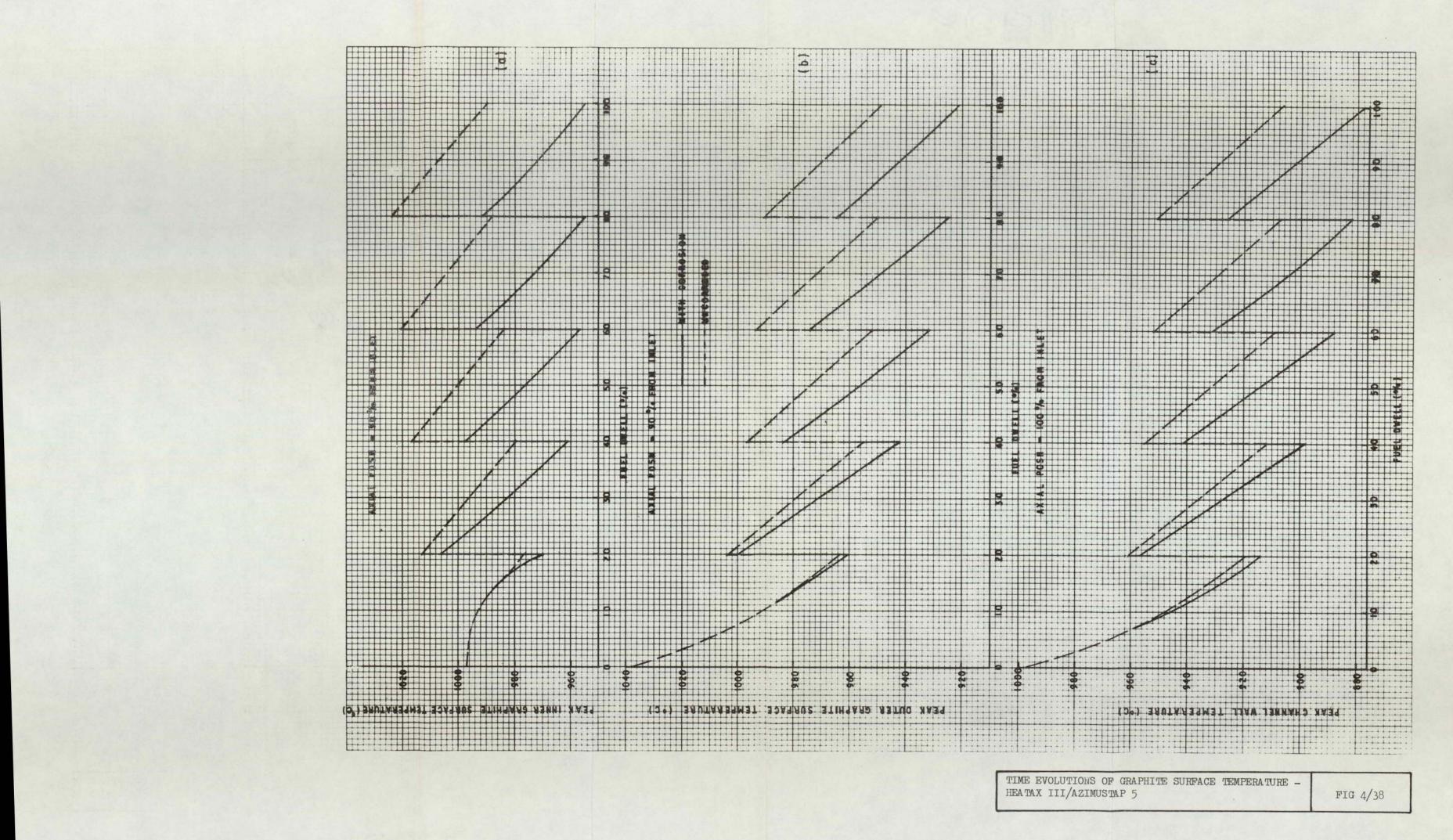
AXIAL (a) AND TIME (b) DISTRIBUTIONS OF ROUGHNESS HEIGHT AND PLANAR REMOVAL

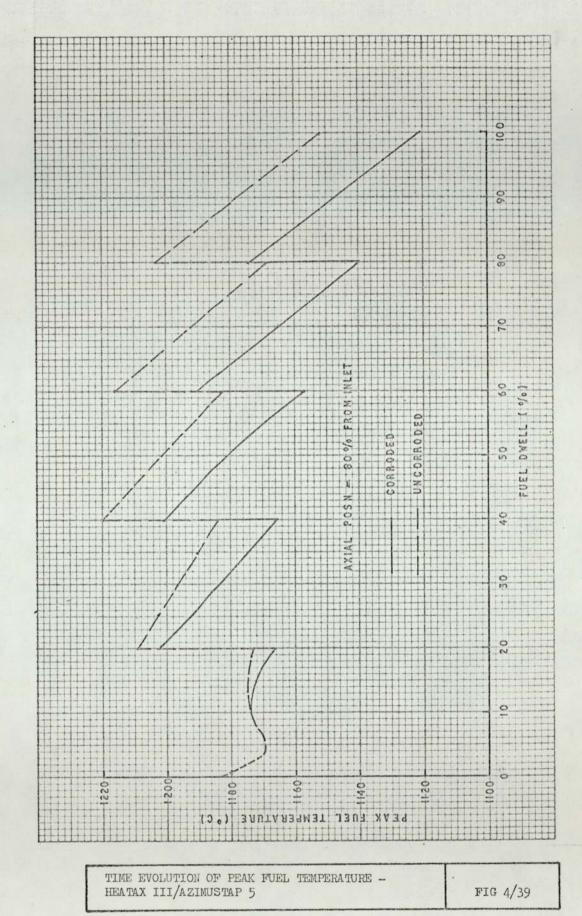




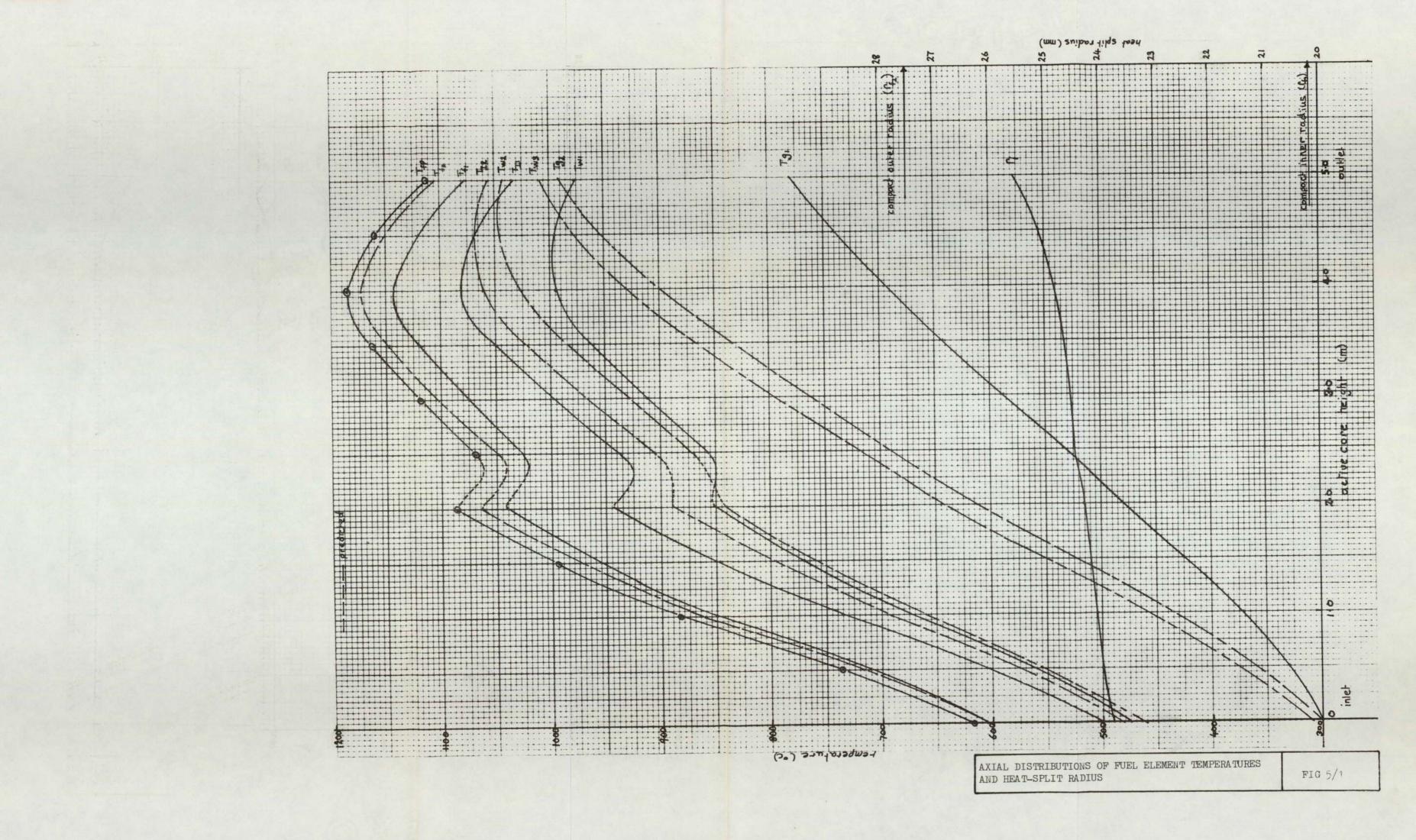


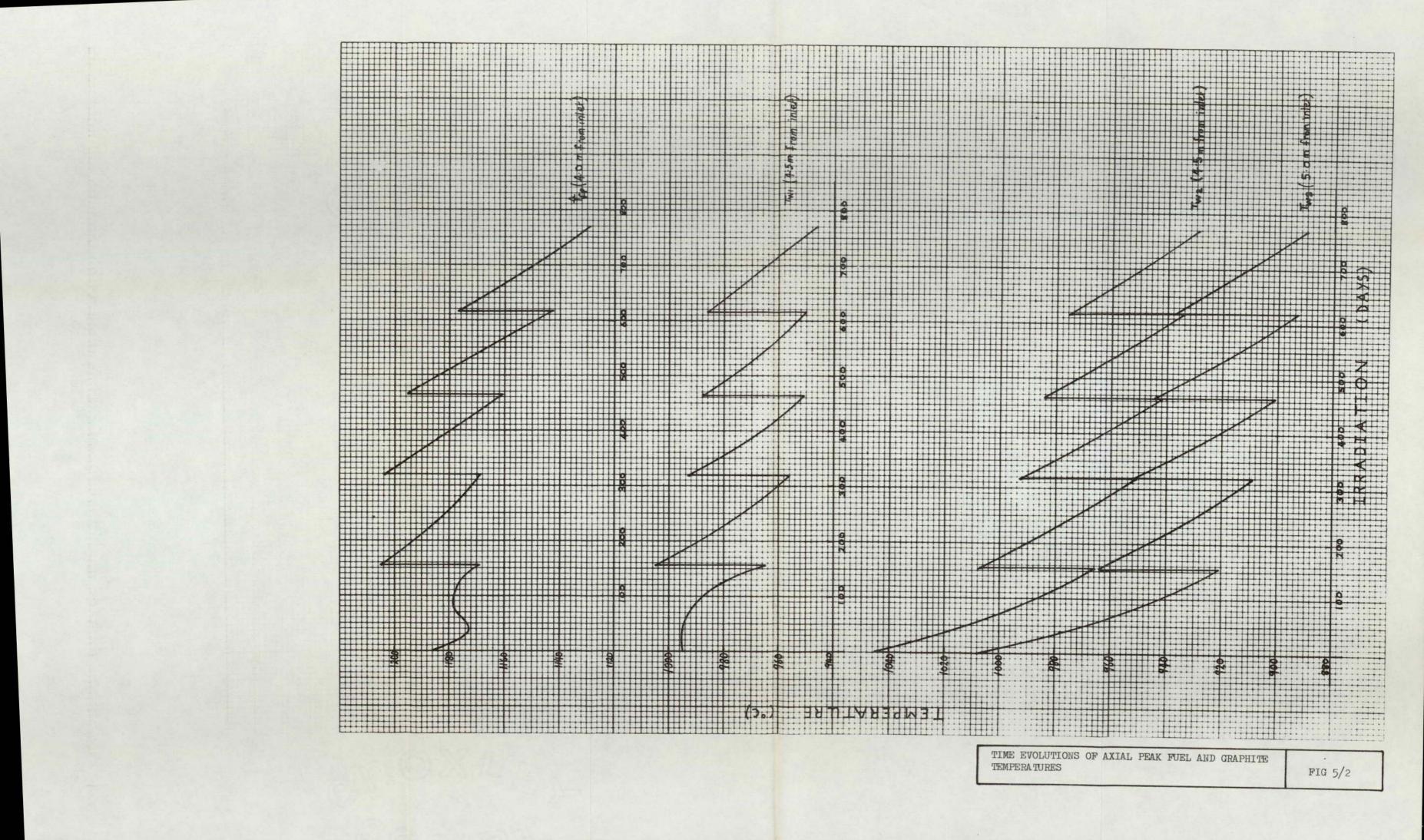


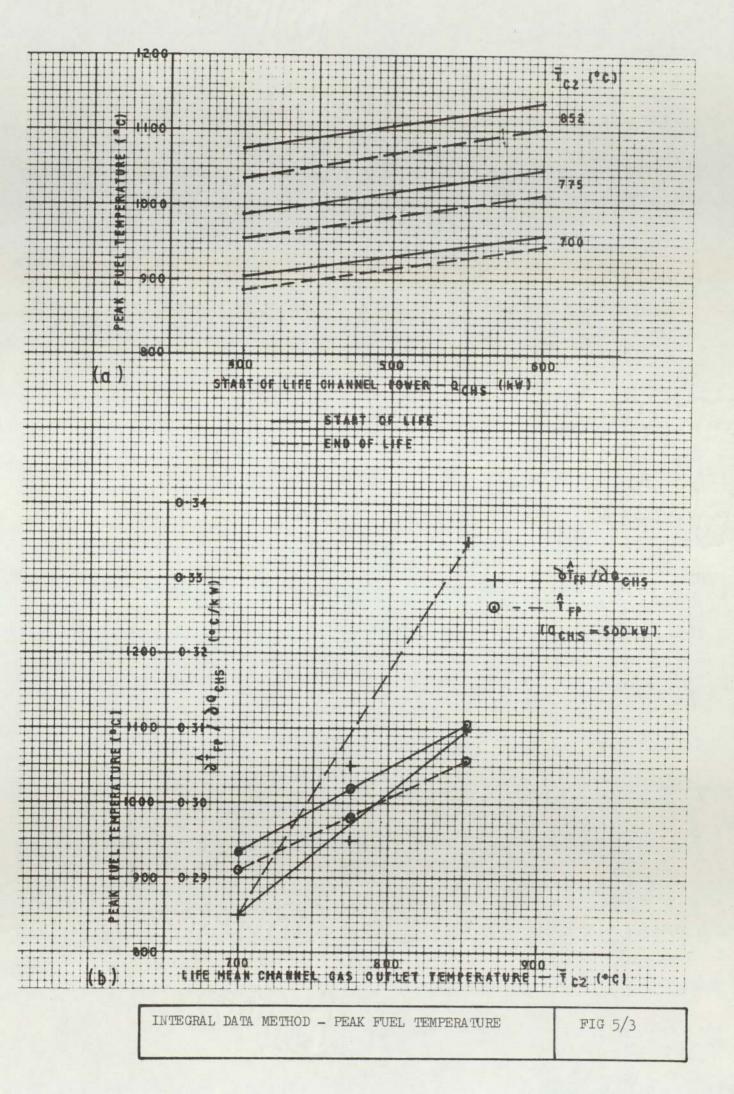


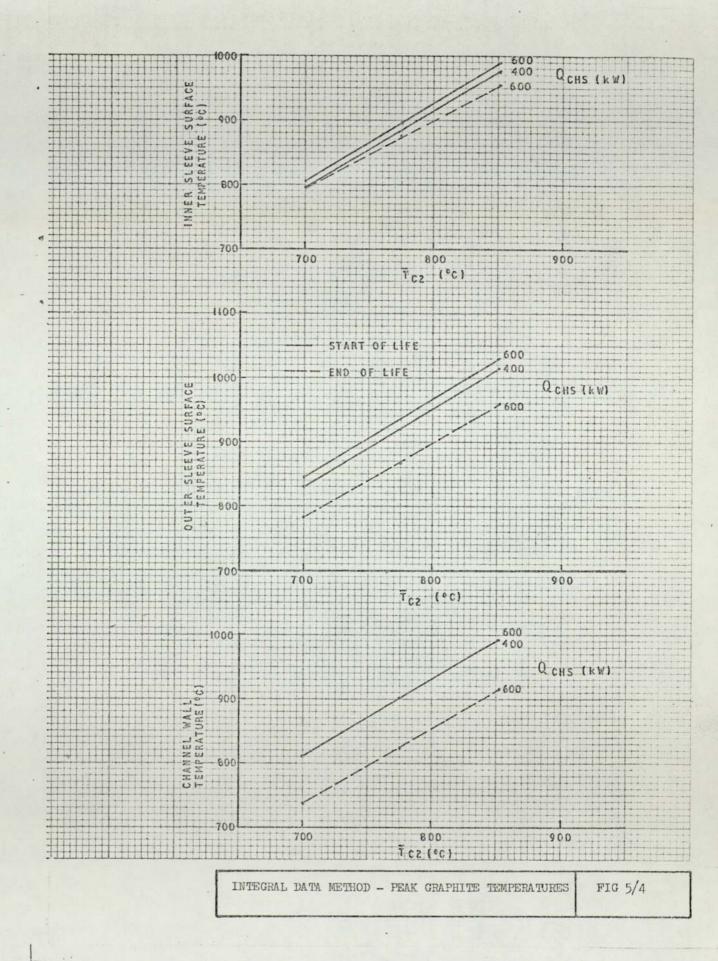


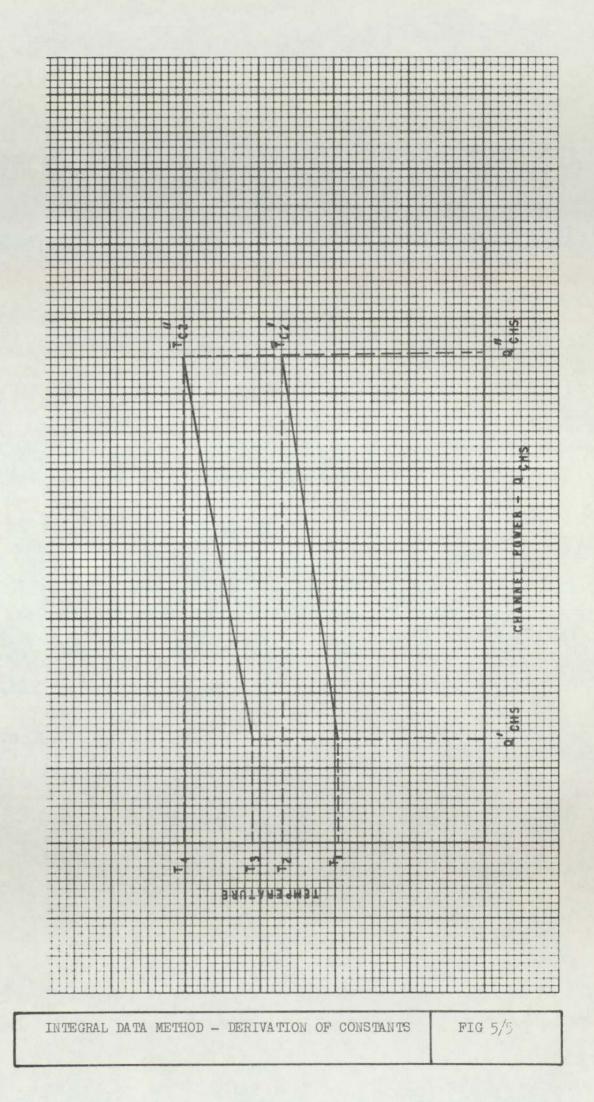
.

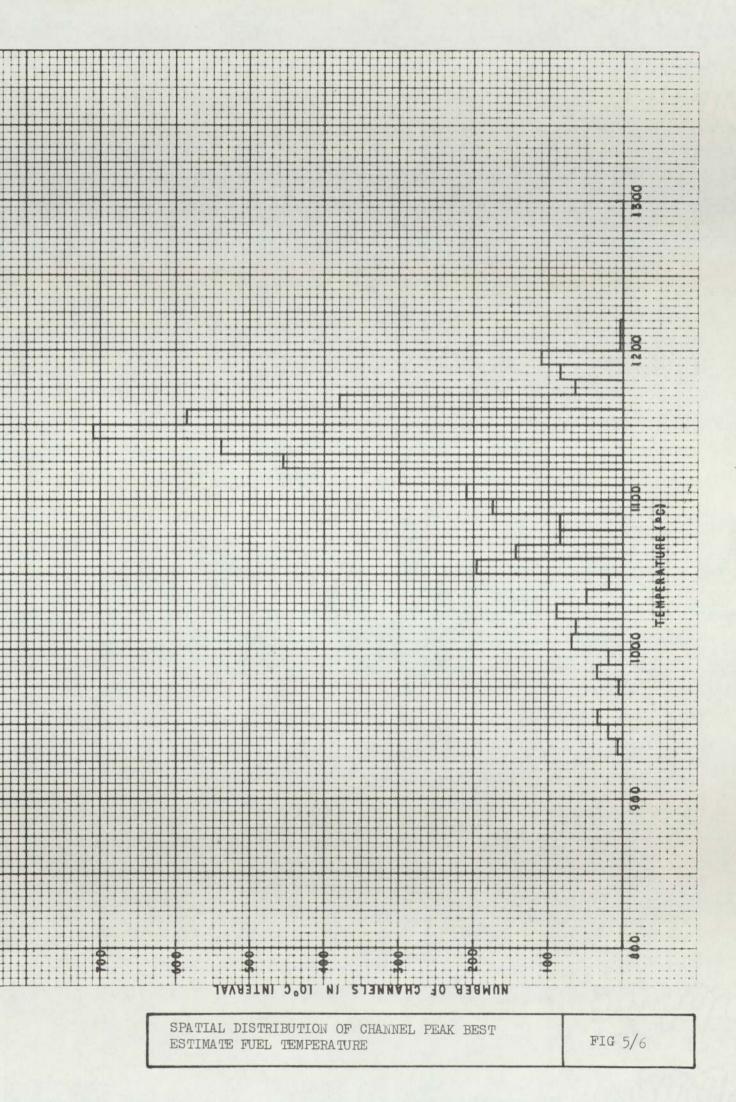


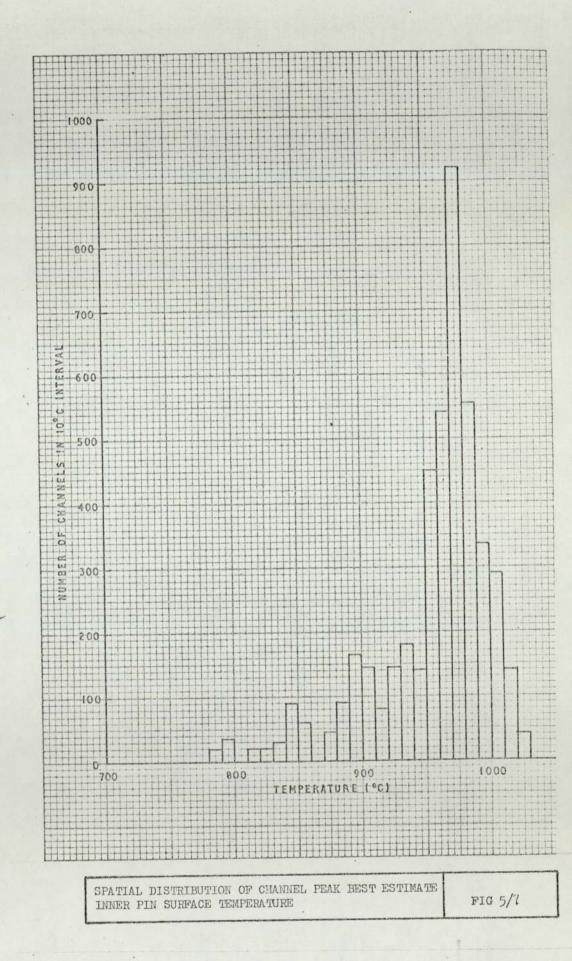


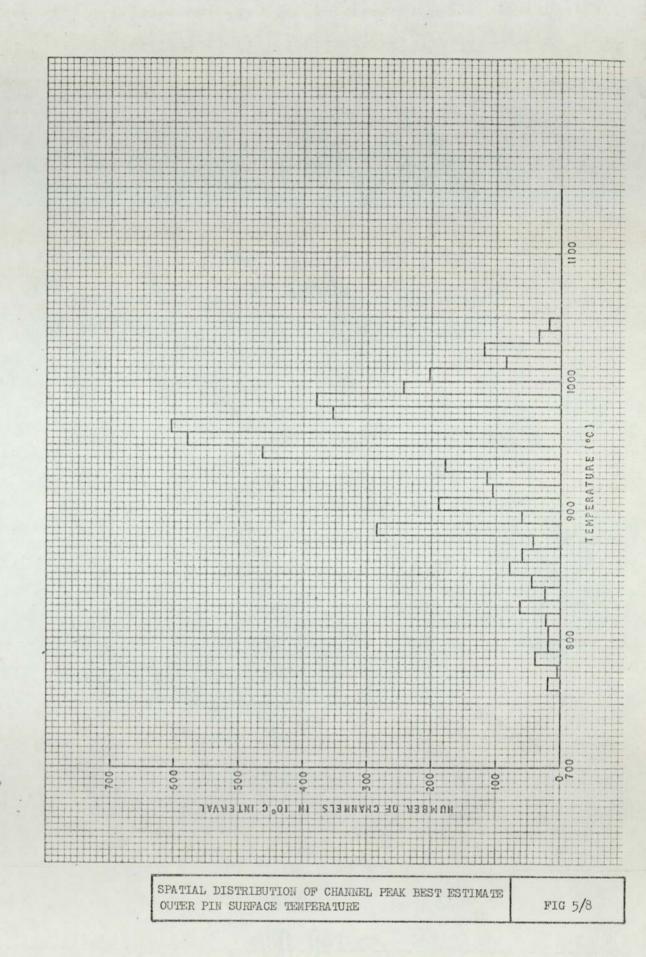


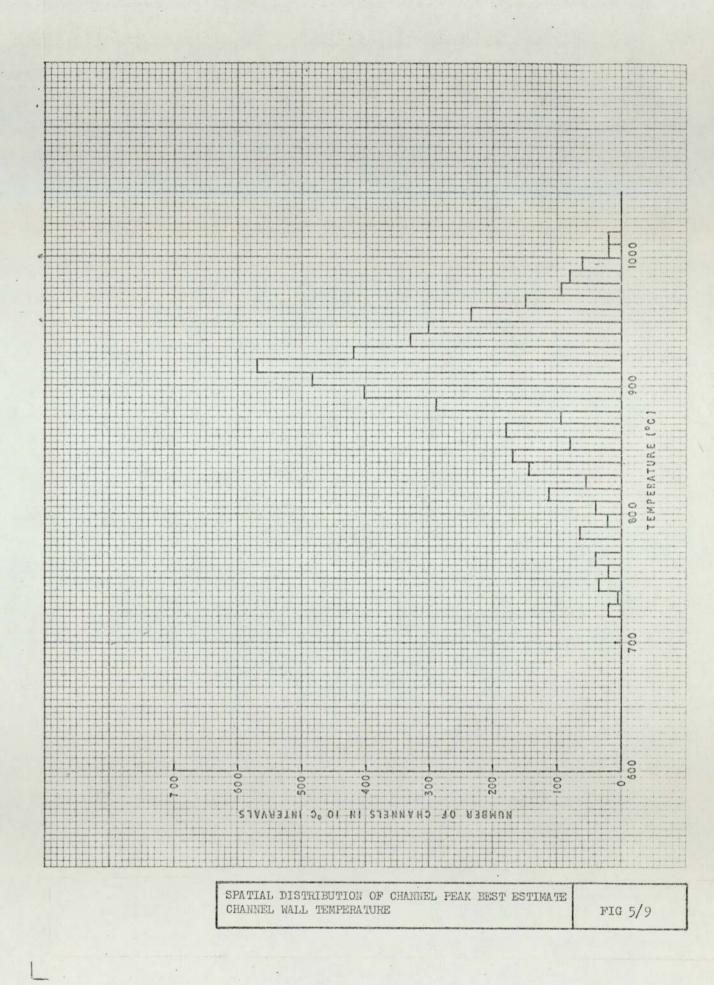


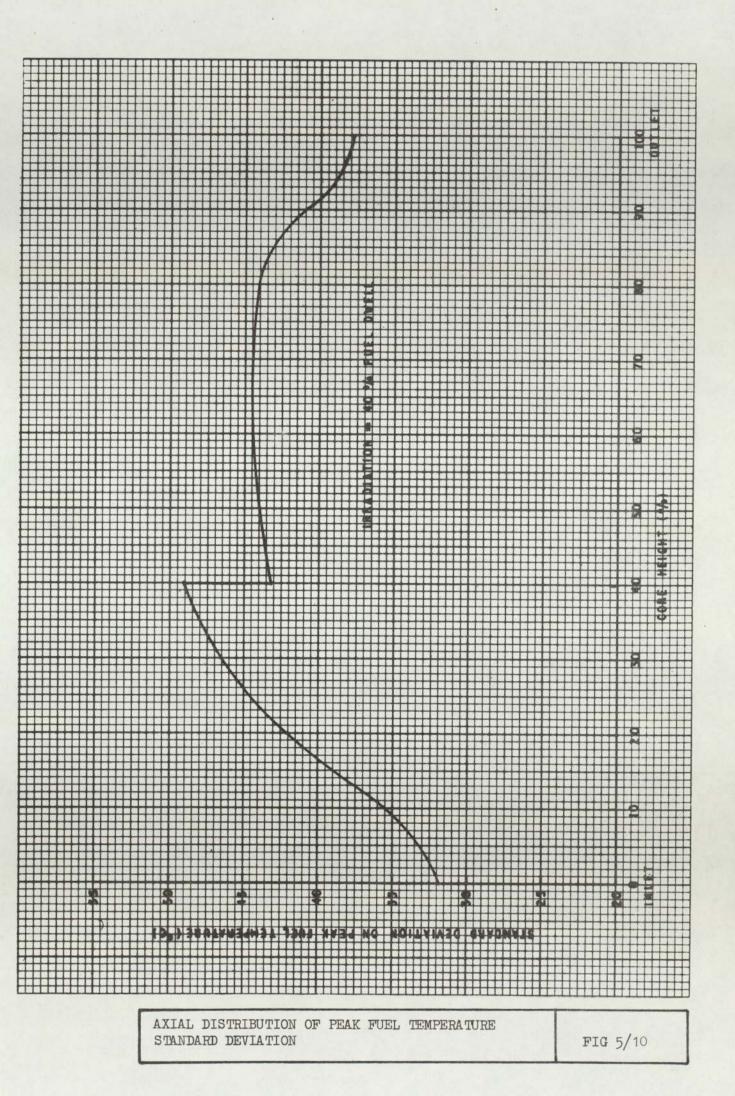


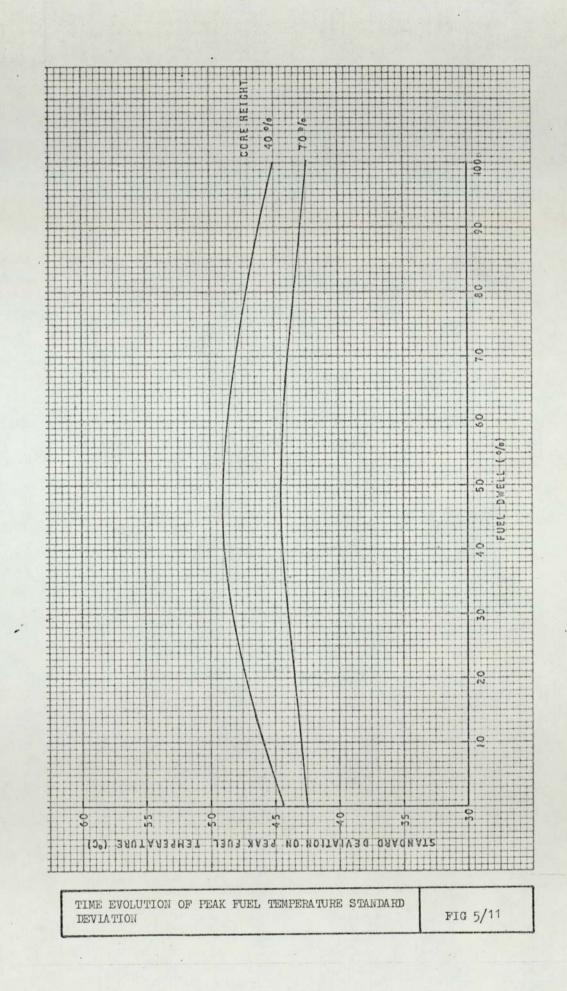


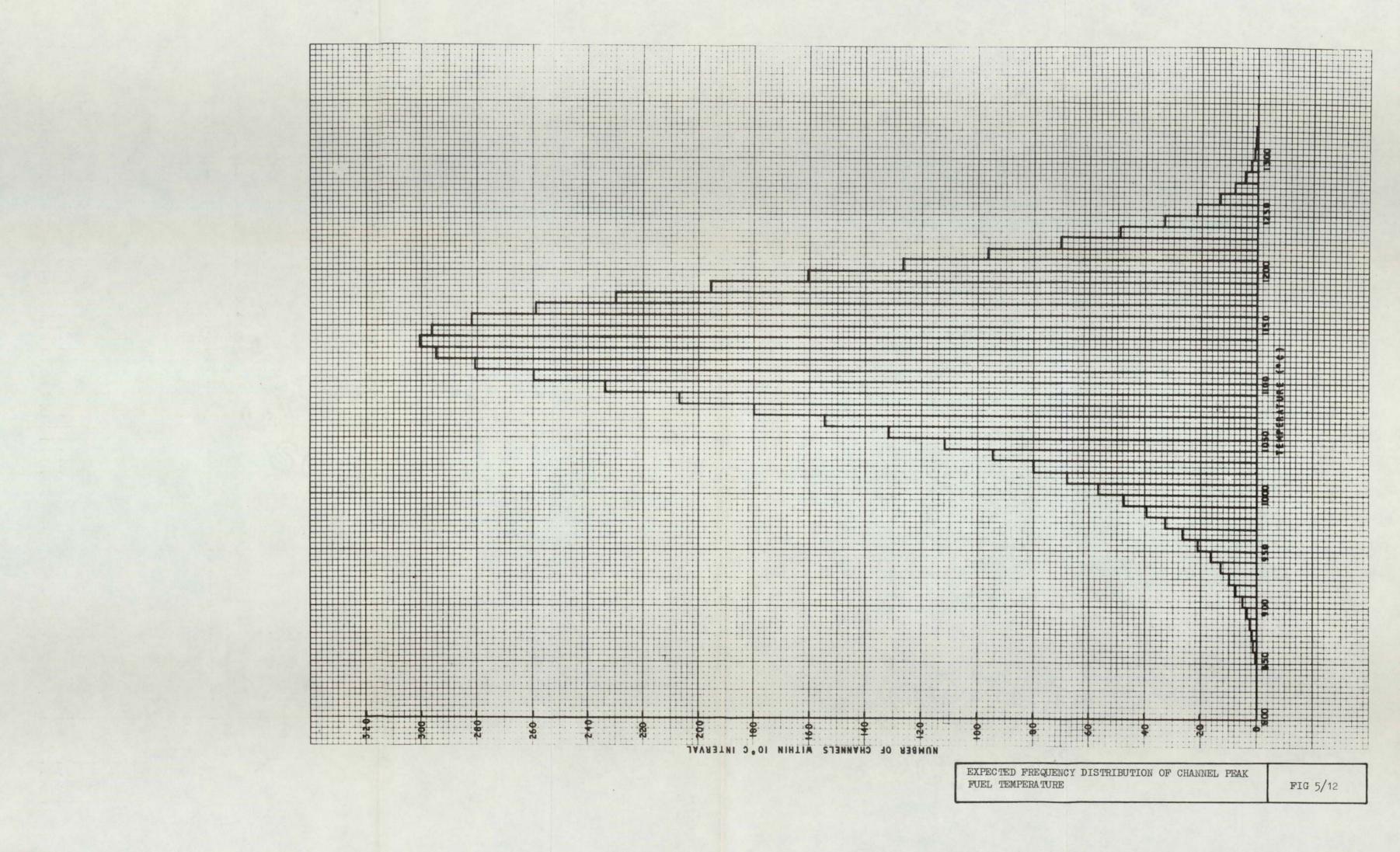


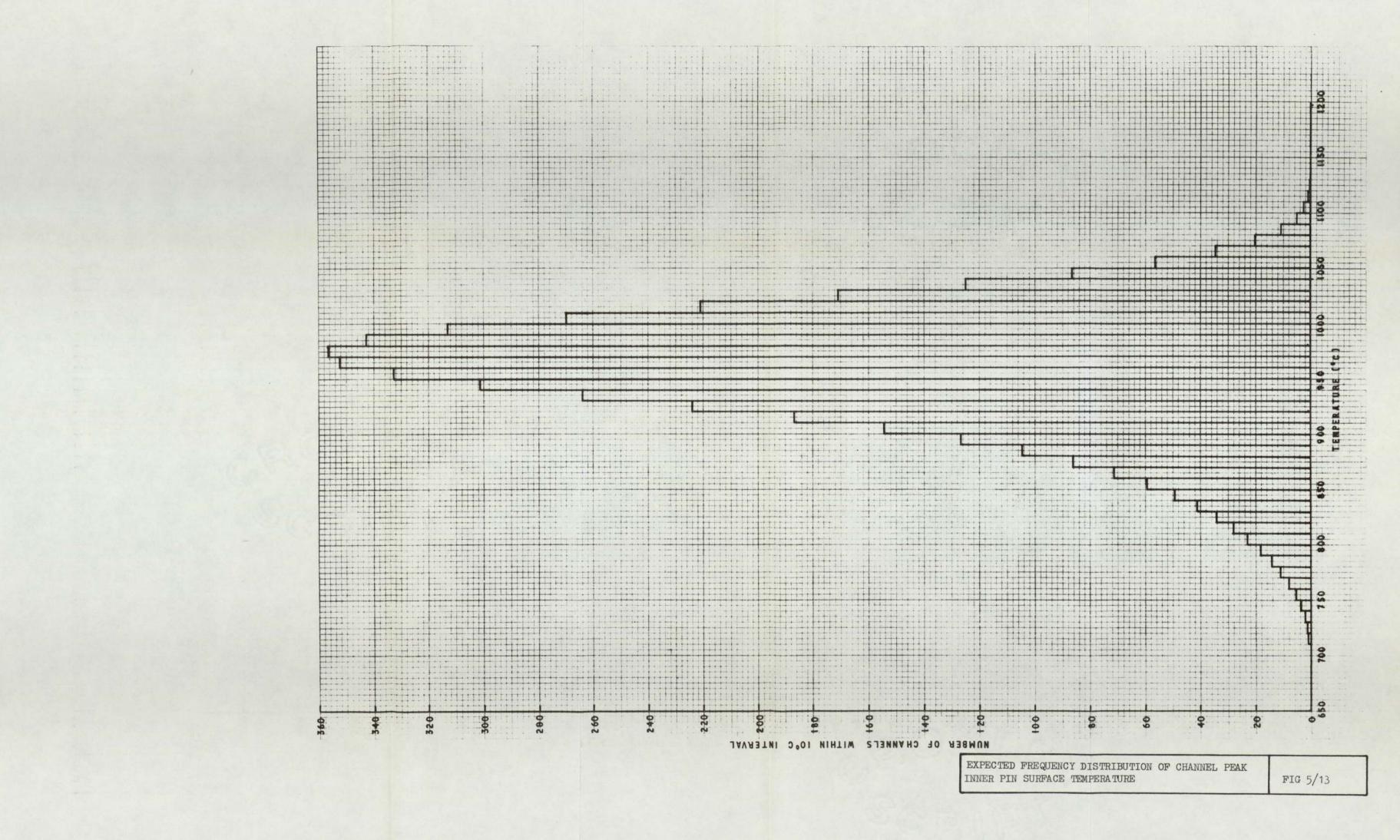


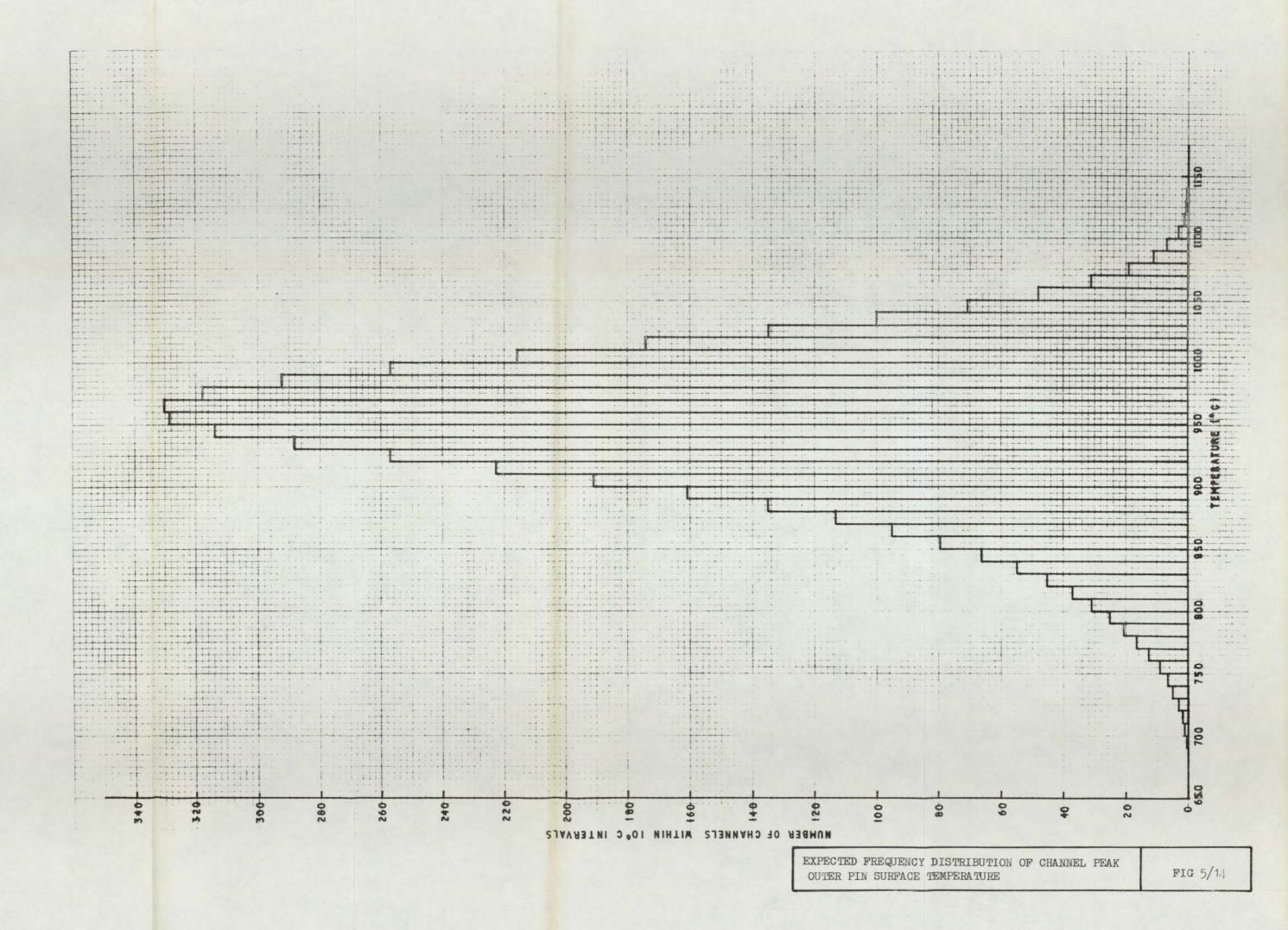


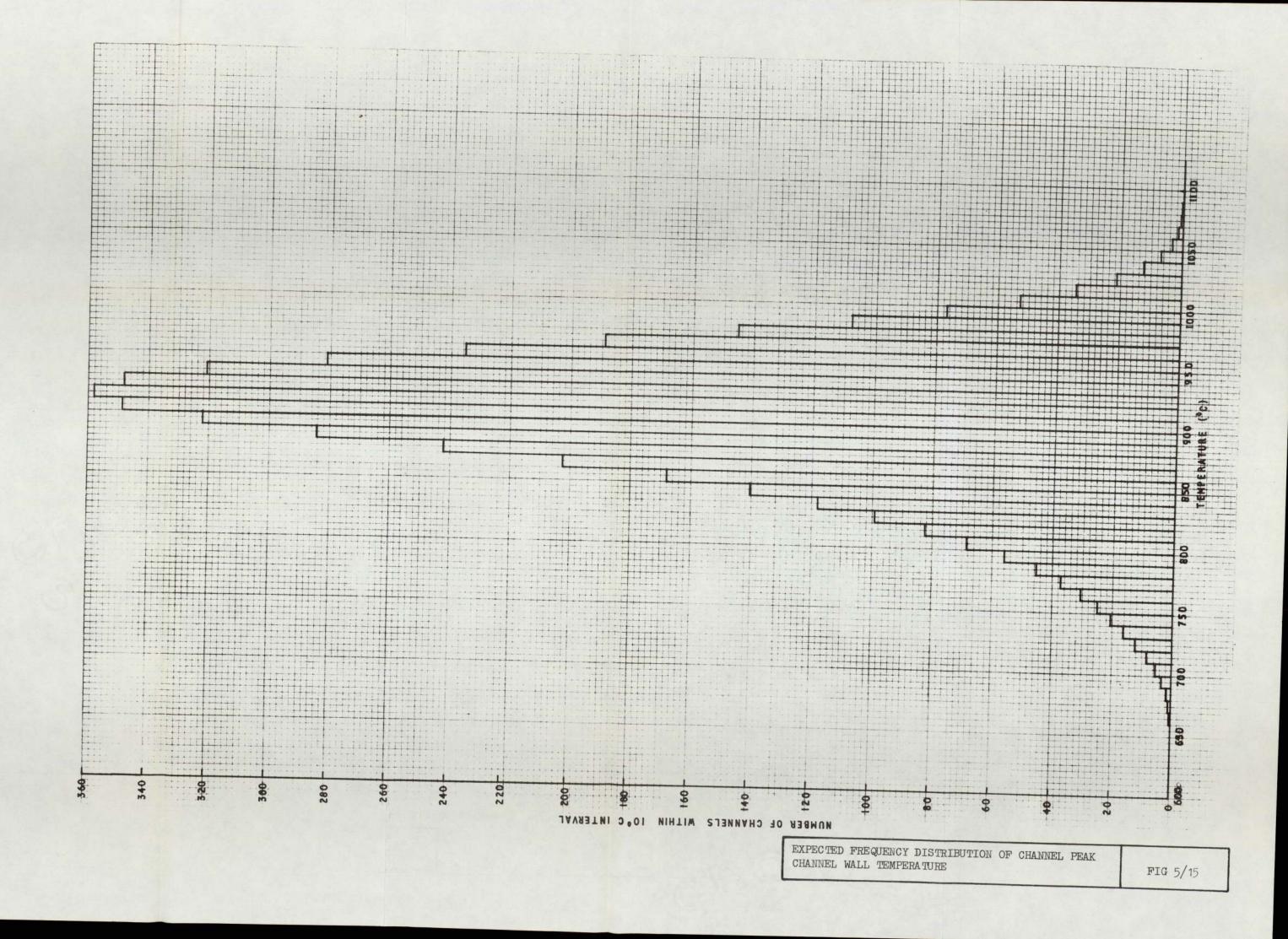












# APPENDICES

Appendix	Title
I	Time gagging effects on channel gas outlet temperature
II	Channel flow variations within a column
III	Reference three group gagging scheme
IV	Thermal expansion as a function of temperature
V	The RUSTAN program
VI	The AZIMUSTAP program
VII	The HEATAX program
VIII	HEATAX III input data
IX	HEATAX III results
X	Expected Frequency Distributions of temperature

#### APPENDIX I

# THE GAGGING EFFECTS ON CHANNEL GAS OUTLET TEMPERATURE

It will be assumed that the channel power falls linearly with time (see Fig 3/4). The Age Factor, A, is then defined as the ratio of the start-of-life power to the half-life power.

Let there be n gag changes. At each gag change the flow is adjusted so as to obtain the same channel peak gas outlet temperature (Fig 3/4). This peak temperature is chosen so as to obtain the desired life mean channel gas outlet temperature  $(\overline{T}_2)$  as the mean for each gag interval.

If a full dwell = 1, the period of each gag interval is 1/(n+1)and as the temperature  $(T_2)$  falls linearly between gag changes it is desired that:

 $T_2(\frac{1}{2}(n+1)) = \overline{T}_2$ 

If  $\hat{T}_2$  is the gas outlet temperature at the start of the gag interval and  $T_1$  is the channel inlet gas temperature:

$$\frac{\mathbf{\hat{T}}_2 - \mathbf{T}_1}{\mathbf{\bar{T}}_2 - \mathbf{T}_1} = \frac{\mathbf{\hat{Q}}_S}{\mathbf{\hat{Q}}_M}$$

where  $Q_S$  is the channel power at the start of the gag interval and  $Q_M$  is that at the mid-point. $Q_M/Q_S$  is clearly given by:

$$\frac{Q_{\rm M}}{Q_{\rm S}} = 1 + \frac{1}{(n+1)} (\frac{1}{\rm A} - 1)$$

Therefore:

$$\hat{T}_2 = T_1 + \frac{(T_2 - T_1)}{(1 + \frac{1}{n+1}(\frac{1}{A} - 1))}$$

In the case of a continuous gagging scheme:

$$n \rightarrow \infty$$
 and  $\overline{T}_2 \rightarrow \overline{T}_2$ 

If there were no gag changes:

n = 0 and  $\hat{T}_2 = \hat{T}_1 + A(\overline{T}_2 - T_1)$ 

### APPENDIX II

# CHANNEL FLOW VARIATIONS WITHIN A COLUMN

Given a uniform heat generation within a column the channel flow distribution would also be expected to be uniform. Rating tilts, however, cause density differences and, as the pressure drop across the column must be a constant for all channels, this leads to flow changes. Let us first ignore the density differences.

Let

$$G = r/r$$

where r is the rating of a channel in a column of mean rating r.

If  $\overline{T}_2$  is the column mean gas outlet temperature and  $T_1$  the column inlet temperature, the gas outlet temperature  $(T_2)$  of this particular channel is given by:

$$T_2 = T_1 + G(\overline{T}_2 - T_1)$$
 ....AII/1

This is assuming uniform flow.

Let us now consider flow variation effects.

If we define an equivalent flow area (Ae) and hydraulic diameter  $(D_{e})$  for the channels then the pressure drop across a 'mean' channel in the column is given by the Guggenhiem equation (Chapter 4, Eq. 67):

$$\Delta P = \frac{1}{2\overline{\rho}} \left(\frac{\overline{W}}{\overline{A}e}\right)^2 \left[\frac{4fL}{D_e} + \frac{4(\overline{T}_2 - T_1)}{(\overline{T}_2 + T_1)} + K_L\right] \qquad \dots \text{AII}/2$$

where:

L = active core height  $\overline{W}$  = column mean flow  $\overline{\rho}$  = column mean density f = friction factor  $K_{T}$  = discontinuity losses

The equivalent for a single channel is:

$$\Delta P = \frac{1}{2\rho} \left(\frac{W}{A_e}\right)^2 \left[\frac{4fL}{D_e} + 4\left(\frac{T_2 - T_1}{T_2 + T_1}\right) + K_L\right] \qquad \dots \text{AII}/3$$

$$W = G\overline{W} \begin{pmatrix} \overline{T}_2 - T_1 \\ T_2 - T_1 \end{pmatrix}$$

The density  $\rho$  , for helium, is given by:

$$\rho = \frac{RP}{T}$$

It will be assumed that:

$$5 \propto \frac{1}{\overline{T}_2 + T_1}$$

and

$$\rho \propto \frac{1}{T_2 + T_1}$$

Substituting for W,  $\rho$  and  $\overline{\rho}$  and setting

$$\frac{4fL}{D_e} + K_L = 4K ; assumed constant,$$

we have:

$$\Delta P = C \left(\frac{\overline{W}}{Ae}\right)^2 \left(\frac{4}{\overline{T}_2 + \overline{T}_1}\right) \left[K + \left(\frac{\overline{T}_2 - \overline{T}_1}{\overline{T}_2 + \overline{T}_1}\right)\right] \qquad \dots AII/4$$

and

$$\Delta P = C G^{2} \left(\frac{\overline{M}}{Ae}\right)^{2} \left(\frac{\overline{T}_{2} - T_{1}}{T_{2} - T_{1}}\right)^{2} \left(\frac{4}{T_{2} + T_{1}}\right) \left[K + \left(\frac{T_{2} - T_{1}}{T_{2} + T_{1}}\right)\right] \dots AII/5$$

C is a constant and since there must be a constant pressure across the column equations AII/4 and AII/5 can be equated, i.e.

$$\mathbb{G}^{2} \left\{ \frac{\overline{\mathbb{T}}_{2} - \mathbb{T}_{1}}{\mathbb{T}_{2} - \mathbb{T}_{1}} \right\}^{2} \left\{ \frac{\overline{\mathbb{T}}_{2} + \mathbb{T}_{1}}{\mathbb{T}_{2} + \mathbb{T}_{1}} \right\} \left[ \mathbb{K} + \left\{ \frac{\mathbb{T}_{2} - \mathbb{T}_{1}}{\mathbb{T}_{2} + \mathbb{T}_{1}} \right\} \right] = \left[ \mathbb{K} + \left( \frac{\overline{\mathbb{T}}_{2} - \mathbb{T}_{1}}{(\overline{\mathbb{T}}_{2} + \mathbb{T}_{1})} \right) \right]$$

The following equation, quadratic in  $T_2$ , is obtained:

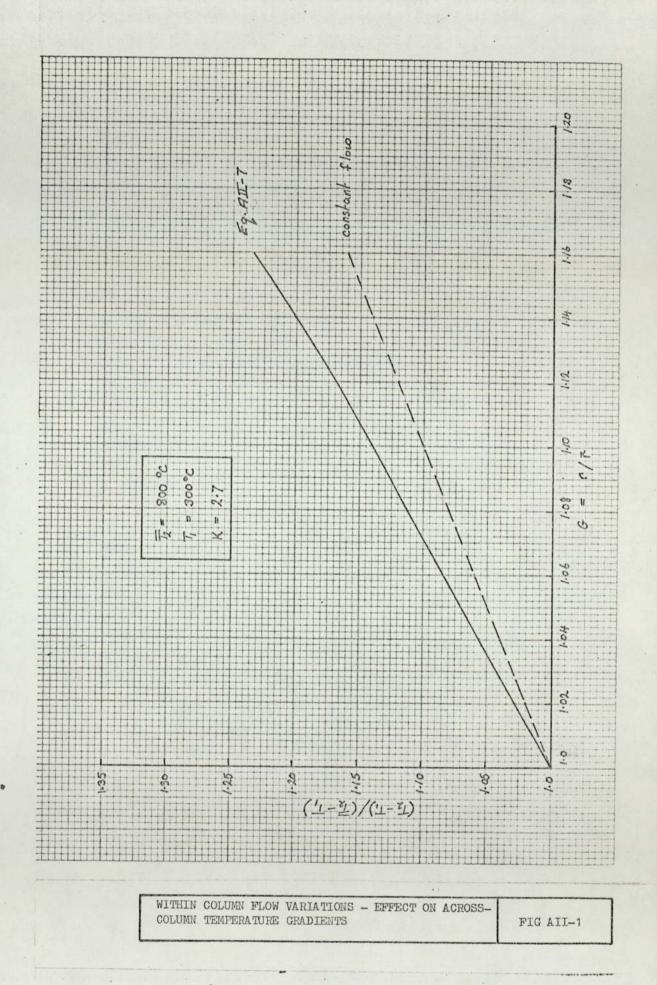
$$T_{2}^{2} - T_{2} \left[ \frac{(\underline{K+1})(\overline{\underline{T}}_{2} - \underline{T}_{1})^{2} \underline{G}^{2}}{\overline{T}_{2}(\underline{K+1}) + (\underline{K-1}) T_{1}} + 2 T_{1} \right] + \left[ T_{1}^{2} - \frac{(\underline{K+1})(\overline{\underline{T}}_{2} - \underline{T}_{1})^{2} \underline{G}^{2} \underline{T}_{1}}{\overline{T}_{2}(\underline{K+1}) + T_{1}(\underline{K-1})} \right] = 0$$
....AII/6

Using a value of K = 2.7 (mean channel) and assuming  $\overline{T}_2 = 800^{\circ}C$  and  $T_1 = 300^{\circ}C$ , the dependence of channel  $T_2$  on rating ratio G is determined.

Fig AII-1 shows  $(T_2 - T_1)/(\overline{T}_2 - T_1)$  versus G. The equation to the curve is:

$$\frac{T_2 - T_1}{(\overline{T}_2 - T_1)} = G^{1 \cdot 4}$$

.....AII/7



## APPENDIX III

# REFERENCE THREE GROUP GAGGING SCHEME

The object is to distribute the 301 columns between three groups and allocate respectively three column gas outlet temperatures such that there is a common peak channel gas outlet temperature between groups.

From the power map shown in Fig 3/3 the maximum rating 'gradient' is 1.147. The three groups are chosen, therefore, as:

0-1.05; 1.05-1.10; 1.10-1.147.

The following table gives the total heat generation  $(\Sigma R)$ , in arbitary units, and maximum gradient  $(\hat{G})$  of each group.

Group	ΣR	Ĝ	F	Т <sub>2</sub>
1	467.9	1.042	1.059	819.2
2	207.1	1.099	1.141	782.1
3	96.17	1.147	1.210	754•4

F is the temperature tilt factor (Eq. AII/7).

From equations 5 and 6 (Chapter 3) the values of the group  $T_2$  values can be found and are given in the table. The peak channel  $T_2$  value that corresponds to this scheme is  $850^{\circ}$ C.

## APPENDIX IV

### THERMAL EXPANSION AS A FUNCTION OF TEMPERATURE

Consider Chapter 4, Eq. 75, expressed in a general form:

$$\frac{\underline{\mathbf{U}}_{\mathbf{r}_{1}}^{1}}{\mathbf{r}_{2}^{2}-\mathbf{r}_{1}^{2}} \int_{\mathbf{r}_{1}}^{2} \mathbf{r} \alpha \mathbf{T} d\mathbf{r}$$

Let  $\alpha = aT + B$  (a good approximation over a 100°C temperature range (TRG 1000(R) (<u>43</u>)).

$$\frac{U}{r_1} = \frac{2r_1}{r_2^2 - r_1^2} \int_{r_1}^{r_2} (r a T^2 + r b T) dr$$

to a good approximation for the graphite sleeve.

T = Ar + B

$$U_{1} = \frac{2r_{1}}{r_{2}^{2} - r_{1}^{2}} \int_{r_{1}}^{r_{2}} [ra(Ar + B)^{2} + rb(Ar + B)] dr$$

Strain S =  $\frac{2}{r_2^2 - r_1^2} \left[ \frac{aA^2}{4} (r_2^4 - r_1^4) + \frac{A(2aB+b)}{3} (r_2^3 - r_1^3) + \frac{B(aB+b)}{2} (r_2^2 - r_1^2) \right] \dots A1V/1$ 

Now let us assume  $\alpha$  is constant but evaluated at  $\overline{T}$ 

$$\overline{T} = \frac{2}{r_2^2 - r_1^2} \int_{r_1}^{r_2} r \, T dr$$

Since T = Ar + B

$$\overline{T} = \frac{2A}{3} \left( \frac{r_2^3 - r_1^3}{(r_2^2 - r_1^2)} + B \right)$$

and  $\alpha(\overline{T}) = \frac{2Aa}{3} \left(\frac{r_2^3 - r_1^3}{(r_2^2 - r_1^2)} + aB + B\right)$ 

The corresponding strain  $\overline{S} = (a\overline{T} + b)\overline{T}$ 

$$\overline{S} = a \left[ \frac{2A}{3} \left( \frac{r_2^3 - r_1^3}{(r_2^2 - r_1^2)} + B \right]^2 + \frac{2bA}{3} \left( \frac{r_2^3 - r_1^3}{(r_2^2 - r_1^2)} + bB \right) \dots AIV/3$$

....AIV/2

The error between S and  $\overline{S}$  is given by:

$$\varepsilon = \frac{\overline{S} - S}{\overline{S}}$$
  
$$\overline{S} - S = aA^{2} \left[ \frac{4}{9} \left( \frac{r_{2}^{3} - r_{1}^{3}}{r_{2}^{2} - r_{1}^{2}} \right)^{2} - \frac{r_{2}^{2} + r_{1}^{2}}{2} \right] \qquad \dots AIV/4$$

Let us consider a graphite sleeve of radii 27.5/32.5 mm with surface temperatures of  $1050/950^{\circ}$ C respectively.

From TRG 1000(R) (43) 
$$a = 1.214 \times 10^{-9} \text{ °C}^{-2}$$
  
 $b = 4.636 \times 10^{-6} \text{ °C}^{-1}$   
Also  $A = -20.0 \text{ °C mm}^{-1}$   
 $B = 1600 \text{ °C}$ 

and  $\overline{T} = 1000^{\circ}C$ 

From Eq. AIV/3

 $\overline{S} = 5.85 \times 10^{-3}$ 

From Eq. AIV/4

 $\overline{S} - S = 1.009 \times 10^{-6}$ 

 $\epsilon = 1.7 \times 10^{-4}$ 

## APPENDIX V

## THE RUSTAN PROGRAM

The RUSTAN code was written in the FORTRAN IV language. It was designed to determine the friction factors in a rough annulus with arbitary specification of roughness height on the two walls and allowing for velocity profile effects.

Fig AV-1 is a flow diagram showing the main calculation steps. (See Chapter 4, section 4, for nomenclature and equations). At the end of this appendix the program listing is shown.

(a) Data input

r <sub>1</sub> , r <sub>2</sub>	channel inner, outer radii	
μ	coolant viscosity	
Nc	number of cases	
W	channel mass flow rate )	Nc values
ε1, ε2	inner, outer roughness height )	NC VALUES

## (b) Initial guesses

The transformed friction factors  $f_1, f_2$  are set equal to the smooth value,  $f_s$ , (Eq. 34) and preliminary values of Re,  $D_e$ , etc. determined by also assuming smooth walls.

(c)  $\varepsilon_*, \varepsilon_*$ 

These are calculated using Eq. 146.

(d)  $\underline{A_1^*, A_2^*}$ 

Depending upon the values of  $\frac{\varepsilon_*}{1}$  and  $\frac{\varepsilon_*}{2}$  the relevant equation for the evaluation of  $A_1^*$  and  $A_2^*$  is used.

It will be noted from the-listing that the limiting values of  $\varepsilon^*$ and the A\* equations are slightly different from those quoted in Chapter 4 equations 136. The values and equations in RUSTAN are taken from NIKURADSE (<u>37</u>) whereas those in the text apply to the HEATAX code. The reason for the discrepancy is given in Appendix VII.

AV-1

(e) Friction factors

The revised values of transformed friction factor are calculated from Eq. 145.

(f) Parameters

Certain parameters are determined e.g.  $De_1 De_2$ ,  $\overline{u}_1/\overline{u}_2$ ;  $Re_1$ ,  $Re_2$ (See equations in Chapter 4, sub-section 4.4.2).

(g) Error

If present  $f_1$ ,  $f_2$ , values differ by more than 0.1% from previous values and not more than 20 iterations have been carried out the calculation returns to (c) above. (Typical number of iterations is four).

(h) Print out

Table 4/4 is a typical RUSTAN output (Units are all S.I. e.g. kg, m, s.)

The parameters printed out are:

RC1, RC2 annulus inner, outer radii

FLOW annulus mass flow rate

EH1, EH2 Inner, outer roughness height (mm)

RE1, RE2 Inner, outer transformed Reynolds number

RM Radius of no shear

UR Inner/outer mean velocity ratio

- E\*1, E\*2 E\*, E\*
- F1, F2 Inner, outer transformed friction factors

. Cooo	RUSTAN ***		
	FORMAT(I)	00000100	
	FORMAT(3F10.1)	00000000	
1000	READ (5.21) RC1.RC2.VIS	00000300	
	WRITE(6+40)	00000500	
	wRITE(6,41)	00000600	S S S S S S S S S S S S S S S S S S S
	WRITE(6+42) RC1+RC2	00000700	
-	WRITE(6+43)	00000800	
22	FOHMAT(4F10.1)	00000900	The state of the set
i ser en	HEAD (5+20) NC	00001000	The second
23/2017 0.00	DO 30 N=1+NC READ(5+22) W+EH1+EH2	00001100	A REAL PROPERTY OF A READ REAL PROPERTY OF A REAL P
1.14 (A. )	I=0	00001200	the second
EW	A=3.14159*(RC2*RC2-RC1*RC1)	00001300	a second s
	RE=2.0*w*(RC2-RC1)/(A*VIS)	00001400	a term of the second se
AND DISTRICT IN	FS1=0.079/RE**0.25	00001500	A CALL AND A
	F1=FS1	00001700	the state of the s
2.3-2	F2=FS1	00001800	commences and an and the same such
	REI=PE	00001900	
institute and the	RECERE	00002000	
	DE1=2.0*(RC2-RC1) DE2=DE1	00002100	
1	ESTAR1=HE1*SORT(F1/2.0)*EH1/DE1	00022000	
BORRETT. a sa	ESTAR2=RE2*SORT (F2/2.0) *EH2/DE2	00002300	
	M=0	00002400	
11.4.19 B	ESTAR=ESTAR1	00002500	
9	IF (ESTAR.LT.3.5) GU TO 2	00002700	the state of the second
A CARE THE	IF (ESTAR.LT.7.0) 60 TO 3	00002800	EST-MERTY (21 TO TO TO THE REAL PROPERTY AND
	IF(ESTAR.LT.14.0) GO TO 4	00002900	and the second sec
#1.00.000.0	IF (ESTAR.LT.68.0) GO TO 5	00003000	The second second second second second
100 E	ASTAR=8.48 GO TO 6	00003100	the state of the second
	ASTAR=2.5*ALOG(ESTAR)+5.55	00003200	The second se
	GO TO 6	00003300	
	ASTAR=1.52*ALOG(ESTAR)+6.59	00003400	the second secon
	GO TO 6	00003500	a the state of the second second second
4	ASTAR=9.59	00003700	and the second
Warran -	GO TO 6	00003800	THE STATES A STREAM
	ASTAR=11.5-0.705*ALOG(ESTAR)	00003900	
6	IF (M.EQ.0) GO TO 7	00004000	The second se
02004.000 Th	ASTAR2=ASTAR GO TO 8	00004100	
	ASTAR1=ASTAR	00004200	
Bartunnur		00004300	
	ESTAR=ESTAR2	00004400	
REPORT OF	GO TO 9	00004600	A CONTRACTOR OF THE STATE OF THE STATE
	F1N=2.0/(ASTAR1-3.75-2.5*ALOG(2.0*EH1/DE1))**2.0	00004700	- and the state of
to the stand of the	F2N=2.0/(ASTAP2-3.75-2.5*ALOG(2.0*EH2/DE2))**2.0	00004800	- a la l
	ERROR=F1N/F1-1.0	00004900	to the second second second second
He sharen a fil	IF (AUS (ERROR) .LT.0.001) GO TO.10	00005000	
5391-101-101	F2=F2N	00005100	
······································		00005200	
ENTER STATE	IF(I.EQ.20) GO TO 25	00005400	
	GO TO 11	00005500	ente de la constante de la const
	ERROR=F2N/F2-1.0	00005600	and the angle of the
	IF (ABS(ERROR) . LT. 0.001) 60 TO 12	00005700	Arte and and a sub-
2	I=I+1 Fl=FlN	00005800	· · · · · · · · · · · · · · · · · · ·
	F2=F2N	00005900	
£	IF (1.EQ.20) GO TO 25	00006000	
11	UR=(1.0+3.75*SQRT(F2/2.0))/(1.0+3.75*SQRT(F1/2.0))	00006100	and a section of the section
	Da=F2/(UR#UR#F1)	00006200	en el contrato de la segui de la contrato de
E.M.	RM=SORT((RC1*RC2+DR*RC1*RC1)/(DR+RC1/RC2))	00006400	the second of a second to second
			and a second
	PE1=2 08/00000 00100011 (001		
and the second damage of the second se	6E1=2,0*(RM*RM-RC1*RC1)/RC1 0E2=2,0*(0C2*PC2-0Value)/RC2	00006500	
	DE2=2.0*(RC2*RC2-RM*RM)/RC2 ROUM1=0.6366*W/(PC1*DE1+PC2*DE2/UR)	00006600	t and the second second
	ROUM2=ROUM1/UR	00006700	
	RE1=ROUM1+DE1/VIS	00006800	the second secon
	REZ=ROUM2+052/VIS	00007000	
	GU TO 1	00007100	The second secon
	EH1=1000.0*EH1	00007200	The Average of the second seco
	EH2=1000.04EH2	00007300	
	DE1=1000.0*DE1 DE2=1000.0*DE2	00007400	
	RM=1000.0*RM	00007500	
	WHITE (6,44) W.EHI. H2. PEI. RE2. RE. DE1. DE2. RM. UR. ESTARI. ESTAR2. FI.F	00007600	
1	+1	00007800	
30	CONTINUE	00007900	and the second second
40	FORMAT(11+20X+ IR USTAN PESULTSI)	00080000	
+1	FUHMAT(///+2x,+RC1+,5x,+RC2+,3x,+(M)+)	00004100	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1
	FORMAT(1X+2(F7.4))	00008200	
	FUHMAT (//.2X. FLOW EH1 EH2'.6X. RE1'.6X. RE2'.5X. RE'.5X. DE		
	1+5X+*DE2*+3X+*RM UR++6X+*E+1*+5X+*E*2*+3X+*F1++6X+*F2+) FOHMAT(/+1X+3(F7+4)+3(F9+0)+3(F6+2)+F6+3+2(FH+2)+2(FB+5)+15X+13)	00004400	
	STOP	00004500	*
1. 3		00008600	AV-3
	END	00008700	AV U

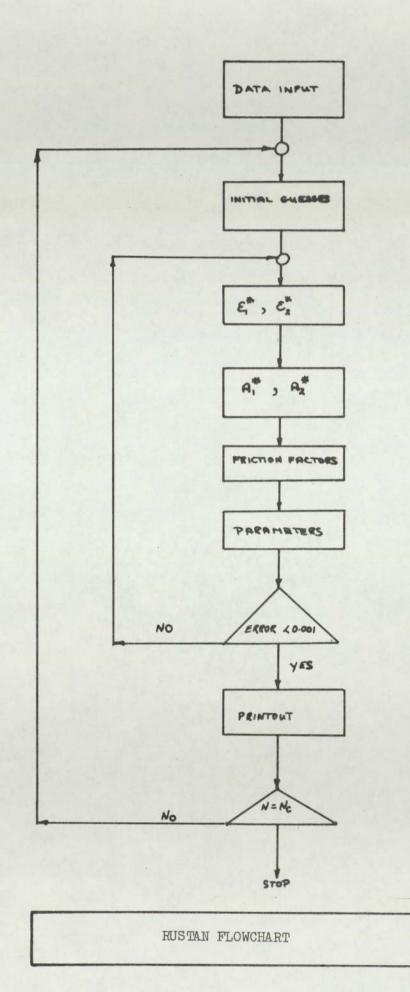


FIG AV-1

#### APPENDIX VI

### THE AZIMUSTAP PROGRAM

There are two parts to the AXIMUSTAP 5 code:

(i) axial calculation

(ii) interface gap and time dependent calculation.

The specification for the latter was made by the Author and is described in Chapter 4, section 3. The axial calculation was not specified by the Author but will be described briefly to give useful background. The program was written by W.S. Sinclair and his report (SINCLAIR (51)) gives further details.

The fuel channel is divided into a number of axial slabs (N). The program performs N + 1 calculations starting at inlet to the fuel channel and finishing at outlet. The channel inlet and outlet gas temperatures are specified, together with the channel power, from which the channel mass flow rate can be determined.

 $W = Q_{CH}/C_P (T_2 - T_1)$ 

In the case of a tubular element the first guess of the flow split is found from the application of a simplified Guggenheim equation.

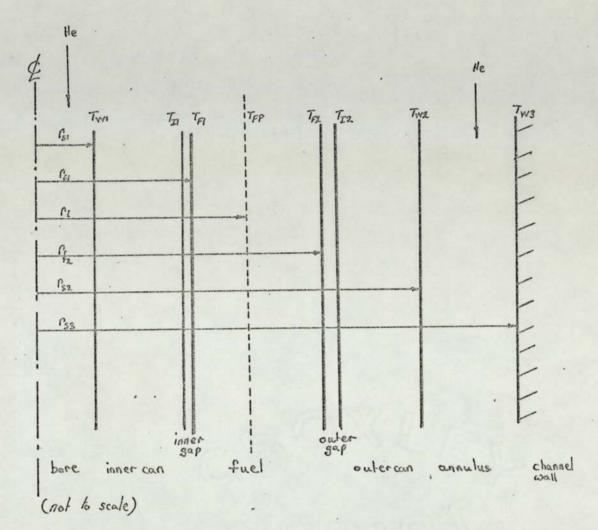
Channel inlet gas temperature  $(T_1)$  provides the boundary conditions for the first axial calculation.

Fig AVI-1 shows a section through the fuel channel at axial position Z. Thermal radiation across the annulus is at first neglected and the fuel element temperatures T<sub>FP</sub>, T<sub>F1</sub>, T<sub>W1</sub> etc. found. The heat generation at the calculation point is determined by combining the axial rating shape and channel power. With values of T<sub>W2</sub> and T<sub>W3</sub> the thermal radiation component can be found and the temperatures recalculated. Within this iterative loop the temperature dependent material properties and interface gaps are continuously updated. On convergence, the heat transfer into the two passages can be found and the temperature rise within the

AVI-1

step determined. The gas temperature boundary conditions are thus obtained for the next calculation step.

At each step the pressure rise within the step is determined for the two passages. When channel outlet is reached the two pressure drops are compared. If they differ by more than a certain percentage (usually 0.1%) the flow split is re-assessed and the axial calculation repeated. Generally, pressure convergence is achieved after two or three iterations.



SECTION THROUGH TUBULAR FUEL ELEMENT

FIG AVI-1

#### APPENDIX VII

## THE HEATAX PROGRAM

There were three stages of development of the FORTRAN IV code - HEATAX:

(i) HEATAX I

This program performed a single axial calculation (similar to the AZIMUSTAP program) given the flow split, channel power etc. Corrosion was neglected and the channel dimensions were independent of temperature. This program was intended as a fast running module to be built into a load following reactor physics code.

# (ii) <u>HEATAX II</u>

This development included temperature dependent channel dimensions and the pressure drop calculation. Flow split and heat transfer effects of sleeve and channel thermal expansion could, therefore, be determined. (Chapter 4 sub-section 3.5).

# (iii) HEATAX III

The final development of the program included the corrosion phenomenon where the flow split, pressure drop and heat transfer effects of temperature dependent planar removal and graphite roughness are determined. As corrosion is progressive the program was also developed to perform the axial calculation over a number of time steps.

This final version of the program will now be described in more detail.

#### Data input

1

NTIME		-		Numbe	r of	time	steps	
NTIME	sets	of	the	follo	wing			
LTIME		-		time	incre	ement	(days)	

BKG	-	Graphite thermal conductivity - 19 values: 300°C to 1200°C in 50°C intervals (W/cm°C)
BKF	-	Fuel thermal conductivity - 25 values $300^{\circ}C$ to $1500^{\circ}C$ in $50^{\circ}C$ intervals (w/cm°C)
QCH	-	Channel power (W)
NAX	-	Number of axial slabs
QZ	-	Axial rating value (NAX + 1 values)
ASLAB	-	Axial slab 'area' (NAX values) giving heat generation within slab.
HMAX	-	Conductance of nominally zero gap (W/cm <sup>20</sup> C)
RI	-	First guess of heat split radius (cm)
TG1	-	Bore inlet gas temperature (°C)
TG2	-	Annulus inlet gas temperature (°C)
Е	-	Emmissivity (fuel and graphite)
RCOC	-	Cold bore radius (cm)
RC1C	-	Cold pin outer radius (cm)
RC2C	-	Cold channel wall radius (cm)
RF1	-	Fuel inner radius (cm)
RF2	-	Fuel outer radius (cm)
RHO	-	Fraction of channel heat generated in moderator
W1	-	Bore flow (g/s)
W2	-	Annulus flow (g/s)
RP	-	Rib height (cm)
RIBW	-	Rib width (cm)
AL	-	Active core height (cm)
FL	-	Fraction of core height containing fuel
PIN	-	Channel inlet pressure (dynes/cm <sup>2</sup> )
NRIB	-	Number of ribs
GS 1	-	Inner cold radial gap (cm) (NAX + 1 values)

GS2 - Outer cold radial gap (cm) (NAX + 1 values)
 Appendix VIII is a typical data input for a seven time step,
 10 axial step calculation.

### The program

2

The program consists of three routines: MAIN, RUST and PRESS. A listing is shown at the end of this Appendix. The main steps in the calculation can be found by referring to the "Comment" statements.

MAIN reads in the input data, performs the axial and time calculation and then prints out the results.

RUST performs the calculation of rough friction factors and heat transfer coefficients as according to Chapter 4 section 4.

PRESS calculates the pressure drop in the bore and annulus according to the Guggenheim equation and determines the flow split for the next iterative loop.

It should be pointed out that the  $\varepsilon * - A*$  relations used in RUST and quoted in Chapter 4 section 4 are not those reported by NIKURADSE (37). By using the NIKURADSE equations it was found:

- (i) If the smooth-rough transition was taken as  $\varepsilon * = 3.5$ (NIKURADSE) friction factors for  $\varepsilon *$  values only a little above 3.5 were calculated as being <u>less</u> than the smooth values. This was overcome by reducing the critical  $\varepsilon *$ to 3.05.
- (ii) The NIKURADSE equations did not give the same values of A\* at the boundary values of  $\varepsilon$ \*. This was solved by changing slightly the boundary  $\varepsilon$ \* values.

#### Results output

RE

3

At each axial calculation step three values of Reynolds number applying to the bore (1) and transformed annulus (2)

AVII-3

DE	Correspo	onding va	alues	of hyd:	raulic diam	nèter (cm)
RM	At each	axial s	tep -	• radius	of no-shea	ar (cm)
DWELL T	IME Cur	nulative	dwe]	l (days	)	
CHANNEL	POWER (	N)				
MIXED GA	S OUTLET	TEMPERA	TURE	(°C)		
INNER FI	LOW RATE	bore	flow	w (g/s)		
OUTER FI	LOW RATE	annu	lus i	flow (g/	s)	
Fo:	r each ca	lculatio	on ste	ep:		
Z	axial p	osition	(Z =	0 at ir	let)	
TG1	Tg1	(°C)				
TW1	T <sub>W1</sub>					
TI1	T <sub>I1</sub>	(°C)				
TF1	T <sub>F1</sub>	(°C)				
TFM	T <sub>FP</sub>	(°C)				
TF2	T <sub>F2</sub>	(°C)				
TI2	T <sub>I2</sub>	(°C)				
TW2	Tw2	(°C)				
TG2	T <sub>g2</sub>	(°C)				
TW3	Tw3	(°C)				
INNER C	AP		radi	al	(cm)	
HEAT SF	LIT RADIU	IS	( cm)			
OUTER G	AP		radi	al	(cm)	
RCO			r <sub>s1</sub>	(hot)	( cm)	
RC1				(hot)		
RC2			r <sub>s3</sub>	(hot)	( cm)	
PD (BOF	E)		bore	pressu	re drop	(dynes/cm <sup>2</sup> )
PD (ANN	ULUS)		annu	lus pre	ssure drop	(dynes/cm <sup>2</sup> )

AVII-4

PLANAR REMOVALat  $r_{s1}$ ,  $r_{s2}$ ,  $r_{s3}$  (cm)ROUGHNESS HEIGHTat  $r_{s1}$ ,  $r_{s2}$ ,  $r_{s3}$  (cm)HEAT TRANSFER COEFFICIENTat  $r_{s1}$ ,  $r_{s2}$ ,  $r_{s3}$  W/cm<sup>20</sup>CFRICTION FACTORat  $r_{s1}$ ,  $r_{s2}$ ,  $r_{s3}$ 

Appendix IX is a typical results output and shows the above values for the seven time steps.

HAN IV	GIEVEL	20 HAIN DATE # 72349 11/50/4	The Free	0001
	c	HEATAX	00101000	
1		DIMENSION FI(50), T(1(50), T(2(51), T(1(50), T(2(50), 111(50),	00102000	
	. 5	1112(50), TF1(50), TF2(50), TF1(X(51), TF(AL(50), 02(50), AL(AB(50), 205(AB(50), GENT(50), PRE(3(), FF(3(), TF(30),	00(03000	
		31T61(50),1T62(50),1T01(50),1T62(50),1T11(50),1T12(50),1TF1(50),	00(05100	
		41TF2(50),1TFMAX(50),1T1ALL(:1),2(50),12(50),61N(50),651(50),652(50	000100000	
		5), PCU(50), RC1(50), RC2(50), DI T1(5(), LI T2(50), DRT1(20,20), DPT2(20,20	000(071.00	
		6), 0RT5(20,20), F1(20), F2(20), F3(2(), HT1(20), HT2(20), HT3(20), LTIM(2(		
		7),FR1(20),FP2(20),EF3(20)	00009000	
2		CUMMON WI,W2,AL, MAX, DE1, DE2, T(1, TG2, FLOA1, FLOA2, 1, HIT1, DPT2, POUT,	00(11/00	
3		11N,L,FF1,FF2 DATA AX1,8X1,CX1,AX2,CX2,CX2/-4,(835-07,1,5724F-03,+C,2541,-6,38F.		
,		107,2,4018-03,4,687/	00(13(00	
		ATEMENT FUNCTIOLS	00(17100	
6		ALFAF(TF)=(AX1*TF+FX1+TF+CX1)/1,0[+06	00(18000	1.40
5		ALFAG(TG)=(AX2*TG*TG+LX2*TG*(X2)/1.(L+06	00(19/00	
0		DELR1(T)=276.0/1X9(2.0174F+(4/(T+273.0))	00120000	
7		DELR2(T)=27ff.0/EXP(2,0174L+04/(T+273,0)) LTIM(1)=0	001226.00	
9		PEAD(5,100) NTIPE	00(23/00	
Ü		NT=1	001241.00	
1	400	NT=NT+1	00(25000	
2		READ(5,99) LTIHE	001.541.00	
5		MT=NT-1	00(27600	
4	99	FURMAT(15)	00128600	
5	140	LTIM(NT)=LTIN(NT)+LTIME FORMAT (13)	00(29000	
o 7		FURMAT (NF10,1)	00(31000	
	C	CONDUCTIVITY DATA	00132100	
8		READ(5,101)(ExG(K), N=1,19)	00033000	
9		PEAD(5,101)(BFF(N),N=1,25)	00(34000	
U		TG(1)=575	00(35000	
1		D0 50 N=2,19	00036600	
3		N1=N-1 TG(N)=TG(M1)+50	00(3)(00	
6	50	CONTINUE	00139100	
5		TF(1)=575	00(40600	* - **
0		00 51 N=2.25	00141700	
7		N1=N+1	00124700	
8	meter sti	TF(N)=TF(N1)+50	00(43000	
			000111000	
9	51	CONTINUE	00(44000	
9 0 1 RAN IV (	с 	RATING DATA READ(5,101) OCH READ(5,100) NAX	00(45000 00(46000 00(47000	
0	с 	PATING DATA READ(5,101) OCH READ(5,100) NAX 20 MAIR DATE = 72349 11/50/4 N=NAX+1 READ(5,101)(02(11),11=1,K)	00(45000 00(46000 00(47000	0002
0 1 RAN IV (	с 	PATING DATA           READ(5,101) OCH           READ(5,100) NAX           20         MAIN           DATE = 72349         11/50/4           N=NAX+1         READ(5,101)(O2(11),11=1,K)           READ(5,101)(O2(11),11=1,K)         READ(5,101)(ASLAG(11),11=1,IAX)	00(4500 0004000 00(47000 48 PAGE 00(48000 00(49000 00(5000	000;
0 1 RAN IV ( 2 3 4	с 	PATING DATA       READ(5,101) OCH       READ(5,100) NAX       20     MAIN       DATE = 72349     11/50/4       N=NAX+1     DATE = 72349       READ(5,101)(O2(11),11=1,K)       PEAD(5,101)(ASLAG(11),11=1,K)       PEAD(5,101)(ASLAG(11),11=1,K)       CHANKEL DATA	00(4500 00(4700 00(4700 48 PAGE 00(4800 00(5000 00(5000 00(5000	
0 1 RAN IV ( 2 3 4	с 	PATING DATA         READ(5,101) OCH         READ(5,101) OCH         READ(5,100) NAX         20       MAIN         DATE = 72349       11/50/4         N=NAX+1       DATE = 72349       11/50/4         READ(5,101)(O2(11),11=1,K)       PEAD(5,101)(ASLAG(11),11=1,IAX)       CHANKEL DATA         PEAD(5,101) HMAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO       PEAD(5,101)	00(4500 00(4700 00(4700 48 PAGE 00(4800 00(5400 00(5100 00(5100 00(5200	
0 1 RAN IV 0 2 3 4 5	с 	PATING DATA         READ(5,101) OCH         READ(5,100) NAX         20       MAIN         DATE = 72349       11/50/4         N=NAX+1       DATE = 72349         READ(5,101)(O2(11),11=1,K)       READ(5,101)(ASLAG(11),11=1,FAX)         CHANNEL DATA       PEAD(5,101) HNAX,PI(1),TC1(1),TC2(1),E.RCOC,RC1C,RC2C,RF1,RF2,RHO         1,W1,W2,RP,RJBW,AL,FL,PIN       N	00(4500 00(4700 00(4700 48 PAGE 00(4800 00(5000 00(5000 00(5000	000;
0 1 RAN IV 0 2 3 4 5	с 	PATING DATA         READ(5,101) OCH         READ(5,100) NAX         20       MAIR         DATE = 72349       11/50/4         N=NAX+1       DATE = 72349         READ(5,101)(O2(11),11=1,K)         READ(5,101)(ASLAG(11),11=1,FAX)         CHANNEL DATA         PEAD(5,101) HHAX,PI(1),TC1(1),TC2(1),E.RCOC,RC1C,RC2C,RF1,RF2,RHO         1,W1,U2,RP,RIBU,AL,FL,PIN         READ(5,100) HPIP	00(4500 00(47000 68 PAGE 00(47000 00(5000 00(5000 00(5000 00(52000 00(5300	000;
0 1 RAN IV 0 2 3 4 5 5	C S LEVEL C	PATING DATA         READ(5,101) OCH         READ(5,100) NAX         20       MAIN         DATE = 72369       11/50/4         N=NAX+1       DATE = 72369         READ(5,101)(O2(11),11=1,K)       PAD(5,101)(ASLAG(11),11=1,IAX)         CHANNEL DATA       PEAD(5,101) HNAX,PI(1),TC1(1),TC2(1),E.RCOC,RC1C,RC2C,RF1,RF2,RHO         1,W1,U2,RP,RIBW,AL,FL,PIN       READ(5,100) HPIP         D0 55 11=1,N       PEAD(5,101) GS2(11)	00(4500 00(4700 00(4700 00(4700 00(5000 00(5000 00(5000 00(5300 00(5000 00(5000 00(5000	nov;
0 1 RAN IV 0 2 3 4 5 6 7 8	C S LEVEL C	PATING DATA         READ(5,101) OCH         READ(5,100) NAX         20       MAIR         DATE = 72349       11/50/4         N=NAX+1       DATE = 72349         READ(5,101)(O2(11),11=1,K)         READ(5,101)(ASLAG(11),11=1,FAX)         CHANNEL DATA         PEAD(5,101) HMAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO         1,W1,W2,RP,RIFW,AL,FL,PIN         READ(5,100) HPIP         D0 55 11=1,K         PEAD(5,101) GS1(11),GS2(11)        HEAT GENEFATION*****	00(4500 00(4000 00(47000 48**********************************	0003
0 RAN IV 0 2 3 4 5 6 7 8 9	C S LEVEL C	PATING DATA         READ(5,101) OCH         READ(5,100) NAX         20       MAIR         DATE = 72349       11/50/4         N=NAX+1       DATE = 72349         READ(5,101)(OZ(11),11=1,K)       PEAD(5,101)(ASLAG(11),11=1,K)         READ(5,101) HMAX,PI(1),T1(1),T02(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO         1,N1,U2,RP,RIBW,AL,FL,PIN         READ(5,100) NPIF         DO 55 11=1,K         PEAD(5,101) GS1(11),GS2(11)        HEAT GENEFATION*****         SUM=0	00(4500 00(4700 00(4700 48 PAGE 00(4800 00(500 00(5100 00(5100 00(5100 00(5500 00(5500 00(5700 00(5700 00(5700	000;
0 1 RAN IV 0 2 3 4 5 5 6 7 8 9 9	C S LEVEL C	PATING DATA         READCS,1013 OCH         READCS,1013 OCH         READCS,1003 NAX         20       MAIN         DATE = 72349       11/50/4         N=NAX+1       DATE = 72349         READCS,1013(O2(11),11=1,K)         READCS,1013(ASLAGC(11),11=1,FAX)         CHANNEL DATA         PEADCS,1013 HMAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO         1,N1,V2,RP,RIBW,AL,FL,PIN         READCS,1003 NPIF         D0 55 11=1,K         PEAD(S,1013)GS1(13),GS2(11)        HEAT GENEFATION*****         SUM=0         D0 30 N=1,NAX	00(4500 00(4700 00(4700 00(4700 00(4700 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5900	000;
0 1 RAN IV ( 2 3 4 5 5 6 6 7 8 8 9 9	C 5 LEVEL C 55 C++++	PATING DATA         READ(5,101) OCH         READ(5,100) NAX         20       MAIN         DATE = 72349       11/30/4         N=NAX+1       DATE = 72349         READ(5,101)(O2(11),11=1,K)       PEAD(5,101)(ASLAG(11),11=1,IAX)         CHANNEL DATA       PEAD(5,101) HMAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO         1,W1,W2,RP,RTBW,AL,FL,PIN       READ(5,100) HPIP         D0 55 11=1,K       PEAD(5,101) GS1(11),GS2(11)        HEAT GENEFATION*****       SUM=0         D0 30 N=1,NAX       SUM=SUM+ASLAB(N)	00(4500 00(4700 00(4700 48 PAGE 00(4800 00(500 00(5100 00(5100 00(5100 00(5500 00(5500 00(5700 00(5700 00(5700	000;
RAN IV ( 2 3 4 5 5 6 7 8 8 9 9	C 5 LEVEL C 55 C++++	PATING DATA         READCS,1013 OCH         READCS,1013 OCH         READCS,1003 NAX         20       MAIN         DATE = 72349       11/50/4         N=NAX+1       DATE = 72349         READCS,1013(O2(11),11=1,K)         READCS,1013(ASLAGC(11),11=1,FAX)         CHANNEL DATA         PEADCS,1013 HMAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO         1,N1,V2,RP,RIBW,AL,FL,PIN         READCS,1003 NPIF         D0 55 11=1,K         PEAD(S,1013)GS1(13),GS2(11)        HEAT GENEFATION*****         SUM=0         D0 30 N=1,NAX	00(4500 00(4700 00(4700 48 PAGE 00(4800 00(500 00) 00(500 00(500 00) 00(500 00 00(500 00 00(500 00 00(500 00 00(500 00 00(500 00 00(500 00 00(500 00 00(500 00 00(500 00 00(500 00 00(500 00 00(500 00 00(500 00 00(500 00 00(500 00 00 00(500 00 00 00(500 00 00 00 00 00 00 00 00 00	nou;
0 RAN IV 0 2 5 6 7 8 9 9	C 5 LEVEL C 55 C++++	PATING DATA         READ(5,101) OCH         READ(5,100) NAX         20       MAIN         DATE = 72349       11/30/4         N=NAX+1       DATE = 72349       11/30/4         READ(5,100) (O2(11),11=1,K)       PEAD(5,101) (O2(11),11=1,K)       PEAD(5,101) (ASLAG(11),11=1,KX)         CHANNEL DATA       PEAD(5,101) HMAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO       1,N1,V2,RP,RIRU,AL,FL,PIN         READ(5,100) HPIP       D0 55 11=1,K       PEAD(5,100) HPIP         D0 55 11=1,K       PEAD(5,101) GS1(11),GS2(11)        HEAT GENEPATION*****       SUM=0         D0 30 N=1,NAX       SUM=SUM+ASLAB(N)         CONST=0CH/SUH       CONST=0CH/SUH         D0 31 N=1,NAX       CONST=0CH/SUH	00(4500 00(4700 00(4700 00(4700 00(4700 00(5000 00(5000 00(5000 00(5500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(600 00) 00(600 00(600 00) 00(600 00) 00(600 00) 00(600 00) 00(600 00) 00(600 00) 00(600 00) 00(600 00) 00(600 00) 00(600 00) 00(600 00) 00(600 00) 00(600 00) 00(600 00) 00(600 00) 00(500 00) 00(600 00) 000 000 000 000 000 000	000;
RAN IV ( 23 5 5 6 7 8 9 9	C 5 LEVEL C 555 C****	PATING DATA         READ(5,101) OCH         READ(5,100) NAX         20       MAIR         DATE = 72349       11/50/4         N=NAX+1       DATE = 72349         READ(5,101)(O2(11),11=1,K)         READ(5,101)(ASLAG(11),11=1,K)         READ(5,101)(ASLAG(11),11=1,K)         READ(5,101) HNAX,PI(1),TC1(1),TC2(1),E.RCOC,RC1C,RC2C,RF1,RF2,RHO         1,W1,W2,RP,RIBW,AL,FL,PIN         READ(5,100) NPIF         D0 55 11=1,K         PEAD(5,101) GS1(11),GS2(11)        HEAT GENERATION*****         SUM=0         D0 30 N=1,NAX         SUM=4SLAB(N)         CONTINUE         CUNST=0CH/SIH         D0 31 N=1,NAX         GSLAB(N)=CONST*ASLAP(N)	00(4500 00(4000 00(47000 48**********************************	000;
RAN IV ( 23 5 5 6 7 8 9 9	C 5 LEVEL C 55 C++++ 30 31	PATING DATA         READCS,101) OCH         READCS,100) NAX         20       MAIR         DATE = 72349       11/30/4         N=NAX+1       DATE = 72349         READCS,101)(OZ(11),11=1,K)       PATE         READCS,101)(OZ(11),11=1,K)       PATE         READCS,101)(OZ(11),11=1,K)       PATE         READCS,101) HAX,PIC(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO         1,W1,W2,RP,RIBW,AL,FL,PIN         READCS,100) NPIF         DO S5 11=1,K         PEADCS,101) GS1(11),GS2(11)        HEAT GENEFATION*****         SUM=0         DU 30 N=1,NAX         SUM=SUM+ASLAB(N)         CONST=OCH/SIM         D0 31 N=1,NAX         OSLAB(M)=CONST+ASLAP(N)         CONTINUE	00(4500 00(4000 00(47000 48 PAGE 00(4800 00(5000 00(5100 00(5100 00(5100 00(5500 00(5500 00(5500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 000 0	
0 RAN IV 0 2 5 6 7 8 9 9 9	C 5 LEVEL C 555 C****	PATING DATA         READCS,1013 OCH         READCS,1003 NAX         20       MAIM         DATE = 72349       11/30/4         N=NAX+1       DATE = 72349       11/30/4         N=NAX+1       DATE = 72349       11/30/4         N=NAX+1       READCS,1013(OZ(11),11=1,K)       PATE = 72349       11/30/4         N=NAX+1       READCS,1013(OZ(11),11=1,K)       PATE = 72349       11/30/4         N=NAX+1       READCS,1013(OZ(11),11=1,K)       PATE = 72349       11/30/4         N=NAX+1       READCS,1013(OS2(11),11=1,K)       PATE = 72349       11/30/4         N=NAX       DATE = 72349       11/30/4       PATE = 72349       11/30/4         N=NAX       DATE = 72349       11/30/4       PATE = 72349       11/30/4         N=NAX+1       READCS,1013(OS2(11),11=1,K)       PATE = 72349       11/30/4       PATE = 72349       11/30/4         N=NAX       PEADCS,1013(HAX,FIC(1),TC1(1),TC1(1),TC2(1),E,RC0C,RC1C,RC2C,RF1,RF2,RHO       1,N1,N2       PATE = 72349       11/30/4         PO 35       11=1,K       PEADCS,1013(OS2(11)	00(4500 00(4700 00(4700 00(4700 00(4700 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(6000 00(6000 00(6000 00(6300 00(6400 00(6400) 00(6400) 00(6500 00(6400) 00(7500) 0000) 00(7500) 0000000000000000000000000000000000	
RAN IV ( 23 5 5 5 6 7 8 9 9 9 1 2 5 5 6 7	C 5 LEVEL C 55 C++++ 30 31	PATING DATA         READ(5,101) OCH         READ(5,100) NAX         20       MAIR         DATE = 72349       11/50/4         N=NAX+1       DATE = 72349         READ(5,101)(O2(11),11=1,K)         READ(5,101)(ASLAG(11),11=1,K)         READ(5,101)(ASLAG(11),11=1,FAX)         CHANNEL DATA         PEAD(5,101) HMAX,PI(1),TC1(1),TC2(1),E.RCOC,RC1C,RC2C,RF1,RF2,RHO         1,N1,U2,RP,RINU,AL,FL,PIN         READ(5,101) GS1(11),GS2(11)        HEAT GENEFATIUN*****         SUM=0         D0 30 N=1,NAX         SUM=4         D0 31 N=1,NAX         OSLAB(N)=CONST*ASLAP(N)         CONTINUE         FIRST GUESSFS         TG2(1)=TF2(1)+273	00(4500 00(4000 00(47000 48 PAGE 00(4800 00(5000 00(5100 00(5100 00(5100 00(5500 00(5500 00(5500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 000 0	nov;
RAN IV ( 2 3 4 5 5 6 7 8 8 9 9 9 1 1 2 3 4 5 5 6 7 8 8 7 8	C 5 LEVEL C 55 C++++ 30 31	PATING DATA         READCS,1013 OCH         READCS,1003 NAX         20       MAIM         DATE = 72349       11/30/4         N=NAX+1       DATE = 72349       11/30/4         N=NAX+1       DATE = 72349       11/30/4         N=NAX+1       READCS,1013(OZ(11),11=1,K)       PATE = 72349       11/30/4         N=NAX+1       READCS,1013(OZ(11),11=1,K)       PATE = 72349       11/30/4         N=NAX+1       READCS,1013(OZ(11),11=1,K)       PATE = 72349       11/30/4         N=NAX+1       READCS,1013(OS2(11),11=1,K)       PATE = 72349       11/30/4         N=NAX       DATE = 72349       11/30/4       PATE = 72349       11/30/4         N=NAX       DATE = 72349       11/30/4       PATE = 72349       11/30/4         N=NAX+1       READCS,1013(OS2(11),11=1,K)       PATE = 72349       11/30/4       PATE = 72349       11/30/4         N=NAX       PEADCS,1013(HAX,FIC(1),TC1(1),TC1(1),TC2(1),E,RC0C,RC1C,RC2C,RF1,RF2,RHO       1,N1,N2       PATE = 72349       11/30/4         PO 35       11=1,K       PEADCS,1013(OS2(11)	00(4500 00(4000 00(47000 48**********************************	nov;
0 RAN IV 0 2 5 6 7 8 9 9 9 1 2 2 3 4 5 5 6 7 8 9 9 9 1 1 2 7 8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	C 5 LEVEL C 55 C++++ 30 31	PATING DATA READCS,101) OCH READCS,100) NAX 20 MAIN DATE = 72349 11/50/4 N=NAX+1 READCS,101)(O2(11),11=1,K) READCS,101)(ASLAGC(11),11=1,FAX) CHANNEL DATA PEADCS,101) HMAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO 1,W1,W2,RP,RIBW,AL,FL,PIN READCS,100) NPIF D0 55 11=1,K PEADCS,101) GS1(1),GS2(11) HEAT GENEFATION***** SUM=0 D0 30 N=1,NAX SUM=SUM+ASLAB(N) CONTINUE CONST=OCH/SUH D0 51 N=1,NAX GSLAB(N)=COLST*ASLAP(N) CONTINUE FIRST GUESSFS TG2(1)=TG2(1)+273 TG1(1)=TG1(1)+273 TG1(1)=TG1(1)+1C0 FIRST GUESFS	00(4500 00(4700 00(4700 00(4700 00(4700 00(5000 00(5000 00(5000 00(5500 00(5500 00(5500 00(5500 00(500 00(500 00(500 00(500 00(600 00(600 00(600 00(600 00(600 00(600 00(600 00(600 00(600 00(600 00(600 00(600 000 0	000;
RAN IV ( 23 34 55 66 7 8 9 9 9 1	C 5 LEVEL C 55 C++++ 30 31	PATING DATA READ(5,101) OCH READ(5,100) NAX 20 MAIR DATE = 72349 11/50/4 N=NAX+1 READ(5,101)(O2(11),11=1,K) READ(5,101)(ASLAG(11),11=1,FAX) CHANNEL DATA PEAD(5,101) HHAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO 1,W1,U2,RP,RIBU,AL,FL,PIN READ(5,100) NPIF D0 55 11=1,K PEAD(5,101) G31(11),G52(11) HEAT GENEFATIUN***** SUM=0 D0 30 N=1,NAX SUM=SUM+ASLAB(N) CONTINUE CUNST=OCH/SUM D0 31 N=1,NAX GSLAB(N)=COLST*ASLAP(N) CONTINUE FIRST GUESSFS TG2(1)=TG2(1)+150 TFMAX(1)=TG2(1)+150	00(4500 00(4000 00(4700 68 PAGE 00(4800 00(500 00(5100 00(5100 00(5100 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(60 000 00(60 000 00(60 000 00(60 000 00	000;
RAN IV C 2 5 6 7 8 9 9 9 1 2 2 3 5 6 7 8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	C 5 LEVEL C 55 C++++ 30 31	PATING DATA READ(5,100) NAX 20 MAIR DATE = 72349 11/30/4 N=NAX+1 READ(5,100) (02(11),11=1,K) READ(5,101) (03(1A)(11),11=1,K) READ(5,101) (03(1A)(1),11=1,K) CHANNEL DATA PEAD(5,101) HHAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO 1,W1,U2,RP,RIBW,AL,FL,PIN READ(5,100) NPIF D0 55 11=1,K PEAD(5,100) NPIF D0 55 11=1,K PEAD(5,100) NPIF D0 55 11=1,K PEAD(5,100) NPIF D0 30 N=1,NAX SUM=0 D0 30 N=1,NAX SUM=SUM+ASLAB(K) CONTINUE FIRST GUESSFS TG2(1)=TG2(1)+273 TF1(1)=TG1(1)+273 TF1(1)=TG2(1)+150 FMAX(1)=TG2(1)+150	00(4500 00(4000 00(4700 00(4700 00(4700 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 000 0	000;
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RAN IV ( 23 5 5 6 7 8 9 9 1 2 5 6 6 7 8 9 9 1 2 5 6 6 7 8 9 9 9 1 1	C 5 LEVEL C 55 C++++ 30 31	PATING DATA READ(5,101) OCH READ(5,100) NAX 20 MAIR DATE = 72349 11/50/4 N=NAX+1 READ(5,101)(O2(11),11=1,K) READ(5,101)(ASLAG(11),11=1,FAX) CHANNEL DATA PEAD(5,101) HMAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO 1,W1,U2,RP,RINU,AL,FL,PIN READ(5,100) HPIF DO 55 11=1,K PEAD(5,101) GS1(11),GS2(11) HEAT GENEPATIUN***** SUM=0 DU 30 N=1,NAX SUM=5UM+ASLAB(N) CONTINUE CUNST=OCH/SUM DO 31 N=1,NAX OSLAB(N)=COLST*ASLAP(N) CONTINUE FIRST GUESSFS TG2(1)=TG2(1)+273 TG1(1)=TG1(1)+273 TF1(1)=TG2(1)+150 TH(1)=TG1(1)+50 TI1(1)=TM1(1)+50 TI1(1)=TG1(1)+50	00(4500 00(4000 00(47000 48**********************************	000;
RAN IV C 2 3 4 5 5 6 7 8 8 9 9 9 1 1 2 3 5 6 7 8 9 9 9 1 1 2 3 5 6 7 8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	C 5 LEVEL C 55 C++++ 30 31	PATING DATA READ(5,101) OCH READ(5,100) NAX 20 HAIN DATE = 72349 11/50/4 N=NAX+1 READ(5,101)(OZ(11),11=1,K) READ(5,101)(OZ(11),11=1,FAX) CHANNEL DATA PEAD(5,101) HMAX,PI(1),T(1(1),T(2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO 1,N1,U2,RP,RIBW,AL,FL,PIN READ(5,100) NRIE D0 55 11=1,K PEAD(5,101) GS1(11),GS2(11) REAT GENEFATION**** SUM=0 D0 30 N=1,NAX SUM=SUM+ASLAB(N) CONTINUE CONST=OCH/SIH D0 31 N=1,MAX SLAB(N)=CONST*ASLAP(N) CONTINUE FIRST GUESSFS TG2(1)=TG2(1)+273 TF1(1)=TG1(1)+273 TF1(1)=TG1(1)+10 TFMAX(1)=TG2(1)+50 TW1(1)=TG2(1)+50 TW1(1)=TG2(1)+50 TWALL(1)=TG2(1)+50	00(45)00 00(47000 00(47000 00(47000 00(5700 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(6000 00(6000 00(6000 00(6000 00(6000 00(6000 00(6000 00(6000 00(6000 00(6000 00(6000 00(6000 00(6000 00(6000 00(6000 00(6000 00(6000 00(6000 000	000;
RAN IV ( 23 5 5 6 7 8 9 9 1 2 5 5 6 7 8 9 9 1 2 5 5 6 7 8 9 9 1 2 5 5 6 7 8 9 9 1 1	C 5 LEVEL C 55 C++++ 30 31	PATING DATA READ(5,101) OCH READ(5,100) NAX 20 MAIR DATE = 72349 11/50/4 N=NAX+1 READ(5,101)(O2(11),11=1,K) READ(5,101)(ASLAG(11),11=1,FAX) CHANNEL DATA PEAD(5,101) HMAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO 1,W1,U2,RP,RINU,AL,FL,PIN READ(5,100) HPIF DO 55 11=1,K PEAD(5,101) GS1(11),GS2(11) HEAT GENEPATIUN***** SUM=0 DU 30 N=1,NAX SUM=5UM+ASLAB(N) CONTINUE CUNST=OCH/SUM DO 31 N=1,NAX OSLAB(N)=COLST*ASLAP(N) CONTINUE FIRST GUESSFS TG2(1)=TG2(1)+273 TG1(1)=TG1(1)+273 TF1(1)=TG2(1)+150 TH(1)=TG1(1)+50 TI1(1)=TM1(1)+50 TI1(1)=TG1(1)+50	00(4500 00(4000 00(47000 48*** PAGE 00(48000 00(5000 00(5100 00(5100 00(5100 00(5500 00(5500 00(5500 00(5500 00(500 00(500 00(600 00(600 00(600 00(600 00(600 00(600 00(600 00(600 00(600 00(700 000 0	000;
RAN IV ( 23 34 55 66 7 8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	c c c c s s c c s s c c s s c c s s c c s s c	PATING DATA READ(5,101) OCH READ(5,100) NAX 20 MAIN DATE = 72349 11/50/4 N=NAX+1 READ(5,101) (ASLAG(11),11=1,K) READ(5,101) (ASLAG(11),11=1,FAX) CHANNEL DATA READ(5,101) HMAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO 1,W1,W2,RP,RIBW,AL,FL,PIN READ(5,100) NBIP DO 55 11=1,K READ(5,100) NBIP DO 55 11=1,K READ(5,101) GS1(11),GS2(11) WEAT GENEFATIUN***** SUM=0 DO 30 N=1,NAX SUM=SUM+ASLAB(N) CONTINUE FIRST GUESSFS TG2(1)=TG2(1)+273 TG1(1)=TG1(1)+273 TF1(1)=TG1(1)+273 TF1(1)=TG1(1)+50 TI1(1)=TG1(1)+50 TI1(1)=TG2(1)+150 TMALL(1)=TG2(1)+150 TMALL(1)=TG2(1)+150 TMALL(1)=TG2(1)+150 TMALL(1)=TG2(1)+150 TMALL(1)=TG2(1)+50 TMALL(1)=TG2(1)+15	00(45)00 00(4)(00 00(4)(00 00(4)(00 00(5)(00 00(5)(00 00(5)(00 00(5)(00 00(5)(00 00(5)(00 00(5)(00 00(5)(00 00(5)(00 00(5)(00 00(6)(00 00(6)(00 00(6)(00 00(6)(00 00(6)(00 00(6)(00 00(6)(00 00(7)(00	000;
RAN IV (2)         S         6         7         8         9         11         22         33         4         5         6         7         8         9         11         22         33         4         5         6         7         8         9         11         22         34         5         6         7         6         7         6         7         6         7         6         7         6         7         6         7         6         7         6         7         6         7         6         7         6         7         6         7         6         7	c c c c s s c c s s c c s s c c s s c c s s c	PATING DATA READ(5,101) OCH READ(5,100) NAX 20 MAIK DATE = 72349 11/50/4 N=NAX+1 READ(5,101)(O2(11),11=1,K) READ(5,101)(ASLAB(11),11=1,FAX) CHANNEL DATA PEAD(5,101) HMAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO 1,M1,U2,RP,RIBU,AL,FL,PIK READ(5,100) HRIF D0 55 11=1,K PEAD(5,100) KRIF D0 55 11=1,K PEAD(5,101) GS1(13),GS2(11) HEAT GENEFATION**** SUM=0 D0 30 N=1,NAX SUM=SUM+ASLAB(N) CONTINUE CONST=OCH/SUM D0 31 N=1,MAX SLAB(N)=COKST*ASLAP(N) CONTINUE FIRST GUESSFS TG2(1)=TG2(1)+273 TG1(1)=TG1(1)+273 TG1(1)=TG2(1)+50 TH(1)=TG2(1)+50 TH(1)=TG2(1)+50 TH(1)=TG2(1)+50 TH(1)=TG2(1)+100 CMANEL CONSTANTS DL=QCH/AL PZ5=C,28318+RF2	00(4500 00(4700 00(4700 00(4700 00(4700 00(500 00(500 00(5100 00(5100 00(5500 00(5500 00(5500 00(5500 00(500 000 0	000
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0 1 RAN IV 0 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 1 1 1 1 1 1 1 1 1 1 1	c c c c c c c	PATING DATA READ(5,101) OCH READ(5,100) NAX 20 PAIM DATE # 72349 11/50/4 N=NAX+1 READ(5,101)(O2(11),11=1,F) READ(5,101)(O2(11),11=1,FAX) CMANNEL DATA PEAD(5,101) HHAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO 1,W1,W2,RP,RIDWAL,FL,PIM READ(5,100) NPIF D0 55 11=1,K PEAD(5,101) GS1(11),GS2(11) HEAT GENCFATICK***** SUM=0 D0 30 N=1,NAX SUM=SUM+ASLAB(N) CONTINUE FIRST GUESSFS TG2(1)=TG2(1)+273 TG1(1)=TG1(1)+273 TG1(1)=TG1(1)+273 TG1(1)=TG1(1)+273 TG1(1)=TG2(1)+50 TIA(1)=TG2(1)+50	00(45)00 00(47000 00(47000 00(47000 00(57000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(5000 00(6000 00(7000 00(7000 00(7100 00(7100 00(7100 00(7700 000 0	000;
0 1 RAN IV 0 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 1 1 1 1 1 1 1 1 1 1 1 1	c c c c c c c	PATING DATA READ(5,101) OCH READ(5,100) NAX 20 PAIN DATE = 72349 11/30/4 N=NAX+1 READ(5,101)(O2(11),11=1,K) READ(5,101)(ASLAG(11),11=1,FAX) CHANNEL DATA READ(5,101) HHAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO 1,M1,W2,RP,RIBW,AL,FL,PIN READ(5,101) GS1(1),GS2(11) HEAT GENEFATION***** SUM=0 D0 30 N=1,NAX SUM=SLAB(N) CONTINUE CONST=OCH/SUH D0 31 N=1,NAX OSLAB(W)=CONST*ASLAP(N) CONTINUE FIRST GUESSFS TG2(1)=TG2(1)+273 TG1(1)=TG2(1)+50 TI1(1)=TG2(1)+50 TI1(1)=TG2(1)+50 TI1(1)=TG2(1)+50 TI1(1)=TG2(1)+50 TI1(1)=TG2(1)+50 TI1(1)=TG2(1)+50 TI1(1)=TG2(1)+50 TI1(1)=TG2(1)+50 TI1(1)=TG2(1)+50 TI2(1)=	00(4500 00(4700 00(4700 00(4700 00(5700 00(5100 00(5100 00(5100 00(5100 00(5700 00(5700 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 000 0	000;
0 1 RAN IV 0 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 1 2 3 4 5 6 7 8 9 0 1 1 2 3 4 5 6 7 8 9 0 1 1 1 2 3 4 5 6 7 8 8 9 0 1 1 2 3 4 5 6 7 8 8 9 0 1 1 2 3 4 5 6 7 8 8 9 0 1 1 2 3 4 5 6 7 8 8 9 0 1 1 2 3 4 5 6 7 8 8 9 0 1 1 2 3 4 5 6 7 8 8 9 0 1 1 2 3 4 5 6 7 8 9 0 1 1 2 3 4 5 6 7 8 9 0 1 1 2 3 4 5 6 7 8 8 9 0 1 1 2 3 4 5 6 7 8 9 9 0 1 1 2 3 4 5 6 7 8 9 9 0 1 1 2 3 4 5 6 7 8 9 9 0 1 1 2 3 4 5 6 7 8 9 9 0 1 1 2 3 4 5 5 6 7 8 9 9 0 1 1 2 3 4 5 5 6 7 8 9 9 0 1 1 1 1 1 1 1 1 1 1 1 1 1	c c c c c soc	PATING DATA READ(S,101) OCH READ(S,100) NAX 20 PAIR DATE T 72349 11/50/4 N=NAX+1 READ(S,101) (O2(11),11=1,K) PEAD(S,101) (ASLAG(11),11=1,FAX) CMANKEL DATA PEAD(S,101) HNAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO 1,V1,V2,RP,RIBN-AL,FL,PIN READ(S,100) NRIP D0 55 11=1,K PEAD(S,101) GS1(13),GS2(11) HEAT GENEFATIUR***** SUM=0 D0 30 N=1,NAX SUP=SUM+ASLAB(K) CONTINUE CONST=OCH/SNH D0 31 N=1,NAX SUP=SUM+ASLAB(K) CONTINUE FIRST GUESSFS TG2(1)=TG2(1)+273 TG1(1)=TG1(1)+273 TG1(1)=TG1(1)+273 TG1(1)=TG1(1)+50 TIM(1)=TG1(1)+50 TIM(1)=TG1(1)+50 TIM(1)=TG1(1)+50 TIM(1)=TG2(1)+50 TIM(1)=	00(4500 00(4700 00(4700 00(4700 00(5700 00(5700 00(5100 00(5100 00(5100 00(5500 00(5500 00(5500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 00(500 000 0	0002
0 1 RAN IV 0 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 1 1 1 1 1 1 1 1 1 1 1	c c c c c c c c c c c c c c c c c c c	PATING DATA READ(S,101) OCH READ(S,101) OCH READ(S,101) OCH READ(S,101) (OZ(11),11=1,K) PEAD(S,101) (OZ(11),11=1,K) PEAD(S,101) (ASLAG(11),11=1,FAX) CHANNEL DATA PEAD(S,101) HHAX,PI(1),TC1(1),TC2(1),E,RCOC,RC1C,RC2C,RF1,RF2,RHO 1,W1,W2,RP,RTBW,AL,FL,PIN READ(S,100) NRIF DO 30 N=1,NAX SUM=0 DU 30 N=1,NAX SUM=0 DU 30 N=1,NAX SUM=0 DU 30 N=1,NAX SUM=0 CONTINUE CONST=OCH/SIH DO 31 N=1,NAX SUM=0 CONTINUE CINST=OCH/SIH DO 31 N=1,NAX SUM=0 CONTINUE CINST=OCH/SIH DO 31 N=1,NAX SILAB(W)=COLST=ASLAP(N) CONTINUE FIRST GUESSFS TG2(1)=TG2(1)+273 TF1(1)=TG1(1)+273 TF1(1)=TG2(1)+100 TFMAX(1)=TG2(1)+100 TFMAX(1)=TG2(1)+50 Tu1(1)=TG2(1)+50 Tu1(1)=TG2(1)+50 Tu1(1)=TG2(1)+50 Tu2(1)=T	00(4500 00(4700 00(4700 00(4700 00(4700 00(500 000 0	0002
0 1 RAN IV 0 2 3	c c LEVEL c	PATING DATA READ(5,101) OCH READ(5,101) (O2(11),11=1,K) DATE F 72349 11/50/4 N=NAX+1 READ(5,101) (O2(11),11=1,K) PEAD(5,101) (O2(11),11=1,K) PEAD(5,101) (O2(11),11=1,K) PEAD(5,101) (O2(11),11=1,K) PEAD(5,101) (O2(11),11=1,K) CMANMEL DATA PEAD(5,101) (O2(11),11=1,K) PEAD(5,101) (O2(11),11=1,K) PEAD(5,101) (O2(11),11=1,K) PEAD(5,101) (O2(11),11=1,K) PEAD(5,101) (O2(11),11=1,K) PEAD(5,101) (O2(11),11=1,K) PEAD(5,101) (O2(11),11=1,K) PEAD(5,101) (O2(11),11=1,K) PEAD(5,101) (O3(11),052(11) 	00(4500 00(4000 00(47000 00(47000 00(47000 00(5700 00(5100 00(5100 00(5100 00(5700 00(5700 00(5700 00(500 00(600 000 0	000;
0 1 RAN IV ( 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 1 2 3 4 5 6 7 8 9 0 1 1 2 3 4 5 6 7 8 9 0 1 1 2 3 4 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 0 1 1 2 3 4 5 5 6 7 8 9 0 0 1 1 2 3 5 5 6 7 8 9 0 0 1 1 2 5 5 5 6 7 8 9 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1	c c c c c c c c c c c c c c c c c c c	PATING DATA READ(5,101) OCH READ(5,101) NAX 20 PAIR DATE = 72349 11/50/4 N=NAX+1 READ(5,101) (O2(11),11=1,K) READ(5,101) (O2(11),11=1,K) READ(5,101) (ASLAC(11),11=1,K) READ(5,101) (ASLAC(11),11=1,K) READ(5,101) NHAX,PI(1),11=1,K) READ(5,101) NHAX,PI(1),11=1,K) READ(5,101) O2(11),T(1(1),T(2(1)),E,RCOC,RC1C,RC2C,RF1,WF2,RHO 1,M1,W2,RP,RINWAL,FL,PIN READ(5,100) NHI READ(5,100) NHI READ(5,100) O3 NHI READ(5,100) O3(11),OS2(11) HEAT GENEPATION***** SUM=0 D0 30 N=1,NAX SUM=SUM=ASLAB(K) CONTINUE FIRST GUESSTS TO(1)=TG(1)+273 TO(1)=TG(1)+273 TO(1)=TG(1)+273 TO(1)=TG(1)+273 TO(1)=TG(1)+273 TO(1)=TG(1)+273 TO(1)=TG(1)+273 TO(1)=TG(1)+273 TO(1)=TG(1)+50 TI(1)=TG(1)+50 TI(1)=TG(1)+50 TI(1)=TG(1)+50 TI(1)=TG(1)+10 CANNEL CONSTANTS DI=SUM=0 SLAB DATA WEITF(C,120) I=0 SLAB DATA WEITF(C,120) I=10 SLAB DATA	00(4500 00(4700 00(4700 00(4700 00(5700 00(5700 00(5100 00(5100 00(5100 00(5500 00(5000 00(5000 00(5000 00(5000 00(5000 00(600 000 0	000;
0 1 RAN IV 0 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 5 6 7 8 9 0 1 1 2 3 4 5 5 6 7 8 9 0 1 1 1 1 1 1 1 1 1 1 1 1 1	c c LEVEL c	PATING DATA READ(5,101) OCH READ(5,101) (O2(11),11=1,K) PEAD(5,101) (O3(11),052(11) 	00(4500 00(4000 00(47000 00(47000 00(47000 00(5700 00(5100 00(5100 00(5100 00(5700 00(5700 00(5700 00(500 00(600 000 0	000;

ATRAN IV G LEVE	L 20 HAIN NATE = 72349 11/	50/48	PAGE OUG
0.69	AKH2=1.4501-03+(T62(1)/275,11)++1.7	00192600	
0/0	PK1=AMU1+5,19/AKH1	001931.00	
0/1	PK2=AM112*5.10/AF12	00(94/00	
)/2 )/3	03#1,0/(6,28312+HPAY+F1) VELTAT=162(1)-TC1(1)	00(95/00	
14	GLF=0L+02(1)+(1,0-RH0)/FL	00197100	
75	0LH=0L+42(1)+PHU	001392100	
1/6	12=0	00199100	
	D IF(12,GT,20) GG TO 8	001001.00	
18	12=12+1	00101/00	
79 C	SLAB VARIAFLES	00102100	
80	IF(I,FQ.1) 60 TO 11 IF(12,6T.1) 60 TO 11	00103000	
*1	N=1-1	00105000	
82	60 TO 12	00100100	
	I N#I	00107100	
c	CALCULATION OF CONDUCTIVITY .	00102000	
84 1.	? TGM1=(TW1(H)+T11(H))/2,U	00109100	
85	TGM2=(TW2(N)+TI2(N))/2,0	001106.00	
*6	TFM = (TF1(N)+TF2(N)+2.U+TF1AX(N))/4.0	00111100	
87	1F(T6M1, LE, TG(1)) 66 T6 52	00112600	
88	IF (TGM2.LE, TG(1)) 60 TU 52	00113000	
89 90	JF (TFM,LE,TF(1)) G( T( 52 DU 20 N2=1,19	00114000	
91	IF(TGM1,LE,TG(12)) 60 TO 21	00116000	
	CUNTINUE	00117000	
	N1=N2-1	00118100	
44	AKG1=BKG(N1)+(T(11-TG(N1))+(1KU(12)+LKG(11))/(TG(N2)-TU(N1))	00119000	
95	DU 22 N2=1,19	00120000	
96	IF(TGM2, LE, TG(N2)) 60 TO 23	00121000	
	CONTINUE	00122000	-
	N1=N2-1	00123000	
99 00	AKG2=BKG(N1)+(TG/2=TG(H1))+(1+6(12)-+KG(11))/(TG(N2)-TG(N1))	00124600	
00	D0 24 N2=1,25 IF(TFM,LF,TF(N2)) G0 TV 25	00125000 -	
	CONTINUE	00127600	
	N1=N2=1	001328000	
04	AKF=BKF(N1)+(TFF-TF(N1))+(BFF(H2)-LKF(N1))/(TF(N2)-TF(H1))	00129100	
c	CALCULATION OF C.T.F.	001301.00	
05	TFM=TFM=273	00131000	
06	TGM1=T.GM1-273	00132100	
	TGM2=TGM2-273	00133000	
UB TRAN IV G LEVEN	CALCULATION OF GAPS GIN(I)=GS1(I)+PF1+(ALFAF(TFI)+(TFH-2(,0)-ALFAG(TGH1)+(TGM1-20, 20 HAIA DATE = 72349 11/	00134000 0)) 00135000 50748	PAGE 000
	CALCULATION OF GAPS GIN(I)=GS1(I)+PF1+(ALFAF(TFI)+(TFM-2(,0)-ALFAG(TGM1)+(TGM1-20, 20 MAIA DATE = 72349 11/ GOUT(I)=GS2(I)+FF2+(ALFAG(T(I2)+(TGH2-20,0)-ALFAF(TFI)+(TFM-20 LCULATION OF DIFERSIONS+*	00134600 0)) 00135000 50748 ,0))00136600 00137600	PAGE 000
08 TRAN IV G LEVEL 09 C++C/ C+TH	CALCULATION OF GAPS GIN(I)=GS1(I)+PF1+(ALFAF(TFI)+(TFM-2(,0)-ALFAG(TGM1)+(TGM1-20, 20 MAIN DATE # 72349 11/ GOUT(I)=GS2(I)+FF2+(ALFAG(T(I2)+(TGN2-20,0)-ALFAF(TFI)+(TFM-20 LCULATION OF DIFERSIONS+* RMAL EXPANSION	00134000 0)) 00135000 50748 ,0))00136000 00137000 0013700	PAGE 000
C TRAN IV G LEVEL 09 C++C/ C+TH	CALCULATION OF GAPS GIN(I)=GS1(I)+PF1+(ALFAF(TFI)+(TFH-2(,0)-ALFAG(TGH1)+(TGM1-20, 20 MAIA DATE = 72349 11/ GOUT(I)=GS2(I)+FF2+(ALFAG(TCI2)+(TGF2-20,0)-ALFAF(TFI)+(TFM-20) LCULATION OF DIFERSIONS+* RMAL EXPANSION RC0(I)=RC0C*(ALFAG(TGM1)+(T(11-2()+1))	00134000 0)) 00135000 50748 ,0))00136000 00137000 00137000 0013700	PAGE 001
C C C C C C C C C C C C C C C C C C C	CALCULATION OF GAPS GIN(I)=GS1(I)+PF1+(ALFAF(TFI)+(TFH-2(,0)-ALFAG(TGH1)+(TGH1-20, 20 MAIA GOUT(I)=GS2(I)+FF2+(ALFAG(T(12)+(TGH2-20,0)-ALFAF(TFI)+(TFH-20) LCULATION OF DIFERSIONS++ RMAL EXPANSION RCO(I)=RCO(+(ALFAG(TGM2)+(T(11-20)+1) PC1(I)=RCO(+(ALFAG(TGM2)+(T(12-20)+1))	0013400 0)) 00135000 50748 ,0))0013600 0013700 0013700 0013700 0013700 0013700	PAGE 001
C TRAN IV G LEVEL 09 C++C/ C+THE 11 12	CALCULATION OF GAPS GIN(I)=GS1(I)+PF1+(ALFAF(TFI)+(TFM-2(,0)-ALFAG(TGM1)+(TGM1-20, 20 MAIA DATE # 72349 11/ GOUT(I)=GS2(I)+FF2+(ALFA6(T(12)+(TGH2-20,0)-ALFAF(TFI)+(TFM-20) LCULATION OF DIFERSIONS** RMAL EXPANSION RCO(I)=RC0C+(ALFAG(TGM1)+(T(11-20)+1) PC1(I)=RC1C+(ALFAG(TGM2)+(T(12-20)+1) PC2(I)=RC2C+(ALFAG(TCM2)+(T(12-20)+1) PC2(I)=RC2C+(ALFAG(TCML(N))+(T(ALL(1)-293)+1)	0013400 0)) 00135000 50748 ,0))0013600 0013700 0013700 0013700 0013700 0014000 0014100	PAGE OUT
C TRAN IV G LEVEL 09 C++CJ C+THI 10 11 12 C++++	CALCULATION OF GAPS GIN(I)=GS1(I)+PF1+(ALFAF(TFI)+(TFM-2(,0)-ALFAG(TGM1)+(TGM1-20, 20 MAIK DATE # 72349 11/ GOUT(I)=GS2(I)+FF2+(ALFAG(T(12)+(TGE2-20,0)-ALFAF(TFI)+(TFM-20) LCULATION OF DIFERSIONS** RMAL EXPANSION RCO(I)=RCOC+(ALFAG(TGM1)+(T(11-2()+1)) PC1(I)=RCOC+(ALFAG(TGM2)+(T(12-2()+1)) PC2(I)=RCCC+(ALFAG(TGM2)+(T(12-2()+1)) PC2(I)=RC2(CALFAG(TCLLL(N))+(TEALL(L)-293)+1) *CORROSTON CALCULATIONS	0013400 0)) 00135000 50748 ,0))0013600 0013700 0013700 0013700 0013700 0013700	PAGE OOD
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C UB TRAN IV G LEVEL 09 C++C/ C+THI 11 12 C++++ 13 14 15 14 15 16 17 18 19 20 21 22 22 24 25 26 27 28 29 50 51 55 54 401 55 402 56 57 57 40 57 40 57 57 40 57 57 40 57 57 40 57 57 40 57 57 40 57 57 40 57 57 40 57 57 57 40 57 57 57 57 57 57 57 57 57 57	CALCULATION OF GAPS GIN(1)=GS1(1)+PF1*(ALFAF(TFI)*(TFH-2(,0)-ALFAG(TGH1)*(TGM1-20, 20 HAIN DATE = 72349 11/ GOUT(1)=GS2(1)+FF2*(ALFAG(TCH2)*(TGH2-20,0)-ALFAF(TFI)*(TFM-20) LCULATION OF DITEPSIONS** RMAL EXPANSION RCO(1)=RCOC*(ALFAG(TGM1)*(TT(11-20)*1) PC1(1)=RC1C*(ALFAG(TGM2)*(TT(12-20)*1) PC2(1)=RC2C*(ALFAG(TCM2)*(TT(12-20)*1) PC2(1)=RC2C*(ALFAG(TCM2)*(TT(12-20)*1) PC2(1)=RC2C*(ALFAG(TCM2)*(TT(12-20)*1) PC2(1)=RC2C*(ALFAG(TCM2)*(TT(12-20)*1) PC2(1)=RC2C*(ALFAG(TCM2)*(TT(12-20)*1) PC2(1)=RC2C*(ALFAG(TCM2)*(TT(12-20)*1) PC2(1)=RC2C*(ALFAG(TCM2)*(TT(12-20)*1) PC2(1)=RC2C*(ALFAG(TCM2)*(TT(12-20)*1) PC2(1)=RC2C*(ALFAG(TCM2)*(TT(12-20)*1) PC2(1)=RC2C*(ALFAG(TCM2)*(TT(12-20)*1) PC2(1)=RC2C*(ALFAG(TCM2)*(TT(12-20)*1) PC2(1)=RC2(1)=RT1(1,MT)*DR2 PR3(L,N)=RT1(1000 DRT3(1,N)=RT1(1,MT)*DR2 DRT3(1,N)=RT3(1,MT)*DR2 DRT3(1,N)=RT3(1,MT)*DR2 DRT3(1,N)=RT3(1,MT)*DR2 PR3(1,N)=RT3(1,MT)*DR3 RC2(1)=RC2(1)*NT3(1,NT) PC1(1)=RC1(1)=DST2(1,NT) PC1(1)=RC1(1)=DST2(1,NT) PC1(1)=RC2(1)*NT3(1,NT) PC1(1)=RC2(1)*NT3(1,NT) PC1(1)=RC2(1)*NT3(1,NT) PC1(1)=RC2(1)*NT3(1,NT) PC1(1)=RC2(1)*NT3(1,NT) PC1(1)=RC2(1)*NT3(1,NT) PC1(1)=RC2(1)*NT3(1,NT) PC1(1)=RC1(1,NT)_{CE,RP}) GU TO 4U3 PC2(1)=RC2(1)*NT3(E,RP) GU TO 4U3 PC2(1)=RC2(1)*NT3(E,RP) PC2(1)=RC2(1)*NT3(E,RP) PC2(1)=RC2(1)*NT3(E,RP) P	0013400 0)) 0013500 50748 ,0)) 0013600 0013700 0013700 0013700 0014000 0014100 0014200 0014500 0014500 0014500 0014600 0014700 0015000 0015000 00155000 00155000 00155000 001550000000000	PAGE OOU
C UB TRAN IV G LEVEL 09 C++CA C+THI 11 12 C++++ 13 14 15 16 17 18 19 20 21 22 25 26 27 26 27 25 26 27 25 26 27 25 26 27 25 26 27 25 26 27 25 26 27 25 26 27 25 26 27 25 26 27 25 26 27 25 26 27 25 26 27 25 26 27 25 26 27 27 25 26 27 27 25 26 27 27 27 27 27 27 27 27 27 27	CALCULATION OF GAPS GIN(1)=GS1(1)+PF1*(ALFAF(TFI)*(TFH-2(,0)-ALFAG(TGH1)*(TGH1-20, 20 HAIN DATE # 72349 11/ GOUT(1)=GS2(1)+FF2*(ALFAG(T(1)2)*(TGF2-20,0)-ALFAF(TFI)*(TFM-20) LCULATION OF DIFEPSIONS** RMAL EXPANSION RCO(1)=RCOC*(ALFAG(TGM1)*(T(11-20)+1) PC1(1)=RCOC*(ALFAG(TGM2)*(T(12-20)+1) PC2(1)=RC2C*(ALFAG(TGM2)*(T(12-20)+1) *COPROSION CALCULATIONS TW1C=TU1(M)-273;0 TW2C=TU1(M)-273;0 TW2(CTU2(K)-273;0 TWALLC=TWALL(N)=273;0 DR1aDELR1(TV2C)+TITE DR3=DELR1(TV2C)+TITE DR3=DELR1(TV2C)+TITE DR3=DELR1(TV2C)+TITE DR3=DELR1(TV2C)+TITE DR3=CLE,0,0) FR3=0,0 DR11(1,1)=0,0 DR12(1,1)=0,0 DR12(1,1)=C,0 DR12(1,1)=C,0 CR11(1,NT)=FR11(1,NT)+LP1 RC1(1)=RC1(1)=FS2(1,NT) FC2(1)=RC2(1)+DF12(1,NT) FC2(1)=RC2(1)+DF12(1,NT) FC2(1)=RC2(1)+DF12(1,NT) FC2(1)=RC2(1)+DF12(1,NT) FC2(1)=RC2(1)+DF13(1,NT) FC2(1)=R	0013&f00 0)) 00135f00 50748 ,0)) 00136f00 00137f00 00137f00 00134f00 00140f00 00142f00 00142f00 00146f00 00146f00 00146f00 00146f00 00146f00 00146f00 0015f00 0016f00 0015f00 0016f00 0016f00 0015f00 0015f00 0015f00 0015f00 0015f00 0016f00 0016f00 0015f00 0000 00000 00000 00000000000000	PAGE DOI
C UB TRAN IV G LEVEL 09 C++C/ C+THI 10 11 12 C++++ 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 50 51 55 54 40 54 40 54 54 54 54 54 54 55 54 54 54	CALCULATION OF GAPS GIN(I)=GS1(I)+PF1+(ALFAF(TFI)+(TFM-2(,0)-ALFAG(TGM1)+(TGM1-20, 20 HAIA DATE # 72349 11/ GOUT(I)=GS2(I)+FF2+(ALFAG(T(I)2)+(TGH2-20,0)-ALFAF(TFI)+(TFM-20) LCULATION OF DIFENSIONS+* RMAL EXPANSIGN RCO(I)=RCUC+(ALFAG(TGM1)+(T(I1-2U)+1) PC1(I)=RCUC+(ALFAG(TGM2)+(T(I1-2U)+1) PC2(I)=RC2C+(ALFAG(TGM2)+(T(I12-2U)+1) PC2(I)=RC2C+(ALFAG(TGM2)+(T(IALU(L))-293)+1) *CORROSION CALCULATIONS TW1C=TU1(N)-273,0 TWALLC=TU2(N)-273,0 DR1=DELR1(Th(I)+(TITE DN2=DELR1(Th(I)+(TITE DN2=DELR1(TH12)+(TITE DN2=DELR1(TH12)+(TITE DN2=DELR1(TH12)+(TITE DN3=DELR2(TALLC)+LTIME IF(DR1(L,N)=CT1(I,MT)+UP3 RCO(I)=RC2(I)+FT3(I,MT)+UP3 RCO(I)=RC2(I)+FT3(I,MT)+UP3 RCO(I)=RC2(I)+FT3(I,MT)+UP3 RCO(I)=RC2(I)+FT3(I,MT) PC1(I)=RC1(I)+CT2(I,FT) PC2(I)=RC2(I)+FT3(I,MT) PC1(I)=RC1(I,MT) GU TO 402 E1=RP IF(DR12(I,MT)=GE,RP) GU TO 4U3 E2=DPT2(I,MT) GU TO 404 E2=RP IF(DR13(I,MT)-GE,RP) GU TO 4U5 E3=RPT3(I,MT)-GE,RP) GU TO 4U5 E3=RPT3(I,MT)-GE,RP)-GU TO 4U5 E3=RPT3(I,MT)-GE,RP)-GU TO 4U5 E3=RPT3(I,MT)-GE	0013400 0)) 0013500 50748 ,0)) 0013600 0013700 0013700 0013700 0014000 0014100 0014200 0014500 0014500 0014500 0014600 0014700 0015000 0015000 00155000 00155000 00155000 001550000000000	PAGE OO
C UB TRAN IV G LEVEL 09 C++C/ C+THI 10 11 12 C++++ 13 14 15 16 17 18 19 20 21 22 24 25 24 25 24 25 24 25 26 27 28 29 50 51 52 53 54 40 54 54 40 54 54 54 54 54 54 54 54 54 54	CALCULATION OF GAPS GIN(1)=GS1(1)+PF1*(ALFAF(TFI)*(TFH-2(,0)-ALFAG(TGH1)*(TGH1-20, 20 HAIN DATE # 72349 11/ GOUT(1)=GS2(1)+FF2*(ALFAG(T(1)2)*(TGF2-20,0)-ALFAF(TFI)*(TFM-20) LCULATION OF DIFEPSIONS** RMAL EXPANSION RCO(1)=RCOC*(ALFAG(TGM1)*(T(11-20)+1) PC1(1)=RCOC*(ALFAG(TGM2)*(T(12-20)+1) PC2(1)=RC2C*(ALFAG(TGM2)*(T(12-20)+1) *COPROSION CALCULATIONS TW1C=TU1(M)-273;0 TW2C=TU1(M)-273;0 TW2(CTU2(K)-273;0 TWALLC=TWALL(N)=273;0 DR1aDELR1(TV2C)+TITE DR3=DELR1(TV2C)+TITE DR3=DELR1(TV2C)+TITE DR3=DELR1(TV2C)+TITE DR3=DELR1(TV2C)+TITE DR3=CLE,0,0) FR3=0,0 DR11(1,1)=0,0 DR12(1,1)=0,0 DR12(1,1)=C,0 DR12(1,1)=C,0 CR11(1,NT)=FR11(1,NT)+LP1 RC1(1)=RC1(1)=FS2(1,NT) FC2(1)=RC2(1)+DF12(1,NT) FC2(1)=RC2(1)+DF12(1,NT) FC2(1)=RC2(1)+DF12(1,NT) FC2(1)=RC2(1)+DF12(1,NT) FC2(1)=RC2(1)+DF13(1,NT) FC2(1)=R	0013400 0)) 0013500 50748 ,0)) 0013600 0013700 0013700 0013700 0014000 0014000 0014400 0014400 0014400 0014400 0014400 0014400 0014600 0014600 001500 001500 001500 0015500 00000 00000 00000 0000000000	PAGE DOU
C UB TRAN IV G LEVEL 09 C++C/ C+THI 11 12 C+++1 13 14 15 16 17 18 19 20 21 22 23 24 25 26 26 27 28 29 50 51 52 53 54 401 55 54 401 55 54 401 55 54 401 55 54 401 55 54 401 55 54 401 55 55 54 401 55 55 55 56 57 55 55 55 55 55 55 55 55 55	CALCULATION OF GAPS GIN(I)=GS1(I)+PF1+(ALFAF(TFI)+(TFM+2(,0)-ALFAG(TGM1)+(TGM1-20, 20 HAIA DATE = 72349 11/ GOUT(I)=GS2(I)+FF2+(ALFAG(TC(I2)+(TGH2-20,0)-ALFAF(TFI)+(TFM-20) LCULATION OF DIFERSIONS+* RMAL EXPANSIGN RCO(I)=RCOC+(ALFAG(TGM1)+(T(I1-2C)+1) PC1(I)=RCOC+(ALFAG(TGM2)+(T(I1-2C)+1) PC1(I)=RCOC+(ALFAG(TGM2)+(T(I2+C)+1) PC1(I)=RCOC+(ALFAG(TGM2)+(T(IA-2C)+1) PC2(I)=RCOC+(ALFAG(TGM2)+(T(A-2C)+1) PC2(I)=RCOC+(ALFAG(TGM2)+(T(A-2C)+1) PC2(I)=RCOC+(ALFAG(TGM2)+(T(A-2C)+1) PC2(I)=RCOC+(ALFAG(TGM2)+(T(A-2C)+1) PC2(I)=RCOC+(ALFAG(TGM2)+(T(A-2C)+1) PC2(I)=RCOC+(ALFAG(TGM2)+	0013400 0)) 0013500 50/48 ,0)) 0013600 0013700 0013700 0013700 0014000 0014100 0014200 0014500 0014500 0014500 0014600 0014500 0014600 001500 001500 00151000 00151000 00151000 0015000 0015000 0000000000	PAGE OOU
C UB TRAN IV G LEVEL 09 C++CA C+THI 10 11 12 C++++ 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 50 51 55 54 40 55 55 40 57 40 57 57 40 57 57 56 57 57 57 57 57 57 57 57 57 57	CALCULATION OF GAPS GIN(I)=GS1(I)+PF1+(ALFAF(TFI)+(TFM-2(,0)-ALFAG(TGM1)+(TGM1-20, 20 HAIK DATE # 72349 11/ GOUT(I)=GS2(I)+FF2+(ALFAG(T(L2)+(TGH2-20,0)-ALFAF(TFI)+(TFM-20) ICULATION OF DIFERSIONS+* RMAL EXPANSIGN RCO(I)=RCOC*(ALFAG(TGM1)+(T(I1-2U)+1) PC1(I)=RCOC*(ALFAG(TGM2)+(T(I1-2U)+1) PC2(I)=RC2C*(ALFAG(TGM2)+(T(I1-2U)+1) PC2(I)=RC2C*(ALFAG(TGM2)+(T(IALL(L)-293)+1) *CORROSION CAL(ULATIONS TM1C=TU1(N)-273;0 TWALC=TWALL(N)-273;0 TWALC=TWALL(N)-273;0 TMALC=TWALL(N)-273;0 TMALC=TWALL(N)-273;0 DR1=DELR1(T1(2)+TIFE PK3=DELR1(T1(2)+TIFE PK3=DELR1(T1(2)+TIFE PK3=DELR1(T1(2)+TIFE PK3=DELR1(T1(2)+TIFE PK3=DELR1(T1(2)+TIFE PK3=DELR1(T1(2)+TIFE PK3=DELR1(T1(2)+TIFE PK3=DELR1(T1(2)+TIFE PK3=DELR1(T1(2)+TIFE PK3=DELR2(TALLC)+F1)+DF1 PK1(I)=RC1(I)+F12(I,MT)+DF2 PK13(I,MT)=ERT1(I,MT)+DF2 PK13(I,MT)=ERT1(I,MT)+DF2 PK13(I,MT)=ERT1(I,MT)+DF2 PK13(I,MT)=ERT1(I,MT)+DF3 RC0(I)=RC0(I)+DET1(I,MT) PC1(I)=RC1(I)+F13(I,MT)	0013400 0)) 0013500 50748 ,0)) 0013600 0013700 0013700 0013700 0014000 0014100 0014200 0014200 0014500 0014500 0014600 0014600 0014600 0014600 001500 001500 0015100 0015100 0015100 00155000 0015500 00155000 0000000000	PAGE OO
C UB TRAN IV G LEVEL 09 C++C/ C+THI 11 12 C++++ 13 14 15 16 17 18 19 20 21 22 24 25 24 25 24 25 24 25 24 25 24 25 26 27 28 29 50 51 55 402 55 54 402 55 54 402 55 54 402 55 56 57 57 56 57 57 57 57 57 57 57 57 57 57	CALCULATION OF GAPS GIN(I)=GS1(I)+PF1+(ALFAF(TFI)+(TFH-2(.0)-ALFAG(TGH1)+(TGH1-20, 20 HAIN DATE = 72349 11/ GOUT(I)=GS2(I)+FF2+(ALFAG(T(L2)+(TGH2-20,0)-ALFAF(TFI)+(TFH-20) (CULATION OF DITEPSIONS+* RMAL EXPANSION RC0(I)=RC00+(ALFAG(TGH1)+(T(I1-20)+1) PC(I)=RC10+(ALFAG(TGH2)+(T(I2-20)+1) PC(I)=RC10+(ALFAG(TGH2)+(T(I2-20)+1) PC(I)=RC10+(ALFAG(TGH2)+(T(I2-20)+1) PC0PROSION CALCULATIONS TH1C=IV1(N)-273,0 TH2C=TU2(N)-273,0 DR1=DELP1(T1(2)+LT1NE IF(DP1,LE,0,0) IR3=0,0 DR1=DELP1(T1(2)+LT1NE IF(DP1,LE,0,0) IR3=0,0 DR1(I,1)=0,0 DR1(I	00134600 0)) 00135600 50748 ,0)) 00136600 00137600 00137600 00146600 00141600 00145600 00145600 00145600 00145600 00146600 00146600 00146600 00156700 00157700 00157700 00157700 00157700 00157700 00157700 00157700 00157700 00157700 00157700 00157700 00175700	PAGE OO
C UB TRAN IV 6 LEVEL 09 C++CA C+TH1 10 11 12 C++++ 15 16 17 18 19 20 21 22 25 24 25 26 27 28 29 50 51 55 54 40 55 54 40 55 54 40 55 54 40 55 54 40 55 54 40 55 56 57 55 56 57 55 56 57 55 56 57 55 56 57 57 56 57 56 57 56 57 56 57 56 57 56 57 56 57 56 57 56 57 56 57 56 57 57 56 57 57 56 57 57 56 57 57 56 57 57 56 57 57 56 57 57 57 57 57 56 57 57 57 57 57 57 57 57 57 57	CALCULATION OF GAPS GIN(I)=GS1(I)+PF1+(ALFAF(TFI)+(TFH-2(,0)-ALFAG(TGH1)+(TGH1-20, 20 MAIA DATE = 72349 11/ GOUT(I)=GS2(I)+FF2+(ALFAG(T(I2)+(TGH2-20,0)-ALFAF(TFI)+(TFH-20) LCULATION OF DIFEPS1(NS** RMAL EXFANSION RCO(I)=RCOC+(ALFAG(TGM1)+(TT(1+2/)+1) PC1(I)=RC1C+(ALFAG(TGM1)+(TT(1+2/)+1) PC2(I)=RC1C+(ALFAG(TGM2)+(TT(1+2/)+1) PC2(I)=RC1C+(ALFAG(TGM2)+(TT(1+2/)+1) PC2(I)=RC1C+(ALFAG(TGM2)+(TT(1+2/)+1) PC2(I)=RC2C+(ALFAG(TGM2)+(TT(1+2/)+1) PC2(I)=RC2C+(ALFAG(TGM2)+(TT(1+2/)+1) PC2(I)=RC2C+(ALFAG(TGM1)+(TT(1+2/)+1) PC2(I)=RC1C+(ALFAG(TGM1)+(TT(1+2/)+1) PC2(I)=RC1(1)=C2(I)+IIIE DR3=DELR1(II)(I)=C1(I)IE DR3=DELR1(II)(I)=C1(I)IE DR3=DELR2(II)(I)=C1(I)IE DR3=DELR2(II)=C1(I)=P2=0.0 IF(DP2(I,AI)=0.0 DR13(I,1)=0.0 DR13(I,1)=0.0 DR13(I,1)=0.0 DR13(I,1)=0.0 DR13(I,1)=RC1(I)=RT1(I,AT)+LP1 DR12(I,AT)=FT1(I,AT)+LP1 DR12(I,AT)=FT1(I,AT)+LP3 RC0(I)=RC2(I)=RT1(I,AT)+LP3 RC0(I)=RC2(I)=RT1(I,AT) PC2(I)=RC2(I)=RT1(I)	00136/00 50/48 ,0)) 00135/00 50/48 ,0)) 00137/00 00137/00 00137/00 00140700 00140700 00142700 00142700 00146700 00146700 00146700 0014700 0014700 0015500 0015000 0015500 0015000 0015500 00015000 0015000 00150000000000	PAGE OO
C UB TRAN IV G LEVEL 09 C++C/ C+THI 11 12 C++++ 13 14 15 16 17 18 19 20 21 22 24 25 24 25 24 25 24 25 24 25 24 25 26 27 28 29 50 51 55 402 55 54 402 55 54 402 55 54 402 55 56 57 57 56 57 57 57 57 57 57 57 57 57 57	CALCULATION OF GAPS GIN(I)=GS1(I)+PF1+(ALFAF(TFI)+(TFH-2(.0)-ALFAG(TGH1)+(TGH1-20, 20 HAIN DATE = 72349 11/ GOUT(I)=GS2(I)+FF2+(ALFAG(T(L2)+(TGH2-20,0)-ALFAF(TFI)+(TFH-20) (CULATION OF DITEPSIONS+* RMAL EXPANSION RC0(I)=RC00+(ALFAG(TGH1)+(T(I1-20)+1) PC(I)=RC10+(ALFAG(TGH2)+(T(I2-20)+1) PC(I)=RC10+(ALFAG(TGH2)+(T(I2-20)+1) PC(I)=RC10+(ALFAG(TGH2)+(T(I2-20)+1) PC0PROSION CALCULATIONS TH1C=IV1(N)-273,0 TH2C=TU2(N)-273,0 DR1=DELP1(T1(2)+LT1NE IF(DP1,LE,0,0) IR3=0,0 DR1=DELP1(T1(2)+LT1NE IF(DP1,LE,0,0) IR3=0,0 DR1(I,1)=0,0 DR1(I	00134600 0)) 00135600 50748 ,0)) 00136600 00137600 00137600 00146600 00141600 00145600 00145600 00145600 00145600 00146600 00146600 00146600 00156700 00157700 00157700 00157700 00157700 00157700 00157700 00157700 00157700 00157700 00157700 00157700 00175700	PAGE DOU

THAN IV G L	LEVEL	20 HAIN DATE # 72349 11/50/	48	PAGE DUUS
40		TF(E1.1E.0, COD01) 60 TO 470	00180600	
44		CALL RUSTERIA, HIA, EA, PHA, FFA, HNAD	00181100	
	**	OUTER CHANNEL	00182660	
50	470	K2=0 R/1=54RT(HC1(1)+1F2(1))	00183000	
52		A1=6.28318+F(1(1)-h+1C+FIBW+(FF1-F(1(1))+NRID+2.0	00185100	
53		A2=6.2+318+1(2(1)-1+18+11++(1)/(1)-1+1)+NP18+2.0	00186100	
54		\$LOA2=3,14159*(F(2(1)*F(2(1)+F(1(1)*FC1(1))+RED*RIF(*(FC2(1)+RC1	(00187600	
			01181600	
55 50		DE2#4,0*FLUA2/(A1+A2) DE3#DE2	00189000	
57		PE2=W2+DE2/(FLUA2+ADU2)	001911.00	
58		RE3#RE2	00191500	1,000 (1000) (1000)
54		HN2=U, N23+RF2++U, 8++P2++N, 4	00192100	
60		HN3=HN2	00193000	
61		FF2=0,08//RF2++0,25	00194000	
62 65		FF3#FF2 TF(E2,LE,0,00001) 60 TO 471	00191400	
64		GU TO 420	00197000	
65	471	1F(ES.LE.0.00001) GO TO 490	00198600	
60	The second	GO TO 420	00199000	
67	421	r2=k2+1	00700600	
68		1F(k2.6T,20) 60 TO 300	00:02000	
64 10		AS=FF2+A7/(FF3+A2) A=3,14159+(1,0+A3)	00203000	
/1		$B = -N \times IB \times FIB \times (1, C + A3)$	00:04000	
12 .		C=NR1B+R1BW+(PC1(1)+A3+PC2(1))=3,14159+(A3+KC2(1)+RC2(1)+PC1(1)+R	00205000	
100 an-1	1	1(1))	00:00000	
5		RM=(-8+\$QRT(B+L+4,0+A+L))/(;,0+A)	00:07000	
14		DE2=4.0*(3.14159*(RM*PF*PC1(1)*FC1(1))=NFIB*RIBW*(H=RC1(1)))/A1 DE3=4.0*(3.14159*(RC2(1)*RC2(1)=N+KF)=NFIB*FIBW*(FC2(1)=RM))/A2	00:09000	
6	420	RE2=W2+DE2/(FLUA2+AU2)	00210000	
1		RE3=W2+DE3/(FLOA2+AH12)	00:110:00	
8		CALL RUST(RF2,DF2,F7,PR2,FFEA,H12)	00212000	
9-		CALL RUST(RF3, DF3, F3, PF2, FF3A, H13)	00713000	
10		ERROP=(FF2A+1,1(1-FF2)/FF2 IF(ABS(EPROF).GT.0.01) 60 T( 422	00214000	
2		FRROR=(FF3A+1.101-FF3)/FF3	00710500	
3		1F(ABS(ERROF), LE, 0, 01) 60 TC 423	00:17100	
54	422	FF2=FF2A+1,101	00;18(00	
85		FF3=FF3A+1,101	00719000	
10		60 10 421	00.20000	
	423	FF2=FF2A+1,101	00:21000	
87		FF3#FF3A*1,101	00722600	PAGE DUD6
87 88 TRAN IV G L N9	EVEL	FF3=FF3A+1,101 20 MAIR DATE = 72349 11/50/4 G0 T0 472	00;21000 00;22000 48 00;23000	PAGE 0006
87 58 TRAN IV G L N9 V0	EVEL 490	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1	00;21000 00;22000 48 00;23000 00;24000	PAGE DUDS
87 58 TRAN IV G L	EVEL 490	FF3=FF3A+1,101 20 MAIR DATE = 72349 11/50/4 G0 T0 472	00;21000 00;22000 48 00;23000	PAGE 0006
55 55 55 55 55 55 55 55 55 55 55 55 55	EVEL 490	FF3=FF3A*1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1 B20=6,28318*RC1(I) B5=1,0/2+(Rc1(I)/RC2(I))*(1,(/E=1) FF3=FF3A*1,101	00;21600 00;22600 48 00;23600 00;24600 00;24600 00;27600	PAGE 0006
57 58 58 50 50 50 52 53 C	EVEL 490 472	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/0 GO TO 472 RM=RM1 B20=6,28318+RC1(I) B5=1,0/E+(RC1(I)/RC2(I))+(1,(/E=1)) P6=5,67/B5 CALCULATION OF CONDUCTABLES	00;21600 00;22600 48 00;23600 00;24000 00;25000 00;2600 00;2760 00;28600	PAGE DUD6
57 58 58 59 50 50 51 52 53 54 54	EVEL 490 472	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/0 GO TO 472 RM=RM1 B20=6,28318+RC1(I) B5=1,0/E+(RC1(I)/FC2(I))+(1,(/E=1)) P6=5,67/B5 CALCULATION OF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,2E318+AKG1)	00;21600 00;22600 48 00;23600 00;24000 00;25000 00;25000 00;25600 00;25600 00;25600 00;25600	PAGE DUD6
FRAN IV G L 199 20 22 23 24 25	EVEL 490 472	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1 B20=6,28318*RC1(I) B5=1,0/E+(RC1(I)/RC2(I))+(1,(/E=1)) P0=5,07/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,2L318*AKG1) R2=ALOG(PC1(/PF2)/(6,2L318*AKG2)	00;21600 00;22600 48 00;23600 00;24600 00;25600 00;25600 00;25600 00;28600 00;28600 00;28600 00;28600	PAGE DUD6
57 585 595 70 70 71 72 73 73 73 75 75 75	EVEL 490 472	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1 B20=6,28318+RC1(I) B5=1,0/E+(RC1(I)/FC2(I))+(1,(/E=1) P6=5,67/B5 C1=AL0G(RF1/RC0C)/(6,2E318+AKG1) R2=AL0G(PC1(/F2)/(6,2E318+AKG2) B16=12,5663+AKF. B12=2+RI(N)+P1(E)/(FI(E)+FI(L)+E1+EF1)	00;21600 00;22600 48 00;23600 00;24000 00;25000 00;25000 00;25600 00;25600 00;25600 00;25600	PAGE DUO6
57 585 595 500 500 52 53 55 56 57 77	EVEL 490 472	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1 B20=6,28318*RC1(I) B5=1,0/E+(RC1(I)/FC2(I))*(1,(/E=1) P6=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/FC0C)/(6,25318*AKG1) R2=ALOG(PC1C/PF2)/(6,25318*AKG2) B16=12,5663*AKF - B12=2*RI(N)*PI(E)/(FI(L)*KI(L)*LF1*FF1) B7=(B12*ALCG(LI(N)/FF1)-1)/(16	00;21600 00;22600 48 00;23600 00;24600 00;24600 00;28600 00;28600 00;28600 00;31600 00;31600 00;33600	PAGE 0006
RAN IV G L 10 10 10 10 11 12 13 14 15 16 16 17 18 19 10 10 10 10 10 10 10 10 10 10	EVEL 490 472	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1 B20=6,28318*RC1(1) B5=1,0/E+(RC1(1)/RC2(1))*(1,(/E=1) P0=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,22318*AKG1) R2=ALOG(PC17/PE2)/(6,22318*AKG1) B16=12,5663*AKF. B16=12,5663*AKF. B16=12,5663*AKF. B16=12,5663*AKF. B16=12,5663*AKF. B16=12,0*R1(1,0)*F1(k)*F1(k)*F1(k))	00;21600 00;22600 668 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;31600 00;31600 00;34600	PAGE DUD6
RAN IV G L 9 0 1 2 2 3 5 5 6 7 7 8 9 9	EVEL 490 472	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/0 GO TO 472 RM=RM1 B20=6,28318+RC1(I) B5=1,0/E+(RC1(I)/RC2(I))+(1,(/E=1) P6=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,22318+AKG1) R2=ALOG(PC1(/FF2)/(6,22318+AKG2) B16=12,5663+AKF. B12=2+RI(N)+PI(E)/(FI(L)+RI(L)-LF1+FF1) B7=(502+ALCG(L)(L)/(FF2)-L)/(16 B17=2,0+RI(L)+FI(L)/(FF2)-L)/(16 B8=(1,0-B17+ALCG(RF2/L)(A))/F1C	00;21600 00;22600 48 00;22600 00;24000 00;24000 00;25600 00;25600 00;28600 00;28600 00;29600 00;32600 00;32600 00;35600	PAGE 0006
TRAN IV G L 199 100 11 122 13 14 15 16 17 18 199 100 11	EVEL 490 472	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/0 GO TO 472 RM=RM1 B20=6,28318+RC1(1) B5=1,0/E+(RC1(1)/FC2(1))*(1,(/E=1) P6=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,2E318+AKG1) R2=ALOG(PC1(/F2)/(6,2E318+AKG1) B12=2:5663+AKF. B12=2:F1(N)*P1(E)/(F1(E)*F1(E)*F1*F1) B7=(B12*ALCG(E1(N)/FF1)-1)/(16 B17=2;0*R1(E)*F1(E)/(F2*F2=E1(N)*F1(E)) B8=(1,0-B17*ALCG(E2/E1(E))*C1(F1)) B8=(1,0-B17*ALCG(E2/E1(E))*C1)/E1	00;21600 00;22600 48 00;24000 00;24000 00;2400 00;2400 00;2400 00;2400 00;2400 00;2400 00;2400 00;3400 00;3400 00;3400 00;3400 00;3400 00;3400	PAGE 0006
RAN IV G L 9 0 1 2 3 C 5 6 7 8 9 0 1 2 3 C 5 6 7 7 8 9 0 1 1 2 3 C	EVEL 490 472	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1 B20=6,28318*RC1(I) B5=1,0/E+(RC1(I)/FC2(I))*(1,(/E=1) P6=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,22318*AKG1) R2=ALOG(RF1/RC0C)/(6,22318*AKG1) R2=ALOG(PC1C/PF2)/(C,26318*AKG1) B16=12,5663*AKF - B12=2*RI(N)*PI(E)/(FI(L)*RI(L)*FI*FF1) B7=(512*ALCG(KI(N)/FF1)-1)/(16 B17=2,0*RI(L)*FI(E)/(FF2*KF2-KI(L)*FI(N)) B8=(1,0-B17*ALCG(RF2/KI(N))/F1C H1=HN1*(TG1(I)/THI(T)**0,15*AFI1/FE1 H2=HN2*(TG2(I)/TH2(L))**0,15*AFI2/DE2	00;21600 00;22600 48 00;22600 00;24000 00;24000 00;25600 00;25600 00;28600 00;28600 00;29600 00;32600 00;32600 00;35600	PAGE DUD6
RAN IV G L 99 00 11 22 3 5 6 6 7 7 8 9 9 00 11 23 5 6 7 7 8 9 9 00 11 23 5 5 6 7 7 8 8 9 9 00 11 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	EVEL 490 472	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/0 GO TO 472 RM=RM1 B20=6,28318+RC1(1) B5=1,0/E+(RC1(1)/FC2(1))*(1,(/E=1) P6=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,2E318+AKG1) R2=ALOG(PC1(/F2)/(6,2E318+AKG1) B12=2:5663+AKF. B12=2:F1(N)*P1(E)/(F1(E)*F1(E)*F1*F1) B7=(B12*ALCG(E1(N)/FF1)-1)/(16 B17=2;0*R1(E)*F1(E)/(F2*F2=E1(N)*F1(E)) B8=(1,0-B17*ALCG(E2/E1(E))*C1(F1)) B8=(1,0-B17*ALCG(E2/E1(E))*C1)/E1	00;21600 00;22600 00;22600 00;24000 00;24000 00;2600 00;2600 00;28600 00;28600 00;38600 00;38600 00;38600 00;38600 00;38600 00;39700	PAGE DUD6
7 8 RAN IV G L 9 0 1 2 3 C 5 6 7 7 8 9 0 1 2 5 6 7 7 8 9 0 1 2 5 6 7 7 8 9 0 1 2 5 6 6 7 7 7 7 7 7 7 7 7 7 7 7 7	EVEL 490 472	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 PM=RM1 B20=6,28318+RC1(I) B5=1,0/E+(RC1(I)/FC2(I))+(1,(/E=1) P6=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,2E318+AKG1) R2=ALOG(PC1(/F2)/(6,2E318+AKG1) B12=2.5663+AKF. B12=2.FRI(N)+PI(E)/(FI(E)+KI(E)+F1+FF1) B7=(B12+ALCG(K1(N)/FF1)-1)/(16 D17=2,0+RI(E)+FI(E)/(FI(E)+KI(E)+F1+FF1) B8=(1,0-B17+ALCG(KF2/KI(E))/F1C H1=HNA+CIG(I)/Tw1(E)2+C,15+ALF1/FE1 H2=HN2+(IG2(I)/Tw2(E))++0,15+ALF1/FE1 H2=HN2+(IG2(I)++0,15+ALF1/FE1 H2=HN2+(IG2(I)++0,15+ALF	00;21600 00;22600 00;22600 00;24000 00;24000 00;25000 00;2800 00;2800 00;2800 00;3100 00;3100 00;3100 00;3100 00;3500 00;3500 00;3500 00;3500 00;3500 00;3500 00;3500 00;3500 00;3500 00;3500 00;3500 00;3500	PAGE 0006
7 8 RAN IV G L 9 0 1 2 3 - 4 5 - 5 - 6 7 7 - 8 - 9 - 0 - - - - - - - - - - - - -	EVEL 490 472	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1 B20=6,28318*RC1(1) B5=1,0/E*(RC1(1)/FC2(1))*(1,(/E=1) P0=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,25318*AKG1) R2=ALOG(PC1C/AF2)/(6,25318*AKG2) B16=12,5663*AKF. B12=2*RI(N)*PI(H)/(FI(L)*KI(L)-FI*FF1) B7=(B12*ALCG(KI(N)/FF1)-1)/(16 B17*2,0*RI(L)*FI(H)/(FF2+KI2+KI(H)*FI(N)) B8=(1,0-B17*ALCG(F2/KI(H))/F10 H1=HN1*(TG1(1)/TH1(H))**0,15*AHI1/FH1 H2=HN2*(TG2(1)/TWALL(N))**0,15*AHI1/FH2 H3=HH3*(TG2(1)/TWALL(N))**(,15*AKH2/DE3 B9=1,0/(6,2831B*FC0(1)*H1) CALCULATION OF (AP CONLICTAICES TIMEN1=(T11(N)*TF1(N))/2,0	00;21600 00;22600 00;22600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;31600 00;31600 00;34600 00;356000 00;356000 00;356000 00;3560000000000000000000000000000000000	PAGE DUD6
7 8 RAN IV G L 9 0 1 2 3 - C 5 6 7 8 9 1 2 5 6 7 7 8 9 10 1 2 5 6 7 7 8 9 0 1 2 5 6 6 7 7 8 9 0 1 2 5 6 6 7 7 8 9 0 1 1 2 2 5 6 6 7 7 7 8 9 0 1 1 7 7 8 7 7 8 7 7 8 7 7 7 8 7 7 7 8 7 7 7 8 7 7 7 8 7 7 7 7 7 7 7 8 7 7 7 7 7 7 7 7 7 7 7 7 7	EVEL 490 472	<pre>FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/0 G0 T0 472 RM=RM1 B20=6,28318+RC1(1) B5=1,0/E+(RC1(1)/RC2(1))*(1,(/E=1) P6=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,22318*AKG1) R2=ALOG(PC1(/FF2)/(6,22318*AKG2) B16=12,5663*AKF. B12=2+RI(N)*PI(E)/(FI(L)*RI(L)*RI(L)*F1*FF1) B7=(5063*AKF. B12=2+RI(N)*PI(E)/(FI(L)*RI(L)*RI(L)*F1*FF1) B7=(5063*AKF. B12=2+RI(N)*PI(E)/(FI(L)*RI(L)*E1*FF1) B7=(5063*AKF. B12=2+RI(N)*PI(E)/(FI(L)*RI(L)*E1*FF1) B7=(5063*AKF. B12=2+RI(N)*PI(E)/(FI(L)*E1*E1*E1*E1*E1*E1*E1*E1*E1*E1*E1*E1*E1*</pre>	00;21600 00;22600 00;22600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;31600 00;31600 00;34600 00;34600 00;34600 00;34600 00;34600 00;34600 00;34600 00;34600 00;34600 00;34600 00;34600	PAGE OUD6
7 8 RAN IV G L 9 0 1 2 3 C 5 6 7 7 8 9 9 1 2 5 6 7 7 8 9 9 0 1 1 2 2 5 6 7 7 8 9 9 0 1 1 2 2 5 6 6 7 7 7 7 7 7 7 7 7 7 7 7 7	EVEL 490 472	<pre>FF3#FF3A*1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1 E20=c,28318*RC1(1) B5=1,0/E+(RC1(1)/FC2(1))*(1,(/E=1) Po=5,07/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,2E318*AKG1) R2=ALOG(PC1(/F2)/(6,2E318*AKG1) B12=2:5663*AKF B12=2:FI(N)*P1(H)/(FI(L)*KI(L)*KF1*FF1) B7=(B12*ALCG(K1(N)/FF1)-1)/(16 B17*2,0*RI(L)*KI(L)/KF2*KF2*KI(N)*FI(N)) B8=(1,0-B17*ALCG(KF2/KI(L))/F1C H1=HN1*(TG1(1)/TH1(H)**0,15*AL11/F11 H2=HN2*(TG2(1)/THAL(C)**0,15*AL11/F11 H2=HN2*(TG2(1)/THAL(C)**0,15*AL12/DE3 B9=1,0/66,7831B*FC0(1)**1(C) HKG1=1,456f-3*(TIFH1/273,1()**C,7</pre>	00;21600 00;22600 00;22600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;31600 00;31600 00;35600 00;25600 00;35700 00;35600 00;35700 00;356000 00;356000 00;3560000000000000000000000000000000000	PAGE DUD6
7 8 RAN IV G L 9 0 1 2 3 C 4 5 6 7 8 9 0 1 2 3 C 5 6 7 7 8 9 0 1 2 3 C 5 6 7 7 8 9 0 1 2 3 C 5 6 6 7 7 8 9 0 1 2 3 C 5 6 6 7 7 8 9 0 1 7 7 8 8 9 0 1 7 7 8 8 9 0 1 7 7 8 8 9 0 1 1 7 7 8 8 9 0 1 1 7 7 8 8 9 0 1 1 7 7 8 8 9 0 1 1 7 7 8 8 9 0 1 1 7 7 8 8 9 0 1 1 7 7 8 8 9 0 1 1 7 7 8 8 9 0 1 1 7 7 8 8 9 0 1 1 7 7 8 8 9 0 1 1 7 8 8 9 0 1 1 8 8 8 9 0 1 1 8 8 8 8 8 8 9 1 8 8 8 8 8 8 8 8 8 8 8 8 8	EVEL 490 472	<pre>FF3#FF3A*1,101 20 MAIN DATE = 72349 11/50/4 G0 T0 472 PM=RM1 B20=6,28318*RC1(I) B5=1,0/E+(RC1(I)/FC2(I))*(1,(/E=1) P6=5,67/B5 C1=AL0G(RF1/RC0C)/(6,2E318*AKG1) R2=AL0G(RF1/RC0C)/(6,2E318*AKG1) B12=2.5663*AKF B12=2.5663*AKF B12=2.4LCG(K1(N)/FF1)-1)/(16 D17=2,0*RI(N)*PI(K)/(FF(K)*KI(L)-FF1*FF1) B7=(B12*ALCG(K1(N)/FF1)-1)/(16 D17=2,0*RI(N)*PI(K)/(FF2*KF2-KI(N)*PI(N)) B8=(1,0-B17*ALCG(RF2/KI(N))/F10 H1=MM1*(TG1(I)/TW1(L))**0,15*AL1/FF1 H2=HN2*(TG2(I)/TW2(L))**0,15*AL1/FF1 H2=HN2*(TG2(I)/TWALL(K))**(,15*AKK2/DE3 B9=1,0/(6,28318*FC0(I)*H1) CALCULATION OF (AP CONLECTAICES TIMEM1=(T11(N)*TF1(N))/2.0 HKG1=1,456F-3*(T1FFH1/273,1()**C,7 HKG2=1,456F-3*(T1FFH1/273,1()**C,7 </pre>	00;21600 00;22600 00;22600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;31600 00;31600 00;34600 00;34600 00;34600 00;34600 00;34600 00;34600 00;34600 00;34600 00;34600 00;34600 00;34600	PAGE DUD6
RAN IV G L 9 0 1 2 3 - - - - - - - - - - - - -	EVEL 490 472	<pre>FF3#FF3A*1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1 E20=c,28318*RC1(1) B5=1,0/E+(RC1(1)/FC2(1))*(1,(/E=1) Po=5,07/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,2E318*AKG1) R2=ALOG(PC1(/F2)/(6,2E318*AKG1) B12=2:5663*AKF B12=2:FI(N)*P1(H)/(FI(L)*KI(L)*KF1*FF1) B7=(B12*ALCG(K1(N)/FF1)-1)/(16 B17*2,0*RI(L)*KI(L)/KF2*KF2*KI(N)*FI(N)) B8=(1,0-B17*ALCG(KF2/KI(L))/F1C H1=HN1*(TG1(1)/TH1(H)**0,15*AL11/F11 H2=HN2*(TG2(1)/THAL(C)**0,15*AL11/F11 H2=HN2*(TG2(1)/THAL(C)**0,15*AL12/DE3 B9=1,0/66,7831B*FC0(1)**1(C) HKG1=1,456f-3*(TIFH1/273,1()**C,7</pre>	00;21600 00;22600 00;22600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;34600 00;35600 00;35600 00;35600 00;35600 00;35600 00;35600 00;34600 00;44600	PAGE 0006
RAN IV G L 99 0 1 2 3 C 5 6 7 8 99 0 1 1 2 3 C 5 6 6 7 7 8 9 9 0 1 1 2 5 6 6 7 7 8 8 9 0 1 1 2 5 6 6 7 7 8 8 9 0 1 1 1 1 1 1 1 1 1 1 1 1 1	EVEL	<pre>FF3#FF3A*1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1 E20=c,28318*RC1(1) B5=1,0/E+(RC1(1)/FC2(1))*(1,(/E=1) P0=5,07/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,2E318*AKG1) R2=ALOG(PC1C/FE2)/(6,2E318*AKG2) B16=12,5663*AKF. B12=2*RI(N)*P1(H)/(FI(L)*KI(L)*F1*FF1) B7=(B12*ALCG(K1(N)/FF1)-1)/(16 B17*2,0*RI(L)*F1(L)/(F2*KF2*KI(N)*FI(N)) B8=(1,0-B17*ALCG(KF2/KI(L))/F10 H1=KN1*(TG1(1)/TH1(H))**0,15*AL11/F11 H2=HN2*(TG2(1)/TWALL(N))**0,15*AL11/F11 H2=HN2*(TG2(1)/TWALL(N))**0,15*AL11/F11 H2=HN2*(TG2(1)/TWALL(N))**0,15*AL11/F11 CALCULATION CF CAN CONLUCTAICES TIMEN1=(T11(N)*TF1(N))/2,0 IMKG1=1,456f-3*(TIFFH1/273,1()**C,7 HKG2=1,456f-3*(TIFFH1/273,1()**C,7 HKG2=1,456f-3*(TIFFH1/273,1()*C,7 HKG2=1,456f-3*(TIFFH1/273,1()*C,7 HKG2=1,456f-3*(TIFFH1/273,1()*C,7 HKG2=1,456f</pre>	00;21600 00;22600 00;22600 00;24600 00;24600 00;24600 00;28600 00;28600 00;28600 00;31600 00;31600 00;33600 00;35600 00;35600 00;35600 00;35600 00;35600 00;3700 00;3600 00;3600 00;3600 00;3600 00;3600 00;3600 00;3600 00;3700 00;400000000	PAGE DUDS
7 8 RAN IV G L 9 0 1 2 3 - 4 5 6 7 7 8 9 0 1 - - - - - - - - - - - - -	EVEL	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1 B20=6,28318*RC1(1) B5=1,0/E+(RC1(1)/FC2(1))*(1,(/E=1) P0=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,2E318*AKG1) R2=ALOG(RC1(/PF2)/(6,2E318*AKG1) B16=12,5663*AKF. B12=2*RI(N)*PI(E)/(FI(L)*KI(L)=LF1*FF1) B7=(B12*ALCG(KI(N)/FF1-1)/(16 D17*2,0*RI(L)*FI(L)/(F1E)*F1(L)=L1*FF1) B8=(1,0-B17*ALCG(RF2/KI(N))/E1C H1=HN1*(TG1(1)/TH1(L))**0,15*AH12/DE2 H3=HN3*(TG2(1)/TWALL(N))**(,1)*AKE2/DE2 H3=HN3*(TG2(1)/TWALL(N))**(,1)*AKE2/DE2 H3=HN3*(TG2(1)/TWALL(N))/2.0 TIMEM1=(T11(N)*TF1(N)/2.0 HKG1=1,456F-3*(TIMEM2/273,1()**C.7 HKG2=1,456F-3*(TIMEM2/273,1()**C.7 HKG2=1,456F-3*(TIMEM2/273,1()**C.7 HKG2=1(L),LF,0,0) CO TO 2(C RADG1*(TF1(L)+T11(L))*(TF1(L))+T11(N)*T11(N))/1.VE12 P30=1/((CH4+PAL(D))*(TF2(L))+T12(N)+T12(N))/1.VE12	00721600 00722600 00722600 00724600 00724600 00724600 00724600 00724600 00724600 00724600 00734600 00734600 00734600 00734600 00734600 00744600 00744600 00744600 00744600	PAGE DUD6
7 8 RAN IV G L 9 0 1 2 3 - - - - - - - - - - - - -	EVEL	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/0 GO TO 472 RM=RM1 B20=6,28318+RC1(1) B5=1,0/E+(RC1(1)/RC2(1))+(1,(/E=1) P6=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(PC1(/PF2)/(C,25318+AKG1) R2=ALOG(PC1(/PF2)/(C,25318+AKG2) B16=12,5663+AKF. B12=2+RI(N)+PI(E)/(FI(L)+RI(L)+F1*FF1) B7=(563+AKF. B12=2+RI(N)+PI(E)/(FI(L)+RI(L)+F1*FF1) B7=(563+AKF. B12=2+RI(N)+PI(E)/(FI(L)+RI(L)+F1*FF1) B7=(563+AKF. B12=2+RI(N)+PI(E)/(F2(L)+R1(L))+F1(E)) B8=(1,0-B17+ALCG(RF2/K1(K)))/E1C H1=HM1*(TG2(1)/TH1(F))**0,15*AF12/DE2 H3=HM3*(TG2(1)/TH2(L))**0,15*AF12/DE3 B9=1,0/(6,28318*FC0(1)*H1) CALCULATION CF GAP CONLICTAICES INFN1=(T11(K)+TF1(K))/2,0 HKG1=1,456F-3*(TIFFE1/273,1()**C.7 HKG2=1,456F-3*(TIFFE1/273,1()**C.7 HKG2=1,456F-3*(TIFFE1/273,1()**C.7 HKG2=1,456F-3*(TIFFE1/273,1()**C.7 HKG2=(TF1(K)+T11(K))*(TF1(1)*TF1(N)*T11(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L)*TF1(N)+T12(N)*T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L)*TF1(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L)*TF1(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L)*TF1(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L)*TF1(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L)*TF1(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF2(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF2(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF2(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF2(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF2(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(N)+T12(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(N)+T12(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(N)+T12(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(K)+T12(K)+T12(K))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF2(N)+T12(K)+T12(K))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(L))*TF1(K)+T12(K)+T12(K))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(L))*TT2(K)+T12(K))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(L))*TT2(K)+T12(K))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(L))*TT2(K)+T12(K)/1.UE12 FADG2=(TF2(L)+T12(K))*(TF1(L))*TF1(L))*TT12(K)	00;21600 00;22600 00;22600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;24600 00;31600 00;31600 00;34600 00;34600 00;34600 00;34600 00;44600 00;44600 00;44600	PAGE DUD6
7 8 RAN IV G L 9 0 1 2 3 C 5 6 7 7 8 9 0 1 2 5 6 7 7 8 9 0 1 2 5 6 7 7 8 9 0 1 2 5 6 6 7 7 8 9 0 1 1 2 2 5 6 6 7 7 8 9 0 1 1 2 5 6 6 7 7 8 9 0 1 1 2 5 6 6 7 7 8 9 0 1 1 2 5 6 6 7 7 7 8 9 0 0 1 1 2 5 6 6 7 7 7 7 7 7 7 7 7 7 7 7 7	EVEL	<pre>FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1 B20=6,28318*RC1(1) B5=1,0/E+(RC1(1)/RC2(1))*(1,(/E=1) P0=5,07/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,2E318*AKG1) R2=ALOG(PC1(/F2)/(6,2E318*AKG2) B16=12,5663*AKF. B12=2*RI(N)*P1(E)/(FI(L)*KI(L)=LF1*FF1) B7=(B12*ALCG(K1(N)/FF1)=1)/(16 B17=2,0*RI(h)*FI(E)/(FI(L)*KI(L)=LF1*FF1) B7=(B12*ALCG(K1(N)/FF1)=1)/(16 B17=2,0*RI(h)*FI(E)/(FI(L)*KI(L)=LF1*FF1) B7=(C12*ALCG(K1(N)/FF1)=1)/(16 B17=2,0*RI(h)*FI(E)/(FI(L)*KI(L)=LF1*FF1) B7=(C12*ALCG(K1(N)/FF1)=1)/(16 B17=2,0*RI(h)*FI(E)/(FI(L)*KI(L))=10 B8=(1,0+G7*ALCG(KF2/KI(L)))/15*ALF1/FI1 H2=HN2*(TG2(1)/TWALL(E))*E(L))*E(L) B9=(1,0/(6,2E31B*FCU(1)*II) CALCULATION CF (AP CONLUCTANCES TIMEN1=(TI1(N)+TF1(N))/2,0 HKG1=1,456F-3*(TIPEP1/273,1()**C,7 HKG2=1,456F-3*(TIPEP1/273,1()**C,7 HKF12(N)*TI2(N)/1,VE12 F(CR3,C12(N)+TI2(N)/1,VE12 F(CR3,C12(N)+TI2(N)/1,VE12 F(CR3,C12(N)+</pre>	00721600 00722600 00722600 00724600 00724600 00724600 00724600 00724600 00724600 00724600 00734600 00734600 00734600 00734600 00734600 00744600 00744600 00744600 00744600	PAGE 0006
RAN IV G L 199 100 11 122 13 14 15 14 15 14 15 14 15 14 15 15 15 15 15 15 15 15 15 15	EVEL 490 472	FF3=FF3A+1,101 20 MAIN DATE = 72349 11/50/0 GO TO 472 RM=RM1 B20=6,28318+RC1(1) B5=1,0/E+(RC1(1)/RC2(1))+(1,(/E=1) P6=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(PC1(/PF2)/(C,25318+AKG1) R2=ALOG(PC1(/PF2)/(C,25318+AKG2) B16=12,5663+AKF. B12=2+RI(N)+PI(E)/(FI(L)+RI(L)+F1*FF1) B7=(563+AKF. B12=2+RI(N)+PI(E)/(FI(L)+RI(L)+F1*FF1) B7=(563+AKF. B12=2+RI(N)+PI(E)/(FI(L)+RI(L)+F1*FF1) B7=(563+AKF. B12=2+RI(N)+PI(E)/(F2(L)+R1(L))+F1(E)) B8=(1,0-B17+ALCG(RF2/K1(K)))/E1C H1=HM1*(TG2(1)/TH1(F))**0,15*AF12/DE2 H3=HM3*(TG2(1)/TH2(L))**0,15*AF12/DE3 B9=1,0/(6,28318*FC0(1)*H1) CALCULATION CF GAP CONLICTAICES INFN1=(T11(K)+TF1(K))/2,0 HKG1=1,456F-3*(TIFFE1/273,1()**C.7 HKG2=1,456F-3*(TIFFE1/273,1()**C.7 HKG2=1,456F-3*(TIFFE1/273,1()**C.7 HKG2=1,456F-3*(TIFFE1/273,1()**C.7 HKG2=(TF1(K)+T11(K))*(TF1(1)*TF1(N)*T11(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L)*TF1(N)+T12(N)*T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L)*TF1(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L)*TF1(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L)*TF1(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L)*TF1(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L)*TF1(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF2(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF2(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF2(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF2(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF2(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(N)+T12(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(N)+T12(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(N)+T12(N)+T12(N))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(K)+T12(K)+T12(K))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF2(N)+T12(K)+T12(K))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(L))*TF1(K)+T12(K)+T12(K))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(L))*TT2(K)+T12(K))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(L))*TT2(K)+T12(K))/1.UE12 FADG2=(TF2(L)+T12(K))*(TF2(L))*TF1(L))*TT2(K)+T12(K)/1.UE12 FADG2=(TF2(L)+T12(K))*(TF1(L))*TF1(L))*TT12(K)	00721600 00722600 00722600 00724600 00725000 00725000 00725000 00727600 00727600 00727600 00731000 0073100 00732600 0073500 0073500 0073500 0073500 0073500 0074000 0074000 0074000 0074500 0074500 0074500 0074500	PAGE 0006
RAN IV G L 199 10 11 12 13 14 15 16 16 18 18 18 18 18 18 18 18 18 18	EVEL 490 472	<pre>FF3#FF3A+1,101 20</pre>	00;216.00 00;226.00 00;226.00 00;246.00 00;246.00 00;286.00 00;286.00 00;286.00 00;286.00 00;316.00 00;316.00 00;336.00 00;356.00 00;356.00 00;356.00 00;356.00 00;356.00 00;466.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;536.00 00;536.00 00;536.00	PAGE 0006
37       100       11       12       13       14       15       16       17	EVEL 490 472	<pre>FF3#FF3A+1,101 20</pre>	00721600 00722600 00722600 00724600 00724600 00725000 00725000 00725000 00728600 00731000 0073100 0073100 0073500 0073500 0073500 0073500 0073500 0073500 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0075100 0075100	PAGE DUDB
37       38       10       11       12       13       14       15       16       17       18       19       10       11       12       13       14       15       16       17       18       11       12       13       14       15       16       17       18	EVEL 490 472	<pre>FF3#FF3A+1,101 20</pre>	00721600 00722600 00722600 00724600 00724600 00724600 00724600 00724600 00724600 00724600 00737600 00737600 00734600 00734600 00734600 00734600 00744600 00754600 00754600 00754600 00754600 00754600 00754600 00754600	PAGE DUDS
S7 S8 S8 S8 S8 S8 S8 S8 S9 S9 S9 S9 S9 S9 S9 S9 S9 S9	EVEL 490 472	<pre>FF3#FF3A*1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 PM=RM1 B20e6,28318*RC1(1) B5=1,0/2+(Rc1(1)/Rc2(1))*(1,(/E=1) P6=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,28318*AKG1) R2=ALOG(PF1/RC0C)/(6,28318*AKG1) B1=2,5663*AKF B12=2*R(10)*P1(H)/(F1(K)*K1(L)*F1*FF1) B7=(B12*ALCG(K1(A)/PF1)-1)/(16 B17=2,0*RI(A)*P1(H)/(F1(K)*K1(L)*F1*FF1) B8=(1,0*B17*ALCG(K1(A)/PF1)-1)/(16 H1=*N1*CTG(1)/TV1(C))**0,15*ANL1/N11 H2=N2*(TG2(1)/TV2(L))**0,15*ANL1/N11 H2=N2*(TG2(1)/TV2(L))**0,15*ANL1/N11 H2=N2*(TG2(1)/TV2(L))**0,15*ANL1/N11 H2=N2*(TG2(1)/TV2(L))**0,15*ANL1/N11 H2=N2*(TG2(1)/TV2(L))**0,15*ANL1/N11 H2=N2*(TG2(1)/TV2(L))**0,15*ANL1/N12 CALCULATION CF CAP CONLUCTANCES TIMEN1*CTG1(1)/TF1(N))/2.0 TIMEN2=(T12(N)*TF2(N))/2.0 HKG1=1,456F-3*(TIMEN2/273,1()**C,7 HKG2=1,456F-3*(TIMEN2/273,1()*C,7 IF (GIN(1),LF,0,0) CO TO 2(C RA0G1=(TF1(K)+T11(L))*(TF1(L))*TF1(N)+T11(N))/1.UE12 Ff (GR(L),LF,0))*(TF2(L))*TF2(N)+T12(N)+T12(N))/1.UE12 IF (GS0,L1,F3) K30=R3 B11=1/((CR4*ARLC2)*(HA2/G(LT(1)))*TF1(N)+T11(N)*TU2(N)+TW2(L)+TWALL(N) *TUAL(N))/1.(H2 IF(12,E,1) G TO 2U1 AmmetaF10/B20=64*B1N Ou*(OLW*R0*FR*F20)/(6,2R311*FL2(1)) FAC1*1,0+0,25*(1,0+CAALCE) </pre>	00;216.00 00;226.00 00;226.00 00;246.00 00;246.00 00;246.00 00;246.00 00;246.00 00;246.00 00;316.00 00;316.00 00;356.00 00;356.00 00;356.00 00;356.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;466.00 00;556.00 00;556.00	PAGE DUDB
57 56 56 56 56 57 52 52 52 52 54 55 56 57 56 57 56 57 56 57 56 57 56 57 56 57 56 57 57 56 57 57 56 57 57 57 57 57 57 57 57 57 57	EVEL 490 472	<pre>FF3#FF3A*1,101 20 MAIN DATE = 72349 11/50// GO TO 472 PH=RM1 B20e6,28318*RC1(1) B5=1,0/L+(Rc1(1)/RC2(1))*(1,(/E=1) Po=5,67/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RCO)/(6,25318*AKG1) B2=ALOG(PC1C/PF2)/(C,2b318*AKG1) B12=2*R(N)*P1(B)/(F1(L)*R1(L)*LF1*FF1) B7=(B12*ALCG(K1(A)/PF1)-1)/(16 B17=2,0*R1(A)*P1(B)/(F1(L)*R1(L)*L1(A)*T1(N)) B8=(1,0+D1*ALCG(RF2/R(1(N))/L*16 H1=HN1*(TG1(1)/TH1(C))**0,15*ALL1/DE1 H2=HN2*(TG2(1)/TH2(L))**0,15*ALL1/DE1 H2=HN2*(TG2(1)/TH2(L))**0,15*ALL1/DE1 B9=1,0/(6,2831B*PC0(1)*H1) CALCULATION OF CAP CONLUCTAICES INFKNI*(T11(A))*TF1(N)/2,0 ITMFN2=(T12(P)*TF2(N)/2,0 HKG1=1,456F-3*(T1FFE1/273,1()**C,7 IKG2=1,456F-3*(T1FFE1/273,1()**C,7 IKG2=1,456F-3*(T1FFE1/273,1()**C,7 IKG2=1,456F-3*(T1FFE1/273,1()**C,7 IKG2=1,456F-3*(T1FFE1/273,1()**C,7 IKG2=1,456F-3*(T1FFE1/273,1()**C,7 IKG2=1,456F-3*(T1FFE1/273,1()**C,7 IKG2=1,456F-3*(T1FFE1/273,1()**C,7 IKG2=1,456F-3*(T1FFE1/273,1()**C,7 IKG2=1,456F-3*(T1FFE1/273,1()**C,7 IKG2=1,456F-3*(T1FE1/273,1()**C,7 IKG2=1,456F-3*(T1FE1/273,1)) *TUXL(N)*T1/2(N)*T1/2(N)*T1/2(N)*T1/2(N)*T1/2(N)/1,UE12 IF(T2,FG2+1,0*C,10*) *TUXL(N)*T1/2(N)*T1/2(N)+T1/2(N)/1,UE12</pre>	00721600 00722600 00722600 00724600 00724600 00724600 00724600 00724600 00724600 00724600 00737600 00737600 00734600 00734600 00734600 00734600 00744600 00754600 00754600 00754600 00754600 00754600 00754600 00754600	PAGE 0006
87         56         17RAN IV G L         49         20         21         20         21         20         21	EVEL 490 472	<pre>FF3#FF3A*1,101 20 MAIN DATE = 72349 11/50/4 GO TO 472 RM=RM1 B20*6,28318*RC1(1) B2*1,0/E*(RC1(1)/RC2(1))*(1,(/E=4) P0*5,07/85 CALCULATION CF CONDUCTANCES P1*ALOG(RF1/RC0C)/(6,2E318*AK61) R2*ALOG(RF1/RC0C)/(6,2E318*AK61) B2*1,0/E*(RC1(N)*P1(K)/(E;(L)*K1(L)*L*F1*FF1) B7*612*ALCG(K1(N)*P1(K)/(F;(L)*K1(L)*L*F1*FF1) B7*612*ALCG(K1(N)*P1(H))*D1//(16 B1*2;0*R1(f)*F1(K)/(F;(L)*K1(L)*L*F1*FF1) B7*612*ALCG(K1(N)*F1(L))*L*C*F1*FF1) B8*(1,0-B1**ALCG(KF2/K1(N))/L*16 H1*HN1*(TG1(1)/TH1(D))**0,15*AF12/DE2 B9*1,0/(6,26318*C0(1)*H1) CALCULATION CF GAP CONLICTAICES TIMFK1*(TG1(1)/TH1(L))**0,15*AF12/DE2 B9*1,0/(6,26318*C0(1)*H1) CALCULATION CF GAP CONLICTAICES TIMFK1*(T11(N)*TF1(N)/2;0 HKG1*1,456F-3*(T1FFD1/273,1()**C,7 HKG2*1,456F-3*(T1FFD1/273,1()**C,7 HKG2*1,456F-3*(T1FFD1/273,1()**C,7</pre>	00;216.00 00;226.00 00;226.00 00;246.00 00;246.00 00;246.00 00;246.00 00;246.00 00;246.00 00;316.00 00;316.00 00;356.00 00;356.00 00;356.00 00;356.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;446.00 00;556.00 00;556.00 00;556.00 00;556.00	PAGE 0006
S7 FRAN IV G L S9 	EVEL 490 472	<pre>FF3*FF3A*1,101 20</pre>	00721600 00722600 00722600 00722600 00724600 00725000 00725000 00727600 00727600 00727600 00731000 0073100 00732600 0073500 0073400 0073500 0073500 0073500 0073500 0073500 0074000 0074000 0074000 0074000 0074500 0074500 0074500 0075100 0075100 0075100 0075100 0075100 0075100 0075100 0075100 0075100	PAGE DUDB
87       88       10       11       12       13       14       15       16       17       18       19       10       11       12       13       14       15       16       17       18       19       20       21       22       23       24	EVEL 490 472 200	<pre>FF3#FF3A+1,101 20 MAIN DATE # 72349 11/50/4 GO TO 472 PMERM1 B20e6,28318*RC1(1) B5=1,0/E*(RC1(1)/RC2(1))*(1,(/E=4) P0=5,07/B5 CALCULATION CF CONDUCTANCES P1=ALOG(RF1/RC0C)/(6,26318*AKG1) R2*ALOG(PC1C/PF2)/(6,26318*AKG2) B16=12,5635*AKF. B12=2*R1(N)*P1(H)/(F1(L)*K1(L)+F1*FF1) B7*(B12*ALCG(K1(N)/PF1)*1)/(16 B17*2,0*R1(N)*F1(L)/(KF2*KF2*K1(N)*P1(N)) B84(1,0+B17*ALCG(RF2/K1(N))/f16 H1=HN1*K163(12)/TU4(L))**0,15*AK12/DE3 B9=1,0/(6,78318*C0(1)*H1) CALCULATION OF CAP CONLUCTAICES TIMEN1=(T11(N)*T12(N)**0,1(1)*T11(N)*T11(N)/1,UE12 RACG2*(TF2(L)*T12(N)*(TF2(L)**6,7 HKG2=1,45&amp;6T-3*(T1FHF1/273,1()**6,7 HKG2=1,45&amp;6T-3*(T1FHF1/273,1()**6,7 HKG2=1,45&amp;6T-3*(T1FHF1/273,1()**6,7 HKG2=1,45&amp;6T-3*(T1FHF1/273,1()**6,7 HKG2=(TF2(L)*T12(N)*(TF2(L))*12(N)*T12(N)*T12(N)/1,UE12 F(17,0,N)*T12(N)*(TF2(L))*12(N)*T12(N)*T12(N)/1,UE12 F(17,10)*T12(N)*(TF2(L))*12(N)*T12(N)*T12(N)/1,UE12 F(17,10)*T12(N)*(TF2(L))*12(N)*T12(N)*T12(N)/1,UE12 F(17,20,1)*T12(N)*T12(</pre>	00721600 00722600 00722600 00724600 00724600 00724600 00725600 00725600 00725600 00725600 00735600 00735600 00735600 00735600 00735600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0075160 0075160 0075160 00755100 00755100 00755100 00755100	PAGE DUDB
57       58       10       11       12       13       14       15       16       17       18       19       10       11       12       13       14       15       16       17       18       19       10       11       12       13       14       15       16       17       18       19       20       21       22       23       24       25	EVEL 490 472 200	<pre>FF3*FF3A+1,101 20</pre>	00721600 00722600 00722600 00724600 00724600 00724600 00724600 00724600 00724600 00724600 00731600 00731600 00734600 00734600 00734600 00734600 00744600 00744600 00744600 00744600 00744600 00744600 00744600 00744600 00744600 00744600 00744600 00744600 00744600 00744600 00744600 00744600 00744600 00744600 00744600 00754600 00744600 0075460000000000000000000000000000000000	PAGE DUDB
87       556       FRAN IV G L       59       70       71       72       73       74       75       76       77       78       79       70       71       72       73       74       75       76       77       78       79       70       70       70       70       70       70       70       70       70       70       71       72       73       74       75       75       76       77       78       79       70 </td <td>EVEL 490 472 200</td> <td>FF3sFF3A+1,101         20       MAIN       DATE = 72349       11/50/4         G0 TO 472         PMERM1       B20e6,28318*RC1(1)       B5=1,0/2+(RC1(1)/RC2(1))*(1,(/E=1)         B&gt;s1,0/2+(RC1(1)/RC2(1))*(1,(/E=1)       PC=0,7785       CALCULATION CF CONDUCTARCES         C1CULATION CF CONDUCTARCES       P1=ALOG(RF1/RC0C)/(6,22318*RK61)         R2=ALOG(RC1(P52)/(6,22318*RK62)       B16=12,5663*AKF       B12=2*e1(N)*P1(H)/(F1(+)*RF1)-F1)         B12=2*e1(N)*P1(H)/(F1)+1)/(16       B17=2,0*R1(H)*F1(H)/(F1(+)*F1*FF1)       B8=(1,0/0+B1/*AL(C6F2/AL(H)))/f16         H1=HN1*CTG1(1)/TH1(H)/F1)=1)/(16       B7=(2,0*R1(H)*F1(H)/F1)=1)/(16       B17=2,0*R1(H)*F1(H)/(F2*KF2*K1(H))*F1(H))         B5=(1,0/0+B1/*AL(C6F2/AL(H)))/f16       H1=HN1*CTG2(1)/THA1((H))*(15*AL(H))*T12(H)*T11(H))       B8=(1,0/0+G2(H)/H)/(2,0)         CALCULATION CF CAP CONLUCTARCES       T1MFN1=(T11(H)+F1(H))/2,0       T1MFN1=(T11(H)+F1(H))/2,0         T1MFN1=(T11(H)+F1(H))/2,0       CALCULATION CF CAP CONLUCTARCES       T1MFN1=(T11(H)+T11(H))/1,0         T1MFN1=(T11(H)+F1(H))/2,0       CALCULATION CF CAP CONLUCTARCES       T1MFN1=(T11(H)+T11(H))/1,0         B0=1,0/C6,2831B*EC0(1)*HE/2/2,0       TMKG1=1,456F-3*(T1PFH2/273,1()**C,7       TK6(T11,0)*(T12(H)+T11(H)+T11(H))/1,0         B0=1,0/C6,2*A,5*(T1PFH2/273,1()**C,7       TK6(T1+C6)+T12(H)+T12(H)+T12(H)+T12(H)+T12(H))/1,0       TMK1(H)/1,0         B10=1/C(</td> <td>00721600 00722600 00722600 00724600 00724600 00724600 00725600 00725600 00725600 00725600 00735600 00735600 00735600 00735600 00735600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0075160 0075160 0075160 00755100 00755100 00755100 00755100</td> <td></td>	EVEL 490 472 200	FF3sFF3A+1,101         20       MAIN       DATE = 72349       11/50/4         G0 TO 472         PMERM1       B20e6,28318*RC1(1)       B5=1,0/2+(RC1(1)/RC2(1))*(1,(/E=1)         B>s1,0/2+(RC1(1)/RC2(1))*(1,(/E=1)       PC=0,7785       CALCULATION CF CONDUCTARCES         C1CULATION CF CONDUCTARCES       P1=ALOG(RF1/RC0C)/(6,22318*RK61)         R2=ALOG(RC1(P52)/(6,22318*RK62)       B16=12,5663*AKF       B12=2*e1(N)*P1(H)/(F1(+)*RF1)-F1)         B12=2*e1(N)*P1(H)/(F1)+1)/(16       B17=2,0*R1(H)*F1(H)/(F1(+)*F1*FF1)       B8=(1,0/0+B1/*AL(C6F2/AL(H)))/f16         H1=HN1*CTG1(1)/TH1(H)/F1)=1)/(16       B7=(2,0*R1(H)*F1(H)/F1)=1)/(16       B17=2,0*R1(H)*F1(H)/(F2*KF2*K1(H))*F1(H))         B5=(1,0/0+B1/*AL(C6F2/AL(H)))/f16       H1=HN1*CTG2(1)/THA1((H))*(15*AL(H))*T12(H)*T11(H))       B8=(1,0/0+G2(H)/H)/(2,0)         CALCULATION CF CAP CONLUCTARCES       T1MFN1=(T11(H)+F1(H))/2,0       T1MFN1=(T11(H)+F1(H))/2,0         T1MFN1=(T11(H)+F1(H))/2,0       CALCULATION CF CAP CONLUCTARCES       T1MFN1=(T11(H)+T11(H))/1,0         T1MFN1=(T11(H)+F1(H))/2,0       CALCULATION CF CAP CONLUCTARCES       T1MFN1=(T11(H)+T11(H))/1,0         B0=1,0/C6,2831B*EC0(1)*HE/2/2,0       TMKG1=1,456F-3*(T1PFH2/273,1()**C,7       TK6(T11,0)*(T12(H)+T11(H)+T11(H))/1,0         B0=1,0/C6,2*A,5*(T1PFH2/273,1()**C,7       TK6(T1+C6)+T12(H)+T12(H)+T12(H)+T12(H)+T12(H))/1,0       TMK1(H)/1,0         B10=1/C(	00721600 00722600 00722600 00724600 00724600 00724600 00725600 00725600 00725600 00725600 00735600 00735600 00735600 00735600 00735600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0074600 0075160 0075160 0075160 00755100 00755100 00755100 00755100	
87       56       TRAN IV G L       49       70       71       72       73       74       75       76       77       78       79       70       78       79       70       78       79       70       78       79       70       78       79       70       78       79       70       78       79       700       70       70       70       71       72       73       74       75       76       77       78       79       700       700       71       71       72       73       74       75       75       76       77       78       79       700       71       71       74       74	EVEL 490 472 200	<pre>FF3*FF3A+1,101 20</pre>	00721600 00722600 00722600 00722600 00724600 0072500 0072500 0072500 0072760 0072760 0073760 0073600 0073500 0073500 0073500 0073500 0073500 0073500 0073500 0074000 007400 007400 0074500 0074500 0074500 0074500 0074500 0074500 0075500 00075500 0075500000000	

FORT	HAN IN	0 1 1	VEL	20 MAIN . PATE # 72349	11/50/48	PAGE 0007
022	4			822=815+821/(813+614)+861+161 .	00:671.00	
023	U			RID=SORT(B22)	00: 61: 60	
025		с		CALCULATION OF HEAT FLUXES AND TEMPIRATURES HEATLOADLE*(PE2**2,0+1.22)/115	00:70400	
025				ru2(1)=TG2(1)+HIATLO+L10	00;71100	
025				112(1) #TW2(1) + 11 ATL0+12	00272100	
0251				TF2D=T12(1)+HIATL0+C11	00;73100	
0255				THALL(1)=T(7(1)+819	00:74000	
0250				HFATLI=QLF+(PIL+RID=RF1+RF1)/b15	00275600	
0251				TW1(1)=TG1(1)+FATL1+69	00:76(00	
0259				T11(1)=TW1(1)+HEATL1+E1 TF1(1)=T11(1)+HEATL1+E30	00:78100	
0240				TFMAX(1)=TF2D+HEATLO+UK	00:791.00	
0241				B23=ARS((RID-HI(N))/RI(N))	00:80600	
0242				IF(R23,61, C, 001) 60 TU 4	00781000	
0243				GO TU 5	00.158,00	
0244				R1(1) *R1D TF2(1) #TF2D	00783600 00784600	
0246				GO TU 10	00785600	'
0247			5	RI(I) #RID	00,86600	
0248				B24=ARS(TF20=TF2(1)) -	00:871.00	
0249				IF (B24.GT, 1, 0) GO TO 6	00;88000	
0250				GO TO 7 TF2(1)=TF2D	00789100	
0252			0	GO TO 10	00:91(00	
0255			7		00.92600	
0254				FF1=FF1+(TW1(1)/TG1(1))++0,(5	00,93100	
0255				FF2*FF2*(TW2(1)/TG2(1))**0,15	00,94000	
0250				FFS=FF3+(TWALL(])/TG2(1))++(,05	00:95600	and the second s
0257				F1(1)=FF2 F2(1)=FF2	00290000	
0258				F2(1)=FF2 F3(1)=FF3	00,98600	
0260				HT1(I)=H1	00146100	
0261				HT2(1)=H2	00300100	
0262				HT3(1)=H5	00301000	
0263				FR1(1)=E1 FR2(1)=E2	00302000 -	
				ER2(1)=E2 ER3(1)=E3	00304000	
0264		1	94	FORMAT(//,1X, ** FE**, 3(2X, F12, 5), 2X, ** DE**, 3(2X, E12, 5), 2X, **		
0264			1	,E12,5)	00300000	
0264				WRITE(6,194) PI1, PE2, PE3, DE1, DE2, DE3, RM	00307000	
0264 0265 0266						
0264 0265 0266			1150	IF(1.E0,1) 60 TC 210	00308600	
0264 0265 0266		c**		IF(I.EO.1) GO TC 210 PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE CALL PRESS	00306600	······································
0264 0265 0266 0267 0268 0269 FORTR 0270	AN IV	G LEV	EL	IF(I.E0.1) GO TC 210 PRESSURE PRESSURE PRESSURE**** CALL PRESS 20 HAIN DATE = 72349 1 IF(I.E0.NAX+1) GO TG 8	00308600 00309600 00310600 11/50/48 00311600	PAGE DOO8
0264 0265 0266 0266 0268 0269 FORTR	IAN IV	G LEV	EL	IF(I.Eo.1) GO TC 210 PRESSURE PRESSURE PRESSU	00308600 00309000 00310600 11750748 00311600 00312600 *RH0 00313600	······
0264 0265 0266 0267 0268 0269 FORTR 0269 FORTR 0270 0271 0272 0273	IAN IV	G LEV	EL	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESS	00306600 00309600 00310600 11750748 00311600 00312600 00312600 00314600	PAGE DOOR
0264 0265 0266 0267 0268 0269 FORTR 0270 0271 0272 0273 0274	AN IV	G LEV	EL	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESS	00306600 00309600 00310600 11/50/48 00311600 00312600 00314600 0031560	PAGE DOOR
0264 0265 0266 0267 0268 0269 FORTR 0269 FORTR 0270 0271 0272 0274 0275	AN IV	G LEV	EL	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESSURE**** CALL PRESS 20 HAIR DATE = 72349 1 IF(I.E0,NAX*1) GO TG 8 HETIN=OSLAF(1)*(1-PHO)*(RI(I)*I(I)-RF1*RF1)/B15 HETOUT=OSLAB(I)*(1-PHO)*(RF7*F2-RI(I)*KI(I))/B15*CSLAB(I)* N=I+1 IG1(N) = IG1(I)*HETI//(K1*5,19) IG2(N) = IG2(I)*HETI//(K1*5,19)	00308600 00309000 00310600 11/50/48 *RH0 00311600 00312600 00314600 00314600	PAGE DOOR
0264 0265 0266 0267 0268 0269 FORTR 0270 0271 0272 0273 0274	AN IV	G LEV	EL	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESS	00306600 00309600 00310600 11750748 00311600 00312600 *RH0 00313600 00314600 0031560 0031560 00315700	PAGE DOOR
0264 0265 0266 0267 0268 0269 FORTR 0269 FORTR 0270 0271 0272 0274 0275	AN IV	G LEV	eL 9	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESSURE**** CALL PRESS 20 HAIR DATE = 72349 1 IF(I.E0,NAX*1) GO TG 8 HETIN=OSLAF(1)*(1-PHO)*(RI(I)*I(I)-RF1*RF1)/B15 HETOUT=OSLAB(I)*(1-PHO)*(RF7*F2-RI(I)*KI(I))/B15*CSLAB(I)* N=I+1 IG1(N) = IG1(I)*HETI//(K1*5,19) IG2(N) = IG2(I)*HETI//(K1*5,19)	00306600 00309000 00310600 11750748 00311600 00312600 00314600 00315600 0031560 00216600 0031760 0031760	PAGE DOOB
0264 0265 0266 0267 0268 0269 FORTR 0270 0271 0272 0273 0275 0276 0277 0278	AN IV	G LEV	eL 9	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESS	0030660 00319600 00319600 11750748 00311600 00312600 *RH0 00313600 00314600 0031560 0031560 0031600 0031600 00318700 00318700 00318700	PAGE DOOR
0264 0265 0266 0267 0268 0269 FORTR 0270 0272 0273 0274 0275 0275 0275 0277 0278 0277	AN IV	G LEV	EL 9 10	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESS	00306600 00309600 00310600 11750748 00311600 *RH0 00312600 00314600 0031600 0031560 0031600 0031600 0031600 00319600 00329600 00321000	PAGE DOOB
0264 0265 0266 0267 0268 0269 FORTR 0270 0271 0272 0275 0276 0276 0277 0278 0278 0278	IAN IV	G LEV	eL 9 10 8	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESS	00306600 00309600 00310600 11750748 00311600 00312600 00312600 00314600 0031560 0031600 0031600 0031600 0031600 00319600 0022600	PAGE DOOB
0264 0265 0266 0267 0268 0269 FORTR 0270 0271 0272 0273 0275 0276 0275 0278 0279 0278 0279 0281	AN IV	G LEV	9 210 8	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESS	0030660 00319600 00319600 11750748 00311600 *RH0 00313600 00314600 00314600 00314600 00314600 00314600 00314600 00318700 00318700 0032600 00322600 00322600	PAGE DOOB
0264 0265 0266 0267 0268 0269 FORTR 0270 0271 0272 0275 0276 0276 0277 0278 0278 0278	AN IV	G LEV	9 9 10 8	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESS	00306600 00309600 00310600 11750748 00311600 00312600 00312600 00314600 0031560 0031600 0031560 0031600 00319600 0032600 0032600 00322600 00322600	PAGE DOOB
0264 0265 0266 0267 0268 0269 0269 0270 0271 0272 0273 0274 0275 0276 0276 0276 0276 0278 0278 0278 0281 0281 0281 0283 0284	AN IV	G LEV	9 910 8	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESS	00306600 00309600 00310600 11750748 00311600 00312600 00312600 00314600 0031560 0031600 0031560 0031600 0031600 00319600 00319600 0032600 0032600 0032600 0032600	PAGE 0008
0264 0265 0266 0267 0268 0269 0269 0270 0271 0272 0273 0275 0276 0275 0276 0275 0276 0277 0278 0275 0278 0279 0281 0282 0283 0284 0285	AN IV	G LEV	9210 8	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESS	00306600 00319600 00310600 11750748 00311600 00312600 00312600 00314600 0031560 0031560 0031560 0031560 0031600 0031600 0032600 0032100 0032600 0032600 0032560 0032560	PAGE 0008
0264 0265 0266 0267 0268 0269 FORTR 0270 0271 0272 0273 0274 0275 0276 0276 0276 0277 0278 0276 0278 0278 0278 0278 0282 0285 0285 0285 0285 0285 0285 028	AN IV	G LEV	9 210 8	<pre>IF(I.Eo,1) GO TC 210 PRESSURE PRESSURE P</pre>	00306600 00309600 00310600 11750748 00311600 00312600 00312600 0031600 0031600 0031600 0031600 0031600 0031600 00319600 0032600 0032600 0032600 0032600 0032660	PAGE 0008
0264 0265 0266 0267 0268 0269 FORTR 0270 0271 0272 0275 0276 0275 0276 0275 0276 0275 0278 0275 0278 0275 0278 0275 0278 0278 0278 0281 0281 0281 0285 0285	AN IV	G LEV	9 10 8	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESS	00306600 00319600 00310600 11750748 00311600 00312600 00312600 00314600 0031560 0031560 0031560 0031560 0031600 0031600 0032600 0032100 0032600 0032600 0032560 0032560	PAGE 0008
0264 0265 0266 0267 0268 0269 0269 0270 0271 0272 0273 0275 0276 0275 0276 0275 0276 0275 0278 0275 0278 0275 0278 0279 0281 0282 0283 0285 0285 0285 0285 0285		G LEV	8	<pre>IF(I.E0,1) GO TC 210 pRESSURE PRESSURE P</pre>	00306600 00309600 00310600 11750748 *RH0 00312600 00312600 00312600 00314600 0031560 0031600 0031600 0031600 00319600 0032600 0032600 0032760 0032760 0032760 0032760	PAGE 0008
0264 0265 0266 0267 0268 0269 FORTR 0270 0271 0272 0275 0276 0275 0276 0275 0276 0275 0278 0275 0278 0275 0278 0278 0278 0278 0278 0278 0278 0278	AN IV	G LEV	9210 8	<pre>IF(1,E0,1) GO TC 210 PRESSURE PRESSURE P</pre>	0030660 00319600 00319600 00310600 11750748 00311600 00312600 *RH0 00313600 00314600 0031560 0031560 0031600 0031600 0031600 0031600 0032600 0032760 0007 00	PAGE 0008
0264 0265 0266 0267 0268 0269 0269 0270 0271 0272 0273 0275 0276 0277 0275 0276 0275 0276 0275 0276 0277 0275 0276 0277 0275 0276 0275 0276 0277 0275 0276 0277 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0275 0275 0275 0275 0275 0275 0275	AN EV	G LEV Z	40 19	IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESS	0030660 00319600 00319600 00310600 11750748 00311600 00312600 *RH0 00313600 00314600 00315600 00315600 0031600 0031600 0032600 0032600 0032600 0032600 00327600 0033000 0033000 00330000 00330000 00330000 00330000 00330000 003300000 0033000000 003300000000	PAGE 0008
0264 0265 0266 0267 0268 0269 0269 0270 0271 0272 0273 0275 0276 0275 0275 0276 0275 0276 0275 0276 0275 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0275 0276 0275 0276 0275 0276 0275 0275 0276 0275 02777 0275 0275 0275 0275 0275 027	AN IV	6 LEV 2 C	40 19	<pre>IF(1.E0,1) GO TC 210 PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE CALL PRESS 20</pre>	0030660 00310600 00310600 11750748 0031100 0031200 *RH0 00313600 00314600 0031560 0031560 0031560 0031560 0031600 0031600 0032600 0032600 0032600 0032600 0032760 0032760 0032760 0032760 0032760 0033760 0037760 00777760 00777760 0077760 0077760 00777700 0077760 00777700 00777700 0077770000000000	PAGE 0008
0264 0265 0266 0267 0268 0269 FORTR 0270 0271 0272 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0277 0280 0281 0281 0281 0281 0281 0281 0281	AN EV	6 LEV 2 c	40 19 142	<pre>IF(1,E0,1) GO TC 210 PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE CALL PRESS 20</pre>	00306600 00309600 00310600 11750748 00311600 00312600 00312600 00314600 00314600 00314600 00314600 00314600 00314600 00314600 0032600 0032600 0032600 0032600 00326600 00326600 00326600 00326600 00326600 00326600 00330600 0033600	PAGE 0008
0264 0265 0266 0267 0268 0269 0269 0270 0271 0272 0273 0275 0276 0275 0275 0276 0275 0276 0275 0276 0275 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0275 0276 0275 0276 0275 0276 0275 0275 0276 0275 02777 0275 0275 0275 0275 0275 027	AN EV	6 LEV 2 c	40 19 42 40	<pre>IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE CALL PRESS 20</pre>	00306600 00309600 00310600 00310600 11750748 *RH0 00312600 00312600 00312600 00314600 0031560 0031600 0031600 00319600 0032600 0032600 0032600 0032600 0032600 0032600 0032600 0032600 0033060 0033600 0033600	PAGE 0008
0264 0265 0266 0267 0268 0269 FORTR 0270 0271 0272 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0277 0280 0281 0281 0281 0281 0281 0281 0281		6 LEV 2 C	40 19 42 19 12 19 12 10	<pre>IF(I.E0,1) GO TC 210 PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE CALL PRESS 20</pre>	00306600 00309600 00310600 11750748 00311600 00312600 00312600 00314600 00314600 00314600 00314600 00314600 00314600 00314600 0032600 0032600 0032600 0032600 00326600 00326600 00326600 00326600 00326600 00326600 00330600 0033600	PAGE 0008
0264 0265 0266 0267 0268 0269 0270 0271 0272 0273 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0278 0279 0281 0282 0285 0285 0285 0285 0285 0285 0285	AN IV	6 LEV 2 c	40 19 42 43 44	<pre>IF(1,E0,1) GO TC 210 PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE CALL PRESS 20</pre>	00306600 00309600 00310600 00310600 11750748 *RH0 00313600 00312600 00312600 0031600 0031600 0031600 0031600 0031600 00319600 0032600 0032600 0032600 0032600 0032600 0032600 0033600 0033600 0033600	PAGE 0008
0264 0265 0266 0267 0268 0269 0269 0270 0271 0272 0273 0275 0276 0277 0276 0275 0276 0277 0275 0276 0277 0275 0276 0277 02775 0276 0277 0275 0276 0277 0275 0276 0277 0275 0276 0277 0275 0276 0277 0275 0276 0277 0277 0277 0277 0277 0277 0277		6 LEV 2 c	40 19 142 40 19 142 40 41 43 44	<pre>IF(1,E0,1) GO TC 210 PRESSURE PRESSURE P</pre>	00306600 00310600 00310600 11750748 0031100 0031200 *RH0 0031360 00314600 00314600 00314600 00314600 00314600 00314600 00314600 0032600 0032600 00327600 00327600 00327600 00327600 00334600 0034600 0034600 00030000000000000000000000000000000	PAGE 0008
0264 0265 0266 0267 0268 0269 0270 0271 0272 0273 0275 0276 0277 0275 0276 0275 0276 0275 0276 0277 0275 0276 0275 0276 0277 0276 0277 02775 0276 02775 0276 02775 0276 02775 02775 0276 02775 02775 0276 02775 0275 02		6 LEV 2 C	40 19 40 19 42 40 1 43 44 41	<pre>IF(1,E0,1) GO TC 210 PRESSURE PRESSURE P</pre>	0030660 00310600 00310600 11750748 0031100 0031200 *RH0 00313600 00314600 00314600 00314600 00314600 00314600 00314600 00314600 0032600 0032600 0032600 0032600 0032600 0032760 0032760 0033760 0033600 0033760 00037760 0033760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 0000 00000 00000 00000 00000 00000 000000	PAGE 0008
0264 0265 0266 0267 0268 0267 0268 0269 FORTR 0272 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0281 0281 0281 0283 0284 0285 0284 0285 0285 0285 0276 0275 0275 0276 0275 0276 0275 0275 0275 0275 0275 0275 0275 0275		6 LEV 2 c	40 19 142 40 19 142 40 142 142 142 142 142 142 142 142 142 142	<pre>IF(1,E0,1) FO TC 210PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE PRESSURE CALL PRESS 20</pre>	00306600 00310600 00310600 11750748 00311600 00312600 00312600 00314600 00314600 00314600 00314600 00314600 00314600 00319600 0032600 0032600 0032600 0032600 0032600 0032600 0033600 003400 003400 0033600 0033600 0033600 0033600 003400 0033600 0033600 003400 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 003400 003400 003400 0003000 0003000 000000 0000000 00000000	PAGE 0008
0264 0265 0266 0267 0268 0269 0267 0272 0273 0274 0275 0276 0276 0276 0276 0276 0276 0276 0276		6 LEV 2 C	40 19 142 40 19 142 40 40 41 42 40 41 42 42 41 42 42	<pre>IF(1,E0,1) GO TC 210 PRESSURE PRESSURE P</pre>	0030660 00310600 00310600 11750748 0031100 0031200 *RH0 00313600 00314600 00314600 00314600 00314600 00314600 00314600 00314600 0032600 0032600 0032600 0032600 0032600 0032760 0032760 0033760 0033600 0033760 00037760 0033760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 00037760 0000 00000 00000 00000 00000 00000 000000	PAGE 0008
0264 0265 0266 0267 0268 0267 0268 0269 FORTR 0272 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0281 0281 0281 0283 0284 0285 0285 0285 0285 0276 0275 0275 0276 0275 0276 0275 0275 0276 0275 0275 0275 0275 0275 0275 0275 0275		6 LEV 2 c	40 19 42 40 19 42 40 142 40 142 44 41 20 21	<pre>IF (I.EO, 1) GO TC 210 PRESSURE PRESSUPE PRESSUPE PRESSUPE**** CALL PPESS 20</pre>	00306600 00310600 00310600 11750748 0031100 0031200 0031400 0031400 0031400 0031400 0031400 0031400 0031400 0031400 0031400 0031400 0032000 003200 003200 003200 003200 003200 003200 003200 003200 003200 003300 000300 003300 000300 000300 0000 0000 000000	PAGE 0008
0264 0265 0266 0267 0268 0267 0268 0269 FORTR 0272 0273 0274 0275 0276 0276 0276 0276 0275 0276 0275 0276 0275 0276 0278 0275 0278 0278 0281 0281 0281 0283 0285 0281 0285 0281 0285 0285 0285 0276 0278 0278 0278 0278 0281 0285 0281 0285 0285 0276 0278 0278 0278 0278 0278 0278 0278 0278		6 LEV 2 C	40 19 142 40 19 142 40 143 44 41 20 21 223 24	<pre>IF(I.E0,1) GO TC 210 PRESSURE PRESSUPE PRESSURE**** CALL PPESS 20</pre>	00306600 00319600 00310600 11750748 00311600 00312600 00312600 0031600 0031600 0031600 0031600 0031600 0031600 00319600 0032600 0032600 0032600 0032600 0032600 0032600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0034600 0004000 0004000000000000000000000	PAGE 0008
0264 0265 0266 0267 0268 0267 0268 0269 0272 0273 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0278 0281 0282 0283 0285 0285 0285 0285 0285 0285 0285 0285		6 LEV 2 C	40 19 42 40 19 42 40 11 42 40 11 42 40 12 22 3 44 41 122 23 44 25	<pre>IF(1,E0,1) GO TC 210 pRESSURE PRESSUPE PRESSURE**** CALL PRESS 20</pre>	00306600 00310600 00310600 11750748 0031100 0031200 *RH0 00313600 0031400 0031400 0031400 0031400 0031400 0031600 0031600 0032600 0032700 0032700 0032700 0032700 0032700 0032700 0033000 0033000 0033600 0003600 0003600 0003600 0003600 00037000 00037000 00037000 00037000 0003000 00000 000000 0000000000	PAGE 0008
0264 0265 0266 0267 0268 0269 0268 0269 0270 0271 0272 0273 0275 0276 0275 0275 0276 0275 0276 0275 0275 0276 0275 0276 0275 0275 0275 0275 0276 0275 0275 0275 0275 0275 0275 0275 0275	AN IV	6 LEV 2 C	40 19 40 19 142 40 1 43 44 1 20 21 23 24 23 24 24 27	<pre>IF(1,E0,1) GO TC 210PRESSURE PRESSURE PRESSURE**** CALL PRESS 20</pre>	00306600 00310600 00310600 11750748 00311600 00312600 00312600 00314600 00314600 00314600 00314600 00314600 00314600 0032600 0032600 0032600 0032600 0032600 0032600 0032600 0032600 0032600 0032600 0032600 0033600 000300000000	PAGE 0008
0264 0265 0266 0267 0268 0267 0268 0269 0270 0271 0272 0273 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0276 0275 0278 0282 0282 0282 0285 0286 0285 0286 0277 0278 0278 0278 0282 0285 0285 0285 0285 0285 0285 0276 0278 0285 0285 0285 0276 0278 0278 0278 0285 0285 0278 0278 0278 0278 0278 0278 0278 0278	AN IV	6 LEV 2 C	40 19 40 19 42 40 19 42 40 12 22 22 22 22 22 22 22 22 22 22 22 22	<pre>IF(1,E0,1) GO TC 210 pRESSURE PRESSUPE PRESSURE**** CALL PRESS 20</pre>	00306600 00310600 00310600 11750748 0031100 0031200 *RH0 00313600 0031400 0031400 0031400 0031400 0031400 0031600 0031600 0032600 0032700 0032700 0032700 0032700 0032700 0032700 0033000 0033000 0033600 0003600 0003600 0003600 0003600 00037000 00037000 00037000 00037000 0003000 00000 000000 0000000000	PAGE 0008
0264 0265 0266 0267 0268 0269 0268 0269 0270 0271 0272 0273 0275 0276 0275 0275 0276 0275 0276 0275 0275 0276 0275 0276 0275 0275 0276 0275 0276 0275 0275 0275 0275 0276 0275 0275 0275 0275 0275 0275 0275 0275		6 LEV 2 C	40 10 8 40 12 40 1 42 40 1 42 40 1 42 22 3 24 41 1 22 23 24 27 12 8	<pre>IF(1,E0,1) 60 TC 210pRESSURE PRESSURE PRESSURE**** CALL PRESS 20</pre>	00306600 00310600 00310600 11750748 0031100 0031200 *RH0 00313600 00314600 00314600 00314600 00314600 00314600 00314600 0032600 0032600 0032600 0032600 0032760 0032600 0032760 0032760 0033760 0033760 0033600 0033760 00337700 0033700 0033700 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 003370000000000	PAGE 0008
0264 0265 0266 0267 0268 0267 0268 0269 FORTR 0272 0275 0276 0276 0277 0276 0277 0276 02770 0275 0276 02770 0276 0270 0270 0270 0270 027		6 LEV 2 C	40 19 40 19 42 40 19 142 40 142 40 12 22 23 24 23 24 27 27 28	<pre>IF (1, E0, 1) 60 TC 210pRESSURE PRESSURE PRESSUR</pre>	00306600 00310600 00310600 11750748 00311600 00312600 00314600 00314600 00314600 00314600 00314600 00314600 00314600 0032600 0032600 0032600 0032600 0032600 0032600 0032600 0032600 0032600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0033600 0034600 00034600 0034600 00000 0000 0000 00000 00000 00000 00000 00000 000000	PAGE 0008
0264 0265 0266 0267 0268 0269 0268 0269 0270 0271 0272 0273 0275 0276 0276 0275 0276 0277 0275 0276 0275 0276 0275 0276 0275 0276 0277 0275 0276 0277 0275 0275 0276 0277 0275 0275 0275 0275 0275 0275 0275		6 LEV 2 C	40 19 10 8 40 19 142 40 142 40 142 40 122 23 24 25 24 25 24 27 12 8	<pre>IF(1,E0,1) 60 TC 210pRESSURE PRESSURE PRESSURE**** CALL PRESS 20</pre>	00306600 00310600 00310600 11750748 0031100 0031200 *RH0 00313600 00314600 00314600 00314600 00314600 00314600 00314600 0032600 0032600 0032600 0032600 0032760 0032600 0032760 0032760 0033760 0033760 0033600 0033760 00337700 0033700 0033700 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 00337000 003370000000000	PAGE 0008

FORTRAN -1	6 LEVIL 20	MAIN	DATE # 12344	11/50/48	PAGE DUD9
0504	175 EURMAT(//,1	1x. "FINED GAS OUTLET	TEMIIRATURE', 5X, FS.()	00355(00	
0510	WHITE (A, 189)			00356600	
0311	WKITF(6,121)	)		003571.00	
0312	WR17F(1, 122)	) O(H		00358100	
0315	WHITE(6,175)	768		00359600	
0314	WRITE(A, 125)			00260600	
0315	WHITE(A, 124)			00761600	
0316	WRITE(6,125)			00262100	
0317	WRITF(A,12/)			00263600	
0518	DU 41 N=1,N1			00364600	
0514	41 WRITE (6, 126)	12(1),1761(1),1711(1	), ITI1(1;), ITF1(N), ITFM/	AX(N), 00265000	and the set of
	211F2(N),1112	(N), ITW2(N), ITG2(N)	ITWALL(N)	00766100	
0320	WRITE(6,119)			00367100	
0321	DU 42 N=1,N1			00747100	
0322	42 WRITE(6,142)	IZ(N), GIN(N), II(N)	, CONT(N)	00369100	
0325	WRITE(6,140)			00270600	
0324	00 43 N=1,N9			00371100	
0325	43 WRITE(6,145)	IZ(N), PCO(N), H(1(K)	),R(2(N) ·	003721.00	
0326	WRITE(A,141)			00373600	
0321	DO 44 N=1,N1			00374600	
0328		IZ(N), DPT1(N), LPT	2(N)	00375100	
	C+++ CORPOSION A			00370600	
0329	189 FURMAT( 11,1	1X, OWELL TIME =	',15, ' DAYS')	00377000	
0350	190 FURMAT( 11.6	X. " OPRUSILA DATA",	///.17X. PLANAR REILVA	L', 32X, 'ROUDUT78100	
	1GHNESS HEIC	HTS")		00779600	
0351	191 FORMAT(/////	,25%, "HEAT TPANSFER	COEFF. ",7X, "AND",7X, "FF	ICTION FACOUZ80000	
	1TUR (TRANSF	ORIID))		00781000	
0332	192 FUPMAT(/, 3X,	"Z",5X,"PCU",13X,"FC	1",13X, "RC2", 13X, "K(C",	13X, 'RC1', 100282000	
	13X, 'RC2')			00283000 -	
0355	193 FURMAT(1X,13			00384000	
0356	WRITE(6,190)			00385000	
0335	WRITE(6,192)			00786600	
0336	DU 45 N=1,N1				
0357	45 WRITE(6,193)	12(h), DPT1(N, NT), 0.P	12(N,NT),DRT3(N,KT),ER1	(N), ER2(N), 003886000	
	1FR3(N)		a state and the state of the st	00389000	
0358	WRITE(6,191)			00390600	
0339	WRITE(6,192)			00391000	
0340	DO 46 NE1,N1			00392000	
0341		12(h) + HT1(h) + HT2(h)	,HT3(N),F1(K),F2(N),F3(	1) 00393100-	
0342	NP=NP+1			00394000	
0343	1F(NP, FQ.6)			00395000	
0344	IF(L,E0,1)	GO TO 301		00396000	
0345	WTOT=W1+W2	where the second s		00397000 -	
0340	DPC=(DPT1(I)	+0912(1))/2.0		00395000	

FORTRAN	١v	G LEVEL	20 MAIR	DATE = 72349	11/50/48	PAGE OUTO
0347			W1=W1*(DPC/PPT1(1))**0.57	4	00399600	
0348			W2=W2*(DPC/DPT2(1))**0.57	4	004.001.00	
0349			W1=W1*WTOT/(11+W2)	A REAL PROPERTY OF A REAL PROPER	00401000	
0350			W2=W2*WT01/(W1+W2)		004.02600	
0351			GO TO 500 .	and the state of t	00403000	
0352		301	IF(NT.LE.NTJPE) GO TO 400		00404000	
0353		300	STOP	and the second s	00405000	
0354			END		00100100	
			and the second			**** ***** **** ******* **************

PORTRAN IV	C LEVEL 20	PUST	DATE # 72349	11/50/48	PAGE OUD1
0001	SURROUTINE	HUSTERI, PT.E. PK.FF	(1.1.)	0070	71.00
0002	# 1=0			0040	T. / / / / T. MT.
0003	HN=0.023+85+	+0. F*PR**0.4		0020	
0004	. HNSEHN				01001
0005	FF=0.079/RE*	.0.25		00/1	
0000	FFS=FF			0041	
0007	407 K1=K1+1				
0008	1F(x1.GT.20)	CL TO 450		0021	
0009		/2.1) + + F . 5 + F / DE			
0010		3.64) 66 76 476.		00/1	
	C+++ FRICTION FACTO			0041	
0011				0021	
0012		7.2) 60 10 409		001.1	
0015		15.1.) 60 TI 410		0041	
		73,0) 60 71 499		. 001.21	1 - 7 - 4 -
0014	ASTAP=8.48			0012	100
0015	60 10 412			. 0042.	26.00
0016	411 ASTAP=11.5=D.	,705+ALGG(ISTAN)		0042.	5100
0017	60 70 412			. 00121	4100
0018	410 ASTAR=0,59			0042	51.00
0019	60 10 412			. 001.21	001
0020	409 ASTAP=1.52*A	LOG(ESTAF) + ( . 59		0042	00:00
0021	60 10 412			. 00423	7400
2200	470 ASTAR=2.5*ALC	OG(ISTAR)+5.5	A second and a second	00421	
0023	412 FFA=2,0/(AST)	AR=3.75=2.5=ALI.1 (2.	0.5***(())**2.0	. 007.51	
0024	FRROR=(FFA=FI	F)/FF		004.25	
0025	IF (ABS (ERROF)	LT.0.005) 60 TC 4	13	. 004.30	
0026	FFWFFA			00/3	
0027	. 60 TO 407			. 00433	
and the second second	C*** HEAT TRANSFER	COLEE.		004.3	
8500	413 FFFFFA			00434	
9500		5.5) 60 10 451		007.35	
0050	85TAR=5.58*F5			Contraction of the second s	
0031	GR=BSTAR*PR**			007.39	
0052	1110 - 11 F - D	A REAL AND ALL AND A REAL AND A	ACOUT/2012 011	00440	
	FARE DODULI TO ATION	**   F/(1,0=(8,48=(R)	054KT(FF/2,0))	0044	
0053	451 K3=0				
0034			where they have a second state	. 00143	600
0035	FFS2=FFS				
	414 IF(K3.GT.20)			00445	
056	K3=K3+1			00440	00310
0037	FFS1=1,0/(1,7	BOA ALL GIRFOSOFTIS	F52))-0.506)**2.0	00447	1.00
038	ERFOR=(FFS1=F	F52)/FF52			
0039		.LE.0.001) (0 TI 4	15	00445	100
0040	FFS2=FFS1			00450	000
0041	GO TO 414			00451	

FORTRAN	IN C	LEVEL	20 RUST DATE = 72349 11/5	0/48 PAGE 0002
0042		415	FFA=FFA+FFS/FFS1 FF=FFA	00452000
0044			1F(ESTAR.LE, 3.5) 60 TO 408	00453600
0045	- Service	a come a	MNS1=0.50RE0PR*FF51/(1.0+3.(1+5(+T(FF51/2.0)) .IF(NNR.LT.NF51) HNR=NNS1	00455000
0047			HN=HNR+HNS/HNS	00455560
0048			60 TO 408	00457000
0049			WRITE(6,460) FORMAT(")"/// "ITERATION ICHBER EXCEEDED IN RUST")	00458100
0051 .			PETURN	00160700
0052			END	00110100 00110100

FORTRAN 1	V G LEVEL 20	PRESS	DATE = 72349	11/50/48	PAGE DUD1
0001	SUBROUTINE		and the second	00462000	
	C***==PRESSURE DR	CP CALCULATION+++		00163500	
0002	DIMENSION T	(1(50), TG2(50), P1(50), P2(	50), I.PT1(50), DFT2(50	00/64000	
0005	COMMON W1,W	2, AL, NAX, DE1, [E2, TG1, TG2,	FLOA1, FLOA2, I, LI T1, D	PT2, POUT, POUL65000	
	11N, L, FF1, FF	2		001118400	
	C ***STATENENT			00467500	
0004		=48,139E=09*P/TGAS		00468500	
0005	N = I = 1			00469000	
0006	P1(1)=PIN	the second secon		00470600	
0007	P2(1)=PIN			00471000	
0008	DPT1(1)=0,0			00472100 -	
0009	DPT2(1)=0,0			00473000	
0010	L=0			00474000	
0011		N)+TG1(1))/2.0		00475000	
0012	TBAP2=(TG2(	<pre>&gt;&gt;+TC2(1))/2.0</pre>		00/7-000	
0013	CP1=P1+W1+(	4.0*FF1*AL/(1.AX*FE1)+2.0*(	TG1(1)-TG1(N))/TBAR	1+1.4/NAX200477000	
A. C. C. C. C. C.	I/ VELUAT#ELU	ATTUIF (IFAFT) FT(FJ) PZ. 0]		00/72000	
0014	DP2=W2+W2+(	4.0*FF2*AL/(LAX+112)+2.0+(	TC2(1)=TG2(1))/TBAR	2+4.5/NAX100/74600	
	1/(FLOA2*FLO	A2+UEN(TBAR2,12(1))+2.0)		00180100	
0015	P1(1)=P1(N)	*DP1		00481600	
0016	P2(1)=P2(N)	+ DP2 '	*	00482000	
0017	DPT1(1)=DPT	1 (N) + DP1		00483000	
0018	DPT2(1)=DPT.	2(N)+[P2	and a second sec	00684100 -	
0019	IF(I.NF.NAX	+1) CO TO 600		00485000	
0020	ERRORP=2.0*	(DPT1(I)=DPT2(I))/(DFT1(I)	+DFT2(1))	00486100	
0021	IF (ABS(ERRI	CRP), LF. U. 005) L=1		00487660	
5500	IF (1.EQ.1)			00485000	
0023	GO TO 600			00489000	
0024	550 POUT=(P1(1)	+P2(1))/2.0		00490000	
0025	600 PETURN			00491000	
0020	END			007051.00	

# APPENDIX VIII

# HEATAX III INPUT DATA

Input data for a seven time, ten axial step calculation for the peak rated channel (Tables 4/1, 5/1)

							-
. / 0							
0,007	0.759	0,711	0,667	0.626	0.591	0.560	0.527
9,498	0.475	0.450	0.431	0.410	. 0,398	0.380	0,317
0.353	U. 345	0,336					
0,288	U.288	0,288	0.288	0.268	0,21.5	0.285	0.215
0,285	0,285	0,285	0,285	0.205	0,265	0.285	0.215
0,285	0,285	0,285	0,285	0,205	0,285	U,285	0.215
0,285							
6,07E+	05						
10,084	0 940	1,098	1 227	1,293	.1.1.98	1.083	1,053
0,974	0,869	0.554	1,223	1.675	11150	1,005	1,055
0.743	0,991	1,176	1,258	1.090	1,192	1.074	1,024
0,889	0,658	and a star war					
2,00	2.6	300.0	300.0	0.81	1,5(5	3.26	3,75
2,015	2,75	0,08	117,0	88.58	0,025	0,5	500.0
· 0.	94 5,5E+	07					
3			the second second	14 1 1 1 1 4 4 1 1 1 1 1 1 1 1 1 1 1 1		· · · · · · · · · · · · · · · · · · ·	· •.
0,015 -	0.01						
0,015	0,01						
0,015	0,01						
0.015	0,01		•				
0,015	0,01					**************************************	
0,015	0,01						
0,015	0,01			enteriore alere a colori			
0,015	0,01						
0,015	0,01					- 1. 20 - S - S	
0,015	0,01						
77	0 770	0 7/7	0 704	0 704	6 11 6	0.200	0 74.4
0,284	0,320	0,363	0,391 0,350	0,395	0,400	0,390	0,384
320	0,315	0.307	0,000	0,540	0.001	0,000	0.525
215	0,215	0.215	0,215	0,205	0,205	0.200	0.2
5,0	0.2	0.2	0.2	0.2	0,2 .	0.2	0,2
2,1	0,2		0,2	1.2	6,2	0.2	5,0
1,2							
5,898+1	05						
10	1 070						
,695	0.879	1,101	1,222	1,259	1,(94	1,082	1,153
0,976	0,783	0,562	1,255	1.091	1,018	1.072	1,022
,891	0.661	1,115	14533		1,000	1.012	11.46
.00	2,6	300,0	300.0	0.87	1,515	3,26	3,79
,015 /	2,75	0,08	115,7	89.66	0.125	0,5	501.0
0.5	94 5,58+						
3					1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1		
1810.0	0,0099						
0,0131	0,0124						
0,0101	0,0166		all the search of the	1.04			
0.0083	0.0195						
.0075	0,0201	1 Mar. 1993	r an she i san s	40.0200/44 C			
0,0079	0.0195						
0.0083	0.0204						
	0.0204						
1,00815						41/777	
0,00815	0.0189					AVIII	-2

154						1	
0,135	0,180	0,220	0,250	0,272	0,28,0	0,281	0,28.1
0,282	0,282	0,282	0,283	0,283	0,283	0,284	0,28.4
0,284	0,284	0.284					
0,155	0,155	0,155	0,155	0,1475	0,1475	0.1425	0.1425
0,1425	0,1425	0.1425	0,1425	0.1425	0,1425	.0.1425	0,1425
0,1425	U,1425	0,1425	0,1425	0.1425	0,1425	U.1425	0,1425
5,516+	0.5						
10	03						
0,/16	0,897	1,104	4 74/	4 9/7			
0,979	0.789	0,577	1,216	1,277	1,082	1,076	1,051
0,771	1,016	1,167	1,249	1:082	1,08	1 017	
0,894	0.668	1,107	116.47	1.002	1,00	1.067	1.019
2,00	2.6	300.0	300.0	0.87	1,505	3,26	3.79
2,015	2.75	0,08	107,9	84.02	0,025	0.5	500.0
υ.					01025	0,5	500.0
3							
0,0117	0,0134	and the second second	• • • • • • • • • • • •	(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,	eren er en an an	es a anna a la s	·
0,0088	U.01/7						
0,0064	0,0241			• • • • •		1. 1. 17. 1. Mark	•••••
0,0075	0,0292						
0,0081	0,0335					and the second second	feren e provinción de la composición de
0,0081	0,0303						
0,0085	0,0303 0,0313		and the second second	**************************************	***************************************		
0,0095	0,0303	a de de come de la come		• • • • • • • • • • • • • • • • • • •			
0.0091	0,0273						
0,0085	0,0223			- and a state			
154							
0,08	0,135	0.177	0,209	0.229	(,241	0.246	0.246
0,246	0.246	0.249	0,257	0,257	0,257	0,257	0,257
0,257	0,257	0,257					011-51
0,12	0,12	0.12	0.12	0,1175	0,1175	0.11 .	0,11
0,11	0,11	0.11	0,11	0,11	0,11	0.11	0,11
0,11	0,11	0.11	0,11	0,11	0,11	U.11	0.11
0.11							
5.14E+0						3.ª - 1	
0,757	0,921	4 107					
0,978	U.817	1,107	1,205	1,201	1,06	1,058	1,036
0,807	1.029	1,162	1,234	4 060			
0,907	0.699	1,102	111.34	1.059	1,06	1,05	1.016
2,00	2.6	300.0	300.0	0,87	1,5(5	3,26	7 71.
2,015	2.75	0.08	100.4	79.15	0.025	0,5	3.79
U.9			· · · · · · · · · · · · · · · · · · ·			· · · · · · · · · · ·	500.0
3							
0.0101	0.0168	·····	and a second second	a to the statement of			
0.0056	0,0223						
0,0069	0,0298						
0.0079	0,0362						
0,0085	0.0418						1.1.1.1.1.1.1.1
0.0087	0,0377					AVIII-3	
0.0095	0,0376						
0.0099	0,0363						
0,0095	0.0328		4				
0.0091	0.0267		· · · · · · · · · · · · · · · · · · ·	a star an			
	and the second se						

154	0. 1.70									
0,045 0,245 0,245	0,120 0,245 0,245	0,162	0,195 0,245	0.215	0,235	0.240 0.245	0.242 0.245			
0.1075	0.10/5	0,1075	0,1075	0.1025	0.1125	0,0975	0,1575			
0,0975	0,0975	0.0975	. 0,6975	1,0975	0,1.675	0.0975	0, 6975			
4.7/E	• 0 5									
0,802	0,947 0,850	1.110 0.643	1,193	1,245	1,036	1.037	1,020			
0.047	1.042	1,157	1,218	1,053	1.038	1.03	1.001			
2,00	0,736	300.0	300.0	0.87	1,505	3,26	3.75		· · · · · · · · · · · · · · · · · · ·	
2,015	2.75 94 5.5E	0,08	93,03	73,59	0,125	0.5	500.0	14	······································	11 1 <b>1</b> 1
5				· · · · · · · · · ·	5					
0.0073	0,0209		()							
0,0075	0,0547								· · · · · · · · · · · · · · · · · · ·	
0,0077	0.0425									
0.0085	0,0441									
0,0087	0,0430	4) 4			· · · · ·					
0,0095	U.0433 U.0413		Summer 1							
0,0099	U.0367								1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	
0,0097	0,0302	· · · · · · · · · · · · · · · · · · ·	** ***							
0,058	0,115	0,155	0,180	0,210	0,215	0,220	0.231			
0,238	U,238 U,238	0,238 0,238	0,238	0,238	0,238	0,238	0,238			
0,1	U.1	0,1	0,1	0.095	0,095	0.0925	0, 15 25		10 10 10 10 10 10 10 10 10 10 10 10 10 1	Constant.
0.0925	0.0925	0.0925	0.0925	0.0925	0,0925	0,0925	0,0925		1	
0,0925		*******			0,0925	0,0925	0,0925			·····
4.40E+								and a second		
0,847	0,972	1,113	1,181	1,228	1,012	1,016	1.003			
0,971	0,885	0,678	1,201	1.007	1,115	1.011	0.992			
0,937 2,00	0,773		e em a la francia de cancia de				reads from the sound			
2,015	2,6 2,75	300,0	300.0	0.87	1,515	3.26	3.79			
3 0,	94 5,5E+	07								
0,0054	0,0247									
0,0064	0,0292		********		•• •••••	***** ******		***		
0,0073	0,0482			1.12 inter-1	10.000			· · · · · ·		
0.0066	0.0552		254 G 1							
0.0077	0,0481	-								
0.0089	0.0472								a a constraint marke	
0,009/	0.0404			· · ·		• 1/4				
77			1.00			1 4				
0.058	0,115	0,155 0,238	0,180 0,238	0.210	0,215	0,220	0,231			
0,238	0.238	0,238			0,238	0,236	0,238			
0,1 0,0925	U.1 U.0925	0.1 0,0925	0,1 0,0925	0.095	0,095	0.0925	0,0925			
0.0925	0,0925	0,0925	0,0925	0.0925	0,1525	0,0925	0,0525			
4.218E+0		· · · · · · · · · · · · · · · · · · ·		· · · · · · · · · · · · · · · · · · ·					· · · · · · · · · · · · · · · · · · ·	1
10,847	0.9/2 .	1.113								
0,971	0.885	0,678	1,181	1,228	1,012	1,016	1,003			
0,886	1,055	1,152	1,201	1,007	1,015	1,011	0,992	* ***		100
0.937	0,775									
2,00	2.6	300,0	300,0 84,73	0,87	1,5(5	3.26 U.5	3,79			
0.9	4 3,5E+0						,,.			
3	. C. 0 24 7									
4.44	L. (292			** ** *******		** * * * * ******	- 10			
0.0.75	1.1432	- +:								
0.6156	0.0552					•				
t.: 77	1	14/12/			•					
L.0 83	1									
1 .1. 157	10.01 13									
U.L.C.D	C. 3336								AVIII-4	

## APPENDIX IX

#### HEATAX III RESULTS

Results output for a seven time, ten axial step calculation for the peak rated channel (Appendix VIII)

UNCORRODED CASE

HEATAX RFSULTS ..... 1.165635 06 1. 249791 (5 . C. 249795 05 +DE+ \* . 30172E "1 0.98134E 30 0.98130F 00 \*KM\* 0. 35217F C1 ..... .. 159811 06 P. 23364E 0.5 0.23364E .75 +DE+ 1. 30189F C1 0.98057E 00 0.98057F 00 ..... 0. 35233E 01 \*RE= 1 . 15 247E 06 0.21621E 05 0. 21621E 05 +DE+ 0. 302128 01 0.97975E DC 0.979755 00 ..... 0. 35255E C1 .... 1 . 1445 3F 06 0. 1996hE 05 C.19960E 35 +DE+ r. 30233E 01 0.98033E 0C 0.98033E 00 . \*PM\* n. 35277E P1 .RE. C. 13687E 06 0.18529E 05 C. 18529E 35 \*DE\* 0.30251E 01 0.98113E 30 0.98113E 00 .... 0.35298E 01 .... 1 . 13' 86F 06 C. 17495E 05 0.17495E 05 +DE+ C. 30251E 01 C. 98349E OL 0.98349F 00 \* .... 0, 35379E 01 \*RE\* L. 12519E 96 C. 16632E 05 C. 16632E 75 +DE+ 0. 30263E 01 0.98455E 00 0.98455E 00 \*RM\* 0.35325E 01 \*RE\* -+ 1200 SE -06 0.15898F 0.5 0.15898E 35 +DE+ P. 30274E 01 0.98540E OC 0.98540E 00 \*RM# 0.3534CE C1 \*RE\* 0.11551F C6 0.15282E 05 0.15282E 05 +DE+ 0. 30281E 01 0.98659E 00 0.99659E CO \*RM# 0.35353E C1 \*RE\* C. 11181E C6 0.148115 05 0.14811E 35 \*DE\* 0. 30279E 01 0. 98827E 00 0.98827E 00 \*RM\* 0.35361E 01 \*1.5\* 0. 10911E C6 0.14510E 05 0.14510E 05 \*DE\* C. 30274E 01 0.98988E DC 0.98988E 00 \*RM\* 0.35363E 01

1.14

DWELL TIME = 0 DAYS CHANNEL POWER 0.66700E 06

MIXED GAS DUTLET TEMPFRATURE 868. INNEF FLOW RATE CUTER FLOW RATE

the set of the set of the set of the set of the

2	TGI	Tw1	TII	TF1	TFM	TF2	TIZ	TH2	TG2	TW
C	3UC	474	501	599	617	600	480	462	310	
50	330	562	602	711	737	717	576	551	358	30
20		675		850	864	861	695	660	434	37
150	425	770	847	955	995	971	797	755	522	45 54
202	482			1042	1087	1063	888	841	613	64
250	534	857	939	1326	1368	1049	906	868	693	71
302	587		997	1075	1118	1101	966	928	764	79
350	642	. 960	1049	1118	1152	1147	1021	983	8 34	86
	695		1082	1143	1196	1173	1062	1027	899	93
+50	742	995	1069	1121	1159	1151	1069	1045	954	97
500	780	976	1033	1076	1112	1106	1057	1043	991	100

Q	3.10847L-C1	C.23805E 01	. (.15418E-01	
51	0.100121-01	0.239615 01	".16541E-C1	
100	2.865196-02	C. 240826 01	0.179565-01	
150	2.7813tL-C2	C. 24196E 01		and a second sec
246			C.102105-01	
	C.683061-02	C. 24299E 01	0.20427E-01	
250	5.683571-02	0.24483E 01	0.209226-01	the state of the same state of the state of the
31%	3.623731-02	C. 24586E U1	0.213/9E-01	
35:	3.56722 -02	C.24681E 01	C.2268CE-01	
400	3-528651-62	U. 24813L 01		
450				- H - C Hanna - C
	0 29621 -02	C. 250 89E 01	C.23741F-01	
500	C.551741-02	C.25557E 01	C.238318-01	
				and the second s
-				
	to be seen to be brought the line of the second back more than	man any white any deniet of warrant reasons and	second second second second second second	

AIX-2

NIGAGE 0       0.0230200 0       0.0230200 0       0.001710 01       0.000000 0 </th <th>11.344E 06       C.253228E 05       C.233228E 35       4000       C. 240000E C0       0.400047E C0       0.400047</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th>*</th> <th></th> <th></th> <th></th> <th></th> <th></th>	11.344E 06       C.253228E 05       C.233228E 35       4000       C. 240000E C0       0.400047E C0       0.400047						*					
15.8.22.0       06       0.230.756       05       0.220.756       05       0.230.756       07       0.302355         130*76E       06       0.220.756       05       0.220.756       05       0.200.766       0       0.302355         130*76E       06       0.220.756       05       0.220.756       05       0.000.766       0       0.302355       01       0.400.555       00       0.302356       0       0.302356       01       0.400.555       00       0.302356       0       0.302356       01       0.400.555       0       0.302366       0       0.302356       01       0.400.555       0       0.302366       0       0.400.555       0       0.400.555       0       0.400.557       02       0.302366       01       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557	128241 06       0.234756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.2362766 01       0.430056 00       0.400556 00		-	HEAT	AX RE	SULTS		· · · · · · · · · · · ·	a. (a. (		2. 2. 20	
15.8.22.0       06       0.230.756       05       0.220.756       05       0.230.756       07       0.302355         130*76E       06       0.220.756       05       0.220.756       05       0.200.766       0       0.302355         130*76E       06       0.220.756       05       0.220.756       05       0.000.766       0       0.302355       01       0.400.555       00       0.302356       0       0.302356       01       0.400.555       00       0.302356       0       0.302356       01       0.400.555       0       0.302366       0       0.302356       01       0.400.555       0       0.302366       0       0.400.555       0       0.400.555       0       0.400.557       02       0.302366       01       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557       00       0.400.557	128241 06       0.234756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.236756 05       0.2362766 01       0.430056 00       0.400556 00	11 364E	06 (.25)	32 BE 05	C- 2532 8F			A 2000				
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Definition         Control of Construction         Cons	Definition         Control of Construction         Cons	142381		975 65	C. 204.375		. 202415 0					
12:300 (4       0.18386E C5       0.18186E 05       *DE*       C.30256F 01       0.48364E 00       0.98364E 00       *AR*       N.35299E         12:22EE 26       0.017340E C5       0.117340E 05       *DE*       C.30256F 01       0.48364E 00       0.98364E 00       *R**       0.35299E         12:22EE 26       0.16397E 05       0.16597E 05       *DE*       C.30226E 01       0.98527E 01       0.98537E 00       *R**       0.353926E         11:1352E C6       0.16597E 05       C.15595E 05       *DE*       0.30227E 01       0.98537E 01       0.98634E 10       *R**       0.353936E         10726E C6       0.15143E 05	12:300 (4       0.18386E C5       0.18186E 05       *DE*       C.30256F 01       0.48364E 00       0.98364E 00       *AR*       N.35299E         12:22EE 26       0.017340E C5       0.117340E 05       *DE*       C.30256F 01       0.48364E 00       0.98364E 00       *R**       0.35299E         12:22EE 26       0.16397E 05       0.16597E 05       *DE*       C.30226E 01       0.98527E 01       0.98537E 00       *R**       0.353926E         11:1352E C6       0.16597E 05       C.15595E 05       *DE*       0.30227E 01       0.98537E 01       0.98634E 10       *R**       0.353936E         10726E C6       0.15143E 05				C.204772	J3 ~0c+	C. 302410 0	1 0.98116	E 00 0	.98116E CO	*RM* 0	. 35 27 NE
122268: 36     0.17340E (3     C.17340E (3     C.130226E 01     C.98527E 01     C.98527E 02     C.98537E (0     F.95314E       11172EE (6     C.15577E (3     C.15577E 03     F0E*     C.302276E 01     C.98527E 01     C.98537E (0     FRM*     C.33549E       11172EE (6     C.15577E 03     C.15577E 35     F0E*     U.30277E 01     C.98537E 20     C.98537E (0     FRM*     C.33549E       11172EE (6     C.15577E 03     F0E*     C.30273E 01     C.98535E 20     C.98935E fo     FRM*     C.33539E       11172EE (6     C.15577E 02     FRM*     F10     F12     FRM     F10     F12       11172EE (7     C.16577E 02     F10     F10     F12     F12     F12     F12       111     F11     F11     F11     F11     F12     F12     F12     F17     F17       365     G22     F11     F11     F11     F11     F12     F12     F12     F17       365     G22     F12     F12     F12     F12     F17     F17     F17	1222480 34       0.173400 C5       0.18597E 05       0.155470E 05       0.1554       0.1554       0.1554       0.155470E 05       0.1554       0.1554       0.1554       0.1554       0.1554       0.1554       0.1554       0.1554       0.1554       0.1554       0.1554       0.1554       0.1554       0.1555       0.1555       0.1555       0.1555       0.15555 </td <td>13438E</td> <td>C6_ 0.191</td> <td>74E 05</td> <td>C.19174E</td> <td>05_*DE*</td> <td>0. 30259E 0</td> <td>1 C. 98165</td> <td>E 00 0</td> <td>.98165E CO</td> <td>*RM* 0</td> <td>• 35 28 9E</td>	13438E	C6_ 0.191	74E 05	C.19174E	05_*DE*	0. 30259E 0	1 C. 98165	E 00 0	.98165E CO	*RM* 0	• 35 28 9E
0411746E       06       041337E       05       00000       0.30276E       01       04.98527E	DMELL TIME     C DAYS       DMELL TIME     C DAYS       DMELL TIME     C DAYS       DMELL TIME     C DAYS       COMMULT POWER     C DAYS	12830E	06 0.181	86E C5	0.181865	05 *DE*	C. 30256F 0	1 0. 98364	E DC C	. 98364E 00	*RM* 0	. 35 299E
All 76 EE G     0.16597L US     0.15965E 05     0.02822E 01     0.98527E 00     0.98527E 00     0.98534E (0     0.98534E (0     0.98534E (0     0.98534E (0     0.98537E 00     0.98535E 00     0.98935E 00     0.98	DMELL TIME     C DAYS       DMELL TIME     C DAYS       DMELL TIME     C DAYS       DMELL TIME     C DAYS       COMMULT POWER     C DAYS	12268E	C6 0.173	40E C5	C-1734CE	05 +05+	0- 3024 AF 0	1 0 08430				•
H1332E     C6     C+1336EF     C5     C+15965E     05     +0E+     C+3022E     01     0-98634E     C0     0.98634E     C0 <td< td=""><td>113327     C6     0.159657     0.159677     0.100000000000000000000000000000000000</td><td></td><td></td><td></td><td></td><td></td><td>Va Suzeon o</td><td>1 0.90957</td><td>EDU</td><td>• 98439E UD</td><td>*RM* 17</td><td>. 35314E</td></td<>	113327     C6     0.159657     0.159677     0.100000000000000000000000000000000000						Va Suzeon o	1 0.90957	EDU	• 98439E UD	*RM* 17	. 35314E
107212     C     C.15470C 05     C.15470C 35     4024     C.130222 0 1     0.98536 0 1     98746 0     88746     0.333412       10722E C6     C.151432 05     0.151432 05     0.151432 05     0.024     0.987352 01     0.98755753     0.98755753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753	107212     C     C.15470C 05     C.15470C 35     4024     C.130222 0 1     0.98536 0 1     98746 0     88746     0.333412       10722E C6     C.151432 05     0.151432 05     0.151432 05     0.024     0.987352 01     0.98755753     0.98755753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753     0.98735753	11768E C	06 C.165	97E C5	0.16597E	05 *DE*	0.30276E 0	1 0.98527	E 00 0	.98527E CO	*RM* 0	35 329E
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10728E C6 0.15143E C5 0.15143E 05 +0E+ C. 30273E 01 0.90935E 0C 0.90935E CA +RH+ A. 33332E A 10728E C6 0.15143E C5 0.15143E 05 +0E+ C. 30273E 01 0.90935E 0C 0.90935E CA +RH+ A. 33332E A DWELL TIME - C DAYS CHANNEL POWER C.58900E C6 C.58900E C6 TIMED 645 OUTLET TEMPERATURE 652. INNEP FLOW FATE OUTER FLOW RATE C.58900E C6 TIME 5111 TEN TEN TET TIZ THZ TOZ TW3 325 536 526 714 556 519 477 466 300 377 325 536 526 714 556 519 477 466 300 377 326 526 724 633 399 977 757 611 577 512 537 650 122 133 399 977 757 611 577 512 538 673 972 1001 1053 1041 666 619 056 642 539 673 972 1001 1053 1041 667 619 256 642 539 673 972 1001 1053 1041 667 619 758 756 617 539 673 972 1001 1053 1041 667 619 758 756 617 539 773 972 1001 1053 1041 667 619 758 756 757 107 1093 1072 1094 1157 1156 978 672 677 107 1093 1072 1094 1057 1158 1025 978 672 677 107 1093 1072 1094 1057 1158 1025 978 672 677 107 1093 1072 1094 1057 1158 1025 978 672 677 107 1093 1072 1094 1057 1158 1025 978 672 677 107 1093 1072 1094 1057 1158 1025 978 672 677 107 1093 1072 1094 1059 1031 1025 978 672 677 107 1093 1072 1094 1059 1031 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 107 1094 105 1158 1025 978 672 677 107 1093 107 1095 939 939 939 939 939 939 939 939 939 9	10728E C6 0.15143E C5 0.15143E 05 +0E+ C. 30273E 01 0.90935E 0C 0.90935E CA +RH+ A. 33332E A 10728E C6 0.15143E C5 0.15143E 05 +0E+ C. 30273E 01 0.90935E 0C 0.90935E CA +RH+ A. 33332E A DWELL TIME - C DAYS CHANNEL POWER C.58900E C6 C.58900E C6 TIMED 645 OUTLET TEMPERATURE 652. INNEP FLOW FATE OUTER FLOW RATE C.58900E C6 TIME 5111 TEN TEN TET TIZ THZ TOZ TW3 325 536 526 714 556 519 477 466 300 377 325 536 526 714 556 519 477 466 300 377 326 526 724 633 399 977 757 611 577 512 537 650 122 133 399 977 757 611 577 512 538 673 972 1001 1053 1041 666 619 056 642 539 673 972 1001 1053 1041 667 619 256 642 539 673 972 1001 1053 1041 667 619 758 756 617 539 673 972 1001 1053 1041 667 619 758 756 617 539 773 972 1001 1053 1041 667 619 758 756 757 107 1093 1072 1094 1157 1156 978 672 677 107 1093 1072 1094 1057 1158 1025 978 672 677 107 1093 1072 1094 1057 1158 1025 978 672 677 107 1093 1072 1094 1057 1158 1025 978 672 677 107 1093 1072 1094 1057 1158 1025 978 672 677 107 1093 1072 1094 1057 1158 1025 978 672 677 107 1093 1072 1094 1059 1031 1025 978 672 677 107 1093 1072 1094 1059 1031 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 1072 1094 105 1158 1025 978 672 677 107 1093 107 1094 105 1158 1025 978 672 677 107 1093 107 1095 939 939 939 939 939 939 939 939 939 9	102815	6 G.154	701 05	C-15470E	25 *DE*	1) 30279E C	0 69700				
OWELL TIME     C DAYS       CHANNEL POWER     C DAYS       CHANNEL POWER     C       CHANNEL POWER     C       C. 19900E     C.       C. 19900E     C.       Status     C.       MIRED GAS OUTLET TEMPERATURE     052.       INNEP FLOW FATE     OUTER FLOW RATE       J. 1990E     C.       JOI     C May Status       101     TH1       TH     TS1       102     TAS       103     Status       104     TH1       TH     TS1       105     G42       106     G42       107     TS1       108     Status       109     TS1       101     TH1       101     TS1       102     TS1       103     Status       104     TH1       105     Status       106     G42       107     TS1       108     Status       109     TS1       101     TS1       101     TS1       102     TS2       103     TS2       104     Batous       105     TS1       106     TS1    <	DWELL TIME         C DAYS           CHANNEL FOMER         C DAYS           CHANNEL POMER         C           CHANNEL POMER         C           C. 19900C C.6.           MIXED GAS OUTLET TEMPERATURE         052.           INNEP FLOW EAR         C.6.00000000000000000000000000000000000		•	• • • • • • • • • • • • • •			0.302172 0	1 0: 90/90	E-DL O	. 9879nE [0	*RM* 0.	35369E
DVELL TIME         C DAYS           CHANNEL PONER C.58900E.Co	DVELL TIME         C DAYS           CHANNEL PONER C.58900E.Co	10726E C	6 0.151	43E .C5	0+15143E	05 *DE*	0. 30 27 35 0	0,989356	00 00	.98935E CO	*84* 0.	35 35 2E · (
DVELL TIME         C DAYS           CANNEL PORER C.58900E.Co	DVELL TIME         C DAYS           CANNEL PORER C.58900E.Co											
DWELL TIME         C DAYS           CHANNEL PORCE C.SEBYOOE.GA         BS2.           TIMED GAS OUTLEY TEMPERATURE         052.           TIMED CAS OUTLEY TEMPERATURE         052.           TIMED GAS OUTLEY TEMPERATURE         052.           TOMEL CAS         OUTER FLOW RATE CASESPORE           COMPS FLOW FATC         OUTER FLOW RATE CASESPORE           TOME THES         TEMP SLATURES           TOTO TAS         002 933 999 971 757 711 577 532 737 016 650 629 4350 4500 651 656 6823 737 123 1373 1065 1642 732 575 640 650 629 714 1551 726 575 540 359 372 731 937 912 123 1373 1064 1660 813 656 6823 737 123 1373 1065 1044 660 813 656 6823 737 11 577 532 737 10 120 131 1017 1039 133 131 131 131 131 131 131 131 131 1	DVELL TIME         C DAYS           ChANNEL PORER C.58900E.C6								in a second			
DELL TIME         C DAYS           CHANNEL POWER	DVELL TIME         C DAYS           CHANNUL POMER C.SEGVORE.CA											
DNELL TIME P. C DAYS           Channiel prover           MIXED GAS DUTLET TEMPERATURE         852.           Inner Falow Kate C.199026.03         Outles Flow Kate O.2005070.03         001111.01           Júčí třůl Tůl Tří	DHELL TIME · C DAYS           CHANNEL POWER C.SE8900E.Cd.           MIREO GAS DUTLET TEMPERATURE B52.           INNER FLOM KATE C.11900E.C3.         OUTER FLOM KATE C.88907E.C3.           THEO GAS DUTLET TEMPERATURE B52.           INNER FLOM KATE C.11900E.C3.         OUTER FLOM KATE C.88907E.C3.           THEO FLOM KATE C.11900E.C3.         OUTER FLOM KATE C.88907E.C3.         THEO C.88907E.C3.           THEO FLOM KATE C.11900E.C3.         THEO FLOM KATE C.88907E.C3.         THEO C.88907E.C3.         THEO C.88907E.C3.           JULY STATUPES C.11900E.C3.         THEO FLOM KATE C.11900E.C3.         THEO FLOM KATE C.12000E.C3.           THE GAP											•
DHELL TIME -         © DAYS           CLAINNIEL POWER C.SEBGOOE.C.6           MIXED GAS OUTLET TEMPERATURE         852.           INNER FLOW RATE C.B6559TE.02         00TER FLOW RATE C.B6559TE.02           JEINER FLOW RATE S.B1050TE.02         00TER FLOW RATE C.B6559TE.02           JEINER FLOW RATE S.B1050TE.02         00TER FLOW RATE C.B6559TE.02           JEINER FLOW RATE S.B1050TE.01         00TER FLOW RATE S.B1050TE.01           JEINER FLOW RATE S.B1050TE.01         00TER RATE S.B1050TE.01           JEINER RATER SPLIT RADIUS         CUTER CAP S.B1050TE.01           VILL'S CAP         HEAT SPLIT RADIUS           VILL'S CAP         HEAT SPLIT RADIUS           VILL'S CAP         U.S2756C1           JESSOFTE-01         C.S28276E.01           JESSOFTE-02         C.S28276E.01           JESSOFTE-02         C.S28276E.01           JESSOFTE-02         C.S28276E.01           JESSOFTE-02         C.S28276E.01           JESSOFTE-02         C.S28596E-01	DHELL TIME · C DAYS           CHANNEL POWER C.SE8900E.Cd.           MIREO GAS DUTLET TEMPERATURE B52.           INNER FLOM KATE C.11900E.C3.         OUTER FLOM KATE C.88907E.C3.           THEO GAS DUTLET TEMPERATURE B52.           INNER FLOM KATE C.11900E.C3.         OUTER FLOM KATE C.88907E.C3.           THEO FLOM KATE C.11900E.C3.         OUTER FLOM KATE C.88907E.C3.         THEO C.88907E.C3.           THEO FLOM KATE C.11900E.C3.         THEO FLOM KATE C.88907E.C3.         THEO C.88907E.C3.         THEO C.88907E.C3.           JULY STATUPES C.11900E.C3.         THEO FLOM KATE C.11900E.C3.         THEO FLOM KATE C.12000E.C3.           THE GAP								-			
CHANNIEL POMER         C.SEBSODE.G.           MIXED GAS OUTLET TEMPERATURE         852.           INNER FLOW RATE         Outer flow rate           T. 11904E C3         Outer flow rate           JC. 406597E.02         TH2           JC. 4062         TH3           JC. 4062         TH4           JC. 4064         TH4           JC. 4064         TH4           JC. 4064         TH4           JC. 4064         TH4           JC. 797         TH2           JC. 797         TH4           JC. 797         TH2           JC. 797         TH2 <th>CHANNEL POWER         C.:SE900E.66           MIXED GAS OUTLET TEMPERATURE         852.           INNER FLOW RATE         OUTER FLOW RATE           T.:II90AE.03         OUTER FLOW RATE           TEMPERATURES         TEMPERATURES           325         556           326         714           371         658           787         797           932         731           658         764           797         912           371         658           787         797           933         776           956         123           939         971           757         711           658         764           933         776           956         123           938         971           939         971           757         711           556         622           767         962           938         972           939         971           937         713           938         976           939         973           937         103</th> <th></th> <th></th> <th>C 041</th> <th></th> <th>-</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th>	CHANNEL POWER         C.:SE900E.66           MIXED GAS OUTLET TEMPERATURE         852.           INNER FLOW RATE         OUTER FLOW RATE           T.:II90AE.03         OUTER FLOW RATE           TEMPERATURES         TEMPERATURES           325         556           326         714           371         658           787         797           932         731           658         764           797         912           371         658           787         797           933         776           956         123           939         971           757         711           658         764           933         776           956         123           938         971           939         971           757         711           556         622           767         962           938         972           939         971           937         713           938         976           939         973           937         103			C 041		-						
C. 5:8900E.16       MIXED GAS OUTLET TEMPERATURE     852.       INNER FLOW RATE F. 11900E.03     OUTER FLOM RATE C. 68597E.02       JEI     THU TIL       JC:0     THU TIL	C. 5.8900E. 6.6         MIXED GAS DUTLET TEMPERATURE       852.         INNER FLOW RATE       OUTER FLOW RATE         C. 5.11906E C3.       C. 6.86597E.02         TEMP ERATURES         TG1       TM1         761       TM1         761       FE4         762       533         763       263         764       TS1         765       744         767       TH         767       702         777       902         793       797         970       922         933       799         971       657         658       650         659       921         121       121         122       1001       1053         123       1064       866       819       656       682         652       657       1067       1053       1157       1126       973       938       88       816         751       993       1072       1074       1161       1014       978       850       877         715       997       1122       1064       <			U UA1	rs				-			
INNER FLOW RATE         OUTER FLOW RATE           TF:         0.86597E 02           TE:         TE:	INNER FLOW RATE C. 11904E C3       OUTER FLOW RATE C. 86597F 02         TEMP SATURES         101       TH1       TF1       TFM       TF2       TH2       TW2       TG2       TW3         325       556       626       714       T51       726       575       540       359       372         321       576       626       714       751       726       575       540       359       372         321       576       626       714       751       721       577       511       577       511       577       512       547       616         427       737       902       933       999       971       757       711       577       516         543       873       972       1001       1063       1041       860       819       656       682         596       921       102       1059       1136       973       933       788       816         715       993       1072       1064       1165       1133       1025       977       976       872       927         7187       976       1630       1047       1099       1281											
INNER FLOW RATE F. 11964E r3         OUTER FLOW RATE O. 86597E 02           TEMP SEATURES           TG1         T11         T51         TFM         T52         T42         T42         T62         TH3           325         536         626         T14         T51         T26         575         540         359         372           321         658         764         833         899         862         669         628         430         450           427         797         902         933         999         971         757         711         547         532           543         873         972         1001         1063         1041         860         819         656         682           593         971         163         1041         806         819         656         682           596         921         1021         1050         1133         1025         976         676         877           751         993         1072         1094         1145         1133         1025         977         976         878         817           751         993         1072         1099	INNER FLOW RATE C. 119904E C3         OUTER FLOW RATE C. 86597E 02           TEMP SKATURES           30:0         T11         T51         TFM         T62         TW2         TG2         TW3           30:0         TM1         T11         T51         TFM         T62         497         466         300         307           32:5         556         620         T14         T51         T26         575         540         359         372           371         658         764         833         689         862         669         628         430         450           427         777         902         933         999         971         757         711         547         532           543         873         972         1001         1063         1041         860         819         656         682           596         921         1121         1157         1136         973         933         788         816           652         657         1667         1053         1131         1025         997         972         924         935           7151         993         1072         10	MIXED G	AS OUTLET	TEMPERAT	TURE 8	352.		•				
IF-MP 3F ATURES           101         TM1         T11         TF1         TFM         TF2         T12         TW2         TG2         TW3           32:5         5:5         6:26         714         751         726         575         560         359         372           31:         6:58         766         .833         .809         862         669         628         430         450           4:37         776         .902         933         .939         971         757         711         517         532           5:3         .873         .972         .1001         1063         .842         792         587         616           5:92         .21         .121         .155         1136         878         722         756           652         .657         .1667         .1025         1157         1136         973         933         788         816           615         .997         .1120         .1179         1161         1014         978         850         877           731         .993         .1072         .1089         .1089         .025         997         972         224 </th <th>TCHP EATURES           101         TM1         T11         TF1         TFM         TF2         T12         TW2         TG2         TW3           325         536         626         714         751         726         575         560         359         372           371         658         764         633         889         862         669         628         430         450           457         797         902         933         999         971         757         711         517         532           453         376         996         1021         1055         842         792         587         616           593         873         972         1001         1063         1041         860         819         656         662           596         921         1021         1050         1112         1079         916         1078         727         756         662         662         662         662         662         662         662         662         662         662         662         662         662         662         662         662         662         662         662         66</th> <th></th> <th></th> <th></th> <th>FLOW RATE</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th>	TCHP EATURES           101         TM1         T11         TF1         TFM         TF2         T12         TW2         TG2         TW3           325         536         626         714         751         726         575         560         359         372           371         658         764         633         889         862         669         628         430         450           457         797         902         933         999         971         757         711         517         532           453         376         996         1021         1055         842         792         587         616           593         873         972         1001         1063         1041         860         819         656         662           596         921         1021         1050         1112         1079         916         1078         727         756         662         662         662         662         662         662         662         662         662         662         662         662         662         662         662         662         662         662         662         66				FLOW RATE							
TG1       TW1       T11       TF1       TFM       TF2       T12       TW2       TG2       TW3         3C5       562       503       623       546       619       497       466       300       307         325       556       626       714       751       726       575       540       359       372         311       658       764       833       889       862       669       628       430       450         427       737       902       933       999       971       757       711       517       532         433       376       956       1023       1093       1065       842       792       587       616         593       977       1023       112       1090       918       878       722       756         652       657       1067       1079       112       1097       918       878       886       816         715       977       1032       1127       1133       1025       997       962       924         731       933       1072       1074       1089       1081       1017       999       939	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$				07E_02					-		
325       503       623       546       619       497       466       300       307         325       556       626       714       751       726       575       540       359       372         371       658       764       833       889       862       669       628       430       450         427       797       902       933       939       971       757       711       57       532         427       797       902       933       939       971       757       711       57       532         427       797       902       933       939       971       757       711       57       532         483       876       172       1001       1063       1041       860       819       656       682         552       567       1067       1095       1157       1136       973       933       788       816         753       997       1093       1071       1089       1017       999       939       955         711       933       1072       1047       1089       1017       999       939       955	325       503       623       546       619       497       466       300       307         371       658       764       633       689       862       669       628       430       450         371       658       764       633       989       862       669       628       430       450         427       797       902       933       999       971       757       711       57       532         423       376       1021       1053       1065       842       792       587       616         596       921       1021       1059       1112       1090       916       878       722       750         652       657       1067       1795       1137       1136       973       933       788       816         751       997       1031       1127       1179       1161       1014       978       850       877         751       997       1031       1047       1089       1081       1017       999       939       935         71       997       1630       1047       1089       1081       1017       999	TGI	TW1	TIL				T12	TW2	T G2	TW3	
371       658       764       833       869       862       669       628       430       450         427       797       902       933       999       971       757       711       547       532         427       797       902       933       999       971       757       711       547       532         543       873       972       1001       1063       1041       860       819       656       682         552       921       1421       1050       1112       1090       916       878       722       756         652       667       1067       1095       1157       1136       973       933       788       816         715       997       1072       1096       1165       1133       1025       997       972       924         787       970       1032       1047       1089       1081       1017       999       939       935       955         NNL8       649       HEAT SPLIT RADIUS       CUTER GAP	371       668       764       833       889       862       669       628       430       450         427       797       902       933       999       971       757       711       517       532         643       873       972       1001       1063       1041       866       819       656       682         543       873       972       1001       1053       1041       866       819       656       682         596       921       1121       10°50       1112       10°90       916       878       722       756         652       567       1067       10°50       1112       10°90       916       878       722       756         652       567       1067       10°50       1133       1025       997       972       976       876       877         751       933       1072       10°9       1081       1017       999       939       939       955         VNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       10°17       999       939       939       955         SMIR GAP       HEAT SPLIT RADIUS       CUTER GAP       10°17	325	536	626	714			497	466	300	307	
\$483       976       990       1223       1073       1765       842       792       587       616         543       873       972       1001       1063       1041       860       819       656       682         552       921       1421       1795       1112       1079       916       878       722       750         652       657       1067       1795       1157       1136       973       933       788       816         715       997       1071       1095       1112       1179       1161       1014       978       850       877         731       993       1071       1094       1163       1012       978       850       877         737       970       1030       1047       1099       1081       1017       999       936       955         NNL & GAP       HEAT SPLIT RADIUS       CUTER GAP	493       376       990       1023       1073       1065       842       792       587       616         543       873       972       1001       1063       1041       860       819       456       682         652       921       1021       1050       1112       1090       919       878       722       756         652       667       1067       1095       1157       1136       973       933       788       816         705       997       1073       1079       1161       1014       978       850       877         711       993       1072       1079       1161       1014       978       850       877         711       993       1071       1094       1145       1133       1025       997       972       924         7167       970       1630       1047       1099       1017       999       939       939       955         NNL & GAP       HFAT SPLIT RADIUS       CUTER GAP       **154075-01       1017       999       939       939       955         NNL & GAP       HFAT SPLIT RADIUS       CUTER GAP       **154075-01       1017			784 .			862	669	628	430	450	
573       873       972       1001       1063       1041       860       819       656       682         596       921       1121       1050       1112       1090       916       878       722       756         652       657       1067       1093       1127       1190       916       878       722       756         652       657       1067       1093       1127       1196       916       878       722       756         652       657       1067       1093       1127       1196       916       878       722       756         652       657       1067       1193       1127       1193       1014       978       850       877         737       970       1031       1047       1089       1081       1017       999       939       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP	553       873       972       1001       1063       1041       860       819       656       682         596       921       1021       1050       1112       1090       916       878       722       756         652       567       1667       1076       1157       1136       973       933       788       816         7(5       997       1(93       1120       1179       1161       1014       978       850       877         737       931       1072       1094       1145       1133       1025       997       972       924         970       1032       1047       1089       1017       999       939       939       955         NNUR GAP       HEAT SPLIT RADIUS       CUTER GAP	485		990	1023							
652       567       1067       1095       1157       1136       973       933       788       816         7(5       997       1093       1120       1179       1161       1014       978       850       877         751       993       1072       1094       1145       1133       1025       997       9(2       924         787       970       10347       1089       1081       1017       999       939       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       1081       1017       999       939       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       1081       1017       999       939       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       1081       1017       999       939       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       1081       1017       999       939       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       1081       1017       999       939       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       108170255       108       1017       999       939       955 </td <td>652       C67       1067       1095       1157       1136       973       933       768       816         7(5       .997       1093       1120       1179       1161       1014       978       850       877         787       .970       1072       1094       1145       1133       1025       997       9(2       924         787       .970       1030       .1047       1089       1081       1017       999       939       955         VNLR GAP       HEAT SPLIT RADIUS       CUTER GAP      </td> <td></td> <td></td> <td></td> <td></td> <td>1063</td> <td>1041</td> <td>860</td> <td>819</td> <td>656</td> <td>682 .</td> <td></td>	652       C67       1067       1095       1157       1136       973       933       768       816         7(5       .997       1093       1120       1179       1161       1014       978       850       877         787       .970       1072       1094       1145       1133       1025       997       9(2       924         787       .970       1030       .1047       1089       1081       1017       999       939       955         VNLR GAP       HEAT SPLIT RADIUS       CUTER GAP					1063	1041	860	819	656	682 .	
7(5       997       1(93       1127       1175       1161       1014       978       850       817         751       993       1072       1994       1145       1133       1025       997       9(2       924         787       970       1630       1047       1089       1081       1017       999       936       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       *156055-01       0.236046 01       *156055-01       0.236046 01       *156055-01       0.3454655-72       0.246796 01       0.24790602-01       0.3454655-72       0.2455346 01       0.276092-01       0.35567-01       0.2455346 01       0.276092-01       0.35567-01       0.2455346 01       0.3756692-01       0.321755-01       0.321755-01       0.321755-01       0.321755-01       0.321755-01       0.321755-01       0.321755-01       0.3221755-01       0.3221755-01       0.328795-01       0.328795-01       0.328795-01       0.328795-01       0.328795-01       0.3285795-01       0.3285795-01       0.3285795-01       0.3285795-01       0.3285795-01       0.3285795-01       0.3285795-01       0.3285795-01       0.3285795-01       0.3285795-01       0.3285795-01       0.3285795-01       0.3285795-01       0.3285795-01       0.3285795-01       0.3285795-01       0	715       997       1093       1120       1179       1161       1014       978       850       877         751       993       1072       1094       1145       1133       1025       997       962       924         787       970       1030       1047       1099       1081       1017       999       936       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       *154095-01       *154095-01       999       936       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       *154095-01       *154095-01       999       936       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       *154095-01       *154095-01       999       936       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       *154095-01       *154095-01       5450700       999       936       955         NNLR GAP       0.246354601       0.335567-01       0.24534601       0.335567-01       532076600       100730926-01       122602-02       0.246972601       0.3320750-01       122270-01       0.328795-01       122270-01       0.328795-01       1007000000       10690776-02       0.247292601       0.328795-01       0.32859862-01       100700	652	567									
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	151       993       1072       1094       1145       1133       1025       997       972       924         187       970       1630       1047       1089       1281       1017       999       939       924         1646425-01       047       1089       1281       1017       999       939       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       11133       1017       999       939       939       955         NNLR GAP       HEAT SPLIT RADIUS       CUTER GAP       111870-01       111370-02       999       939       939       955         1166025-01       0.23604601       0.167906-01       0.167906-01       0.167906-01       0.167906-01       0.167906-01       0.167906-01       0.167906-01       0.167906-01       0.167906-01       0.167906-01       0.128066-01       0.1280566-01       0.1280596-01       0.1280596-01       0.1280596-01       0.1280596-01       0.1280596-01       0.1107076-02       0.246686-01       0.331925-01       0.31303E-01       0.16907E-02       0.226706-01       0.2285986-01       0.16907E-02       0.2252766-01       0.2885986-01       0.15648E-02       0.2552766-01       0.2885986-01       0.16907E-02       0.2552766-01       0.2885986-01       0.16			10.93	1120	1179	1161	1014				
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0 55 55 55 55 55 55 55 55 55 55 55 55 55	PLANAR RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0	RC1           0.0           C.D           C.O           C.O	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.
0 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC0         0.0           0.4/276E-02         0.4/154^0E-02	FC1           0.0           C.D           C.O           C.O	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.
0 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2           0.0	RC0         0.0           0.0	FC1         0.0         C.D         C.O         C.T025E-02         C.74559E-02         C.74559E-02         C.74730E-02         C.75526E-C2	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.
0 550 552 552 552 552 552 552 552 552 55	PLANAR RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2           0.0	RC0         0.0           0.4/276E-0.2         0.42884E-0.2	FC1         0.0         C.D         C.O         C	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.
C S S S S S S S S S S S S S	PLANAR RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	BC2           0.0	RC0         0.0           0.0	FC1         0.0         C.0         C.7321F-02         C.74321F-02         C.75326E-02         C.75368E-02         C.77816E-02         C.77816E-02	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.
0 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	BC2           0.0	RC0         0           0.0         0.0           0.0	FC1         0.0         C.D         C.O         C.T3559E-02         C.T4730E-02         C.T5526E-C2         C.T6368L-C2         C.T7816E-02         C.T8312E-02	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.
0 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2           0.0           0.245162E           0.23421E           0.224988           0.229988           0.229988	RC0         0.0           0.0	FC1         0.0         C.0         C.7321F-02         C.74321F-02         C.75326E-02         C.75368E-02         C.77816E-02         C.77816E-02	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.
0 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2           0.0           0.20           0.20           0.20           0.20           0.20           0.20           0.20           0.22459E           0.22459E           0.22459E	RC0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4	FC1         0.0         C.D         C.O         C.T3559E-02         C.T4730E-02         C.T5526E-C2         C.T6368L-C2         C.T7816E-02         C.T8312E-02	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.
0 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2           0.0           0.245162E           0.23421E           0.224988           0.229988           0.229988	RC0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4	FC1         0.0         C.D         C.O         C.T3559E-02         C.T4730E-02         C.T5526E-C2         C.T6368L-C2         C.T7816E-02         C.T8312E-02	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.
0 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	BC2           0.0	RC0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4	FC1         0.0         C.D         C.O         C.T3559E-02         C.T4730E-02         C.T5526E-C2         C.T6368L-C2         C.T7816E-02         C.T8312E-02	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.
0 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2           0.0           0.20           0.20           0.20           0.20           0.20           0.20           0.20           0.22459E           0.22459E           0.22459E	RC0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4	FC1         0.0         C.D         C.O         C.T3559E-02         C.T4730E-02         C.T5526E-C2         C.T6368L-C2         C.T7816E-02         C.T8312E-02	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.
0 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	BC2           0.0	RC0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4         0.2           0.4	FC1         0.0         C.D         C.O         C.T3559E-02         C.T4730E-02         C.T5526E-C2         C.T6368L-C2         C.T7816E-02         C.T8312E-02	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.

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• 997( 2E	05	. C. 143875	05	0•14387E	95	*DE*	C.30273E	01	C. 98904E	oc	C. 989C4E	00	*RM*	0.35350E
. 102008	66	C.14711F	(5	0.14711E	25	*DE*	0.3028CE	C 1	0.98765E	00	0. 98765E	00	*RM*	0.35346E
. 105228	06	C.15194E	05	0.15194E	25	*DE*	0. 30282E	01	0.98614E	00	0.98614E	00	*RM*	(.35338E
109105	C6	C.15802E	05	0.158C2E	05	*DE *	C. 30277E	01	C. 98512E	90	C. 98512E	00	*RM*	n. 35325F
113758	66	0.16513E	r5	0.165135	25	*DE*	C. 30268E	01	0.98427E	90	0.98427E	00	*RM*	C. 35 31 1E
118855	06	C.17320E	05	C.17320E	35	*DE *	C. 30257E	01	0.98355E	00	C. 98355E	00	*RM*	C. 35296E
124425	ce	C.18249E	C5_	0.18249E	25	*DE*	r. 30260E	01	0.98170E	oc	, 0.98170E	00	*RM*	0.35286E
131748	96	C.195036	05	0.19503E	05	*DE *	C. 30244E	91	0.98112E	00	0.98112F	00	*RM*	C . 35268E
130405	1.6	(.20909E	(5	C. 23939E	25	*DE *	C. 30224E	01	C. 58089E		C. 98189E	00	*RM*	C. 35249E
14691F	<b>~</b> 6	C.224278	05	0.22427E	05	*DE*	. C. 30198E	01	0.98108E	00	0.98108E	00	.*RM*	C. 35231E
15266E	00	C. 23895E	C5.	C.23895E	25	*DE *	L. 30177E	01	0.98126E	00	0.98126E	00	*RM*	C. 35217E

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CHANNEL POWER

MIXED GAS OUTLET TEMPERATURE 851.

INNER FLOW RATE OUTER FLOW RATE 0.11108E 03 0.81697E 02

\_\_\_\_\_TEMPERATURES

305				TFM	TP2	116	TW2	TG2	TW3
Deserves and the second second	*:85	549	613	651	622	493	452	300	308
332	588	673	709	766	736	508	524	355	369
379	71'8		843	919	886	665	*14	423	442
430	84.0	921	950	1035	1001	751	696	497	522
497.	878	161.6	10 37	1132	1093	831	774	576	6114
551	872	982	1009	1389	1060	850	803	643	668
6:6	922	10 31	1058		1119	919	862	71:9	736
64.	967	1075	1101	1181	1153	963	918	774	802
	927	1099	1123	1199 .	1174	1006	964	835	863
758	992	1677	1097	1151	1143	1018	586	889	911
		10.36	1052	. 1124	10 92	1013	992	927	943

5

INNEF GAP	HEAT SPLIT RAT	DIUS G	UTER GAP	
_0.72358E-U2	L. 23981 E	01	C.18754E-01	
D.32237E-62	0.243116	01	v.238792-01	
-2.65433L-03		01	C. 31263E-01	1211-2
-0.51 . 86 E=03	1.24546E	01	A. 373471-01	
-0.51687E-C3		01	0.426518-01	
-1.428128-1.3	1.24648E 1	01	0.4: 7595-01	
-2.546(4E-03	1).24659E	01	C.419318-01	
-3.618765-03	U. 24692E 1	01	4.427520-01	
-1.52897E-03	1 24733E	01	C.42496E-01	
-2.649622-03	· 0.24866E	01	0.39977L-01	
-0.11 J56E-02		01	0.35244E-01	

AIX-6

GFAPHITE SI	JEACE DI	MENSI	GNS
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Z	FCC	F.C.1	PC2 .
- 5	1.150 895 01	1.326758 01	0.37957E 61
	2.150996 01	0.326 9CE 01	0.37970E C1
126.	t. 151121 f1	3.327.8F 1.1	0.37989E 01
15'	1.15122 01	0.32726c 01	0.3007E 01
230	C.151328 01	1. 32743. 41	C. 380278 11
250	C.15129L 01	0.32748± 01	C.38042E 01
300	0.15134: 01	0.327611 01	0.380601 01
35L	U.151382 01	0.32773: 01	0.39076E 01
400	3.151416 01	C.32783E C1	0.38792E 01
454	C.15147E C1	0.32787t 01	0.381U5E 01
500	0.151377 01	0.32787E UL	0.38113E 01
	PRESSURE DROPS		
	PD(BORE)	DOI ANNUL LICA	
Z	PO (BURE)	PD(ANNULUS)	
50	3.13996E 05	C.0 0.13322E 05	
11	1.3 1110 (5	0.26321E 05	
150	J.48128r 05	C.45080E 05	
200	C.677831 05	0.636526 05	
25	2.87927 6 05	0.835375 05	
310	Calc 724c 06	0.104898 06	
350	5.131633 (6	G.12769E C6	
400	0.154920 06	0.151816 06	
450	2.178726 06	0.176975 06	
500	L.2"2415 06	C.20274E 06	
211		0+202142 00	

CORROSION DATA

	C. C	LANARREMOVAL			GHNESS HEIGHT	the second second
1	300	RC1	RC2	RCC	RC1	RC2
0	0.0	0.0	0.0	0.0	0.0	0.0
50		0.0		0.0	C.0	. 0.0
100	0.0	0.0	0.0	0.0	0.0	0.0
150	2.0	0.0	0.0	0.0	0.0	C.0
200	0.0	0.0	0.0	0.0	C.0	0.0
250	0.0	0.0	0.0	0.0	C.0	0.0
300	0.9	0.0	0.0	0.0	0.0	0.0
351	2.0	0.0	0.0	0.0	0.0	C.0
400	0.0	0.0	0.0	0.0	0.0	0.0
450	2.0	0.0		0.0	C.0	0.0
500	2.0	0.0	0.0	0.0	0.0	0.0

			HEAT	TRANSFEI	R COEFF.	AND	FRICTION	FACTOR (TRANS	FORMED
2	RCD		RC1		RC2 ·		RCO	RC1	RC2
0	_0.211148	CO	C.122	297E UO	0.37390E	03	0.40532E-02	C.7C8(5E-02	C. 70028E-02
51.	J. 21 385	[1]	0.125	524E 00	1.31.975E	00	C.41070E-02	0.71944E-02	C.71169E-Ca
100	2.21:66E	00	0.127	767E 00	0.27883E.	00	0.417205-02	C.73231E-02	0.72450E-02
150	3.21283	Un	1.13	135F 00	P.26340E	62	C. 42334E-02	0.74468E-02	0.73734E-02
234	21567E	.co	0.133	BILL LO_	0.24595E	C2	C.429165-02	0.7564LE-02	0.74976E-02
250	0.220276	00	0.13	5655 UD	0.24077E	00	0.432525-02	1.76418F-02	r. 75947E-0;
3.10	_J.22296E	00	9.13	779E UD	0.23381E	00	0.436825-02	C.7731 5E-02	C.76851E-02
350	0.22557E	CO	0.139	981E CO	0.22798E	00	0.440825-02	C. 780 97E-02	C. 776 99E-C2
433	2.228341	.00	U.14	169E 00	0.22373F	00	0.44425E-02	C.78792E-02	C. 78457E-02
650	2.231665	00	0.14	3502 60	0.22046E	00	0.44659E-02	C.79314E-02	0.79071E-02
500	1.23468E	60	0.14	SUSE CO.	0.21689E	03	0.44802E-02	0.79647E-02	U. 79490E-02

AIX-7

HEATAT RESULTS         1.162266 0. 0.222956 05 0.223956 05 0000 (.1001816 01 0.001286 00 0.001286 00 0.001286 00 0.001286 01 0.001286 00 0.001286 01 0.001286 00 0.001286 01 0.00													
1.14220E 0.0       0.22335E 05       0.22335E 05       0.0000       0.30120E 01       0.40120E 00		. н. ғ.		RE	SHLT	\$							
13x51E Cd 0.20014E US 0.20014E DS 00E0 C.30225E D1 0.90124E DC 0.90124E 00 0.00125E					500	5							
.12°4 32 ° 6 C. 19214E ° 5 C. 19514E 05 ° 00° C. 30225E 01 C. 98070E 0C C. 98130E CO *R** C. 35287E .12231E (6 C. 1821CE ° 5 C. 18210E 03 *02* C. 30235E 01 0.00128F CC 0.00128F CO *R** C. 35287E .11531E 06 C. 17058E 05 0.17058E 03 *02* C. 30235E 01 0.00128F CC 0.00128F CO *R** C. 35285E .11531E 06 C. 16205E 05 0.12646E 05 *02* C. 30236E 01 0.00128F CC 0.00128F CO *R** C. 35285E .11531E 06 C. 16407E 05 0.12466E 05 *02* C. 30236E 01 0.00128F CC 0.00128F CO *R** C. 35326E .11531E 06 C. 16407E 05 0.12466E 05 *02* C. 30236E 01 0.00148F CC 0.00128F CO *R** C. 35326E .11531E 06 C. 16407E 05 0.14468E 05 *02* C. 30236E 01 0.00462E 0C 0.90926E CO *R** C. 35324E .110174E 36 C. 16407E 05 0.14402F 05 *02* C. 30236E 01 0.00462E 0C 0.90926E CO *R** C. 35330E .10174E 36 C. 16407E 05 0.13466E 05 *02* C. 30230E 01 0.90949E 0C 0.90926E CO *R** C. 35330E .10174E 36 C. 16407E 05 0.13466E 05 *02* C. 30230E 01 0.90968E 0C 0.90926E 00 *R** C. 35330E .00264E 05 C. 13444E 05 0.13444E 05 *02* C. 30230E 01 0.90868E 0C 0.909266E 0 *R** C. 35330E .02264E 05 C. 13444E 05 0.13444E 05 *02* C. 30230E 01 0.90868E 0C 0.90926E 0 *R** C. 35350E .11870 6AS 0UTLET TEMPFRATURE 051. THEFERATURES .11870 6AS 0UTLET TEMPFRATURE 051. .11870 7AS 200 C. 20242 0.2 .11870 7AS 200 C. 20242 0.2 .11870 7AS 200 C. 20242 0.2 .11870 7AS 200 C. 20244E 0.2 .11870 7AS 200 C. 202472 .1287 7AS 200 C. 202472 .1287 7AS 200 C. 203474 .1297 7AS 200 C. 203474 .1297 7AS 200 C. 203774 .1297 7AS 200 C. 203774 .1197 7AS 200 C. 203774 .1197 7AS 200 C. 203774 .1197 7AS 200 C. 204074	.14228E 06	C. 22305E	C5 C	• 22305E	15 *DE	* 1.º 301	81E 01	0.98128E	co 0.	98128E 00	*RM*	n. 35 21 8E	
.12231E ( 6 C.1821CE ( 5 C.1821CE ) S * 0E* C. 3C243E 01 0.9813CE 0C 0.9813BE CO *R** C.35225E .11254E 0.C. C.17058E C5 0.17058E 03 *0E* C.30239E 01 0.98128F CC 0.98128E CO *R** C.35225E .11254E 0.C. C.18276E C5 0.15209E 05 *0E* C.30236E 01 0.98128E CC 0.98128E CO *R** C.35225E .11254E 0.C. C.18276E C5 0.15466E 05 *0E* C.30236E 01 0.9844CE 0C 0.98128E CO *R** C.35307E .11574E 0.7.15466 C5 0.15466E 05 *0E* C.30235E 01 0.9844CE 0C 0.98527E C0 *R** C.353307E .110174E 32 C.14407E C3 C.14407E 05 +0E* C.302375E 01 0.98520E 0C 0.98527E C0 *F** C.35337E .110174E 32 C.14407E C3 0.15466E 05 *0E* C.30231E 01 0.98613E 3C 0.98613E 00 *F** C.35337E .456754E C5 0.16233E C5 0.13768E 03 *0E* C.30230E 01 0.98749E 00 0.98749E 00 *F** C.35336E .22864E C5 C.13444E 05 0.13464E 05 *0E* 0.30275E 01 0.98868E 2C 0.98868E C0 *F** C.35336E .22864E C5 C.13444E 05 0.13464E 05 *0E* 0.30275E 01 0.98868E 2C 0.98868E C0 *F** C.35335CE .11100E FLOW FATE OUTER FLOW RATE .11100E FLOW FATE OUTER FLOW RATE .1110E FLOW FATE OUTER FLOW RATE .11100E FLOW FATE OUTER FLOW RATE .11100E FLOW FATE OUTER FLOW FATE .1	.13651E 06	0.20916E	05 0	. 20916E	05 *DE	¢ (.362	01E C1	0.98126E	oc c.	98126E 00	*RM*	0.352328	E 1
12231E ( 6 C.1821CE ( 5 C.18210E ) 5 *0E* C.30238E 01 0.9013CE 0C 0.90130E 00 *R** 0.35267E         *11501E 06. C.17058E 05 0.17058E 05 *0E* C.30239E 01 0.90128E CC 0.90128E C0 *R** 0.35267E         *11501E 06. C.15209E 05 0.17058E 05 *0E* C.30239E 01 0.90128E CC 0.90128E C0 *R** 0.35295E         *11501E 06. C.15209E 05 0.15466E 05 *0E* 0.30236E 01 0.90440E 0C 0.90372E 0C *R** 0.35295E         *11571E 06 0.14207E 03 0.15466E 05 *0E* 0.30236E 01 0.90440E 0C 0.90840E 00 *R** 0.35307E         *10174* 10 0.14407E 03 0.14407E 05 0.14233E 05 *0E* 0.30236E 01 0.90840E 0C 0.90840E 00 *R** 0.35337E         *10174* 10 0.14233E *5 0.14233E 05 *0E* 0.30230E 01 0.90843E 0C 0.90841E 00 *R** 0.35337E         *10174* 10 0.14233E *5 0.14233E 05 *0E* 0.30230E 01 0.90843E 00 0.90843E 00 *R** 0.35336E         *10174* 10 0.14233E *5 0.14233E 05 *0E* 0.30230E 01 0.90749E 00 0.90843E 00 *R** 0.35336E         *10174* 11 11 11 11 11 11 11 11 11 11 11 11 11	.12043E 06	C. 19514E	15. 0	. 19514E	05_*DE	+ C. 302	25E 01	C. 98096E	oc o.	980965 00	*RM*	0.352498	E
+11501E 06.       0.17058E 05.       0.17058E 05.       0.001       0.001E8F CC       0.00128F CC       0.00128F CC       0.00128F CC       0.00127E CC													
H1156E 0E 0.16209E 05 0.16239E 05 00E+ 0.30226E 01 0.98372E 0C 0.98372E 0C *RM+ 0.35205E         +1157E 7E 0.15466E 05 0.15466E 05 00E+ 0.30226E 01 0.98440E 0C 0.98372E 0C *RM+ 0.35309E         +10174E 3E 0.14807E 05 0.14623E 05 00E+ 0.30275E 01 0.98520E 0C 0.98520E C0 *RM+ 0.35324E         +98764E C5 0.14233E 15 0.14233E 35 00E+ 0.30280E 01 0.98613E 00 0.98613E 00 *RM+ 0.35337E         +98753E C5 0.14233E 05 0.14233E 35 00E+ 0.30280E 01 0.98613E 00 0.98613E 00 *RM+ 0.35336E         +98753E C5 0.14233E 05 0.14233E 35 00E+ 0.30280E 01 0.98749E 0C 0.98749E 00 *RM+ 0.35336E         +98753E C5 0.13768E 05 0.13866 05 00E+ 0.30280E 01 0.98749E 0C 0.98749E 00 *RM+ 0.35336E         +02848E C5 0.13768E 05 0.13844E 05 00E+ 0.30280E 01 0.98668E 0C 0.98868E (0 *RM+ 0.35336E         HARD 045 00TLET TEMPERATURE       091.         TIMEDEATURES       0.1623 760 722         1001 111 111 111 111 111 111 111 111 11	.122312 (6	(.1821CE	C5 0	.182192	05 +UC	A. Dedic	438 01	0.981305	00 0.	98130E CU	*RM*	0.352076	-
AICSYCE C6 0.15446E 05 0.15466E 05 +01+ 0.30246E 01 0.9844CE 0C 0.98520E 00 +RM+ 0.353204E INITZE 36 0.16807E +5 0.14233E 5 +01+ 0.30280E 01 0.98520E 00 -0.98520E 00 +RM+ 0.35324E .987 64E C5 0.14233E +5 0.14233E 5 +01+ 0.30280E 01 0.98613E 00 -0.98613E 00 +RM+ 0.35337E .957 58E C5 0.14233E +5 0.14233E 5 +01+ 0.30280E 01 0.98749E 00 0.98749E 00 +RM+ 0.35336E .927 58E C5 0.13768E 05 0.13768E 05 +01+ 0.30280E 01 0.98749E 00 0.98749E 00 +RM+ 0.35356E .927 58E C5 0.13768E 05 0.13444E 05 +01+ 0.30280E 01 0.98868E 00 0.98868E 10 +RM+ 0.35356E .927 58E C5 0.13764E 05 0.13444E 05 +01+ 0.30280E 01 0.98868E 00 0.98868E 10 +RM+ 0.35356E .927 58E 0.12444E 03 0.13444E 05 +01+ 0.30280E 01 0.98668E 00 0.98868E 10 +RM+ 0.35356E .11040E 0.5 TIME 0.001ES FLOM RATE .11340E 0.5 TIME 0.001ES FLOM RATE .11340E 0.5 TIME 0.0158 FLOM RATE .11340E 0.5 .1140E 0.5 TIME 0.0158 FLOM RATE .11351 1000 747 0.53 574 0.02 .1140E 0.5 TIME 0.0158 FLOM RATE .11351 1000 747 0.53 574 0.02 .1140E 0.5 .1140E 0.5 .1140	.11561E_06	C. 17058E	C50	.17058E	05 *DE	¢ C. 302	59E 01	0.98188F	.cc 0.4	98188E CO	*RM*	C. 35 28 5E	. 0
.10174E 38 6.16807E 05 6.16297E 05 *DE* C.30275E 01 0.905320E 00 0.905220E C0 *FM* C.353324E .907 64E 05 0.16233E 05 0.16233E 25 *DE* C.30281E 01 0.90613E 00 0.90843E 00 *FM* C.35337E .977 56E C1 0.16233E 05 0.13766E 05 *DE* C.30280E 01 0.90843E 00 0.90849E 00 *FM* C.353346E .92244E 05 0.13464E 05 0.13464E 05 *DE* C.30275E 01 0.90866E 00 0.90849E 00 *FM* C.35336E .92244E 05 0.13444E 05 0.13464E 05 *DE* C.30275E 01 0.90866E 00 0.90849E 00 *FM* C.35336E .92244E 05 0.13464E 05 0.13464E 05 *DE* C.30275E 01 0.90866E 00 0.90866E 00 *FM* C.353356E .92244E 0.001FFT TEMPFFRATURE 51. THEF 0 GAS OUTLET TEMPFFRATURE 51. THEF 0 GAS 0.01FFT TEMPFFRATURE 55. THEF 0 GAS 0.01FFT TEMPFFFT TEMPFFFT TEMPFFFT TEMPFFFT T	.11056E 06	C. 16209E	US 0	.16239E	05 *DE	¢ 0.302	56E 01	C.98372E	cc 0.	98372E OC	*RM*	0.352958	÷ c
+96' 45E (5       0.14233E (5       0.14233E 35       *DE*       C.30280E 01       0.98613E 30       *A98213E 00       *AN*       C.33337E         +97' 55E (5       C.1376EE 05       0.13766E 05       0.13766E 05       *05*       C.30280E 01       0.98749E 00       0.98749E 00       *AN*       C.35336E         -22244E (5       C.133444E 05       0.13444E 05       *05*       0.30275E 01       0.98868E 00       0.98868E f0       *AN*       C.35336E         MIAFO GAS OUTLEY TEMPFRATURE       851.         Innis, FLOW RATE       0.16244E 02       851.         Innis, FLOW RATE       0.16244E 02       744       752       512       762       709         335       clo       655       714       771       642       752       512       623       643         464       760       752       512       553       527       309       335       626       967       912       911       623       643       643       644       653       642       522       364       646       642       542       542       542       542       543       542       643       643       644       653       644       653       645       646       642 <td>.1(59/E /6</td> <td>0.15466E</td> <td>05 0</td> <td>. 154665</td> <td>05 *DE</td> <td>* 0.302</td> <td>66E 01</td> <td>0.9844CE</td> <td>oc r.</td> <td>98440E CO</td> <td>*RM*</td> <td>C. 35309E</td> <td>E 1</td>	.1(59/E /6	0.15466E	05 0	. 154665	05 *DE	* 0.302	66E 01	0.9844CE	oc r.	98440E CO	*RM*	C. 35309E	E 1
+96' 45E (5       0.14233E (5       0.14233E 35       *DE*       C.30280E 01       0.98613E 30       *A98213E 00       *AN*       C.33337E         +97' 55E (5       C.1376EE 05       0.13766E 05       0.13766E 05       *05*       C.30280E 01       0.98749E 00       0.98749E 00       *AN*       C.35336E         -22244E (5       C.133444E 05       0.13444E 05       *05*       0.30275E 01       0.98868E 00       0.98868E f0       *AN*       C.35336E         MIAFO GAS OUTLEY TEMPFRATURE       851.         Innis, FLOW RATE       0.16244E 02       851.         Innis, FLOW RATE       0.16244E 02       744       752       512       523       527       309         335       clo       655       714       710       752       512       523       543       624       645       622       463       642       523       643       643       644       735       624       764       752       512       553       507       309       335       646       764       752       512       553       507       309       345       77       932       645       674       713       100       774       931       646       642       646       642 <td>10174F 16</td> <td>0-14807E</td> <td>05 0</td> <td>146076</td> <td>04 *DE</td> <td>. 0.302</td> <td>75E 01</td> <td>*</td> <td>ac c.</td> <td>00520F CO</td> <td>***</td> <td>C- 35324E</td> <td></td>	10174F 16	0-14807E	05 0	146076	04 *DE	. 0.302	75E 01	*	ac c.	00520F CO	***	C- 35324E	
				275.7									
	.98165E 05	C. 14233E	15 0	•14233E	35 * #DE	¢ C.302	81E 01	0.98613E	oc 0.	98613E 00	*RM*	C.35337E	0
DWELL TIME         © DAYS           CHANNEL POWER         C.114102           C.114102         C.6           MIXED CAS OUTLET TEMPERATURE         051.           INNER FLOW RATE         0.16244E.02           TOI         THI           TOI         THI           TOI         C.6224E.0.3           TOI         THI           TOI         TTI	.95( 36E CS	0.13768E	05 0	.13768E	05 *D5	¢ C. 302	80E 01	0.98749E	00 0.	98749E 00	*RM*	C. 35346E	: 0
CHANNEL POWER C.\$1440E C6 MIXED GAS OUTLET TEMPERATURE 851. INNER FLOW RATE OUTER FLOW RATE C.10350E C.3 OUTER FLOW RATE C.10350E C.3 OUTER FLOW RATE C.10350E C.3 OUTER FLOW RATE TG1 MM T11 TF1 TFM TF2 T12 TM2 TG2 TW3 30° CO 655 T14 TR8 752 57C 522 356 370 335 CCO 655 T14 TR8 752 57C 522 356 370 354 CO 655 T14 TB8 752 57C 522 356 370 364 77.9 824 849 701 551 1009 747 699 907 521 501 872 LCC2 1031 1023 1049 1055 842 793 660 666 607 913 1023 1042 1049 1055 842 793 660 666 617 557 1066 1090 1184 1150 955 908 768 766 758 994 1062 1101 1160 1155 1021 568 830 676 758 994 1062 1101 1160 1155 1021 566 884 576 758 994 1062 1101 1160 1155 1021 566 884 576 759 975 1064 1009 1122 1107 1019 594 525 944 INUER SAP HEAT SPLIT RADIUS CUTER GAP 0.42257F-63 C.224103E01 C.221406F-01 0.422162F-64 C.22405E01 C.221406F-01 0.422162F-64 C.22405E01 C.8307F-01 0.42257F-63 C.22405E01 C.8307F-01 0.42257F-63 C.22405E0 01 C.82507F-01 0.42257F-63 C.22405E0 01 C.8307F-01 0.42257F-63 C.22405E0 01 C.8307F-01 0.42257F-63 C.22405E0 01 C.8307F-01 0.42257F-64 C.22405E0 01 C.8403E0F-01 0.42257F-64 C.22405E0 01 C.8403E0F-01 0.42257F-64 C.22405E0 01 C.8403E0F-01 0.42257F-64 C.22405E0 01 C.8403E0F-01 0.42257F-64 C.22405FE0 01 C.8403E0F-01 0.445257F-64 C.2405FE0 01 C.8403E0F-01 0.445257F-64 C.2405FE0 01 C.8403E0F-01 0.45525	.92848E (5	C.13444E	05_0	. 134448	05 *DE	* 0.302	75E 01	0.98868E	00 0.	98868E (·O	*RM*	C. 3535CE	E' t
CHANNEL POWER         INIXED GAS OUTLET TEMPERATURE       851.         INNER FLOW RATE       OUTER FLOW RATE         0.1035CL 03       O.102624E 02         TGI       TMI         TGI       TFI         TFMPERATURES       TCC         TGI       TGI         TGI       TGI         TGI       TTGI         TGI       TGI         TGI													
CHANNEL POWER         MIXED GAS OUTLET TEMPFRATURE       851.         INNER FLOW RATE       OUTER FLOW RATE         0.1035CL 03       O.16264E 02         TGI       TMI         TGI       TFI         TFMPERATURES       TC2         TGI       TMI         TGI       TGI         TGI       TTGI         TGI       TGI         TGI					-				• • • • • • • • • • • • • • • • • • •				
CHANNEL POWER         MIXED GAS OUTLET TEMPFERATURE       051.         INNER FLOW RATE       OUTER FLOW RATE         0.1025CL 03       O.10262642 02         TGI       TMI       TII       TFI         TGI       TMI       TII       TFI         701       511       512       622         TGI       TMI       TII       TFI         703       511       575       624       676         703       511       571       624       676       642         703       511       572       570       522       356       370         354       779       826       849       910       666       611       423       443         561       677       913       1009       747       699       977       521         564       663       975       999       1394       1359       842       793       660       666         661       957       1666       1090       1184       1150       955       908       768       766         755       975       1644       1059       1122       1107       1019       994       925 </td <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>-</td> <td></td> <td></td> <td></td>										-			
CHANNEL POWER         INIXED GAS OUTLET TEMPERATURE       851.         INNER FLOW RATE       OUTER FLOW RATE         0.1035CL 03       O.102624E 02         TGI       TMI         TGI       TFI         TFMPERATURES       TCC         TGI       TGI         TGI       TGI         TGI       TTGI         TGI       TGI         TGI										- 1		a martine	
CHANNEL POWER (*\$1440E 06 MIXED GAS OUTLET TEMPERATURE 851. INNER FLON RATE OUTER FLON RATE 0.076224E 02 TEMPERATURES TG1 TW1 T11 TF1 TFM TF2 T12 TW2 TG2 TW3 30° 500 0.76224E 02 TEMPERATURES TG1 TW1 T11 TF1 TFM TF2 T12 TW2 TG2 TW3 30° 500 0.76224E 02 TEMPERATURES TG1 TW1 T11 TF1 TFM TF2 T12 TW2 TG2 TW3 30° 500 0.76224E 02 TEMPERATURES TG1 TW1 T11 TF1 TFM TF2 T12 TW2 TG2 TW3 30° 500 0.76224E 02 TEMPERATURES TG1 TW1 T11 TF1 TFM TF2 T12 TW2 TG2 TW3 30° 500 0.775 0.7652 356 370 30° 500 0.775 0.776 0.99 0.977 521 50° 50° 50° 50° 50° 50° 50° 50° 50° 50°													A
MIXED GAS OUTLET TEMPERATURE     851.       INNER FLOW RATE 0.103554_03     OUTER FLOW RATE 0.762646_02     0.762646_02       TEMPERATURES 101     TH1     TE1     TF4     TF2     TL2       TG1     TW1     T11     TE1     TF4     TF2     TL2       30'     5'1     575     624     676     642     5U0     453     30'n       30'     5'1     575     624     676     642     5U0     453     30'n       31'     5'1     575     624     676     642     5U0     453     30'n       31'     5'1     575     624     941     971     522     356     370       325     ct0     657     714     788     752     576     522     356     370       561     672     0.97     1031     10'0     74'n     699     477     521       554     663     10'2     1031     10'8     10'8     662     793     640       661     957     1164     1159     150     955     976     768     768       712     991     10'94     117     1205     1175     1001     958     830     857       756<	CHANNEL PO	WER								*	-		
INNER FLOW RATE         OUTER FLOW RATE           0.10354C_03         0.16264E_02           TEMPERATURES         TIL TF1         TFM         TF2         TI2         TW2         TG2         TW3           30°2         50°1         57°5         624         67°6         642         50°         52°         30°9           335         60°0         695         714         788         75°         522         356         30°9           356         60°0         695         714         788         75°         522         356         30°9           356         60°0         695         714         788         75°         522         356         30°9           364         796         920°         94°1         90°1         666         611         423         443           641         796         820°         765         574         60°2         574         60°2         575         574         60°2         575         574         60°2         66°1         66°1         677         913         1023         1048         113°3         110°8         90°2         793         644         67°8         796         712°91         1	MIXED GAS	UTLET TE											
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	INNER FLOW	RATE	OUTER F	LOW RATE							14		
TG1       TW1       TI1       TF1       TFM       TF2       TI2       TW2       TG2       TW3         30:7       50:1       575       624       676       642       500       453       300       309         335       cuto       655       714       788       752       570       522       356       370         364       77.9       826       849       941       901       666       611       423       443         440       79.9       826       947       1019       825       765       574       602       554       863       974       999       1394       1359       842       793       640       664       667       612       131       142       1099       825       765       574       602       662       623       104       131       661       957       1166       1090       1184       1150       955       978       768       768       768       767       713       991       1094       1117       1206       1175       1001       958       830       857         712       991       10:94       1117       1206       1175       <			0.76264	E_02									
335       6C0       695       714       788       752       570       522       356       370         364       7'9       826       849       941       901       666       611       423       443         64/6       796       920       947       1051       1009       747       699       423       443         551       872       10C2       1031       1142       1079       825       765       574       602         555       863       974       999       1079       1059       842       793       640       666         661       957       1166       1090       1184       1150       955       908       768       796         758       994       1064       1117       1206       1175       1001       958       830       857         758       994       1059       1122       1107       1019       994       925       944         INNER SAP       HEAT SPLIT RADIUS       CUTER GAP	TG1	TW1 .											
646       796       920       947       1051       1009       747       699       497       521         501       872       1002       1031       1142       1099       825       765       574       662         554       863       974       999       1034       1059       842       793       640       664         661       957       1066       1090       1184       1150       955       978       768       794       731         712       991       1094       1177       1205       1175       1001       958       830       857         712       991       1094       1155       1001       958       830       857         712       991       1099       1122       1107       1019       994       925       944         1NH 8       SAP       HEAT SPLIT RADIUS       CUTER GAP       521467-01       5464       884       976       944         10.44207E-03       C+24103E 01       C+221407E-01       54509E+01	335 . 1	600	695	714	78	88	752	570	522	356	370	0	
5(1       872       1022       1031       1142       1099       825       765       574       602         554       863       975       999       1394       1359       842       793       640       664         667       913       1023       1048       1143       1108       900       853       704       731         661       957       1066       1090       1184       1150       955       908       768       796         712       991       1094       1117       1206       1175       1001       958       830       857         758       994       1622       1101       1160       1155       1021       586       884       668         795       975       1064       1059       1122       1107       1019       994       925'       944         1NNIS       SAP       HEAT       SPLIT       RADIUS       CUTER GAP       54/42216-01													
667       913       1023       1048       1143       1108       900       853       704       731         661       957       1064       1090       1184       1150       955       908       768       796         712       991       1094       1117       1206       1175       1001       958       830       857         758       994       1682       1101       1150       1155       1021       586       884       968         795       975       1644       1059       1122       1107       1019       994       925       944         INNER SAP       HEAT SPLIT RADIUS       CUTER GAP       6.21465-01       6.21465-01       6.21465-01       6.21465-01       6.21465-01       6.21465-01       6.21465-01       6.21465-01       6.2453655-01       6.2453655-01       6.2453655-01       6.2453655-01       6.2453655-01       6.2453655-01       6.2453655-01       6.2453655-01       6.2453635-01       6.2453635-01       6.2453635-01       6.2453635-01       6.2453635-01       6.2453635-01       6.2453635-01       6.2453635-01       6.2453635-01       6.2453635-01       6.2453635-01       6.2453635-01       6.2453635-01       6.2453635-01       6.2453635-01	5(1	872	1002	1031	110	421	0.99	8 25	765	. 574	· 602	2.	
661       957       1C66       1090       1184       1150       955       908       768       796         712       991       1094       1117       1206       1175       1001       958       830       857         758       994       1C82       1101       1160       1155       1021       586       884       968         795       975       1C44       1059       1122       1107       1019       994       925       944         INNER SAP       HEAT SPLIT RADIUS       CUTER GAP         c.544(22-C2       C.24103E 01       C.221407E-01													
758       994       1082       1101       1180       1155       1021       586       884       968         795       975       1644       1059       1122       1107       1019       994       925       944         INNER SAP       HEAT SPLIT RADIUS       CUTER GAP       0.22140F-01       0.22140F-01       0.22140F-01       0.22140F-01       0.22140F-01       0.22140F-01       0.22140F-01       0.22140F-01       0.22140F-01       0.24510F       0.24560F       0.24560F       0.24560F       0.24560F       0.24560F       0.24560F       0.24550F	661	957	1066	1090	118	84 1	150	955	908	768	796	6	
795       975       1044       1059       1122       1107       1019       994       925       944         INNER SAP       HEAT SPLIT RADIUS       CUTER GAP       0.21405F-01       0.221405F-01       0.221405F-01       0.21405F-01       0.21405F-01       0.21405F-01       0.24505F-01       0.24505F-01       0.24505F-01       0.24505F-01       0.24505F-01       0.24505F-01       0.24505F-01       0.25559E-04       0.25559E-04       0.25559E-04       0.25559E-01       0.53778E-01       0.47295F-01       0.457295F-01       0.25559E-04       0.24651E 01       0.47295F-01       0.25559E-04       0.24651E 01       0.47295F-01       0.24651E 01       0.47295F-01       0.24650E-01       0.24650E-01 <td>758</td> <td>994</td> <td>1082</td> <td>1101</td> <td>118</td> <td>80 1</td> <td>155</td> <td>1021 .</td> <td>586</td> <td>489</td> <td>908</td> <td>9</td> <td></td>	758	994	1082	1101	118	80 1	155	1021 .	586	489	908	9	
2.5544(2E-C2       C.241C3E 01       C.2214CF-01         3.152C7E-C3       (.24394E 01       C.28305E-01         0.64215E-C6       (.24866E 01       C.83374E-01         3.15819E-C6       (.24560E 01       C.85374E-01         3.15819E-C6       (.24560E 01       C.85779E-01         2.5559E-C4       C.24597E 01       C.57793E-01         2.8559E-C4       C.24597E 01       C.85795E-01         2.8559E-C4       C.24651E 01       0.47295E-01         2.25559E-C3       C.24651E 01       C.84795E-01         2.25574E-C3       C.24650E 01       C.84795E-01         2.25574E-C3       C.24650E 01       C.84795E-01         2.25574E-C3       C.24650E 01       C.849294E-01         2.25574E-C3       C.24650E 01       C.84534E-01         2.25574E-C3       C.249967E 01       C.83736E-01         2.45265E-C3       C.24967E 01       C.8373683C-01													
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### GRAPHITE SURFACE DIMENSIONS

2	PCG	KC1	RC2 ·
1.	0.156910 01	1. 32676E 41	*.37958E 01
5)	3.151(16 (1		. C. 37971E C1
13.	0.151125 01		0.37789E (1
150	2.151221 01		0.361076 01
2(-)	5.1513JE 01		0.38026L (1
2: 1	0.151286 61		C. 38741E (1
31.	0.15133t (1		C. 38058E (1
354	2.15137: 01		0.38075E 01
4.30	3.151416 61		2.38091E 01
45:	P.15140E C1		0.38104E 01
500	0.15137E 01	0.32789E 01	0.38112E 01
	1. 1999 - 199 - 199 - 199		
	PESSURE DROPS		
Z	PD(BORE)	PD(ANNULUS)	
1	Got		
51	).12512E 05		and the second sec
1.70	0.268251 15		
153	0.42670E 05		
2:00	0.599218 65		
25	U. 775605 115		· · · · · · · · · · · · · · · · · · ·
3).	0.96216c 05		
351	0.11579F 06		
1.3%	0.13621t 06		
45.	0.15711E 06		
5.	2.178L1E C6	0.17835E ('6	
	10: 15: 20: 3: 4: 5: 10: 5: 10: 5: 10: 5: 10: 5: 4: 5: 4: 5: 10: 5: 4: 5: 5: 10: 5: 5: 5: 5: 5: 5: 5: 5: 5: 5	U 0.150910 01 S) J.151(16 01 100 0.151127 01 100 0.151127 01 200 0.151280 01 210 0.151280 01 250 0.151280 01 350 J.151280 01 350 J.15140 01 500 0.15140 01 500 0.15140 01 500 0.15140 01 500 0.151370 01 9FESSURE DRDPS PD(BORE) C.1 51 J.12512E 05 100 0.268251 05 200 0.56921E 05 201 0.5711E 06	C         6.156.91f         0.1         D.32676E         0.1           5.3         J.151(1E         0.1         0.32669E         01           1.5°         J.151(1E         0.1         0.32669E         01           1.5°         J.151(2E         0.1         0.32726E         01           1.5°         J.15122E         01         0.32726E         01           20.5         S.15133E         01         0.3274E         01           21.9         D.15123E         01         0.3276E         01           31.0         J.15133E         01         0.32782E         01           4.50         J.15141E         01         0.32782E         01           4.50         J.15141E         01         0.32782E         01           4.50         J.15141E         01         0.32782E         01           4.50         J.15137E         01         0.32782E         01           50°         D.15137E         01         0.32789E         01           50°         D.15137E         01         0.32789E         01           50°         D.15137E         01         0.32789E         01           50°         D.15137E </td

CORROSION DATA

and the second		PLANAR REMOVAL			JGHNESS_HEIGHTS	
	00	RC1	RC2	RCO	RC1	RC2
	.0	0.0	0.0	0.0	(.0	0.0
	0.0	0.0	0.0	0.0	0.0	.0.0
	.0	0.0	0.0	0.0.	C.0	0.0
152 2	•0	0.0	0.0	C.0	0.0	C.0
	•0	C.0	0.0	0.0	L.D	0.0
	0.01	0.0	0.0	0.0	0.0	0.0
101111 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	•0	0.0	0.0	0.0	0.0	0.0
35			C.0	0.0	0.0	0.0
	•0	0.0	0.0	0.0	0.0	0.0
451 2	2.	C.0	0.0	0.0	()	0.6
537 3	• 5	0.0	0.0	0.0	6.0	0.0

12

	HFAT TRANSFER COEFF.	AND FRICTION	FACTOR (TRANSF	ORMED)
Z RCD C 2.14898E CD S0 0.14897E CD UC 0.1595E2 CD 5. 0.27166E CD 5. 0.27166E CD 5. 0.27668E CO 0.2 9.881 CO 0.0 0.21114E CD 5. 0.21866E CD 0.0 0.2117E CD 0.0 0.22177E CD	RC1         RC2           0.11649E         0         C.33404E           0.12097E         0         26535E           0.12097E         0         926534E           C.12097E         0         926534E           C.12097E         0         926534E           C.12097E         0         926534E           C.12052E         0         0.223125E           0.12853E         60         0.22594E           C.13045E         0         0.21977E           0.13233E         0         0.21461E           C.13408E         00         0.21078E           0.13785E         0         0.2003E           0.13786E         00         0.22017E	00 U+41850E-U2 00 0+42495E-02 00 0+43108E-02 00 0+4409E-02 00 0+44649E-02 00 0+44649E-02 00 0+4548E-02 00 0+4550E-02 00 0+4556E-02	RC1 C • 72C3PF-02 C • 73197F-02 O • 74492E-02 C • 76731E-02 C • 769C4E-C2 C • 7775E-02 C • 76567E-02 O • 79368E-02 C • 80F 89F-02 O • 60653E-02 C • 81C22E-02	RC2 0+712495-02 0+72424E-02 0+73712E-02 0+75009E-02 0+77208E-02 0+78119E-02 0+7872E-02 0+7872E-02 0+80396E-02 0+80396E-02 0+80857E-02
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				ULTS	• • • • • •					
11	нг	ATA	K KLS							
.131880 06	C. 2)728E	<b>C5</b> C	. 20728E 0	5 *DE*	L. 30185E C	1 0.9814CE	00 0	. 9814PE	00 *RM*	r. 35218
					•					
1.260 2E 116	C. 19435L	05 (	· 19435E 0	15 *DE*	(. 30203F 0	1 0.98128E	00 0	.98128E	00 *RM*	0.35232
1194 3E U6	C. 18123L	15 (	0.18123E 3	5 *DE*	r. 30 225E 0	1 0.981208	00 00	. 9812CF	0 *RM*	0.35249
.112895 (.6	0.16926E	05 0	. 16926E 3	5 *DE*	(+ 30242E C	1 0.98162E	00 00	98162E	00 *RM*	0.35266
10680E . C6	C. 1587 3E	05 0	. 15873E 0	5 *DE*	C. 30258E 0	1 0.982216	00 0	.98221E	00 *RM*	0. 35 28 3
10224E 06	C. 15104E	05 0	0.15104E 0	5 *DE*	r. 30253E	1 0.984COE	00 0	. 98400E	00 *RM*	0.35293
. 98/ 19E 1 5	C. 14425E	05 0	. 14425F 0	5 *DE*	1. 30263E C	1 0.984618	00 0	.93461E	00 *RM*	r. 35307
	(*1442)1					*				
• 4244E 115	C. 13819E	05 (	• 13819E 0	5 *DE*	1.30273E	1 0.98536E	00 0	•98536F	00 *RM*	n. 35321
					r. 30280E	1 0.9862CE		9862FE	00 *RM*	C. 35335
.918 PE C5	G. 13287E	() (	-13287E (	S +UL .	1 . SUZOUE .	1 Ve 900200			<b>U</b> U + NH+	
. 88162E 1.5	C. 1284 2E	(5 (	. 12842E C	5 *DE*	0. 30281E M	1 0.987128	00 00	.98712E	00 *RM*	C. 35345
										0 35350
85944E (5	C. 12516E	n5 (	0.12516E :	)5 *DE*	r. 30276E	1 0.988528	00 0	0.98852E	00 *RM*	C. 35 350
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	and the second statement with the second statement of the									
OWELL TIM	1E =	C DAYS	s							
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DWELL TIM	WER	C DAYS	s							
DWELL TIN	UWER C 6			851.				······································		
DWELL TIM CHANNEL PO D.477COE MIXED GAS INNER FLOW	OWER C6 OUTLET TE	MPERATI	URE FLOW RATE	851.				······································		
DWELL TIM CHANNEL PO D.477COE MIXED GAS INNER FLOW D.95584E	OUTLET TE	MPERATI	URE FLOW RATE	851.						
DWELL TIM CHANNEL PO Q.477COE MIXED GAS INNER FLOV 0.95584E TEMP TG1	OUTLET TE OUTLET TE RATE O2 PERATUPES TW1	MPERATI CUTER I C. 7087	UKE FLOW RATE 1E 92 TF1	TFM	TF2		Tw2	ŢĞ		TW3
DWELL TIM CHANNEL PO D.477COE MIXED GAS INNER FLOV 0.95584E TEME TGI 300	OUTLET TE N RATE 02 PERATURES TW1 522	MPERATI CUTER I C. 7087	UKE FLOW RATE 1E 92 TF1 622	TFM	TF2 651 760		T W2	TG 30 35	in	T W3 310 371
DWELL TIM CHANNEL PO D.477COE MIXED GAS INNER FLOU D.95584E TEMP TG1 340 337 388	UUTLET TE OUTLET TE N RATE O2 PERATURES TW1 522 of 8 711	MPERATI CUTER I C. 7087 TI1 600 7/0 620	URE FLOW RATE 1E 92 TF1 622 719 843	TF4 685 798 941	651 760 899	T12 497 570 658	450 523 607	30 35 7 2	10 6 14	310 371 444
DWELL TIM CHANNEL PC D.477COE MIXED GAS INNER FLOW 0.95984E TEMP TGI 340 339 388 445	DWER C6 DUTLET TE N RATE 02 PSRATUPES TW1 522 of 8 711 793	MPERATI CUTER ( C. 7087 TI1 600 700 620 912	UKE FLOW RATE 1E_92 TF1 622 719 843 937	TFM 685 798 941 1246	651 760 899 1003	T12 497 570 658 736	450 523 607 682	30 35 / 2 / 9	n 6 14. 17	310 371 444 521
OWELL TIM CHANNEL PO 0.477COE MIXED GAS INNER FLOW 0.95584E TEMP TGI 300 337 388 445 505	OUTLET TE OUTLET TE N RATE 02 PERATUPES TW1 522 0'8 711 793 867	MPERATI CUTER I C. 7087 TI1 600 700 620 912 993	URE FLOW RATE 1E_92 TF1 622 719 843 937 1019	TFM 685 798 941 1046 1134	651 760 859 1003 1090	T12 497 570 658 736	450 523 607	30 35 7 2	n 6 7 13	310 371 444
DWELL TIM CHANNEL PC Q.477COE MIXED GAS INNER FLOW 0.95984E TEMP TG1 340 339 388 645	UUTLET TE OUTLET TE N RATE 02 PERATURES TW1 522 678 711 793 867 455 9004	MPERAT( CUTER ( C. 7087. T11 &CC 700 62C 912 991 991 1C1C	UKE FLOW RATE 1E 92 TF1 622 719 843 937 1019 983 1032	TFM 665 798 961 1046 1134 1081 1129	651 760 899 1003 1090 1046 1094	T12 497 570 658 736 812 828 887	450 523 607 682 756 782 842	30 35 4 2 4 9 5 7 6 3 6 9	n 6 7 7 3 	310 371 444 521 601. 660 725
OWELL TIM CHANNEL PC 0.477CCE MIXED GAS INNER FLOW 0.95584E TEMP TG1 340 339 388 445 555 557 617 662	OVER C 6 OUTLET TE A RATE 02 PERATUPES TW1 522 of 8 711 793 867 857 904 904 9	MPERATI CUTER I C. 7087 TIL 600 770 620 912 993 961 1010	URE FLOW RATE 1E_92 TF1 622 719 843 937 1019 983 1032 1075	TFM 665 798 941 1046 1134 1081 1129 1127	651 760 859 1003 1090 1046 1094 1136	T12 497 570 658 736 812 828 887 942	450 523 607 682 756 782 842 897	30 35 22 57 63 69 76	n 6 7 13 13 16 9 2	310 371 444 521 601. 660 725 789
DWELL TIM CHANNEL PO D.477COE MIXED GAS INNER FLOW 0.95584E TG1 300 337 388 445 505 505 557 610 662 713	OUTLET TE OUTLET TE A RATE O2 PERATURES TW1 522 678 711 793 867 355 90% 949 585	MPERATI CUTER 1 6.7087 770 620 912 993 961 1010 1053	URE FLOW RATE 1E_92 TF1 622 719 843 937 1019 983 1032 1075 1176	TFM 685 798 941 1046 1134 1081 1129 1171 1129	651 760 859 1003 1090 1046 1094 1136 1165	T12 497 570 658 736 812 828 887 942	450 523 607 682 756 782 842	30 35 4 2 4 9 5 7 6 3 6 9	n 66 77 13 16 16 19 12 22	310 371 444 521 601. 660 725
OWELL TIM CHANNEL PC 0.477CCE MIXED GAS INNER FLOW 0.95584E TEMP TG1 340 339 388 445 555 557 617 662	UVER C 6 UUTLET TE A RATE 02 PERATURES TW1 522 of 8 711 793 867 711 793 867 855 90% 949 585 597 597	MPERATI CUTER I C. 7087 TII 60C 700 62C 912 993 62C 912 993 1010 1055 1085	URE FLOW RATE 1E 92 TF1 622 719 843 937 1019 983 1032 1075 1106 1103	TFM 6655 798 941 1346 1134 1281 1129 1171 1195 1171	651 760 899 1003 1090 1046 1094 1136 1165 1159	T12 497 570 658 736 812 828 887 942 942 942 942	450 523 607 682 756 782 842 842 897 948	30 35 22 57 63 69 76 82	n 6 7 7 3 	310 371 446 521 601 660 725 789 850
DWELL TIM CHANNEL PC Q.477COE MIXED GAS INNER FLOD Q.95584E TG1 30( 339 388 (45) 555 557 617 662 713 759	UVER C 6 UUTLET TE A RATE 02 PERATURES TW1 522 of 8 711 793 867 711 793 867 855 90% 949 585 597 597	MPERATI CUTER I C. 7087 TII 60C 700 62C 912 993 62C 912 993 1010 1055 1085	URE FLOW RATE 1E 92 TF1 622 719 843 937 1019 983 1032 1075 1106 1103	TFM 6655 798 941 1346 1134 1281 1129 1171 1195 1171	651 760 899 1003 1090 1046 1094 1136 1165 1159	T12 497 570 658 736 812 828 887 942 942 942 942	450 523 607 682 756 782 842 897 948 982	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601. 660 725 789 850 904
DWELL TIM CHANNEL PC D.477COE MIXED GAS INNER FLOW 0.95984E TG1 340 339 388 445 515 557 617 617 662 713 759 797	DWER C 6 DUTLET TE N RATE 02 PERATURES TW1 S22 of 8 711 793 867 455 900 900 900 900 900 900 900 900 900 9	MPERATI CUTER I C. 7087 TII 600 700 620 912 993 661 1053 1053 1053 1085 1051 SFLIT	UKE FLOW RATE 1E 92 TF1 622 719 843 937 1019 983 1032 1075 1106 1103 1105 RADIUS	TFM 665. 798 941 134 135 1129 1171 1129 1187 1133. CUTER	651 760 859 1003 1090 1046 1094 1136 1165 1159 1115 6AP	T12 497 570 658 736 812 828 887 942 990 1019 1021	450 523 607 682 756 782 842 897 948 982 995	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601. 660 725 789 850 904
DWELL TIM CHANNEL PC D.477COE MIXED GAS INNEP FLOV D.95584E TEMP TGI 300 337 388 645 535 557 610 662 713 759 797 INNLEF GAP C.237845-02	DWER C 6 DUTLET TE A RATE 02 PERATUPES TW1 522 of 8 711 793 867 867 85 90% 949 585 99% 949 585 99% 949 585 99% 949 585 99% 949 585	MPERATI CUTER I C. 7087 TIL 600 620 993 961 1053 1053 1055 1085 1055 1085 1051 1051 1051 1085 1051 1051	UKE FLOW RATE 1E 92 TF1 622 719 843 937 1019 983 1032 1075 1106 1103 1105 RADIUS	TFM 665. 798 941 1346 1134 1051 1129 1171 1199 1187 1133. CUTER C.261 C.261	651 760 869 1003 1090 1046 1094 1136 1165 1159 1115 86P 78E-01 851-01	T12 497 570 658 736 812 828 887 942 990 1019 1021	450 523 607 682 756 782 842 842 948 982 995	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601. 660 725 789 850 904
OWELL TIM CHANNEL PC D.427CCE MIXED GAS INNER FLOU 0.95584E TG1 300 388 445 557 610 662 713 759 797 INNEF GAP 0.237845-02 0.237845-02	UVER C 6 OUTLET TE A RATE 02 PERATURES TW1 522 of 8 711 793 867 955 904 949 555 904 949 568 597 962 HEAT 0 0 0 0 0 0 0 0 0 0 0 0 0	MPERATI CUTER I C. 7087 TII 600 700 620 912 993 061 1010 1055 1085 1051 1085 1051 1085 1051 1085 1051	URE FLOW RATE 1E 92 TF1 622 719 843 937 1019 9A3 1032 1075 1106 1103 1065 RADIUS E 01 E 01 E 01 E 01 E 01 E 01 E 01	TFM 665. 798 941 134 1051 1129 1127 1129 1187 1133. CUTER C.261 C.261 C.316 C.415	651 760 859 1003 1090 1046 1094 1136 1165 1159 1115 6AP 78E-01 651-01 851-01 83E-01	T12 497 570 658 736 812 828 887 942 990 1019 1021	450 523 607 682 756 782 842 842 948 982 995	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601. 660 725 789 850 904
DWELL TIM CHANNEL PO D.477COE MIXED GAS INNER FLOW 0.95584E TG1 300 320 320 5557 610 662 713 759 797 INNEF GAP 0.237862-02 0.12664-02 0.12664-02 0.12664-02	OWER C 6 OUTLET TE A RATE 02 PERATURES TW1 522 of 8 711 793 867 355 90% 96% 96% 96% 96% 96% 96% 96% 96	MPERATI CUTER I C. 7087. TIL 600 7700 620 993 961 10153 1053 1055 1085 1055 1085 1055 1085 1051 24293 244'4 24511 245511	URE FLOW RATE 1E_92 TF1 622 719 843 937 1019 983 1032 1075 1106 1103 1065 RADIUS E 01 E 01 E 01 E 01 E 01	TFM 6655 798 941 1046 1134 1081 1129 1171 1195 1187 1133 CUTER CUTER C.261 C.316 C.415 C.523	651 760 859 1003 1046 1094 1136 1165 1159 1115 6AP 78E-01 85E-01 83E-01 83E-01 83E-01	T12 497 570 658 736 812 828 887 942 990 1019 1021	450 523 607 682 756 782 842 897 948 982 995	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601. 660 725 789 850 904
DWELL TIM CHANNEL PC D.477COE MIXED GAS INNER FLOD 0.95984E TG1 300 330 388 445 535 557 610 662 713 759 797 INNLF GAP 0.237665-02 J.13778-03 0.51652-03 0.136765-04	DWER C6 DUTLET TE N RATE 02 PERATURES TW1 S22 of 8 711 793 867 	MPERATI CUTER I C. 7087 FII 600 700 620 912 993 961 1053 1085 1085 1085 1085 1053 1085 1053 1085 1053 1085 1053 1085 1053 1085 1053 1053 1053 1053 1053 1053 1053 105	URE FLOW RATE 1E_92 TF1 622 719 843 937 1019 9A3 1032 1075 1106 1103 1365 RADIUS E 01 E 01 E 01 E 01 E 01 E 01 E 01	TFM 665. 798 941 1346 1134 1291 1127 1127 1133 1133 CUTER C.261 C.261 C.415 C.523 C.535	651 760 869 1003 1090 1046 1094 1136 1165 1159 1115 651-01 835-01 651-01 835-01 835-01 835-01	T12 497 570 658 736 812 828 887 942 990 1019 1021	450 523 607 682 756 782 842 897 982 995	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601. 660 725 789 850 904
DWELL TIM CHANNEL PC D.477COE MIXED GAS INNER FLOW 0.95984E TEMP TG1 300 309 309 309 309 505 505 505 515 557 610 662 713 759 797 INNLF GAP 0.237665-02 3.651652-03 (.126065-04 3.13070-060	DWER C6 DUTLET TE N RATE 02 PERATURES TW1 S22 of 8 711 793 867 	MPERATI CUTER I C. 7087 FII 600 700 620 912 993 961 1053 1085 1085 1085 1085 1053 1085 1053 1085 1053 1085 1053 1085 1053 1085 1053 1053 1053 1053 1053 1053 1053 105	URE FLOW RATE 1E_92 TF1 622 719 843 937 1019 9A3 1032 1075 1106 1103 1365 RADIUS E 01 E 01 E 01 E 01 E 01 E 01 E 01	TFM 6655 798 961 10%6 1134 1081 1129 1171 1133 1133 CUTER (.261 C.316 C.553 C.553 C.553	651 760 869 1003 1090 1096 1094 1136 1165 1159 1115 65F-01 85F-01 85F-01 82F-01 34E-01 34E-01 34E-01 31F-01 15F-01	T12 497 570 658 736 812 828 887 942 990 1019 1021	450 523 607 682 756 782 842 897 982 995	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601. 660 725 789 850 904
DWELL TIM CHANNEL PC D. 47.7COE MIXED GAS INNER FLOV 0.95584E TG1 340 339 398 645 555 610 662 713 759 797 INNLF GAP 0.237645-02 1.9718F-C3 0.42645-02 1.9718F-C3 0.1267645-02 1.13775-03 1.12825-04	DWER C 6 OUTLET TE A RATE 02 PERATUPES TW1 522 of 8 711 793 867 855 904 904 904 904 904 904 904 904 904 904	MPERATI CUTER I C. 7087. TIL 600 7700 620 993 961 1015 1053 1053 1085 1055 1085 1055 1085 1055 1085 1051 24293 24444 24511 24545 24661 24664	URE FLOW RATE 1E_92 TF1 622 719 843 937 1019 983 1032 1075 1106 1103 1065 RADIUS E 01 E 01 E 01 E 01 E 01 E 01 E 01	TFM 6655 798 941 1046 1134 1081 1129 1171 1198 1187 1133 CUTER CUTER CUTER CUTER C-316 C-415 C-503 C-535 C-533 C-534	651 760 859 1003 1090 1046 1094 1136 1165 1159 1115 6AP 78E-01 651-01 835-01 835-01 835-01 345-01 345-01 345-01 335-01	T12 497 570 658 736 812 828 887 942 942 942 942 942 942 942 942 942 942	45° 523 607 682 756 782 842 897 948 982 995	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601. 660 725 789 850 904
DWELL TIM CHANNEL PC 0.477CCE MIXED GAS INNER FLOV 0.95584E TEMF TG1 300 330 388 445 445 555 557 610 622 713 759 797 INNEF GAP 0.237842-02 3.1375-03 0.12676-04 5.156-05 3.13225-04 4.12076-03 3.122821-04 4.12076-03 3.122821-04 4.12076-03 3.122821-04 4.12076-03 3.122821-04 4.12076-03 3.122821-04 4.12076-03 3.122821-04 4.10165-03 3.122821-04 4.10165-03 3.122821-04 4.10165-03 3.122821-04 5.10165-03 5.1285-04 5.10165-03 5.1285-04 5.10165-03 5.1285-04 5.10165-03 5.1285-04 5.10165-03 5.1285-04 5.105-05	DWER C6 DUTLET TE A RATE 02 PERATUPES TW1 522 of 8 711 793 867 867 85 90% 96% 96% 96% 96% 96% 96% 96% 96% 96% 96	MPERATI CUTER I C. 7087. TIL 600 993 961 1053 1053 1053 1053 1055 1055 1055 105	URE FLOW RATE 1E_92 TF1 622 719 843 937 1019 983 1032 1075 1106 1103 1065 RADIUS E 01 E 00 E 00 E 00 E 00 E 00 E 00	TFM 6655 798 941 1046 1134 1081 1129 1171 1199 1171 1133 CUTER (.261 C.316 C.553 C.553 C.5533 C.5544 C.535 C.544	651 760 869 1003 1090 1046 1094 1136 1165 1159 1115 6AP 78E-01 651-01 832-01 832-01 832-01 834-01 345-01 345-01 335-01	T12 497 570 658 736 812 828 887 942 990 1019 1021	45° 523 607 682 756 782 842 897 948 982 995	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601. 660 725 789 850 904
DWELL TIM CHANNEL PC 0.477CCE MIXED GAS INNER FLOV 0.95584E TEMF TG1 300 337 388 445 555 557 610 662 713 759 797 INNEF GAP 0.237842-02 3.13718F-03 0.12676E-04 0.12076F-03 0.12676F-03 0.122821-04 1.1276F-03 0.122821-04 1.1276F-03 0.12676F-03 0.122821-04 1.1276F-03 0.12676F-03 0.122821-04 0.12765-03 0.12676-03 0.122821-04 0.12765-03 0.122821-04 0.12765-05 0.12676-03 0.1286-05 0.1286-05 0.128765-03 0.1286-05 0.12876-03 0.1286-05 0.1286-05 0.128765-03 0.1286-05 0.1286-05 0.128765-03 0.1286-05 0.1	DWER C6 DUTLET TE A RATE 02 PERATUPES TW1 522 of 8 711 793 867 867 85 90% 96% 96% 96% 96% 96% 96% 96% 96% 96% 96	MPERATI CUTER I C. 7087. TIL 600 993 961 1053 1053 1053 1053 1055 1055 1055 105	URE FLOW RATE 1E_92 TF1 622 719 843 937 1019 983 1032 1075 1106 1103 1065 RADIUS E 01 E 00 E 00 E 00 E 00 E 00 E 00	TFM 6655 798 941 1046 1134 1081 1129 1171 1199 1171 1133 CUTER (.261 C.316 C.553 C.553 C.5533 C.5544 C.535 C.544	651 760 859 1003 1090 1046 1094 1136 1165 1159 1115 6AP 78E-01 651-01 835-01 835-01 835-01 345-01 345-01 345-01 335-01	T12 497 570 658 736 812 828 887 942 990 1019 1021	45° 523 607 682 756 782 842 897 948 982 995	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601. 660 725 789 850 904
DWELL TIM CHANNEL PC 0.477COE MIXED GAS INNER FLOD 0.95584E TG1 3.0 3.95 3.92 4.45 5.15 5.57 61' 662 713 759 797 INNEF GAP 0.237862-02 3.13272-04 2.12822-04 2.12825-03 3.132225-04 2.1285-03 3.12225-04 2.1285-03 3.12225-04 2.1285-03 3.12225-04 2.1285-03 3.12225-04 2.1285-03 3.12225-04 2.1285-03 3.12225-04 2.1285-03 3.1285-03 3.1285-03 3.1	DWER C 6 DUTLET TE N RATE 02 PERATURES TW1 S22 of 8 711 793 867 49 793 867 962 964 965 962 969 982 HEAT 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	MPERATI CUTER ( cuTER ( cuTE	URE FLOW RATE 1E_92 TF1 622 719 943 1019 943 1032 1075 1106 1103 1065 RADIUS E 01 E 01	TFM 665. 798 941 1346 1134 1291 1129 1171 1133 1171 1133 CUTER C.261 C.261 C.316 C.415 C.535 C.533 C.544 C.535 C.533 C.544 C.552 C.533 C.544 C.553 C.543 C.543	651 760 869 1003 1090 1096 1094 1136 1165 1159 1115 6AP 785-01 651-01 825-01 825-01 825-01 825-01 341-01 35-01 35-01 35-01 35-01	T12 497 570 658 736 812 828 887 942 990 1019 1021	45° 523 607 682 756 782 842 897 948 982 995	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601. 660 725 789 850 904
DWELL TIM CHANNEL PC 0.477COE MIXED GAS INNER FLOU 0.95984E TG1 3.0 3.95 3.9 4.45 5.55 5.57 61 662 713 759 797 INNEF GAP 0.237662-02 3.13272E-04 2.12718F-C3 1.1227E-04 2.1227E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1325E-03 3.1322E-04 3.1325E-03 3.1325E-03 3.1322E-04 3.1325E-03 3.1225E-04 3.1325E-03 3.1225E-04 3.1225E-03 3.1225E-04 3.1225E-03 3.1255E-03 3.1555E	DWER C 6 OUTLET TE A RATE 02 PERATURES TW1 522 678 711 793 867 855 90% 96% 96% 96% 96% 96% 96% 96% 96% 96% 96	MPERATI CUTER 1 600 700 620 993 961 1015 1053 1055 1085 1055 1085 1055 1085 1055 1085 1051 24293 244'4 24511 24574 24612 24649 24661 2469 24661 2469 24661	URE FLOW RATE 1E_92 TF1 622 719 843 937 1019 983 1032 1075 1106 1103 1065 RADIUS E 01 E 00 E 00	TFM 6655 798 941 1046 1134 1091 1129 1171 1195 1187 1133 CUTER CUTER C.261 C.316 C.415 C.533 C.533 C.534 C.533 C.534 C.532 C.493 C.431	651 760 859 1003 1090 1046 1094 1136 1165 1159 1115 6AP 78E-01 851-01 851-01 827-01 341-01 331-01 01E-01 721-01	T12 497 570 658 736 812 828 887 942 990 1019 1021	45° 523 607 682 756 782 842 897 948 982 995	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601. 660 725 789 850 904
DWELL TIM CHANNEL PC 0.477COE MIXED GAS INNER FLOU 0.95984E TG1 3.0 3.95 3.9 4.45 5.55 5.57 61 662 713 759 797 INNEF GAP 0.237662-02 3.13272E-04 2.12718F-C3 1.1227E-04 2.1227E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1322E-04 2.1227E-03 3.1325E-03 3.1322E-04 3.1325E-03 3.1325E-03 3.1322E-04 3.1325E-03 3.1225E-04 3.1325E-03 3.1225E-04 3.1225E-03 3.1225E-04 3.1225E-03 3.1255E-03 3.1555E	DWER C 6 OUTLET TE A RATE 02 PERATURES TW1 522 678 711 793 867 855 90% 96% 96% 96% 96% 96% 96% 96% 96% 96% 96	MPERATI CUTER I C. 7087 TIL 600 700 620 993 961 1053 1085 1053 1085 1053 1085 1053 1085 1053 24444 245511 24574 24511 24549 24661 24661 24661 24668	URE FLOW RATE 1E_92 TF1 622 719 843 937 1019 983 1732 175 176 1103 1765 103 1765 RADIUS E 01 E	TFM 665. 798 961 10%6 1134. 1091 1129 1171 1133 1133 CUTER C.261 C.316 C.415 C.535 C.533 C.544 C.535 C.533 C.544 C.535 C.493 C.431	651 760 869 1003 1090 1046 1094 1136 1165 1159 1115 64P 785-01 651-01 835-01 835-01 835-01 345-01 345-01 345-01 357-01 315-01 012-01 721-01	T12 497 570 658 736 812 828 887 942 990 1019 1021	45° 523 607 682 756 782 842 897 948 982 995	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601 660 725 789 850 904 942
DWELL TIM CHANNEL PC 0.477COE MIXED GAS INNER FLOD 0.95584E TG1 3.0 3.95 3.92 4.45 5.15 5.57 61' 662 713 759 797 INNEF GAP 0.237862-02 3.13272-04 2.12822-04 2.12825-03 3.132225-04 2.1285-03 3.12225-04 2.1285-03 3.12225-04 2.1285-03 3.12225-04 2.1285-03 3.12225-04 2.1285-03 3.12225-04 2.1285-03 3.12225-04 2.1285-03 3.1285-03 3.1285-03 3.1	DWER C 6 OUTLET TE A RATE 02 PERATURES TW1 522 678 711 793 867 855 90% 96% 96% 96% 96% 96% 96% 96% 96% 96% 96	MPERATI CUTER I C. 7087 TIL 600 700 620 993 961 1053 1085 1053 1085 1053 1085 1053 1085 1053 24444 245511 24574 24511 24549 24661 24661 24661 24668	URE FLOW RATE 1E_92 TF1 622 719 843 937 1019 983 1732 175 176 1103 1765 103 1765 RADIUS E 01 E	TFM 665. 798 961 10%6 1134. 1091 1129 1171 1133 1133 CUTER C.261 C.316 C.415 C.535 C.533 C.544 C.535 C.533 C.544 C.535 C.493 C.431	651 760 869 1003 1090 1046 1094 1136 1165 1159 1115 6AP 78E-01 851-01 851-01 827-01 341-01 331-01 01E-01 721-01	T12 497 570 658 736 812 828 887 942 942 942 942 942 942 942 942 942 942	45° 523 607 682 756 782 842 897 948 982 995	30 35 22 49 57 639 76 82 87	n 6 7 7 3 	310 371 444 521 601. 660 725 789 850 904

#### GEAPHITE SURFACE DIMENSIONS

	a contract to prove the second state of the second state of the					
2	FCL		AC1		RC2	•
t	C.150 930	01	0.32675c	C1	C. 37958E	01
. 51.	C.15101L	01		e1	0.37972E	C1
115	2.151125	01	C.32707E	61	0.37989E	r1
151	1.15121:	01	n. 32723L	t:1	C. 38006E	.01
2.1	3.151291	01	0.32739E	U1	0.38026E	01
2".	5.15127:	C1	C.32743L	C1	P. 38340E	C1
3.1	: . 151321	C1	B. 327565	•1	r.36157E	e1
. 35'	L . 151365				0.38773E	
40 -	6.15140F	01	C.32780E		36969E	(A) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1
451	2.151415		C.32787E	175122	C.38102E	
561	0.151381	01	C. 32789F	c.1.	0.38112E	(1

	PESSURE DROPS	
Z	FD(ECRE)	PD(ANNULUS)
	. C.C	0.0
50	3.11145E US	C.1/295E 05
114	1.2368 E C.5	0.218686 05
150	3.375(8) 05	0.34756E 05
201	3.52510E C5	0.48985E C5
251	1.007818L L5	C.64164E 05
-3.31	D.83486E (5	0.80439E 05
350	C.11 L 951 6.6	0.976L2E U5
412	6.11864± C6 .	0.11620E 06
450	0.136865 66	C.13551E 06
500	0.15515L 06	0.15544E_06

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CORROSION CATA

		ANAR REMOVAL			JGHNESSHEIGHTS.	
1	BCO	RC1	RC2	RCO	RCI	RC2
c	0.0	0.0	0.0	0.0	0.0	. 0.0
. 5(	0.0	0.0	0.0	C.0	0.0	0.0
100	0.0	0.0	0.0	0.0	0.0	C.C
15	0.0	U.C.	0.0	C.0	0.0	0.0
235	3.0	0.0	0.0	0.0	C.D	c.c
251	3.0	0.0	0.0	0.0	C.0	0.0
300	0.0	0.0	0.0	0.0	C.0	0.0
350	2.0	0.0	0.0	C.0	0.0	r.r
4.	2.0	0.0	0.0	0.0	0.0	0.0
451	2.0	0.0	0.0	0.0	C.0	0.0
500	Cat	0.0	0.0	0.0	0.0	0.0

		HEAT TRANSFER	COEFF.	AND	FRICTION FACTOR	(TRANSFORMED)
2	300	RC1	RC2	RCO	· RC1	RC2
Contraction of Contraction	C.186498 CO	0.11011E VO	0.29105E C	0.42	141E-02C.733	59E-02 0.72575E-02
50	2.1871CE 00	0.11201E 00	2.26378E C	0.42	702E-02 C.745	57E-02 0.737705-02
100	0.188110 02	0.114268 00	1.24398E C	0 0.43	3485-02 C.758	62E-02 C.75( 97E-0)
15	5.191278 60	3.11669E 00	0.22528E L	0.43	9595-02 1.771	C2E-02 0.76393E-0
201	2.19278L 60	0.11909L 00	C.21548E (	0 0.44	5425-02 0.782	76F-02 C.77636E-0
25.	J.19680E LA	0.12132E 40	0.21098E C	0 0.44	863E-02 C.790	65E-02 0.78581E-0
300	La199125 (0	9-123086 00	C.20560E (	0 0.45	294E-02 C.799	308-02 0.794935-0
350	T . 2' 1315 ( )	0.12481E UD	0.20100E (	0 0.45	696E-02 C.8C7	38F-02 U.81 347E-02
460	2.2' 354' 00	U.12643E LO	-C.19758E (	C.46	C56E-02 0.814	73E-02 0.81133E-02
45:	3.2'6121 00	0.12848F CU	0.19378E (	19 0.46	3365-02 (.820	81E-02 C.81817E-0
502	3.2. 8695 00	0.13006H 60	0.18764E 0	0.46	507E-02 0.824	97E-02 C.82319E-02

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AIX-11

2.2. .....

INNER FL	OW RATE	CUTER FI C.654144 T11 618 746 816 962 979 596	LOW RATE E 02 TF1 633 724 837 925 1003 966	TFM 750 805 934 1231 1114	TF2 666 767 894 990 1073	T12 500 572 654 726 860	T W2 453 524 604 676 748	TG2 3C0 358 426 498 572	TW3 311 374 446 522 600	
INNER FL	OW RATE				· · · · · · · · · · · · · · · ·			······		
MIXED G	as concer it									
C.44LCC	AS OUTLET TE	MPERATU	RE 851		•					
CHANNEL		C DAYS								
•										
• 79135Ę C	5 0.11572	E 05 0	.11572E 05	*DE* C.	3C 278E 01	∩.98841F	cc c.9	8641F ( N	*PM*	r. 35 35CE
• 81167E C			.11892E 05		30 28 2E 01	C. 98704E			*PM*	C. 35344E
• 863888 0	6 158		.12804E 05		3027CE 01	0.98557E		8557E CO	*RM*	0.35319E
., 90314E C			•13355E 05		30261E 01	0.98489F *	00 0.9	00 46848	*RM*	r. 35 30 5E
.94131E 0	5 C.13966	E OS O	.13966E 05	*DE* 0.	30251E 01	0.98433E	00 0.9	98433E 00	*RM*	0, 35 29 10
. 98226E. 0	5 0.14655	E CS C	•14655E 05	*DE* C.	30256E C1	C. 98257E	00 0.4	8257E 00	*RM*	∩. 35 28 2E
.10377E C			0.15604E 05	-	30224E 01	C. 98197E		98197E CO	*RM*	0.35249E
.10975E 0			.17904E 05		30204E 01	0. 98119E		98119E 00	*RM* .	0. 35 23 2F
11588E C					30188E 01	C. 98134E	CO 0.	98134E 00	*RM*	C.35218E

	GEAPHITE SURF	ACE DIMENSIONS				
L						
L.	PCC C.151545 C1	FC1 0.32676E 01	C.37958E 61			
с 17	J. 151(2.) 01 C. 15112: 01	0.326902 01 0.3271 61 01	1.37971L C1			
	3.13120. 01 3.13128c 61	Co327211 01	0.380071 01			
-	C.15125E 01	0.32737E 01	0.38026E 01 0.38040E 01			
2	3.15132 C1 3.151351 01	0.327545 (1 0.327662 01	7.38756E (1 C.38772E C1			
6	0.151390 01	C.32777E 01	C.38387F 01			
ċ	0.151395 01	0.32787E C1 0.32789E C1	0.38131E C1 0.38111E 01		the second second	19 1. 19 1. 19 <b>1</b>
			- the second			
z	PRESSURE CROPS	PC(ANNULUS)				
i.	jeU .	0.0				
	0.97255F 04 J.2 5828 (5	0.89376F 04 0.16963E 05				
(. r	0.325172 05 0.45410E 05	0.3(1C2E 05 0.423685 05				
6	3.585315 05 0.724121 05	C.55427E 65	· · · · · · · · · · · · · · · · · · ·			
	1.849666 05	0.694182 05 0.84313E 05				
C 4	0.10216E 06 0.11787E 06	C.10012E 06 D.11675E 06				A ST STATIST
à	C.13372E.06					1 1
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	CORROSION DATA					
	CORROSION DATA	D DEWOVAL				
	PLANA	R REMOVAL	· · · · · · · · · · · · · · · · · · ·	ROUGHN		
2	PLANA R.C.' 0 • 0	RREMOVAL 	RC2 0+3		RC1	RC2 0-C
2	PLANA RCC 0.0 2.0	RC1 0.0 0.9	RC2 0+0 0+0	RC0	RC1 C.0 C.0	0.0
2	PLANA R.C.' 0 • 0	RC10.0	RC2 0.0 0.0 0.0 0.0		RC1 C.0 D.0 0.0	0.0 0.0 0.0
Z	PLANAI RCC 0 • 0 0 • 0 0 0 • 0 0 • 0 0 0 0 0 0 0 0 0 0 0 0 0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0	RC2 0.0 0.0 0.0 0.0 0.0 0.0	ROUGHN RCO 0.0 0.0 0.0 0.0 0.0	RC1 C.0 C.0 C.0 G.0 G.0 C.0	0.0 0.0 0.0 0.0 0.0
	PLANA R.C. 0.0 0.0 0.0 0.0 0.0 0.0	RC1 0.0 0.0 0.0 0.0 0.0	RC2 0+0 0+0 0+0 0+0 0+0 0+0	RC0 RC0 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C	RC1 C+0 C+0 C+0 C+0 C+0 C+0	0.0 0.0 0.0 0.0 0.0 0.0
Z	PLANAI RCC 0 • 0 0 • 0 0 0 • 0 0 • 0 0 0 0 0 0 0 0 0 0 0 0 0 0	RC1 0.0 0.0 0.3 0.0 0.0 0.0 0.0 0.0 0.0 0.0	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHN RC0 0.0 7.0 0.0 0.0 0.0 0.0 0.0 0.	RC1 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0	0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAI RCC 0+0 2+C 0+0 2+C 0+0 2+C 0+C 0+C 0+C 0+C 0+C 0+C	RC1           0×0	RC2 0+3 0+0 0+0 0+3 0+0 0+3 0+0 0+0 0+0 0+0	ROUGHN RC0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0	RC1 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAI RCC 0 • 0 2 • C 0 • 0 2 • C 2 • 0 2 • 0 0 • 0 2 •	RC1 0+0 0+0 0+0 0+0 0+0 0+0 0+0 0+0 0+0 0+	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHN RC0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0	0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAI RCC 0+0 2+C 0+0 2+C 0+0 2+C 0+C 0+C 0+C 0+C 0+C 0+C	RC1           0×0	RC2 0+0 0+0 0+0 0+0 0+0 0+0 0+0 0+0 0+0 0+	ROUGHN RC0 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C	RC1 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAI RCC 0 • 0 0 • 0 0 0 • 0 0 • 0 0 0 0 0 0 0 0 0 0 0 0 0 0	RC1           0.0           0.2           0.3           0.0           0.3           0.0           0.3           0.0           0.3           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0	BC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHN RC0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
Z	PLANAI RCC 0 • 0 0 • 0 0 0 • 0 0 • 0 0 0 0 0 0 0 0 0 0 0 0 0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2           0.3           D.0           0.0	ROUGHN RC0 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C	RC1 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAI RCC 0 • 0 2 • C 0 • 0 2 • C 2 •	RC1 0.0 0.2 0.2 0.2 0.0 0.0 0.0 0.0	RC2           0+3           0+0		RC1 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C+0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAI RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2           0.3           0.0	ROUGHN RC0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 C.0 C.0 G.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAI RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1           0.0           0.2           0.3           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.1	RC2           0+3           0+0           0+3           0+0           0+20           0+2156E           0+2156E           0+2156E           0+2156E		RC1 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAI RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1           0.0           0.1/529E           0.1/41E           0.1/41E           0.1/191E	RC2           0+3           D+0           0+0	ROUGHN RC0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAM RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2           0+0           0+20           0+21562           0+21562           0+21562           0+19930E           0+19930E           0+199370E           0+199370F           0+199370F           0+199370F	ROUGHN RC0 C 0 C 0 C 0 C 0 C 0 C 0 C 0 C	RC1 C.O C.O C.O C.O C.O C.O C.O C.O	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANA RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1           0.0           0.2           0.3           0.0           0.3           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.1           0.1           0.1           0.1           0.1           0.1           0.1           0.1           0.1           0.1           0.1           0.1           0.1           0.1           0.1           0.1           0.1	RC2           0+3           D+0           0+19930E           0+19930E           0+19535E           0+19535E           0+19535E           0+19505E           0+19505E           0+186506E           0+186506E	ROUGHN RC0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAM RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1           0.0           0.2           0.3           0.0           0.10 529E CO           0.11712E CO           0.11713E GO           0.11713E GO           0.11862E 00           0.12259E 00	RC2           0+0           0+20           0+21545           0+19355           0+19355           0+19355           0+19355           0+19355           0+183590           0+183592           0+183592           0+183592           0+177204	ROUGHN RC0 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C	RC1 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANA RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1           0.0           0.2           0.3           0.0           0.3           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.1           2.2.2 CO           0.1.52 CO           0.1.52 CO           0.1.52 CO           0.1.52 CO           0.1.52 CO           0.1.55 CE           0.1.1396E           0.11713E           0.11862E           0.11862E	RC2           0.3           D.0           0.0	ROUGHN RC0 C+0 C+0 C+0 C+0 C+0 C+0 C+0 C	RC1 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAM RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1           0.0           0.2           0.3           0.0           0.10 529E CO           0.11712E CO           0.11713E GO           0.11713E GO           0.11862E 00           0.12259E 00	RC2           0+0           0+20           0+21545           0+19355           0+19355           0+19355           0+19355           0+19355           0+183590           0+183592           0+183592           0+183592           0+177204	ROUGHN RC0 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C	RC1 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAM RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1           0.0           0.2           0.3           0.0           0.10 529E CO           0.11712E CO           0.11713E GO           0.11713E GO           0.11862E 00           0.12259E 00	RC2           0+0           0+20           0+21545           0+19355           0+19355           0+19355           0+19355           0+19355           0+183590           0+183592           0+183592           0+183592           0+177204	ROUGHN RC0 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C	RC1 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAM RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1         0.0         0.2         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.1         1.524E         0.11524E         0.11524E         0.11554E         0.11554E         0.11662E         0.12214E         0.12214E	RC2           0+0           0+20           0+21545           0+19355           0+19355           0+19355           0+19355           0+19355           0+183590           0+183592           0+183592           0+183592           0+177204	ROUGHN RC0 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C	RC1 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
	PLANAM RCC 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	RC1           0.0           0.2           0.3           0.0           0.10 529E CO           0.11712E CO           0.11713E GO           0.11713E GO           0.11862E 00           0.12259E 00	RC2           0+0           0+20           0+21545           0+19355           0+19355           0+19355           0+19355           0+19355           0+183590           0+183592           0+183592           0+183592           0+177204	ROUGHN RC0 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C	RC1 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

	н	ЕАТА	AX RES	ULTS						
C.12115E 0	6 t.18916	6E 05	0.18916E 35	*DE* 1	. 30186E 01	0.98152E	00 0.98	152E 00	*RM* C	• 35 21 8E
C. 11467E 0			0.17737E 05		. 30202E D1	0.98138E		138E CU	*RM* C.	. 35231E
C.10876E 0			(.16568E 35		C. 30221E 01		JC 0. 98			. 35247E
. 10295E (			0.15516E 05		. 30237E C1	0.98214E		214E 66		• 35263E
(. 97566E C			0.14595E 35		. 30252E 01	0, 98271E		271E 00	· <del>· · · · · · · · · ·</del>	• 35279E
(. 93574E 0			0.13924E 35		. 30247E 01	C. 98441E		3441E 00		• 35288E
	05 (.13924		0.13327E 05		(, 30257E 01			3493E_00		. 35301E
			0.127885 05		. 30257E 01			559E 00		. 353155
0.86500E C										
			0.12307E 05		C. 30273E C1			3632E 00_		35328F
C. 80896E 0	t		0.11893E 05		6. 30277E 31	C. 98702E		37C2E 00	** *** **	• 35339F
C.739.38.0	050,1157.7	LE _05	0.11577E 05	*DE* C	C. 30273E 01	C, 98834E	20 0.98	1834E 00	*RM* 0.	. 35 34 5E
		11.0								
DWELL CHANNEL Sa4218		U DA	(YS							
	GAS OUTLET T	TEMPER	ATURE 834	6.						
INNEF. F	FLOW RATE	OUTER	R FLOW RATE							
	TEMPERATURES		TF1	TFM	TF2	T12	TW2	TG2	Т₩З	
TG1 	527 605	607	622 710	586	653 752	494 563	448 517	311	311 371	
387		799 883		913 1007	875 969	64 3 712	594	422		
51 2	844831	958	981	1083	1049	783	734 757	563 623	590	
652	878	973 1015	992	- 1382 -	1253	854	814 868	682	71 6	
701	959	1050	1068	1154	1124	957 993	918	759	825	
786	969	10.35	1048	LII3	1094	999	974	899	919	
INNEF GAP C.4(7225- 0.618485-	-1.3	6.2435	T RADIUS 50E 01 315 01	1.29928E	E-01					
3.78861	-03	1. 2454	44F 21	1.454495	5-01					
-3.185625- -0.161226-	-02	0,2464	15E 01 44E 01	- 0.53762F	F-01	÷		-		
-1,75149E- -3,8397(E-	-63	0.2467	98E 11 74E 01	1.59)1(E	E-01	· · · · · · · · · · · · · · · · · · ·				
-0.69025H- -0.48388L-	-13	W. 2467	725 01 756 01	0.555285	L-C1 5-01					
0.420 35E-	-64	0.2469	96E 01 38E 01	0.526438	E-01			•		
		200	A STATE OF THE OWNER WATER OF THE OWNER						AIX	-14
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			:			······································				

	GRAPHITE SURFACE	DIMENSIONS				
1012	er er al de la company de la company de la company		· · · · · · · · · · · · · · · · · · ·			
2	RCC 3.150935 f1	RC1 1.32675E 61,	RC2 5.37958E (1	• • • • • • • • • • • • • • • • • • •		
50		C. 32688E 01	C. 37)71E C1	A second second		and the second
50	0.15111E i 1	1.3271 4E 01	1.37988E 01			
50 30	J. 15126L + 1	3.32718E L1 U.32733E U1	0.38) JSE (1			
513	2.111262 (1	3.32737E (1	".38337E 01		and the second second	
3.1	9.15128L C1	0.32756E 01	C. 38752F 01			
50 00	2.15133E (1 0.15137E (1	0.32761E 01 0.32773E 01	0.38767E (1 1.38383E 01			A A A A MARANA
52		C.32782E U1	0.38796E C1		and the second second	
50	0.15137E (1	0.32784E 01	0.381C6E C1			
	PRESSURE DROPS				-	
L U		PDIANNULUSI				
50	5,943593 (4	0.87078E C4		· · · · · · · · · · · · · · · · · · ·		
30. 50		0.29241E U5				
33	J. 43938E 05	0.410992 1.5				
5.	J. 5661 86 05	0.537/8E 05		4 ···		
50	0.699993 05 0.846 32E 05	0.6719CE 05		and the fighter and the second	and the second	
36.	0.98671E C5	0.96755E 65				
50	J. 1138LL 66	P.11275F 06				
30	C.12906E_G6	0.12930E 06				
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		and the second second				
						and the second se
-					a test at the second	and the second s
				* **************		
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	······································					
		· · · · · · · · · · · · · · · · · · ·				
	CORROSIEN DATA					
*	CORROSIEN DATA	REMOVAL		······································	ESS HEIGHTS	
·			RC2	ROUGHNE	ESS MEIGHTS RC1	RC2
·	PLANAR RCD 0+0	REMOVAL	RC2 0+0	RDUGHNE RCO J • 0	ESS HEIGHTS RC1 C+C	· C.C ·
	PLANAR <u>RCD</u> D+0 D+C	REMOVAL RC1 0.0 0.0	RC2 0.0 0.0	RDUGHNE RCO 0+0 0+0	RC1 C.C C.D	· C.C ·
00	PLANAR RCD D+0 D+0 D+0 D+0	REMOVAL RC1 0.0 0.0 0.0 0.0	RC2 0.0 0.0 0.0 0.0	RDUGHNE RCO J • 0	ESS HEIGHTS RC1 C+C	· C.C ·
00 57 00	PLANAR RCD D+0 3+0 0+0 0+0 0+0 0+0 0+0 0+0	REMOVAL RC1 0.0 0.2 0.2 0.0 0.0 0.0 0.0 0.0	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ESS HEIGHTS RC1 C+C C+D C+D C+D C+D C+D	· C.A. D.A. O.A. C.A. C.A. C.A.
00 51 00 50	PLANAR 3.0 3.0 3.0 3.0 0.0 0.0 0.0 0.0	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0	RDUGHNE RCO 0+0 0+0 0+0 0+0 0+0 0+0 0+0 0+0 0+0	RC1 C+D C+D C+D C+D C+D C+D C+D C+D C+C	· C.C · C.C · C.C · C.C · C.C · C.C
00 51 50 50	PLANAR RC0 D+0 D+0 D+0 D+0 D+0 D+0 D+0 D+	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 3.0 3.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0	RC1 C.C C.D C.D C.D C.D C.C C.C C.C C.C C.C	· C.f · C.f · C.f · C.f · C.f · C.f · C.f
00 50 50 50 50 50	PLANAR RCD D+D D+D D+D D+D D+D D+D D+D D	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0	RDUGHNE RCO 0+0 0+0 0+0 0+0 0+0 0+0 0+0 0+0 0+0	RC1 C+D C+D C+D C+D C+D C+D C+D C+D C+C	· C.C · C.C · C.C · C.C · C.C · C.C
00 50 50 50 50 50 50 50	PLANAR RCD D+D D+D D+D D+D D+D D+D D+D D	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0x0 0x0 0x0 0x0 0x0 0x0 0x0 0x0 0x0 0x	RDUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC1 C+C C+C C+C C+C C+C C+C C+C C+C C+C C	· C • f C • f f • f C • f
00 50 50 50 50 50 50 50	PLANAR <u>RC0</u> D+0 J+0 J+0 D+0 D+0 D+0 D+0 D+0 D+0 D+0 D	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RDUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ESS HEIGHTS RC1 C+C C+C C+C C+C C+C C+C C+C C	· C.f C.f C.f C.f C.f C.f C.f C.f C.f C.f
00 50 50 50 50 50 50 50	PLANAR RCD D+D D+D D+D D+D D+D D+D D+D D	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0x0 0x0 0x0 0x0 0x0 0x0 0x0 0x0 0x0 0x	RDUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC1 C+C C+C C+C C+C C+C C+C C+C C+C C+C C	· C • f C • f f • f C • f
00 50 50 50 50 50 50 50	PLANAR RCD D+D D+D D+D D+D D+D D+D D+D D	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC1 C+C C+C C+C C+C C+C C+C C+C C+C C+C C	Cof Cof Cof Cof Cof Cof Cof Cof Cof Cof
00 57 50 50 50 50 50 50 50	PLANAR <u>RC0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u>3.0</u> <u></u>	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC1 C+C C+C C+C C+C C+C C+C C+C C+C C+C C	C.F C.F C.F C.F C.F C.C C.F C.F C.F C.F
00 50 50 50 50 50 50 50 50 50 50 50 50 5	PLANAR <u>RC0</u> 3.0 3.0 3.0 0.0 0.0 0.0 0.0 0.0	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	SS       HEIGHTS         RC1       C.0         C.0       C.0         FACTCR       (TRANSI         RC1       C.75C43E-02	Cof Cof Cof Cof Cof Cof Cof Cof Cof Cof
00 51 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RC0 D.0 D.0 D.0 D.0 D.0 D.0 D.0 D.	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	SS       HEIGHTS         RC1       C.C         C.D       C.D         C.O       C.C         C.O       C.C         C.O       C.D         C.O       C.C         C.O       C.D         C.O       C.D         C.O       C.D         FACTCR       (TRANS)         RC1       C.TSCLASE-D2         C.TSCLASE-D2       C.TSCLASE-D2         C.TSCLASE-D2       C.TSCLASE-D2	Cof Cof Cof Cof Cof Cof Cof Cof Cof Cof
00 500 500 500 500 500 500 500 500	PLANAR <u>RCP</u> 3.0 3.0 3.0 0.0 0.0 0.0 0.0 0.0	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ESS HEIGHTS RC1 C.C C.D C.D C.D C.D C.C C.C C.C	Cof Cof Cof Cof Cof Cof Cof Cof Cof Cof
500 500 500 500 500 500 500 500 500 500	PLANAR RCD 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	SS     HEIGHTS       RC1     C.C       C.D     C.D       C.O     C.C       C.O     C.O       FACTCR     (TRANSI RC1       C.TS5C43E-02     C.T535E-02       C.T535E-02     C.T7535E-02       C.T7535E-02     C.T9891E-02	Cof Cof Cof Cof Cof Cof Cof Cof Cof Cof
00 50 50 50 50 50 50 50 50 50 50 50 50 5	PLANAR           3.0           3.17384E (C)           3.183(32) (C)	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ESS HEIGHTS RC1 C+C C+C C+C C+C C+C C+C C+C C	Cor Cor Cor Cor Cor Cor Cor Cor
00 55 209 550 550 550 550 550 550 550 550 550 5	PLANAR           3.0           3.17384E (C)           3.183(32 (3))           3.195(32 (3))           3.195(4 (2))	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC1         C+C         C+O         C	C.F C.F C.F C.F C.F C.F C.C C.C C.C C.C
00 500 500 500 500 500 500 500 500 500	RC0           3.17284E           3.18363E           3.18363E           3.18694E           3.18694E           3.18694E	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2           0.0	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	SS       HEIGHTS         RC1       C.C         C.O       C.O         C.O <t< td=""><td>Cof Cof Cof Cof Cof Cof Cof Cof Cof Cof</td></t<>	Cof Cof Cof Cof Cof Cof Cof Cof Cof Cof
00 50 00 00 00 00 00 00 00 50 00 00 50 00 0	PLANAR           3.0           3.17384E (C)           3.17384E (C)           3.18362 (D)           3.18352 (D)           3.18352 (D)           3.18352 (D)           3.19096F (	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC1         C+C         C+C         C+O         C	C.F C.F C.F C.F C.F C.F C.F C.F C.F C.F
00 50 00 00 00 00 00 00 00 50 00 00 50 00 0	PLANAR           3.0           3.173846 (C)           3.173846 (C)           3.173846 (C)           3.17758 (C)           3.183(33) (C)           3.183(33) (C)           3.184	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ESS       HEIGHTS         RC1       C.C.         C.O.       C.O.         FACTCR       (TRANSF         RC1       C.75C43E-O2         C.77535E-O2       C.77535E-O2         C.79891L-O2       U.BI651E-O2         C.82296E-O2       C.82296E-O2         L.83336E-O2       C.82396E-O2	C.F C.F C.F C.F C.F C.F C.F C.F C.F C.F
200 55 550 550 550 550 550 550 550 550 5	PLANAR           3.0           3.17384E (C)           3.17384E (C)           3.18362 (D)           3.18352 (D)           3.18352 (D)           3.18352 (D)           3.19096F (	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC1         C+C         C+C         C+O         C	C.F C.F C.F C.F C.F C.F C.F C.F C.F C.F
00 5 200 200 200 200 200 5 200 5 200 5 200 5 200 5 200 5 200 5 200 5 200 5 200 200	PLANAR           3.0           3.17384E (C)           3.17384E (C)           3.18362 (D)           3.18352 (D)           3.18352 (D)           3.18352 (D)           3.19096F (	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC1         C+C         C+C         C+O         C	C.F C.F C.F C.F C.F C.F C.F C.F C.F C.F
00 5 200 200 200 200 200 5 200 5 200 5 200 5 200 5 200 5 200 5 200 5 200 5 200 200	PLANAR           3.0           3.17384E (C)           3.17384E (C)           3.18362 (D)           3.18352 (D)           3.18352 (D)           3.18352 (D)           3.19096F (	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC1         C+C         C+C         C+O         C	C.F C.F C.F C.F C.F C.F C.F C.F C.F C.F
00 5 200 200 200 200 200 5 200 5 200 5 200 5 200 5 200 5 200 5 200 5 200 5 200 200	PLANAR           3.0           3.17384E (C)           3.17384E (C)           3.18362 (D)           3.18352 (D)           3.18352 (D)           3.18352 (D)           3.19096F (	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC1         C+C         C+C         C+O         C	C.F C.F C.F C.F C.F C.F C.F C.F C.F C.F
00 500 500 500 500 500 500 500 500 500	PLANAR           3.0           3.17384E (C)           3.17384E (C)           3.18362 (D)           3.18352 (D)           3.18352 (D)           3.18352 (D)           3.19096F (	REMOVAL RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHNE RCO 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC1         C+C         C+C         C+O         C	C.F C.F C.F C.F C.F C.F C.F C.F C.F C.F

CORRODED CASE

(b)

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0,13662/0       0,185220       03       0,185270       05       +12+       0,302316       01       0,9811376       70       -*##*       0,332786         0,13066       06       0,1725196       05       +12+       0,302316       01       0,9811376       70       -*##*       0,332786         0,125196       06       0,166326       05       +12+       0,302316       01       0,983476       70       -###*       0,332356         0,125196       06       0,166326       05       +12+       0,302366       01       0,985476       70       +##*       0,353357         0,115516       06       0,152826       0,152826       0,152826       0,1528276       00       0,985476       70       +##*       0,353357         0,110116       06       0,145106       05       0,152826       0,302796       01       0,986377       70       +##*       0,353357         0,100116       06       0,145106       05       0,145106       05       +02+       0,302796       01       0,988277       70       +##*       0,355357         0,100116       06       0,145106       05       0,145106       05       0,152026       05       00<					• · · · · · · · · · · · · · · ·	0,96033E	00 0,9803	3F 00	*RM+ - 0,3527
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0,1203080 00 0,16432E 03 0,16432E 03 0,16432E 03 0,26432E 01 0,98435E 00 0,98455E 00 4.844 0,35325E 0,12035E 04 0,15482E 05 0,15482E 05 0,05 0,05 0,05 0,05 0,058546 0 0,88457E 00 4.844 0,35335E 0,11551E 04 0,15282E 05 0,15282E 05 0,05 0,05 0,05 0,05227E 01 0,98547E 00 4.844 0,35355E 0,11181E 06 0,14481E 05 0,14510E 05 0,05 0,05 0,07 0,05827E 01 0,98827F 00 4.844 0,353515 0,11181E 06 0,14481E 05 0,14510E 05 0,05 0,05 0,07 0,07827E 01 0,98827F 00 4.844 0,353515 0,10011E 06 0,14510E 05 0,14510E 05 0,05 0,05 0,07 0,07827E 01 0,98827F 00 4.844 0,353555 0,10011E 06 0,14510E 05 0,14510E 05 0,05 0,05 0,07 0,07827E 01 0,98827F 00 4.844 0,353555 10,10011E 06 0,14510E 05 0,14510E 05 0,05 0,05 0,07 0,07855E 00 0,08987F 00 4.844 0,353555 10,10011E 06 0,14510E 05 0,14510E 05 0,05 0,05 0,07 0,07855E 00 0,08987F 00 4.844 0,353555 118858 FLOW 8ATC 00178 FLOW 8ATC 0,120458 03 001CET TEMPERATURE 865, 118858 FLOW 8ATC 00178 FLOW 8ATC 0,120458 03 0,05 0,07 0,07 0,07 0,07 0,07 0,07 0,07									
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0,115516 0.0 0,152822 05 0,152822 05 002* 0,302762 01 0,986516 10 *PA* 0,353535 - 0,1118316 04 0,148116 05 0,148116 05 0,020 0,302762 01 0,986276 00 0,988277 00 *RA* 0,353516 - 0,109116 06 0,148116 05 0,145102 05 002* 0,302762 01 0,9898076 00 0,988277 00 *RA* 0,353515 - 0,109116 06 0,145106 05 0,145102 05 002* 0,302762 01 0,9898076 00 0,989876 00 *RA* 0,353555 - 0,109116 06 0,145106 05 0,145102 05 002* 0,302762 01 0,9898076 00 *RA* 0,353555 - 0,109116 06 0,145106 05 0,145102 05 002* 0,302762 01 0,9898076 00 *RA* 0,353555 - 0,109116 06 0,145106 05 0,145102 05 002* 0,302762 01 0,9898076 00 *RA* 0,353555 - 0,109116 06 0,145106 05 0,145102 05 002* 0,302762 01 0,9898076 00 *RA* 0,353555 - 0,109116 06 0,145106 05 0,145102 05 002* 0,302762 01 0,9898076 00 0,989876 00 *RA* 0,353555 - 0,109116 06 0,145106 05 0,145102 05 002* 0,302762 01 0,9898076 00 0,989876 00 *RA* 0,353555 - 0,109116 0,0 0,145106 05 0,145102 05 002* 0,302762 01 0,9898076 00 0,989876 00 *RA* 0,353555 - 0,109116 0,0 0,145106 05 0,145102 05 002* 0,1000 0,9898076 00 0,989876 00 *RA* 0,353555 - 0,109106 0% - 1115 101 111 110 100 RAFE - 0,1004876 0,0 0,100 RAFE - 0,100487 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	0,12519E 06	0,16632E 05	0,160328 05	*DE* 0	.30263E 01	0,96455E			
. 0,11531E 06 0,15502E 05 0,15502E 05 0,2502F 03 0,30279E 01 0,90277E 00 0,98827F 00 +Rw+ 0,35361E 0,110911E 06 0,14510E 05 0,14510E 05 +DE+ 0,30274E 01 0,90985E 00 0,088827F 00 +Rw+ 0,35363E DuftL TIME * 0 DAVS CHANNEL FOULT 0,007000 08 HIXED GAS OUTLET TEMPERATURE 868, INMES LIDU ATE 001FP FLOU BATE 0,12049E 03 00700 FLOU BATE 0,12049E 03 0070 FLOU FLOU BATE 0,12049E 03 0070 FLOU FLOU FLOU FLOU FLOU FLOU FLOU FLOU	0,12005E 06	0,15898E 05	0,158988 05	*DE*0	.30274E 01-	0.9854UE	000,9854	PF-00	*RM* 0,35341
• 0,10911E 06         0,14510E 05         0,14510E 05         0,14510E 05         0,14510E 05         0,150274E 01         0,90908E 00         0,0098FF 00         +R++         0,35553           DWELL TIME *         0 DAYS	0,11551E 06	0,15282E 05	0,152828 05	ob£. 0	.302818 01	0,98659E	00 0,9865	SE (0	*RM* 0,3535
0.10711E 03	. 0,11181E 06	0,148118 05	0 44814E 05	- ope 0	.30279E 01	0,98827E	00 0,9882	7F 00 -	*RM* 0,3536
DWELL TIME         0 DAYS           CHAMMEL POURR 0, 60700E 06         268,           RIXED GAS OUTLET TEMPERATURE         868,           INCED FLOW FATE 0, 60700E 05         00176 FLOW BATE 0.45602E 02           TEMPERATURES         00177 FLOW BATE 0.45602E 02           TEMPERATURES         00178 FLOW FATE 0.100 from 0.100 for 0.100 f	0,10911E 06	0,14510E 05	0,14510E 05	op:* 0	.30274E 01	0,98988E	00 0.9898	FF 00	*RN* 0,3536
DWELL TIME         0 DAYS           CHANNEL POURR 0,60700E 08         668,           HNER FLOW MATE 0,1004E 03         007ER FLOW MATE 0,1004E 03         007ER FLOW MATE 0,1004E 03           THNER FLOW MATE 0,1004E 03         007ER FLOW MATE 0,1004E 03         111         122         112         142         167         143           THNER FLOW MATE 0,1004E 03         007ER FLOW MATE 0,1004E 04         161         111         122         112         142         167         143           161         141         141         141         162         112         142         167         143           161         141         141         747         756         551         356         372           330         562         602         111         747         755         552         544           162         163         164         165         666         646         719           330         562         602         114         1161         966         928         774         755         552         544           162         1131         1162         1162         1023         988         841         643         645           174 <th< td=""><td>- and a second second second</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></th<>	- and a second second second								
DWELL TIME         0 DAYS           CHANNEL POUER 0.60700E 06         665           MIXED GAS DUTLET TEMPERATURE         865.           INNER FLOW RATE 0.12005E 03         DUTER FLOW RATE 0.12005E 03         0017R FLOW RATE 0.12005E 03           TEMPERATURES         017R FLOW RATE 0.12005E 03         017R FLOW RATE 0.12005E 03         017F FLOW RATE 0.12005E 03           101         111         111         111         111           101         111         111         111         111           101         111         111         111         111         111           101         111         111         112         112         112         112           101         111         111         112         112         112         112         112           101         111         112         112         102         112         102         102							The second s		
0,12049E 03         0,85402E 02           TEMPERATURES           161         111         111         1F1         1F2         112         112         102         167         113           300         474         501         599         617         600         486         642         306         308           330         562         602         711         737         717         576         551         556         572           425         770         847         955         995         971         797         755         522         548           425         770         847         955         995         971         797         755         522         548           542         853         944         1642         1067         1063         868         640         719           547         911         997         1075         1118         1162         1147         1021         983         834         866           645         955         1082         1143         1186         1173         1062         1027         896         930           742         955         <	0,60700 Mixed GA	E 06 S OUTLET TEMPER		8.					
T61       TU1       TF1       TF1       TF2       T	0,12049	E 03 0,85							
330       562       602       711       737       717       576       551       350       372         372       675       736       850       856       861       695       660       434       455         425       770       847       955       995       971       797       755       522       548         534       857       930       1022       1064       1063       864       641       613       645         534       857       930       1022       1064       1064       904       868       690       719         542       960       1049       1118       1162       1147       1021       983       834       866         50       642       960       1049       1121       1159       1151       1062       1022       895       930         50       742       995       1069       1121       1159       1151       1065       1045       954       979         50       770       033       1076       1110       1106       1057       1043       991       1008         2       10847F=01       0.23805E 01       (	161 300	TW1 TI1 474 501	1 599	617	600	480	462	300	308
4.62       10.3       944       10.42       10.67       10.63       88P       841       A13       645         5.54       857       939       10.26       10.64       10.49       90.       868       600       719         5.74       951       997       10.75       1114       1101       966       928       764       794         6.42       960       10.49       1118       1162       1147       1021       983       834       866         6.42       960       10.49       1118       1162       1147       1021       983       834       866         6.95       995       10.82       1143       1166       1173       10.62       1027       896       930         742       995       10.69       1121       1159       1151       10.65       1043       991       10.08         0       0.10.025E-01       0.23605E 01       0.15541E-01       0.24682E 01       0.16541E-01       0.08519E-02       0.24682E 01       0.1956E-01       0.085375E-02       0.24682E 01       0.19562E-01       0.085375E-02       0.24682E 01       0.2102E-01       0.085375E-02       0.24681E 01       0.21092E-01       0.085375E-02	330 372	562 602 675 736	2 711 6 850	866	861	695	660	434	455
0         534         937         937         1075         1116         1101         964         928         764         794           0         642         960         1049         1118         1162         1147         1021         983         834         866           0         695         995         1082         1143         1186         1173         1062         1027         895         930           0         742         995         1089         1143         1186         1173         1065         1045         954         979           0         780         976         1033         1076         1110         1106         1057         1043         991         1008           2         INNER GAP         HEAT SPLIT KADIUS         01 TER CAP         (, 15418E+c1         0.033         991         1008           0         0, 03850F=01         (, 15418E+c1         (, 15418E+c1         0.04850F=02         0, 24632E         01         (, 17456E+c1         0.048275E+c1         0.048275E+c1         0.048275E+c1         0.05722         0.24463E         01         (, 21427E+c1         0.048275E+c2         0.24632E         01         (, 21427E+c1         0.0572	482	853 944	4 1042	1087	1063	88H 906	841 868	613	645
0         0         0         0         0         0         1082         1143         1186         1173         1062         1027         896         930           0         742         995         1069         1121         1159         1151         1064         1045         954         979           0         780         976         1033         1076         1110         1106         1057         1043         991         1008           2         INNER GAP         HEAT SPLIT KADIUS         01 TER CAP         0         1057         1043         991         1008           2         INNER GAP         HEAT SPLIT KADIUS         01 TER CAP         0         1057         1043         991         1008           2         INNER GAP         HEAT SPLIT KADIUS         01 TER CAP         01 TER CAP         0         1043         991         1008           2         0         10028-01         0         105418-01         0         105418-01         0         0         1083         991         1008           0         0         10028-01         0         10427E-01         0         10427E-01         0         10427E-01         0	u 587 ·	911 997	7 1075	1118	1101	966 1021	.928 983	764 834 -	866
0     780     976     1033     1076     1110     1106     1057     1043     991     1008       2     INNER GAP     HEAT SPLIT KADIUS     01 TER CAP       0     0,10847F=01     0,23805E 01     0,15418E=01       0     0,10002F=01     0,23805E 01     0,15418E=01       0     0,10002F=01     0,23805E 01     0,17956E=01       0     0,24082E 01     0,17956E=01       0     0,78136F=02     0,24196E 01     0,19210E=01       0     0,68597F=02     0,24488E 01     0,2192E=01       0     0,68597F=02     0,24586E 01     0,2192E=01       0     0,58722F=02     0,24681E 01     0,2160E=01       0     0,52605F=02     0,24586E 01     0,2192E=01       0     0,5272F=02     0,24586E 01     1,214(9E=01       0     0,52605F=02     0,24581E 01     1,23515E=01       0     0,52605F=02     0,25587E 01     1,23515E=01       0     0,55174F=02     0,25557E 01     1,235131E=01	0 695	995 1082	2 1143	1986	1173	1062	1027 1045	895 954	930 979
0 0 0 0 0 0 0 0 0 0 0 0 0 0									
0       0,10002F=01       0,23961F       01       (,16541E=01         0       0,88519F=02       0,24682E       01       (,17956E=01         0       0,78136F=02       0,24196E       01       (,19210E=01         0       0,68036F=02       0,24299E       01       (,20427E=01         0       0,68357F=02       0,24483E       01       (,2092E=01         0       0,68357F=02       0,24684E       01       (,21109E=01         0       0,56722E=02       0,24681E       01       (,21109E=01         0       0,56722E=02       0,24681E       01       (,22420E=01         0       0,52962F=02       0,24678E       01       (,23741E=01         0       0,55174F=02       0,25557E       01       (,23731E=01				1,154188	E=C1				
0 0,78136F=02 0,24196E 01 (,19210E=C1 0 0,68004F=02 0,24299E C1 (,20427E=C1 0 0,68357F=02 0,24483E C1 (,2092E=C1 0 0,62375F=02 0,24586E 01 (,21109E=C1 0 0,52805F=02 0,24681E 01 (,2240E=C1 0 0,52805F=02 0,24681E 01 (,23315E=C1 0 0,52962F=02 0,25689E 01 (,23741E=C1 0 0,55174F=02 0,25557E 01 (,23531E=01		0,239	961E 01	( 16541E	E=01 E=01				
0 0,68357F=02 0,24483E 01 (,20922E=01 0 0,62375F=02 0,24586E 01 (,211(9E=01 0 0,56722E=02 0,24681E 01 (,22480E=01 0 0,52962F=02 0,24673E 01 (,23355E=01 0 0,52962F=02 0,25589E 01 (,23741E=01 0 0,55174F=02 0,25557E 01 (,23531E=01	U 0,10002E=0		196E 01	( .19210E ( .20427E	E=01 E=01				
00         0.56722F=02         0.24681F         01         (.22640E=01           00         0.52805F=02         0.24613E         01         (.23315E=01           00         0.52962F=02         0.25689E         01         (.23315E=01           00         0.55174F=02         0.25557E         01         (.23431E=01	0 0,10002E=0 0 0,88519E=0 0 0,78136E=0							1. 11. 1. A. A. A.	
0 0,52962F+02 0,25089E 01 (,23741E+01 0 0,55174F+02 0,25557E 01 (,23831E+01	0 0,10002E=0 0 0,88519E=0 0 0,78136E=0 0 0,68904E=0 0 0,68357E=0	0.242	483E 01	1,211096					
	0 0,10002F=0 0 0,88519F=0 0 0,78136F=0 0 0,68994F=0 0 0,68357F=0 0 0,62373F=0 0 0,56722F=0	02 0.242 02 0.244 02 0.244 02 0.245 02 0.245	483E 01 586E 01 681E 01	( ,21109E ( ,22680E ( ,23315E	E=01 E=01				
AIX-17	0 0,1002E=0 0 0,88519E=0 0 0,78136E=0 0 0,6859E=0 0 0,6859E=0 0 0,6857E=0 0 0,6837E=0 0 0,56722E=0 0 0,52805E=0 0 0,52962E=0	02 0.24 02 0.24 02 0.24 02 0.24 02 0.24 02 0.24 02 0.24 02 0.25	483E 01 586E 01 681E 01 613E 01 689E 01	( ,21109E ( ,22680E ( ,23385E ( ,23741E	E=01 E=01 E=01				
A1X-17	0 0,1002E=0 0 0,88519E=0 0 0,78136E=0 0 0,6859E=0 0 0,6859E=0 0 0,6857E=0 0 0,6837E=0 0 0,56722E=0 0 0,52805E=0 0 0,52962E=0	02 0.24 02 0.24 02 0.24 02 0.24 02 0.24 02 0.24 02 0.24 02 0.25	483E 01 586E 01 681E 01 613E 01 689E 01	( ,21109E ( ,22680E ( ,23385E ( ,23741E	E=01 E=01 E=01				
	0 0,1002E=0 0 0,88519E=0 0 0,78136E=0 0 0,6859E=0 0 0,6859E=0 0 0,6857E=0 0 0,6837E=0 0 0,56722E=0 0 0,52805E=0 0 0,52962E=0	02 0.24 02 0.24 02 0.24 02 0.24 02 0.24 02 0.24 02 0.24 02 0.25	483E 01 586E 01 681E 01 613E 01 689E 01	( ,21109E ( ,22680E ( ,23385E ( ,23741E	E=01 E=01 E=01				
	0 0,1002E=0 0 0,88519E=0 0 0,78136E=0 0 0,6859E=0 0 0,6859E=0 0 0,6857E=0 0 0,6837E=0 0 0,56722E=0 0 0,52805E=0 0 0,52962E=0	02 0.24 02 0.24 02 0.24 02 0.24 02 0.24 02 0.24 02 0.24 02 0.25	483E 01 586E 01 681E 01 613E 01 689E 01	( ,21109E ( ,22680E ( ,23385E ( ,23741E	E=01 E=01 E=01				4IX-17

50 100 200 250 300 550	0,15094F 01 0,15106F 01 0,15117F 01 0,15126F 01 0,15126F 01 0,15131F 01 0,15137F 01	0,32693E 01 0,32717E 01 0,32737E 01 0,327556E 01 0,32756E 01 0,32761E 01 0,32775E 01 0,32788E 01	0,37957E 01 0,37957E 01 0,37970E 01 0,36013E 01 0,36037E 01 0,36055E 01 0,36074E 01 0,36074E 01	· · · · · · · · · · · · · · · · · · ·		
400 450 500	0,15140F 01 0,15140F 01 0,15137F 01	0,32797E 01 0,32800E 01 0,32799E 01	0.38109E 01 0.38121E 01 0.38129E 01	· · · · · · · · · · · · · · · · · · ·	·····	
- 2	PRESSURE DROPS PD(BORF)	PD CANNULUS)				
0 50	0,0 0,16039E 05	0,0 0,14596E 05				
100	0,54221F 05	0.31305E 05				
200	0,54538E 05 0,76711E 05	0.50292E 05 0.71550E 05		•		
300	0,99536F 05 0,12385F 06	0,944192 05 0,119022 06				
400	0,14950F 06 0,17629F 06.	0,14530E 06 0,17307E 06				
450 500	0,20370F 06 0,23109F 06	0,201952 06				
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				and a construction of a construction of the second s		
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						······································
	CORROSION DATA					
	PLANAR			ROUGHN	ESS HLIGHTS	
Z	PLANAR RCU 0,0	RC1 0,0	RC2 0,0	RDUGHN RC0 0.0	kC1 0.0	RC2 0.0
50 100	PLANAR RCU 0,0 0,0 0,0	RC1 0.0 0.0 0.0	RC2 0.0 0.0 0.0	ROUGHN RC0 0.0 0.0 0.0	kC1 0.0 0.0 0.0	0.0
0 50 100 150 200	PLANAR RCU 0,0 0,0 0,0 0,0 0,0 0,0	RC1 0.0 0.0 0.0 0.0 0.0 0.0	RC2 0.0 0.0 0.0 0.0 0.0 0.0	ROUGHN RC0 0.0 0.0 0.0 0.0 0.0 0.0 0.0	kC1 C, 0 C, 0 C, 0 C, 0 C, 0 C, 0	0.0 0.0 0.0 0.0 0.0
50 100 150 200 250 300	PLANAR RCU 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0	RC1 0.0 0.0 0.0 0.0 0.0	RC2 0.0 0.0 0.0 0.0 0.0 0.0	ROUGHN RC0 0.0 0.0 0.0 0.0 0.0 0.0	kC1 U,0 U,0 U,0 U,0 U,0 U,0 U,0	
0 50 100 150 200 250 300 350 400	PLANAR RCU 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC1 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHN RC0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	kC1           C.0	0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0
50 100 150 200 250 300 350	PLANAR RCU 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0	RC1 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHN RC0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	kC1 U,0 U,0 U,0 U,0 U,0 U,0 U,0 U,0	
0 50 100 150 200 250 300 350 400 450	PLANAR RCU 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC1 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0	ROUGHN RC0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	kC1           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0	
0 50 100 200 250 300 350 400 450	PLANAR RCU 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHN RC0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	kC1 U,0 U,0 U,0 U,0 U,0 U,0 U,0 U,0	
0 50 100 150 200 250 300 350 400 450 500	PLANAR RCU 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2           0.0	ROUGHN RC0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	kC1           G.0	
0 50 100 250 300 400 450 500 250 300 250 300 250 300 250 300 400 450 500 400 450 500 400 4	PLANAR RCU 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC2           0.0	ROUGHN RC0 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C	kC1         0.0         0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
2 2 2 2 2 2 2 2 2 5 0 2 2 2 0 5 0 2 0 5 0 2 0 2 5 1 5	PLANAR RCU 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC1 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	ROUGHN RC0 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C	RC1           0.0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0 50 100 150 250 350 400 500 500 2 0 50 100 50 100 200	PLANAR RCU 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	RC1 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC2           0.0           0.13509E           0.0           0.25829E           0.0	ROUGHN RC0 C.0 C.0 C.0 C.0 C.0 C.0 C.0 C	RC1         C.0         FACTUR         CTURTAR         FACTUR         CTURTAR         C.7L0773E=02         C.71311E=02	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
2 0 50 100 250 350 400 450 500 250 500 200 500 150 200 250 300	PLANAR RCU 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC1 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC2           0.0	ROUGHN RC0 C,0 C,0 C,0 C,0 C,0 C,0 C,0 C	kC1         0.0         0.7246E=02         0.72746E=02         0.72746E=02         0.72746E=02         0.72746E=02	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0 50 100 150 250 350 450 500 500 250 500 250 500 250 350 450 500 500 500 500 500 500 5	PLANAR RCU 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC1 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC2           0.0	ROUGHN RC0 C,0 C,0 C,0 C,0 C,0 C,0 C,0 C	kC1         0.0         0.72746-02         0.727462-02         0.727452-02         0.727452-02         0.77971E-02	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
2 3 2 3 3 3 2 3 3 3 3 3 3 3 3 3 3 3 3 3	PLANAR RCU 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC1 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC2           0.0	ROUGHN RC0 C,0 C,0 C,0 C,0 C,0 C,0 C,0 C	RC1         0.0         0.71311E-02         0.74143E-02         0.75430E-02         0.76291E-02         0.77175E-02	0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0
0 50 100 150 200 250 350 400 450 500 250 100 150 250 300 350 400 450 400 450 500 400 450 400 450 45	PLANAR           RCU           0,0           0,25549F           0,22549F           0,22543F           0,23683F           0,23683F           0,24248F           00           0,242600F           0,242600F           0,242600F	RC1 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC2           0.0           0.1327E           0.0           0.35019E           0.0           0.24857E           0.0           0.24857E           0.0           0.2355E           0.0           0.24767E	ROUGHN RC0 C,0 C,0 C,0 C,0 C,0 C,0 C,0 C	RC1         0.0         0.71311E-02         0.71311E-02         0.74143E-02         0.75491E-02         0.77971E-02         0.75655E-02         0.75446E-02	0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0
0 50 100 150 250 360 350 400 500 250 500 200 200 200 250 350 350 350 200 250 350 350 350 200 250 350 350 350 350 350 350 350 3	PLANAR           RCU           0,0           0,25549F           0,22549F           0,22543F           0,23683F           0,23683F           0,24248F           00           0,242600F           0,242600F           0,242600F	RC1 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,	RC2           0.0           0.1327E           0.0           0.35019E           0.0           0.24857E           0.0           0.24857E           0.0           0.2355E           0.0           0.24767E	ROUGHN RC0 C,0 C,0 C,0 C,0 C,0 C,0 C,0 C	RC1         0.0         0.71311E-02         0.71311E-02         0.74143E-02         0.75491E-02         0.77971E-02         0.75655E-02         0.75446E-02	0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0

0.35218E 01 0.9809CE 00 ..... 0.30171E 01 0,95090E 00 0,25314E U5 \*DE\* 0,16371E 06 0,25314E 05 +RE+ 0.35233E 01 0,98081E 00 ..... 0.30192E 01 0.980818 00 0,23661E U5 \*PE\* 0.15830E 06 0,23661E 05 .RL. 0.98086F 00 0,35251E 01 ..... 0.92086E 00 +1.8+ 0.30220E 01 0.21995E US 0,21995E 05 0,15083E 06 +RE+ 0,98121E 00 .RM+ U. 35251E-01 0.96121E 00 0,20484E US \*DE\* 0.30244E 01 0,20484E 05 0,14244E 06 .RE. 0,35251E 01 ..... 0.98197E 00 0.98192E 00 0.30269E 01 0,19161E US ADES 0,19161E 05 0,13441E 06 .RE. 0,35251E-01 0,98423E 00 -... 0.984238 00 0,18173E 05 -+DE+ 0.30266E 01 0,128326 06 0.18173E 05 .RE. 0.35251E 01 0,98633E 00 +RM\* 0.98633E 00 0,17326E US 0,30286E 01 #DE# 0,173268 05 0,12266E 06 .RE. 0,35251E 01 0.99075E-00 0,99075E 00 --\*R## 0,16577E-05 \*PE\* 0.30313E C1 0.16577E 05 .RE. 0.11760E 06 0,35286E 01 0.10234E 01 .RM+ 0.97096E 00 0,15481E 05 0,16317E U5 \*DE\* 0,30334E 01 .... 0,11318E 06 0-35201E-01 0,10734E-(1--+RH+ 0,16372E 05 \*DE\* 0.93733E-0U 0:30329E-01 0,14297E 05 0.10967E 06 .... 0.35071E 01 .RM. 0,11365E 61 0.8525E 00 0.30311E 01 0,16780E C5 \*DE\* 0,10719E 06 0,13065E 05 +RE+ . 77 DAYS DWELL TIME = CHANNEL POWER 0,58900E 06 852, HIXED GAS OUTLET TEMPERATURE INNER FLOW RATE 0,11909E 03 OUTER FLOW PATE . 0.86548E 02 TW3 307 372 TEMPERATURES 162 TF2 112 TW2 TEL TF1 623 - - Z TW1 TIT TG1 300 498 575 669 466 640 619 ō 300 462 503 359 540 714 328 371 566 626 50 436 450 869 862 100 698 784 711 792 819 51.7 532 757 999 933 971 902 150 427 797 616 1065 842 1023 876 990 682 200 656 1041 1091 1063 860 543 873 977 250 879 934 978 997 723 926 1022 1050 1112 598 922 300 768 817 974 1137 652 967 1068 1096 350 856 877 11/6 1160 1119 705 996 992 1093 600 923 902 1025 1072 1094 450 999 939 953 1082 1017 1009 787 970 1030 1047 500 OTTER CAP HEAT SPLIT RADIUS INNER GAP z 1.15410E=01 0.18800E=01 0.14662F=01 0.79467E=02 0.34553F=02 0.23604E 01 0 0.24079E 01 0.24415E 01 50 24030E=01 27971E=01 30559E=01 100 0.54559E-03 -0.12869E-02 0.24535E 01 150 200 0.24558E 01 0.24670E 01 30195E=01 30474E=01 32127E=01 250 -0.53455E-03 -0,11451F-02 -0,12286F-02 0.24682E 01 300 0,24732E 0,24805E 01 32191E=01 31609E=01 -U.16776F=02 -U.10563F=02 U.15028F=02 01 400 0.249816 01 450 20599E-01 0.25274E 01 500 AIX-19 , GRAPHITE SURFACE DIMENSIONS

HEATAX RESULTS

	GRAPHITE SURFA	CE DIMENSIONS				
2	RCO	RC1	KC2 .			
ū	U.15086F 01	0.326/7E 01	0,37957E 01		· · · · · · · · · · · · · · · ·	
50	0,15096E 01	0.326928 01	0,37971E (1			
100	0,15110E 01	0,32710E 01	0.37990E C1			
150	0,15122F 01	0.32728E 01	0.31009E (1			
200	0.15134E 01	0.32745E 01	0.36030E 01	a many many distance		and a service the last
250	0,15133F 01	0.32749E 01	0.36047E 01			
500	0,15143F 01	0.32759E 01	0.31069E 01		and and the set of the	a (1)
350	0,15150F 01	0,32765E 01	0.38100E 01		194 (	
600	0,15167E 01	0.32765E 01	0.36150E 01-			
650	0.15165F 01	0,32763E 01	0.36214E 01		5	
500	0,15155E 01	0,32761E 01	0.38273E 01			· · · · · · · · · · · · · · · · · · ·
	PRESSURE DROPS					
2	PD(BORF) U,U	PD CANNULIIS) 0.0				
50	0.15455F 05	0.14963E 05				
100	U. 33339E 05	0.31857E 05				
50	0.536388 05	0.50829E 05				
00	0,75856E 05	0.71843E 05				
50	0,98618E 05	0,94333E 05				
500	0,12275E 06	0.11857E 06				1
50	0,14812F 06	0,14375E 06				
DU	0.17489F 06	0,17068E 06				
50-	0,20216F 06	0.19944E 06				**************************************
500	0,22899F 06	0,229408 06				· · · · · ·
	0,228996 06					
	U,22899F 06					
	U, 22699F 06					
	U, 22599F 06	0,22940E 06				
	U,22899F 06 CORROSION DATA PLANAS	0,22940E 06		RCUGHNI		
2	U, 22599F 06 CORROSION DATA PLANAS RCU	0,22940E 06	RC2	RCO	FC1	RC2 0,15280F+09
2	0,22899F 06 0,22899F 06 CORROSION DATA PLANAJ RCU 0,26138E=07	0,22940E 06	0,15280E=09	RC0 0,26138E-07	FC1 C.31123E=07	RC2 0,15780F+09 0,48999F+08
2 50	0,22899F 06 0,22899F 06 CORRUSION DATA PLANAN RCU 0,26138E=07 0,77137E=06	0,22940E 06	0,15280E+09 0,46999E+08	RC0 0,26138E=07 C,77137E=06	FC1 0.31123E-07 0.37078E-06	0.15780E=09 - 0.48999E=08
2 0 50 00	0,22899F 06 CORROSION DATA PLANAS RCU 0,26138E=07 0,77137E=06 0,20182E=04	0,22940E 06	0.15280E=09 0.46999E=08 0.16543E=06	RC0 0,26138E=07 C,77137E=06 0,20182E=04	FC1 C.31123E=07	0,15780E=09 - 0,48999E=08 0,16543E=06 0,28667E=05
2 0 50 000 50	0,22899F 06 0,22899F 06 CORRUSION DATA PLANAN RCU 0,26138E=07 0,77137E=06	0,22940E 06	0,15280E+09 0,46999E+08	RC0 0,26138E=07 C,77137E=06	FC1 U,31123E-07 U,37U78E-06 U,40914E-05	0.15780E=09 0.48999E=08 0.16543E=06
2 0 50 50 50 00	0,22899F 06 0,22899F 06 CORROSION DATA PLANAI RCU 0,26138E=07 0,77157E=06 0,20182E=04 0,13836F=03	0,22940E 06	0.15280E=09 0.46999E=08 0.16543E=06 0.26667E=05	RC0 0,26138E-07 0,27137E+06 0,20182E+04 0,13836E-03	FC1 C,31123E-07 C,37078E-06 C,40914E-05 U,26714E-04 U,12680E-03 C,20163E-03	0,15780E=09 - 0,48999E=08 0,16543E=06 0,28667E=05
Z 0 50 00 50 00 550 80 00	0,22899F 06 0,22899F 06 CORROSION DATA PLANAS RCU 0,26138E=07 0,77157E=06 0,20182E=04 0,13836E=03 0,50193F=03	R REMOVAL RC1 0,22940E 06 RC1 0,31123E=07 0,37078E=06 0,40914E=05 0,26714E=04 0,12680E=03	0,15280E+09 0,46999E+08 0,16543E+06 0,2667E+05 0,30938E+04 0,14720E+03 0,66514E+03	RC0 0,26138E=07 C,77137E=06 0,20162E=04 C,13836E=03 0,50193E=03 0,48234E=03 C,98179E=03	FC1 C, 31123E-07 C, 37078E-06 U, 40914E-05 U, 20714E-04 U, 12680E-03 C, 20163E-03 U, 52229E-03	0,15280F+09 0,48999F+08 0,16543F+06 0,28667F+05 0,30938F+04 0,14720F+03 0,60514F+03
2 0 50 100 250 250 250 250 250	0,22899F 06 0,22899F 06 CORROSION DATA PLANAI RCU 0,26138E=07 0,77157E=06 0,20182E=04 0,3836E=03 0,50193F=03 0,48254E=03	REMOVAL RC1 0,22940E 06 RC1 0,31123E+07 0,37078E+06 0,40914E+05 0,26714E-04 0,12680E+03 0,20163E+03	0,15280E+09 0,45999E+08 0,16543E+06 0,25667E+05 0,30938E+04 0,14720E+03 0,66514E+03 0,20245E+02	RC0 0,26138E=07 C,77137E=06 0,20182E=04 G,13836E=03 0,50193E=03 0,48234E=03 C,98179E=03 C,18296E=02	FC1 C, 31123E=07 C, 37078E=06 U, 40914E=05 U, 20714E=04 U, 12680E=03 C, 20163E=03 C, 52229E=03 C, 11552E=02	0,15280F+09 0,48999F+08 0,16543F+06 0,28667F+05 0,30938F+04 0,14720E+03 0,60514F+03 0,20245F+02
2 50 100 150 250 250 250 250 250 250	0,22899F 06 0,22899F 06 CORROSION DATA PLANAI RCU 0,26138E=07 0,77157E=06 0,20182E=04 0,13836F=03 0,50193F=03 0,50193F=03 0,48254E=03 0,98179E=03 0,98179E=03 0,18290E=02 0,26382E=02	R REMOVAL RC1 0,22940E 06 RC1 0,31123E+07 0,37078E+06 0,40914E+05 0,26714E+04 0,12680E+03 0,20163E+03 0,52229E+03 0,52229E+03 0,11552E+02 0,20882E+02	0,15280E+09 0,45999E+08 0,16543E+06 0,25667E+05 0,30938E+04 0,14720E+03 0,65514E+03 0,20245E+02 0,53885E+02	RC0 C,26138E=07 C,77137E=06 C,20182E=04 C,13836E=03 C,50193E=03 C,48234E=03 C,98179E=03 C,18296E=02 C,26382E=02	FC1 C, 31123E=07 C, 37078E=06 C, 40914E=05 C, 26714E=04 C, 12680E=03 C, 20163E=03 C, 20163E=03 C, 52229E=03 C, 52229E=03 C, 11552E=02 C, 20882E=02	0,15780F+09 0,48999F+08 0,16543E+06 0,28667E+05 0,30938F+04 0,14720E+03 0,60514E+03 0,20245E+02 0,53885E+02
2 0 50 50 50 50 50 50 50 55 50	0,22899F 06 0,22899F 06 CORROSION DATA PLANAS RCU 0,26138E=07 0,77137E=06 0,20182E=04 0,13836F=03 0,50193F=03 0,50193F=03 0,98179E=03 0,18296E=02	0,22940E 06	0,15280E+09 0,45999E+08 0,16543E+06 0,25667E+05 0,30938E+04 0,14720E+03 0,66514E+03 0,20245E+02	RC0 0,26138E=07 C,77137E=06 0,20182E=04 G,13836E=03 0,50193E=03 0,48234E=03 C,98179E=03 C,18296E=02	FC1 C, 31123E=07 C, 37078E=06 U, 40914E=05 U, 20714E=04 U, 12680E=03 C, 20163E=03 C, 52229E=03 C, 11552E=02	0,15280F+09 0,48999F+08 0,16543F+06 0,28667F+05 0,30938F+04 0,14720E+03 0,60514F+03 0,20245F+02

4	RCO	RC1	PC2	RCO	NCI	
U	0,22443F 00	0.128U8E 00	0.45117E CO	C.39768E=02	0.698591-02	0.690196-02
50	0,22296E 00	0.13076E 00	0.34679E 00	C.40271E=02	0.71035E=02	0,702181-02
00	0.22233F 00	0.13367E 00	0.29722E 00	0.410948-02	0.72332E=02	0,715386-02
50	0,22428F 00	0.13665E 00	0,27393E 00	C.41718E=02	U.74009E=02	0.73269E.02
00	0;22722E 00	0.13947E 00	0.25993E 00	0.42303E=02	0.75191E-02	0.745148.02
50	0,23200F 00	0.14228E 00	0.25190E 0C	C.42646E-02	1.75996E=02	0,75487E-02
100	0,23482E 00	0.14426E 00	0.24437E 00	C.43080E=02	U.70049E=02	0.76396F=U2
550	0,23739F 00	0.14585E 00	0,23703E 00	0.43795E=02	1,77638E=02	0.77743E-02
00	0,24194E 00	0.1475UE 00	0.23159E 00	0,45417E=02	1.789011-02	0.816901-02
50	0,24499F 00	0.14924E CO	0.24180E 00	0.45353E+02	U,803681-02	0.93111E-02
500	0.24718E 00	0.151/1E 00	0.25162E 00	0.44364E=02	U.82079E-02	0.10440F-01

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#### HEATAX RESULTS.

0.98128F 00 ..... 0.35217E 01 0.30178E 01 0.98128E 00 0.15175E 06 0,24074E 05 0.24074E US \*1.5\* \*R1+ 0.35231E 0 0.98108E 00 0.98108E 00 ..... 0.30199E 01 0,14599E 06 0,22603E 05 0,22603E U5 +DE+ \*RE\* 0.98091F 00 ..... 0.35249E 01 0,98091E OU 0,21079E U5 0.30226E 01 .... 0.13859E 06 0,21079E 05 \*DE\* 0,352498 01 0.981228 60-..... 0.30253E 01 0.96122E OU 0,19006E US \*DE\* .... 0,13083E 06 0,19666E 05 0.35249E 01 0.98232E 00 0.98232F 60 ..... 0,30292E 01 \*DE\* \*RE\* 0.12346E 06 0,18405E 05 0.18405E US 0,984988 00- +RM 0-35249E 01 0.30287E 01 0.98498E 00 0,11793E 06 0,17470E 05 0,17470E 05 \*DE\* .... 0.35249E 01 0.30326E 01 0.98908E OU 0.9890EF 60 +RH+ +DE+ 0,16651E 05 0,16051E US 0,11275E 06 .... 0.35275E-01 0,16240E-05 \*DE\* 0.30377E 01 0,97534E 00 0.101858 61 \*84\* 0,15551E 05 0.10807E 06 .... 0.35174E 08 0,1084CE 61 ..... 0,10396E 06 0,14114E 05 0,16286E 05 .DE. 0,30417E 01 0.9394UE 00 .RE. 0.34932E 01 0,84634E 00 0,12102E 01----0,17129E U5 ....... 0,30413E-01 0.100726 06 0.11979E 05 .... 0,1231CE 61 \*RM\* 0.35014E 01 0,87895E 00 0,11823E 05 0,16558E 05 \*DE\* 0,30384E 01 0,98488E 05 \*RE\*

DWELL TIME = 231 DAYS

CHANNEL POWER 0,55100E 06

MIXED GAS OUTLET TEMPERATURE 851.

INNER FLOW RATE OUTER FLOW RATE 0,11040E'03 0,82310E 02

		TEM	PERATUR	ES								1
1	Z	TGI	TWI	111	TF1	TFI	TF2	112	TWZ	167	1.0	
	0	300	486	549	613	651	622	493	451	300	30	
	50	332	589	673	709	766	736	568	523	355	36	
	100	380	709	817	843	919	885	604	613	422	44	2
	150	436	801	921	950	1030	1001	750	695	496	- 52	0 0
	200	498	880	1007	1038	1130	1094	830	772	574	60	3
	250	552	873	983	1010	1089	1060	849	801	641	66	6
	300	607	921	1031	1057	1137	1108	908	861	707	· 73	4
	350 -	661	957	1066	1092	11/3	1147	959	914	772	80	0
		/14	978	1081	1106	1165	1162	997	957	832	85	8
	400	A Fair West	COR1 (21)	1063	1084	1150	1133	1009	978	884	90	2
1	450	761	978	10110-0710-0	1047	1099	1087	1008	986	921	23	5
	500	798	960	1031	1047	1077	1001					
1		and the second second					-		and and the	and marine .		
	2	INNER GAP	HE	AT SPLIT R	ADIUS	ULTER CAP	and the second second					

2	INNER GAP	HEAT SPLIT RADIUS	ULTER GAP
0	U.72306F=02	0.23972E 01	C.10746E=C1
50	0,32153F=02	0,24301E 01	C.238(8E+C1
100	-U. 46472E-03	0.24474E 01	(,31247E=01
150	-0.51410F-03	0.24534E 01	1,3/326E=01
200	-0,53392F=03	0,24574E 01	( , 420.28E=01
250	=0.44347F=03	0.24633E 01	C.40036E=01
300	=U.53912F=03	0.24654E 01	( .409(7E=01
350	-0.52740E=03	0,24732E 01 .	1,42730E=C1
400	-0.34050F=03	0,24818E 01	( 424421=01
450	-0.51626E-03	0.24917E 01	C. 39901E=01
500	-0,96662E=03	0,25078E 01	(,35193E+01

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GRAPHITE SURFACE DIMENSIONS

2 50 100 150 200 250 300	RC0 Q,15089F 01 Q,15099F 01 Q,15113E 01 Q,151126F 01 Q,15143F 01 Q,15143F 01 Q,15163F 01	RC1 0,32675E 01 0,32689E 01 0,32748E 01 0,32725E 01 0,32745E 01 0,32748E 01 0,32748E 01	KC2 0,37957L 01 0,37970E 01 0,37978E 01 0,35006E 01 0,36027E 01 0,36027E 01 0,36026 01	· · · · · · · · · · · · · · · · · · ·	······	· · · · · · · · · · · · · · · · · · ·
350 400 450 500	0.15188F 01 0.15209F 01 0.15206F 01 0.15206F 01 0.15192F 01	0,32743E 01 0,32729E 01 0,32712E 01 0,32712E 01	0,38074E 01 0,38125E 01 0,38356E 01 0,38356E 01 0,38505E 01			
2 0 50 100 150 200 250 300 350 400 450 500	PRESSURE DROP PD(BORE) 0,0 0,13850E 05 0,29831E 05 0,47683F 05 0,670%6F 05 0,87003F 05 0,10647E 06 0,13187E 06 0,15720F 06 0,18303E 06 0,20808E 06	S PD (ANNULUS) 0.0 0.134946 05 0.286806 05 0.457086 05 0.645476 05 0.846686 05 0.106066 06 0.128816 06 0.128816 06 0.153728 06 0.181746 06 0.208226 06		•		•
				-		
2 0 50 50 50 50 50 50 50 50 50 50 50 50 5	CORROSION DATA PLANA RCU 0,15435F=06 0,37446E=05 0,71572E=04 0,43478E=03 0,15675E=02 0,14488F=02 0,29288E=02 0,50786E=02 0,6926E=02	R REMOVAL RC1 0,65869E=07 0,810/1E=06 0,95864E=05 0,64404E=04 0,30350E=03 0,49836E=03 0,13124E=02 0,29421E=02	RC2 0,46151E=09 0,13260E=07 0,40580E=16 0,64558E=05 0,74513E=06 0,35547E=03 0,14879E=C2 0,49398E=C2 0,49398E=C2	ROUGHN RCO 0,15435E+06 C,37446E+05 C,71572E+04 -0,43478E+03 C,15675E+02 C,14428E+02 C,29288E+02 C,50786E+02 C,50786E+02	RC1 U,65869E-07 U,81071F-06 U,95864E-05 G,64404E-04 U,3U350E-03 U,49836E-03 U,13124E-02 U,29421E-02	R(2 0,44151E=09 0,13260E=07 0,40580E=06 0,64558E=05 0,74513E=04 0,35547E=03 0,14879E=02 0,49398E=02
0 50 100 150 150 150 150	PLANA RCU 0,15435F=06 0,37446E=05 0,71572E=04 0,43478E=03 0,15675E=02 0,14488F=02 0,29288E=02	R REMOVAL RC1 0.65869E+07 0.810/1E+06 0.95864E+05 0.64404E+04 0.30350E+03 0.49836E+03 0.13124E+02	0,46151E=09 0,13260E=07 0,40580E=06 0,64558E=05 0,74513E=04 0,35547E=03 0,14879E=02	RC0 0,15435E+06 C,37446E+05 C,71572E+04 0,43478E+03 C,15675E+02 C,14428E+02 0,29288E+02	kC1 U,65869E-07 U,81071F-06 U,95864E-05 U,64404E-04 U,3U350E-03 U,49836E-03 U,13124E-02	0,48151E+09 0,13260E+07 0,40580E+06 0,68558E+05 0,74513E+04 0,35547E+03
0 50 100 50 50 50 50 50 50	PLANA RCU 0,15435F=06 0,37446E=05 0,71572E=04 0,43478E=03 0,15675E=02 0,14488F=02 0,29288E=02 0,50786F=02 0,69226E=02 0,67776F=02	R REMOVAL RC1 0.65869E+07 0.810/1E+06 0.95864E+05 0.64404E+04 0.30350E+03 0.49836E+03 0.13124E+02 0.29421E+02 0.53242E+02 0.69123E+02	0,46151E=09 0,13260E=07 0,40580E=+6 0,64558E=05 0,74513E=04 0,35547E=03 0,14879E=02 0,49398E=02 0,12918E=01 0,25437E=01 0,39536E=01	RC0 0,15435E=06 0,37446E=05 0,71572E=04 0,43478E=03 0,15675E=02 0,14468E=02 0,2928E=02 0,69226E=02 0,69226E=02 0,55692E=02	kC1 U,65869E-07 U,81071F-06 U,95864E-05 U,64404E-04 U,3U350E-03 U,49836E-03 U,13124E-02 U,29421E-02 U,53242E-02 U,69123E-02	0.48151E+09 0.13260E+07 0.40580E+06 0.68558E+05 0.74513E+04 0.35547E+03 0.14879E+02 0.49398E+02 0.12913E+01 0.25600E+01 0.25600E+01

•	0,898866 05	0,1	119566	E 05	0,1510	07E U5	*DE*	0.30454E 01	0,97427	00 0.1	2311E 61	*RM*	0,35218E 01
		2	-					7 - 1.				in .	
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								1.1	• • •			5. 5 5	. 3.5
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	DWELL TIP	-	1	385 DAY	5				• • • • • • • •				·····
	CHANNEL PO	OWER							- director and a				
	0,51400E	08											
-	HIXED GAS	OUTI	LET T	EMPERAT	URE	851	٩		and Street	2			
	INNER FLO	W RÁ1 03	E	OUTFR 0.7818	FLOU B	RATE.							
	TEM	PERAT	TURES	5				1.1.1.1			-162		TW3
	T61 300	TW1- 503		577		TF1 625	1FI 676	TF2 641	498	451 520	300	3	309
	335 385	605 712		697 827	1	716	768	752 901	663	607 685	421		440 517
	442	801 876		923	10	950	1052	1009	744	760	576	1. 1	597 658
	557	868		977	11	001	1095	1059	837 894	· 788 846	634 698	1	724 .
	665 718	938	1 2 4	1049	11	073	1170	1138 1155	944 984	898 942	761	1	788 842
	767 804	970 965	1 .	1059	11	048	1159 1111	1136	1002	968 982	872 911		891 926
				T SPLIT	RADII	16	OL TER CA	AP					
	1NNFR GAP 0.54201F=02	1	near	0,24078	8E 01		1,2211	36+01					
)	-0.17019F-03 0.64112F-05	5		0,24452	26 01		( , 3011) ( , 4414)	76+01					
0	0.11145F=03 =0.63795F=04	4		0.24562	28 01		1,5076	68=09					
0	0.40554F=04 =0.20673F=03	3		0.24628	8E 01		1 .479e C.491c	16=(1					
5	0,31396F=03	3		0.24728	01 30		1,4511	01=10					- ser -
0	-0.16355F-04 -0.52448F-03	ŝ		0,2495	PE DI		1,3945	9E=01					
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HPATAX RESULTS 0,981378 60 +RH+ 0.98132E 00 0.35218E 01 0,22847E US +LE. '0,30181E 01 0.13934E 06 0,22867E 05 .... 0.981285 00 0.98128# f0 .RM. 0,352318 01 0.30202E C1 0.21467E 05 0,21467E .05 +DE\* 0,133668 06 .... 0.98097F 00 +RM+ 0.35231E 01 0,30228E 01 0.96097E 00 0,126658 06 0,20049E 05 0.20049E US +[E\* .... 0,98143# f.0 . .RMa- 0,352318-04 0,187248 05 - 0,187248 US +DE+ 0,302598 01- 0,981438 00-0,11957E 06 .... 0.98271 E 10 .RM. 0.352318 01 0,30311E 01 0.98278E 00 0,17551E 05 0,17551E 05 +DE+ 0,112838 06 .... 0,10787E 06 0,16684E 05 0,16684E 05 +DEP 0,30303E 01 0,92579E 00 0,98579E 00 +RM+--0;39231E-01. .... 0,99145 F 00 +RH+ 0,352318 01 0,15916E 05 0,15916E 05 +LE+ 0,30357E 01 0.99149E 00 0,10316E 06 .... 0,98881E 05 0,14747E 05 0,15631E 05 +DE+ 0,30422E 01 0,97390E 00 0,10323E 61 - +RM+ \*RE\* 0.30481E 01 0.89557E 00 0.11457E 61 #RM+ 0,35047E 01 0,95043E 05 0,12725E 05 0,16208E 05 +DE+ .....

anis spice

z	PCU	PC1			and the second s	
0 50	0.15091F 01 0.15101F 01	0,32675E 01	U. 37958E 01		and a second	
100	0,15114F 01	0.32689E 01 0.32707E 01	0,37971E 01 0,37987E 01			
150 200	0,15129F 01 0,15156F 01	0.32723E 01 0.32736E 01	0.32006E 01			
250	0,15151F 01	0,32738E 01	0.35026E 01 0.35045E 01			
300 350	0,15179£ 01 0,15211F 01	0,32758E 01 0,32726E 01	0,36079E 01 0,36147E 01			
400	0,15240F 01	0,32699E 01	0,38278E 01			
500	0,15244E 01 0,15227E 01	0,32677E 01 0,32667E 01	0.38479E 01 0.38719E 01			
	and the second second		0,001192 01			
2	PPESSURE DRUP	The second se		a second s		
ő	PD(BORE) 0,0	PDCANNULUS)				
50	0,12082E 05	0,12280E 05				
150	0.25938F 05 0.41261E 05	0,26117E 05 0,41541E 05				
200 250	0,58152F 05 0,75316E 05	0,58548E 05				
300	0.94023E 05	0.76652E 05 0.95790E 05				······································
350	0.11488F 06 0.13775F 06	0.11639E 06			**	
450	0,16135E 06	0,139/9E 06 0,16341E 06				
500	0,18430E 06	0,18482E 06			and the second	
			and the second se			
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						and the second se
• • • • • • •	CORROSION DATA				· · · · · · · · · · · · · · · · · · ·	
· ······	CORROSION DATA			ROUGHN	ESS HEIGHTS	···· ·
2 0	PLANAS	R REMOVAL	PC2	RCO	RC1 .	RCZ
50	PLANAS	R REMOVAL RC1 0.99986E=07	0,866826+09	RC0 0,37591E=06	RC1	RC2 0.86682E=09
50	PLANAI RCU 0,37591F=06 0,79957E=05 0,12620F=03	R REMOVAL RC1 0.99986E=07 0.11960E=05 0.14391E=04	0.86682E+09 0.22968E+07 0.63157E+06	RCO	RC1 .	0,86682E=09
50 00 50	PLANAI RCU 0,37591F=06 0,79957E=05 0,12620E=03 0,72911F=03 0,25643E=02	REMOVAL RC1 0.99986E=07 0.11960E=05 0.14391E=04 0.95060E=04	0.86682E+09 0.22968E=07 0.63157E+06 0.10448E=04	RC0 C,37591E+06 C,79957E+05 C,12620E+03 G,72911E+03	RC1 U.99986E-07 U.11960E-05 U.14391E-04 U.95060E-04	
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	0.47700E MIXED GAS INNER FLO 0.93030E	06 DUTLET Y W RATE 02	OUTER 0,735	TURE FLOW RAT 90E 02		•						· · · · · · · · · · · · · · · · · · ·		
	0,47700E HIXED GAS INNER FLO 0,93030E TEM	06 OUTLET T W RATE 02 PERATURES TW1	OUTER 0,735	FLOW RAT	E		152				·	62		
0 50	0,47700E HIXED GAS INNER FLO 0,93030E TEM TG1 300 339	06 OUTLET Y W RATE 02 PERATURES TW1 526 613	OUTER 0,735 8 T11 602 703	FLOW RAT 90E 02 TF1 624 722	E	TFI: 686 799	651 760		495	448	Y 3 3	62 06 55	31	8
0 50 00	0,47700E MIXED GAS INNER FLO 0,93030E TEM TG1 300	06 OUTLET Y W RATE 02 PERATURES TW1 526	OUTER 0,735 8 111 602	FLOW RAT 90E 02 TF1 624 722 847	E	TFI: 686 799 942	651		495 568 654	448 520 602		65	31 36 43	0 8 ?
0 50 50 50	0,47700E MIXED GAS INNER FLO 0,93030E TEM TG1 300 339 390 448 509	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871	OUTER 0,735 3 111 602 703 824 917 996	FLOW RAT 90E 02 TF1 624 722 847 942 1021	E	1047 1134	651 760 899 1003 1089		495 568 654 731 805	448 520 602 676 749	Y 3 3 4 4 5	62 06 55 21 92 66	31 36 43 51 59	0 8 9 5 2
0 50 50 50 50 50 50 50	0,47700E HIXED GAS INNER FLO 0,95030E TEM TG1 300 339 390 448	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800	OUTER 0,735 3 111 602 703 824 917	FLOW RAT 90E 02 TF1 624 722 847 942	E	YFI: 686 799 942 1047	651 760 899 1003		495 568 654 731	448 520 602 676	Y 3 3 4 4 5 6	62 06 55 21 92	31 36 43 51	0 8 9 5 2 1
0 50 50 50 50 50 50 50	0,47700E MIXED GAS INNER FLO 0,95030E TEM TG1 300 339 390 448 509 562 615 669	06 OUTLET 1 W RATE 02 PERATURES TW1 526 613 717 800 871 861 898 927	OUTER 0,735 3 111 602 703 824 917 996 965 1003 1037	FLOW RAT 90E 02 TF1 624 722 847 942 1021 986 1025	E	TFI: 686 799 942 1047 1047 1047 1082 1122 1153	651 760 899 1003 1089 1045 1086 1120		495 568 654 731 805 821 877 926	448 520 602 676 749 775 831 882	1 3 4 4 5 6 6 7	62 06 55 21 92 66 28 96 50	31 36 43 51 59 65 71 77	0 8  5  5 
0 50 50 50 50 50 50 50 50 50	0,47700E HIXED GAS INNER FLO 0,93030E TEM TG1 300 339 390 448 509 562 615 669 722 771	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871 861 861 898 927 950 967	OUTER 0,735 3 703 824 945 1003 1032 1052 1057	FLOW RAT 90E 02 TF1 624 722 847 942 1021 986 1025 1054 1074 1074	E	TFI: 686 799 942 1047 1134 1082 1122 1153 1170 1161	651 760 899 1003 1089 1045 1086 1120 1139 1135		495 568 654 731 805 821 877 926 966 994	448 520 602 676 749 775 831 882 925 959	7 3 4 4 5 6 6 7 7 8 8	62 06 55 21 92 96 50 08 07	31 36 43 51 59 65 71 77 82 88	0 8  5  5  5 
0 50 00 50 00 50 00 50 00 50 00	0,47700E HIXED GAS INNER FLO 0,93030E TEM TG1 300 339 390 448 509 562 615 669 722 771 811	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871 861 861 898 927 950 950 966	OUTER 0,735 3 111 602 703 824 916 965 1003 1032 1052 1057 1055	FLOW RAT 90E 02 7F1 624 722 847 942 1021 986 1025 1054 1075 1050	E	7FI: 686 799 942 1047 1134 1082 1122 1122 1153 1176 1161 1116	651 760 899 1003 1089 1045 1086 1120 1139 1135 1098		495 568 654 731 805 821 877 926 966	448 520 602 676 749 775 831 882 925	7 3 4 4 5 6 6 7 7 8 8	62 06 55 21 92 66 28 96 50 08	31 36 43 51 59 65 71 77 82	0 8  5  5  5 
0 50 00 50 00 50 00 50 00 50 00 50 00 50 00	0,47700E MIXED GAS INNER FLO 0,95030E TEM TG1 300 339 390 448 509 562 615 669 722 771 811 INNER GAP 0,23404F=02	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871 861 898 927 950 950 950 966 HEAT	OUTER 0,735 3 T11 602 703 824 917 996 965 1003 1032 1052 1057 1055 1055 1055 1055 1055	FLOW RAT 90E 02 TF1 624 722 847 942 1021 986 1025 1054 1074 1075 1050 RADIUS 4E 01	E	TFI: 686 799 942 1047 1134 1082 1122 1153 1176 1161 1116 00 TER 6 6,2613	651 760 899 1003 1089 1045 1086 1120 1139 1135 1098 AP 4E=01		495 568 654 731 805 821 877 926 966 994	448 520 602 676 749 775 831 882 925 959	7 3 4 4 5 6 6 7 7 8 8	62 06 55 21 92 96 50 08 07	31 36 43 51 59 65 71 77 82 88	0 8  5  5  5 
0 50 00 50 00 50 00 50 00 50 00 50 00 50	0,47700E HIXED GAS INNER FLO 0,93030E TEM TG1 300 339 390 448 509 562 615 669 722 771 811 INNER GAP U,23404F-02 0,15249E-03	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871 861 898 927 950 967 966 HEAT	OUTER 0,735 3 T11 602 703 824 965 1003 1032 1052 1057 1035 1035 7 5PLIT 0,2425 0,2435	FLOW RAT 90E 02 TF1 624 722 847 942 1021 986 1025 1054 1074 1075 1050 RADIUS 4E 01	E	YFI: 686 799 942 1047 1134 1082 1153 1176 1161 1116 01 TER C 6,2613 C,31(2	651 760 899 1003 1089 1045 1086 1120 1139 1135 1098 AP 4E=01 6E=01		495 568 654 731 805 821 877 926 966 994	448 520 602 676 749 775 831 882 925 959	7 3 4 4 5 6 6 7 7 8 8	62 06 55 21 92 96 50 08 07	31 36 43 51 59 65 71 77 82 88	0 8  5  5  5 
50 00 50 00 50 00 50 00 50 00 50 00 50 00 50	0,47700E HIXED GAS INNER FLO 0,93030E TEM TG1 300 339 390 448 509 562 615 669 722 771 811 INNER GAP 0,23404F-02 0,5249E-03 0,59745F=04	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871 861 898 927 950 967 966 HEAT	OUTER 0,735 3 T11 602 703 824 917 996 965 1003 1032 1052 1057 1055 1055 1055 1055 1055 1055 1055	FLOW RAT 90E 02 TF1 624 722 847 942 1021 986 1025 1054 1074 1075 1050 RADIUS 4E 01 6E 01 9E 01 7E 01	E	TFI: 686 799 942 1047 1134 1082 1123 1176 1153 1176 1116 00 TER 6 6,2613 6,3162 6,3162 6,5027	651 760 899 1003 1089 1045 1086 1120 1135 1098 1135 1098 AP 4E=01 6E=C1 7E=C1 3E=C1		495 568 654 731 805 821 877 926 966 994	448 520 602 676 749 775 831 882 925 959	7 3 4 4 5 6 6 7 7 8 8	62 06 55 21 92 96 50 08 07	31 36 43 51 59 65 71 77 82 88	0 8  5  5  5 
0 50 00 50 5	0,47700E MIXED GAS INNER FLO 0,95030E TEM TG1 300 339 390 448 509 562 015 669 722 771 811 INNER GAP U,23404F=02 0,15249E=03 0,59745E=04 -0,60309E=03	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871 861 898 927 950 967 966 HEAT	OUTER 0,735 3 711 602 703 824 917 996 965 1003 1032 1057 1035 7057 1035 7057 1035 7057 1035 702425 0,2445 0,2456	FLOW RAT 90E 02 TF1 624 722 847 942 1021 986 1025 1054 1074 1074 1075 1050 RADIUS 4E 01 6E 01 9E 01 7E 01 2E 01	E	YFI: 686 799 942 1047 1134 1082 1153 1176 1153 1176 1161 1116 01 TER ( 6,2613 6,31(2 (,415) 6,5027 (,582(	651 760 899 1003 1089 1045 1086 1120 1139 1135 1098 AP 4E=01 6E=C1 7E=C1 3E=C1 0E=C1		495 568 654 731 805 821 877 926 966 994	448 520 602 676 749 775 831 882 925 959	7 3 4 4 5 6 6 7 7 8 8	62 06 55 21 92 96 50 08 07	31 36 43 51 59 65 71 77 82 88	0 8  5  5  5 
0 50 00 50 00 50 00 50 00 50 00 50 00 50 00 50 00 50 00 50 00 50 00 50 00 50 00 50 5	0,47700E HIXED GAS INNER FLO 0,93030E TEM TG1 300 339 448 509 562 615 669 722 771 811 INNER GAP 0,23404F-02 0,59249E-03 0,599M5F-04 -0,6309F-03 -0,71440F-04 -0,6359C-05	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871 861 898 927 950 966 HEAT	OUTER 0,735 3 T11 602 703 824 917 996 965 1003 1037 1052 1057 1057 1055 1055 1055 1055 102455 0,2445 0,2456 0,2459 0,2459	FLOW RAT 90E 02 TF1 624 722 847 942 1021 986 1025 1054 1074 1075 1050 RADIUS 4E 01 8E 01 7E 01 2E 01 5E 01 4E 01	E	YFII 666 799 942 1047 1134 1082 1123 1176 1153 1176 1153 1176 1153 1176 1161 1116 00 TER 6 6,2613 6,3162 6,3162 6,5162 7,5314	651 760 899 1003 1089 1045 1086 1120 1135 1098 4E=01 6E=01 6E=01 6E=01 3E=01 0E=01 3E=01 0E=01 4E=01		495 568 654 731 805 821 877 926 966 994	448 520 602 676 749 775 831 882 925 959	7 3 4 4 5 6 6 7 7 8 8	62 06 55 21 92 96 50 08 07	31 36 43 51 59 65 71 77 82 88	0 8  5  5  5 
0 50 00 50 5	0,47700E HIXED GAS INNER FLO 0,93030E TEM TG1 300 339 390 448 509 562 015 069 722 771 811 INNER GAP 0,23404F-02 0,15249E-03 0,59170F-03 -0,59945E-04 -0,6039F-03 -0,59945E-04 -0,6399F-03 -0,59945E-04 -0,6399F-05 -0,71440E-04	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871 861 898 927 950 966 HEAT	OUTER 0,735 3 111 602 703 824 917 996 965 1003 1032 1052 1057 1057 1055 1057 1055 1057 1055 1057 1055 1057 1055 0,2445 0,2445 0,2459 0,2454 0,2471	FLOW RAT 90E 02 TF1 624 722 847 942 1021 986 1025 1054 1074 1075 1050 RADIUS 4E 01 6E 01 9E 01 7E 01 2E 01 2E 01 4E 01 6E 01	E	TFI: 686 799 942 1047 1134 1082 1123 1176 1135 1176 1101 1116 017ER ( 0,2613 0,31(2) (,4159 0,502( 1,5339) (,5334 (,5423)	651 760 899 1003 1089 1045 1086 1120 1135 1135 1098 AP 4E=01 6E=01 6E=01 6E=01 3E=01 0E=01 0E=01 0E=01 0E=01 0E=01		495 568 654 731 805 821 877 926 966 994	448 520 602 676 749 775 831 882 925 959	7 3 4 4 5 6 6 7 7 8 8	62 06 55 21 92 96 50 08 07	31 36 43 51 59 65 71 77 82 88	0 8  5  5  5 
0 50 50 50 50 50 50 50 20 50 00 50 00 50 00 50 00 55 00 00 55 00 00	0,47700E HIXED GAS INNER FLO 0,93030E TEM TG1 300 339 390 448 509 562 015 069 722 771 811 INNER GAP 0,23404F-02 0,5249E-03 0,59170F-03 0,59085F-04 -0,0309F-03 -0,71440F-04 0,25102F-03 0,20975F-03 0,44405F-03	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871 861 898 927 950 967 966 HEAT	OUTER 0,735 T11 602 703 824 996 905 1003 1032 1052 1052 1052 1052 1052 1055 0,2455 0,2455 0,2455 0,2455 0,2451 0,2456 0,2471 0,2476	FLOW RAT 90E 02 TF1 624 722 847 942 1021 1055 1054 1075 1055 1050 RADIUS 4E 01 6E 01 7E 01 2E 01 2E 01 4E 01 4E 01 9F 01	E	YFII           686           799           942           1032           1124           1082           1123           1170           11116           001 TER G           6,2613           6,3162           6,3162           6,5326           7,5339           6,5314           6,5423           1,5291           6,5827           6,5314           7,5423           7,5423	AP 4E + C1 6E + C1		495 568 654 731 805 821 877 926 966 994	448 520 602 676 749 775 831 882 925 959	7 3 4 4 5 6 6 7 7 8 8	62 06 55 21 92 96 50 08 07	31 36 43 51 59 65 71 77 82 88	0 8  5  5  5 
0 50 50 50 50 50 50 50 20 50 00 50 00 50 00 50 00 55 00 00 55 00 00	0,47700E HIXED GAS INNER FLO 0,93030E TEM TG1 300 339 390 448 509 562 615 669 722 771 811 INNER GAP 0,23404F-02 0,15249E-03 0,59170F-03 -0,5995FE-04 -0,6309FE-03 -0,71440FE-04 -0,54765E-04 0,250075E-03 0,20975E-03	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871 861 898 927 950 967 966 HEAT	OUTER 0,735 3 111 602 703 824 965 1003 1032 1052 1057 1035 7 0,2455 0,2445 0,2445 0,2451 0,2456 0,2451 0,2451 0,2451 0,2451 0,2451	FLOW RAT 90E 02 TF1 624 722 847 942 1021 1055 1054 1075 1055 1050 RADIUS 4E 01 6E 01 7E 01 2E 01 2E 01 4E 01 4E 01 9F 01	E	YFI: 686 799 942 1047 1134 1082 1123 1153 1176 1161 1116 01 TER C 6,2613 C,31(2 C,31(2 C,5127 C,5339 C,5314 C,5423 C,544 C,5423	AP 4E + C1 6E + C1		495 568 654 731 805 821 877 926 966 994	448 520 602 676 749 775 831 882 925 959	7 3 4 4 5 6 6 7 7 8 8	62 06 55 21 92 96 50 08 07	31 36 43 51 59 65 71 77 82 88	0 8  5  5  5 
0 50 50 50 50 50 50 50 50 50 5	0,47700E HIXED GAS INNER FLO 0,93030E TEM TG1 300 339 390 448 509 562 015 069 722 771 811 INNER GAP 0,23404F-02 0,5249E-03 0,59170F-03 0,59085F-04 -0,0309F-03 -0,71440F-04 0,25102F-03 0,20975F-03 0,44405F-03	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871 861 898 927 950 967 966 HEAT	OUTER 0,735 T11 602 703 824 996 905 1003 1032 1052 1052 1052 1052 1052 1055 0,2455 0,2455 0,2455 0,2455 0,2451 0,2456 0,2471 0,2476	FLOW RAT 90E 02 TF1 624 722 847 942 1021 1055 1054 1075 1055 1050 RADIUS 4E 01 6E 01 7E 01 2E 01 2E 01 4E 01 4E 01 9F 01	E	YFII           686           799           942           1032           1124           1082           1123           1170           11116           001 TER G           6,2613           6,3162           6,3162           6,5326           7,5339           6,5314           6,5423           1,5291           6,5827           6,5314           7,5423           7,5423	AP 4E + C1 6E + C1		495 568 654 731 805 821 877 926 966 994	448 520 602 676 749 775 831 882 925 959	7 3 4 4 5 6 6 7 7 8 8	62 06 55 21 92 96 50 08 07	31 36 43 51 59 65 71 77 82 88	0 8  5  5  5 
0 50 50 50 50 50 50 50 20 50 00 50 00 50 00 50 00 55 00 00 55 00 00	0,47700E HIXED GAS INNER FLO 0,93030E TEM TG1 300 339 390 448 509 562 015 069 722 771 811 INNER GAP 0,23404F-02 0,5249E-03 0,59170F-03 0,59085F-04 -0,0309F-03 -0,71440F-04 0,25102F-03 0,20975F-03 0,44405F-03	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871 861 898 927 950 967 966 HEAT	OUTER 0,735 T11 602 703 824 996 905 1003 1032 1052 1052 1052 1052 1052 1055 0,2455 0,2455 0,2455 0,2455 0,2451 0,2456 0,2471 0,2476	FLOW RAT 90E 02 TF1 624 722 847 942 1021 1055 1054 1075 1055 1050 RADIUS 4E 01 6E 01 7E 01 2E 01 2E 01 4E 01 4E 01 9F 01	E	YFII           686           799           942           1032           1124           1082           1123           1170           11116           001 TER G           6,2613           6,3162           6,3162           6,5326           7,5339           6,5314           6,5423           1,5291           6,5827           6,5314           7,5423           7,5423	AP 4E + C1 6E + C1		495 568 654 731 805 821 877 926 966 994	448 520 602 676 749 775 831 882 925 959	7 3 4 4 5 6 6 7 7 8 8	62 005 55 55 50 50 66 50 66 07	31 36 43 51 59 65 71 77 82 88	0 8  5  5  5 
0 50 50 50 50 50 50 50 50 00 50 50 00 55 00 00	0,47700E HIXED GAS INNER FLO 0,93030E TEM TG1 300 339 390 448 509 562 015 069 722 771 811 INNER GAP 0,23404F-02 0,5249E-03 0,59170F-03 0,59085F-04 -0,0309F-03 -0,71440F-04 0,25102F-03 0,20975F-03 0,44405F-03	06 OUTLET Y W RATE 02 PERATURES TW1 526 613 717 800 871 861 898 927 950 967 966 HEAT	OUTER 0,735 T11 602 703 824 996 905 1003 1032 1052 1052 1052 1052 1052 1055 0,2455 0,2455 0,2455 0,2455 0,2451 0,2456 0,2471 0,2476	FLOW RAT 90E 02 TF1 624 722 847 942 1021 1055 1054 1075 1055 1050 RADIUS 4E 01 6E 01 7E 01 2E 01 2E 01 4E 01 4E 01 9F 01	E	YFII           686           799           942           1032           1124           1082           1123           1170           11116           001 TER G           6,2613           6,3162           6,3162           6,5326           7,5339           6,5314           6,5423           1,5291           6,5827           6,5314           7,5423           7,5423	AP 4E + C1 6E + C1		495 568 654 731 805 821 877 926 966 994	448 520 602 676 749 775 831 882 925 959	7 3 4 4 5 6 6 7 7 8 8	62 005 55 55 50 50 66 50 66 07	31 36 43 51 59 65 71 77 82 88 8 91/	0 8  5  5  5 

\*RE\* 0,12782E 06 0,21523E 05 0,21523E U5 \*DE\* 0,30186E 01 0,98146E 00 0,98146F. 00 \*RM\* 0,35217E 0

\*RE\* 0,12202E 06 0,20215E 05 0,20215E 05 #0E\* 0,30204E 01 0,98129E 00 0,98129E 00 +RH\* 0,35231E 0

HFATAX PESULTS

	GRAPHITE SURFAC	CE DIMENSIONS				
2 50 100 250 250 350 400 450 500	RCU U,15093F 01 U,15102F 01 U,15113F 01 U,15132F 01 U,15132F 01 U,15134F 01 U,15191F 01 U,15230F 01 U,15280F 01 U,15280F 01 U,15280F 01 U,15263F 01	RC1 0,326/5E 01 0,32689E 01 0,32700E 01 0,32732E 01 0,32732E 01 0,32733E 01 0,32730E 01 0,32731E 01 0,32675E 01 0,32675E 01 0,32625E 01	FC2 0,37958E 01 0,37971E 01 0,37971E 01 0,31005E 01 0,36025E 01 0,36045E 01 0,36045E 01 0,36045E 01 0,36343E 01 0,36547E 01 0,36547E 01			
2 50 100 150 200 250 300 350 400 450 500	PRESSURE DROPS PD(BORE) 0,0 0,10594F 05 0,22516E 05 0,35647E 05 0,50179E 05 0,64951E 05 0,64951E 05 0,99493E 05 0,11970E 06 0,16164E 06	PD(ANNULUS) 0.0 0.10983F 05 0.23354F 05 0.37100E 05 0.52214E 05 0.68248E 05 0.85114E 05 0.10337E 06 0.12460E 06 0.14427E 06 0.16145E 06				
•	CORROSION DATA	REMOVAL		POUGNNE		
2 0 50 100 250 250 350 350 400 450 500		REMOVAL RC1 0.12991E=06 0.15783E=05 0.18530E=04 0.12027E=03 0.55772E=03 0.9169UE=03 0.24322E=02 0.54285E=02 0.54285E=02 0.13903E=01 0.15901E=01	RC2 0,12748E=08 0,32638E=07 0,85273E=06 0,13771E=04 0,13771E=04 0,13771E=03 0,67310E=03 0,67310E=03 0,28049E=02 0,93513E=02 0,24020E=01 0,49097E=01 0,80514E=01	RCUGMME RCO 0,83794E=06 0,13445E=04 C,18587E=03 0,10172E=02 C,34998E=02 C,34998E=02 C,31204E=02 C,59870E=02 C,96312E=02 C,13174E=01 C,14227E=01 C,14255E=01	RC1 0,12991E-06 0,15783E-05 0,15536E-05 0,15530E-04 0,1527E-03 0,55772E-03 0,91690E-03 0,91690E-03 0,9410E-02 0,94410E-02 0,94410E-02 0,15901E-01	RC2 0,12748E=08 0,32638E=07 0,85273E=06 0,13771E=04 0,14521E=03 0,67310E=03 0,67310E=03 0,28640E=02 0,93513E=02 0,24620E=01 0,25600E=01 0,25600E=01
0 50 100 250 250 350 350 450 500	PLANAR RC0 0,83794E=06 0,13445E=04 0,18587E=03 0,10172E=02 0,34998E=02 0,31204E=02 0,59870E=02 0,96312E=02 0,13174E=01 0,14227E=01 0,12655E=01	RC1 0.12991E=06 0.15783E=05 0.18530E=04 0.12027E=03 0.55772E=03 0.24322E=02 0.54285E=02 0.54285E=02 0.13903E=01 0.15901E=01 HEAT TRAESFEP	0,12748E=08 0,32638E=07 0,85273E=06 0,13771E=04 0,14521E=03 0,28049E=02 0,93513E=02 0,28049E=02 0,93513E=02 0,24020E=01 0,49097E=01 0,80514E=01	RC0 0,83794E=06 0,13445E=04 C,18587E=03 0,10172E=02 C,34998E=02 C,59870E=02 C,59870E=02 C,96312E=02 C,13174E=01 C,14227E=01 C,12655E=01 FRICTION	RC1 0,12991E-06 0,15783E-05 0,1530E-04 0,152027E-03 0,55772E-03 0,91690E-03 0,24322F-02 0,9440E-02 0,15901E-01 0,15901E-01 FACTUR (TRANS)	0,12748E=08 0,32638E=07 0,85273E=06 0,13771E=04 0,14521E=03 0,67310E=03 0,28049E=02 0,93513E=02 0,24020E=01 0,25000E=01
0 50 100 250 250 350 400 450 500 200 200 200 200 200 200 350 450 450 450 450 450 450 450 4	PLANAR RC0 0,83794E=06 0,13445E=04 0,18587E=03 0,10172E=02 0,34998E=02 0,31204E=02 0,59870E=02 0,59870E=02 0,96312E=02 0,13174E=01 0,14227E=01	RC1 0.12991E=06 0.15783E=05 0.18530E=04 0.55772E=03 0.91690E=03 0.24322E=02 0.54285E=02 0.99410E=02 0.13903E=01 0.15901E=01	0,12748E=08 0,32638E=07 0,85273E=06 0,13771E=04 0,14521E+03 0,67310E=03 0,28049E=02 0,93513E=02 0,24020E=01 0,49097E=01 0,80514E=01	RC0 0,83794E=06 0,13445E=04 0,18587E=03 0,10172E=02 0,34998E=02 0,31204E=02 0,96312E=02 0,13174E=01 0,14227E=01 0,12655E=01	RC1 0,12991E-06 0,15783E-05 0,18530E-04 0,12027E-03 0,55772E-03 0,91690E-03 0,24322F-02 0,54285E-02 0,94410E-02 0,13903E-01 0,15901E-01	0,12748E=08 0,32638E=07 0,85273E=06 0,13771E=04 0,14521E=03 0,67310E=03 0,28049E=02 0,93513E=02 0,24020E=01 0,25000E=01
0 50 100 150 250 300 350 400 450 500 200 200 250 100 150 250 250 250	PLANAR RC0 0,83794E=06 0,13445E=04 0,13687E=03 0,10172E=02 0,34998E=02 0,31204E=02 0,96312E=02 0,96312E=02 0,13174E=01 0,14227E=01 0,12655E=01 RC0 0,18175E 00 0,18247E 00 0,18337F 00 0,18537F 00 0,18537F 00 0,18537F 00 0,18537F 00 0,18537F 00 0,2579E 00 0,2579E 00 0,255221F 00	RC1 0.12991E=06 0.15783E=05 0.18530E=04 0.12027E=03 0.55772E=03 0.9169UE=03 0.24322E=02 0.54285E=02 0.99410E=02 0.13903E=01 0.15901E=01 RC1 0.11347E 00 0.11756E 00 0.1225E 00 0.12667E 00 0.12667E 00 0.12667E 00 0.13640E 00	0,12748E=08 0,32638E=07 0,85273E=06 0,13771E=04 0,14521E=03 0,28049E=02 0,93513E=02 0,28049E=02 0,93513E=02 0,24020E=01 0,49097E=01 0,80514E=01 0,80514E=01 0,27853E 00 0,25407E 00 0,25858E 00 0,25858E 00 0,25858E 00 0,22858E 00 0,21217E 00 0,21458E 00 0,21458E 00 0,25147E 06 0,25147E 06 0,2563E 00	RC0 0,83794E=06 0,13445E=04 C,18587E=03 0,10172E=02 0,34998E=02 C,31204E=02 C,59870E=02 C,96312E=02 C,14227E=01 C,14227E=01 C,12655E=01 FRICTION RC0 C,42481E=02 C,43921E=02 C,43921E=02 C,43526E=02 C,4554E=02 C,47520E=02 C,47538E=02 C,59515E=02 C,68304E=02	RC1 0,12991E-06 0,15783E-05 0,15530E-04 0,12027E-03 0,55772E-03 0,91690E-03 0,24322F-02 0,9410E-02 0,9410E-02 0,9410E-02 0,9410E-02 0,9410E-02 0,9410E-02 0,75638E-02 0,75538E-02 0,72658E-02 0,72538E-02 0,72538E-02 0,77912E-02 0,77912E-02 0,77952E-02 0,7693E-02 0,953E-02 0,7693E-02 0,9631E-02 0,10492E-01	0,12748E=08 0,32638E=07 0,85273E=06 0,13771E=04 0,14521E=03 0,28049E=02 0,93513E=02 0,28049E=02 0,25000E=01 0,25000E=01 0,25000E=01 FORMED RC2 0,71692E=02 0,73643E=02 0,74768E=02 0,74768E=02 0,77768E=02 0,77645E=02 0,77645E=02 0,77645E=02 0,77645E=02 0,77910E=02 0,79410E=02 0,12495E=01 0,12545E=01

RESULTS HFATAX 0,11660E 06 0,20118E 05 0,20118E U5 \*08\* 0.30189E 01 0.9814UE 00 0,9814(F 60

0,11098E 06 0.98122E 00 0,18870E 05 0,18870E 05 +DE\* 0,30206E 01 0.352312-01 +RE+ 0.98122E 00-+RM+ ORE 0,104968 06 0,17628E 05 0,17628E U5 0.30230E 01 0,98142E 00 0,98142E 00 ..... 0,35231E 01 +DE+ 0,99058E 05 .... 0,165062 05 0,16506E-05 PDE\* 0.30268E 01 0,98215E 00 0.982158 00- .RN+ 0.35231E-01 .RE. 0,93496E 05 0,15521E 05 0,15521E US #DE# 0.30344E 01 0.98385E OU 0.98388E 00 ..... 0.35231E 01 .... 0,89559E 05 0,148048 05 0,14804E 05 PDEW 0,30329E 01 0.91730E 00 0,9873(F 60 ..... 0.35231E 01 +RE+ 0,85705E 05 0,14155E 05 0.14155E 05 \*DE\* 0,30403E 01 0.99530E 00 0,9953(E 60 0,35231E 01 \*R#\* .... 0,82147E 05 0,12984E 05 0.3049%E 01 0.9722UE 00-0,1052CE 01- +RM+ 0.35225E 01 0,78911E 05 +RE+ 0,11323E 05 0.14428E U5 +DE+ 0,30586E 01 0,99828E 00 0,11701E 01 ..... 0.35054E 01 0,13239E 05 \*DE\* .RE. 0,761906 05 0,11569E 05 0,306318 01 0,10350E 01 0,11851E 01 \*RM\* 0,35317E 01 \*RE\* 0.74257E 05 0,11591E 05 0.12396E 05 \*DE\* 0,30602E 01 0,11454E 01 0.12249E 01 0,35581E 01 \*R\*\*

DWELL TIME = 693 DAYS CHANNEL POWER 0,44000E 06

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MIXED GAS OUTLET TEMPERATURE 852

		FLOW RATE	0,68785	LOW RATE							
		TEMPERATUR	ES								
2	TG1	TW1	· TI1	TF1	TFI	TF2	112	TW2	T1.2	TW3	
0.	. 300	539	621	636	702	666	498	450	300	310	
50	342	621	710	728	806	767	569	520	356 -	370	
00	396	719	822	842	936	894	649	597	422	440	
50	452	798	909	931	1033	991	719	668	492 -	514	
00	513	866	983	1006	1116	1071	791	738	563	589	
50	565	854	951-	970	1001-	1026	805	762	623	645	
00	618	888	986	1006	1099	1064	860	817	682	707	
50	671	916	1015	1035	1129	1097	908	868	749	765	
00	725	963	1039	1058	1151	1121	950	911	797	818	
50-	775	967	1055	1073	1157	1130	987	951	850	871 -	
00	817	969	1037	1051	1116	1098	998	972	893	913	

U	0,28017F=03	0.24290E 01	(.;	299298=01	
50	0.45347E=03	0.24364E 01		35213E=C1	
00	0.57722F=03	0,24463F 01	C. (	454448=01	
50	-0,43367F-03	0.24526E 01	···· (.!	55256E=01	
200	=0.18401E=02	0.24564E 01		37128=01	
250	=0.99302E=03	0.245988 01	C. 5	591228=01	
100	-0,94472E-03	0.24440E 01	( . :	50055E=01	
15.0	=0.633/3F=03	0.24710F 01		51933E=01	
00	=0, 50636F=03 ·	0.24745E 01	(.)	50419E=01	
50	0,24558F=03	0.24764E 01-	C.1	52506E=01	
00	0,41797E=03	0.24818F 01	(,)	6203E=01	
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			CALCUMPTER OF THE PARTY OF		

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0.35218E 01

112233445

#### GRAPHITE SURFACE DIMENSIONS

0,15103F (	)1	PC1 0,32675E 0,32689E	01	KC2 0,37958E 0,37971E	01
		0.327USE	01	0.37987E	01
	39/211	0.327188	01	0.38005E	01
	21.0		01	0.38025E	01
		0.32728E	01	0.38045E	01
		0,32722E	01	0.38085E	01
	1	0.32699E	01	U. 36177E	61
		0,32655E	01	0.38362E	01
	1	0.32611E	01	U. 38683E	01
0.153018 0	1	0,32585E	01	0,39081E	01
PRESSURE DR	OPS				
PD(BORE)		PDCANNULL	\$3		
0.0					
0.90824E 0	4		04		-
0.19227E 0	5		05		
0,30351F 0	5		05		100110
0.42695E 0	5				
0,55205E 0	5				
0.69147E 0	5	0.74852E	05		
0.84805E 0	5		05		
0.10224E 0	6		06	4	
0,12076E 0	6		06		
0.13918F 0	6		06		
	0,150946 ( 0,151036 ( 0,151136 ( 0,151136 ( 0,151136 ( 0,151726 ( 0,152025 ( 0,152025 ( 0,152035 ( 0,152035 ( 0,153165 (	0,15094E 01 0,15103F 01 0,15134F 01 0,15172F 01 0,15172F 01 0,15202F 01 0,15202F 01 0,15203F 01 0,15301F 01 0,15301F 01 PRESSURE DROPS PD(BORE) 0,0 0,90824E 04 0,19227E 05 0,30351F 05 0,5205E 05 0,69147F 05 0,84805E 05 0,10224F 06 0,12076E 06	0,15094E         01         0,32675E           0,15103E         01         0,32705E           0,15103E         01         0,32705E           0,15103E         01         0,32705E           0,15172E         01         0,32728E           0,15172E         01         0,32728E           0,15202F         01         0,32728E           0,15202F         01         0,32728E           0,15203F         01         0,32699E           0,15301F         01         0,32699E           0,15301F         01         0,32699E           0,00         0,0         0,0           0,90824E         04         0,97424F           0,30351F         05         0,46096E           0,5205E         05         0,60146E           0,69147F         05         0,74852E           0,48056         05         0,60146E           0,10224F         06 <td>0,15094E       01       0,32675E       01         0,15103F       01       0,32649F       01         0,15113F       01       0,32705E       01         0,15113F       01       0,32705E       01         0,15113F       01       0,32705E       01         0,15113F       01       0,32728E       01         0,15172F       01       0,32728E       01         0,15202F       01       0,32728E       01         0,15202F       01       0,32728E       01         0,15202F       01       0,32649E       01         0,15301F       01       0,32641E       01         0,0       0.0       0.0       0.0         0,0       0.0       0.0       0.0         0,0       0.00       0.0       0.0         0,0       0.00       0.0       0.0         0,0       0.00       0.0       0.0</td> <td>0,15094E       01       0,32675E       01       0,37975E         0,15103E       01       0,32649E       01       0,37971E         0,15113E       01       0,32705E       01       0,37977E         0,15113E       01       0,32705E       01       0,37977E         0,15113E       01       0,32705E       01       0,37977E         0,15172E       01       0,32728E       01       0,38025E         0,15104E       01       0,32728E       01       0,38025E         0,15202F       01       0,32728E       01       0,38025E         0,15202F       01       0,32728E       01       0,38025E         0,15202F       01       0,32699E       01       0,38045E         0,15202F       01       0,32655E       01       0,38045E         0,15203F       01       0,32655E       01       0,38045E         0,15203F       01       0,32655E       01       0,38585E         0,15301F       01       0,32655E       01       0,39081E           PRESSURE pROPS       PD(ANNULUS)       0,00         0,0       0       0,00       0       0</td>	0,15094E       01       0,32675E       01         0,15103F       01       0,32649F       01         0,15113F       01       0,32705E       01         0,15113F       01       0,32705E       01         0,15113F       01       0,32705E       01         0,15113F       01       0,32728E       01         0,15172F       01       0,32728E       01         0,15202F       01       0,32728E       01         0,15202F       01       0,32728E       01         0,15202F       01       0,32649E       01         0,15301F       01       0,32641E       01         0,0       0.0       0.0       0.0         0,0       0.0       0.0       0.0         0,0       0.00       0.0       0.0         0,0       0.00       0.0       0.0         0,0       0.00       0.0       0.0	0,15094E       01       0,32675E       01       0,37975E         0,15103E       01       0,32649E       01       0,37971E         0,15113E       01       0,32705E       01       0,37977E         0,15113E       01       0,32705E       01       0,37977E         0,15113E       01       0,32705E       01       0,37977E         0,15172E       01       0,32728E       01       0,38025E         0,15104E       01       0,32728E       01       0,38025E         0,15202F       01       0,32728E       01       0,38025E         0,15202F       01       0,32728E       01       0,38025E         0,15202F       01       0,32699E       01       0,38045E         0,15202F       01       0,32655E       01       0,38045E         0,15203F       01       0,32655E       01       0,38045E         0,15203F       01       0,32655E       01       0,38585E         0,15301F       01       0,32655E       01       0,39081E           PRESSURE pROPS       PD(ANNULUS)       0,00         0,0       0       0,00       0       0

CORROSION DATA

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	PLANAR	REMOVAL		ROUGHNI	ESS HEIGHTS	
z	RCU	RC1	RC2	RCO	RC1	RC2
0	0.15394E=05	0.16290E+06	0,17020E+08	0.15394E+05	U.10290E-06	0.170208-08
50	0.204298-04	0,19654E=05	0.41659E+07	0.20429E=04	U. 19654E=05	0.418596.07
00	0,24837E=03	0.222338=04	0,108328-05	0.24837E=03	1.222331-04	0.108326-05
50	0,129/1E=02	0.14122E+03	0.1/0198-04	0.12971E-02	U.14122E=03	0.170198-04
00	0,43635F=02	0.65002E=03	0.175736=03	C.43635E=02	U.65002E-03	0.175736-03
50	0,38316F=02	0.10626E=02	0.80001E=03	0.38316E=02	C. 10026E=02	0.800016-03
00	0.71864E=02	0.28204E-02	U. 33099E=02	0,71864E-02	1.28204E-02	0.330998-02
50	0.1144UE=01	0.63043E+02	0,109705-01	C.11440E-01	1.63U43E=02	0.100705-01
00	0.15788E-01	0.11607E-01	0,281296-01	0.15788E=01	C.11007E-01	0.25000F-01
50	0.1783bF=01	0,16826F=01	0.588396-01	0,178386-01	0.108261-01	0.25000E=01
00	0,16448E=01	0.19863E+01	0,976546=01			
	0,104402401	0,198032=01	0,970548=01	0,16448E=01	0,19863E=01	0.250.00E=01

2	RCO	RCI	802	RCO	- 0.01	- 0.02
U	0.16843E 00	0,10753E 00	0.28278E 00	0.43506E=02	1.73906E-02	0.731208-02
50	0,16941E 00	0.10946E CO	0.25589E 00	0.44306E=02	0.75093E-02	0.743151-02
00	U. 17064E 00	0.11155E 00	0.23758E CC	0.449818-02	1.768231-02	0.700636-02
50	0,17255F 00	0.11382E 00	0.223156 00	0.456516+02	U.750291-02	0.77335E-02
00	0.17714E 00	0.115918 00	0.21216E CO	0.49383E=02	1.791721=02	0.785436-02
50	0,18017E 00	0.11772E 00	0.20766E (0	0.48985E=02	1.799348-02	0.794578-02
00	0.19499E 00	0.11850E 00	0.199351 00	0.55147E=02	U.807871-02	0.803566-02
50	U.21510E 00	0.11997E 00	0.202878 00	0.630566-02	1.871201-02	0.947135-02
00	0,23509F 00	0.127U3E 00	0.23489E 00	0.70995E=02	L. 10101E=01	0.126546-01
50	0.24374E 00	0.12687E 00	0.21465E (0	0.74249E=02	U.10996E=01	0.12445F=01
00	0,23991F 00	0.12115E 00	U.16771E 00	0,71666E=02	U.11238E=01	0,121456-01

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			HE	A T /	AX RE	s u	ULIS	•								
*E *	0,11482E	06	0,19972E	05	0,19972E	v5	*DE*	0,30187E	01	0,98156E	00	0,981586	00	***	0,35217E	01
4E *	0,10947E	06	0,18773E	05	0,187736	05	+DE	0.30204E	01	0,98141E	00	0,981418	00	*R**	0.35230E	01
15+	0,103638	06	0,17573E	05	0,17573E	05	*06*	0,302286	01	0.981618	00	0,98161F	00	+RM+	0,35230E	01
2E *	0,97909E	05	0,16485E	05	0,164858	05	*DE*	0,302678	01-	0.962346	00	0,98234F (	00	*RM*	U,35230E-	01
RE.	0,924965	05	0,15526E	05	0,15526E	05	*DE*	0,30347E	01	0.984108	00	0,9841(F	0.0	*RM*	0,35230E	01
0 E+-	0,88671E	05	0,148268	05	0,14826E	05	DE*	0,30331E	01-	0.987608	00	0,9876CF	00-		-0,35230E-	01-
PE+	0,84907E	05	0,14189E	05	0,14189E	05	*DE*	0.30408E	01	0,99597E	00	0,99597E	00	*RM*	U,35230E	01
** E *	0,81418E	05	0,12968E	05	0,14146E	05	+DE+	0.305038	01-	0.96931,8	00	0,105748 (	01-	*R#*	- 0,35211E-	01
RE*	0,782358	05	0,11456E	05	0,14407E	U5	*DE*	0,30602E	01	0.92865E	00	0,1167EE (	61	*R#*	0,35070E	01
P E +	0,75555E	05	0,11728E	05	0,13195E	05	-opeo-	0,306548	01	0,10530E	01	0,11847E	01	***	0,35346E	01-
RE*	0,73662E	05	0,117528	05	0,12344E	05	ODEO	0.306268	01	0.11695E	01	0,12284E (	01	*RM*	0.35624E	01

DWELL TIME = 770 DAYS . CHANNEL POWER 0,42180E 06

MIXED GAS OUTLET TEMPERATURE 835.

1

	INNER FL 0,83568		OUTFR F 0,68287	LOW RATE E 02							
	TE	MPERATUR	ES								
2	TG1	TW1	111	TF1	YFI	TF2	115	TW2	TG2	TW3	
0	300	532	611	625	688	654	491	444	300	310	
50	341	611	697	714	769	752	559	512	354	368	1000 C C C C C C C C C C C C C C C C C C
100	391	707	806	825	915	875	637	587	417	435	
150	448	784	891	912	1010	969	705	655	485	506	
500	508	850	962	985	1089	1047	773	723	554	577	
220-	559	838	931	950	1037	1003	787	746	612	633-	
300	610	870	964	983	10/3	1040	840	799	669	692	
350	662	897	992	1011	1102	1071	867	848	725	748	······································
400	716	925	1015	1034	1923	1096	920	889	786	799	
450	763	946	1030	1048	1129	1103	963	929	831	850	and the second sec
500	804	948	1014 .	1027	1099	1072	974	949	872	890	
2 50 150 250 250 350 350 450 550	1 NNER GAP 0,35769F=0 0,55541F=0 0,28757F=0 -0,28757F=0 -0,16726E=0 -0,35004F=0 -0,43263E=0 -0,9877W0F=0 0,63929E=0	3 3 3 3 3 2 2 3 3 3 3 4 4 5	AY SPLIT P 0,24301E 0,24362E 0,24467E 0,24532E 0,24532E 0,2450E 0,2460E 0,24650E 0,24721E 0,24751E 0,24768E 0,24816E	01 01 01 01 01 01 01 01 01 01 01	DITER GAP (,291766 (,35132E (,45333E (,55712E (,55712E (,55712E (,55712E (,55712E (,55712E (,55712E (,55712E (,57712E (,57712E (,57712E (,45872E)	-01 -01 -01 -01 -01 -01 -01 -01 -01 -01		2, 2 <sup>6</sup> 2, 2, 2 3 <sup>2</sup>	· · · · ·		

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	CDADHITE BUDEA	CE DINENSIS				*
	GRAPHITE SURFA	CE DIMENSICHS		· · · · · · · · · · · · · · · · · · ·		
20	RCU 0,15094F 01	RC1 0,32674E 01	RC2 0,379581 01	ilie		
50	0,15102E 01 0,15114E 01	0,32687E 01 0,32703E 01	0.37970E 01			
50	0,15134E 01	0,32715E 01	0.37986E 01 0.36003E 01			
50	0,15174F 01 0,15165F 01	0,32724E 01 0,32724E 01	0.38022E 01 0.36042E 01			
50	0.15204F 01 0.15252F 01	0.32717E 01 0.32691E 01	0.380838 01			
00	0,15301E 01	0,32644E 01	0.38178E 01 0.38372E 01			
50	0,15327E 01 0,15313E 01	0,32595E 01 0,32565E 01	0.38712E 01 0.39137E 01			
		-				
z	PRESSURE DRUPS PD(BORE)	PD (ANNULUS)				
50	0.0 0.87589F 04	0.0 0.95607E 04		•		
00	0,18520E 05	0,20268E 05				
00	0.29209E 05 0.41089F 05	0,32096E 05 0,45023E 05				
50	0,53129E 05 0,66601E 05	0,58673E 05 0,72925E 05				
50	0,81775F 05 0,98691E 05	0,88540E 05				
50	0.11670F 06	0.10607E 06 0.12153E 06	4			·····
00	0,134668 06	0,13438E 06				
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	CORROSION DATA			· · · · · · · · · · · · · · · · · · ·		
	••• ••••••••••••••••••••••••••••••••••	REMOVAL		RDUGHN	ESS HEIGHTS	
	PLANAR	RC1	kC2	RCO	PC1	RC2
2 0 50	PLANAR RCO 0,18191F=05 0,23148E=04	RC1 0,17624E-06 0,21167E-05	0.19100E+08 0.45947E+07	RC0 C.18191E-05 C.23148E-04	PC1 C.17624E-06 U.21167E-05	0.19100F-08 0.45947E-07
2 0 50 50	PLANAR RCO 0,18191F=05 0,2314bE=04 0,27275E=03 0,14006E=02	RC1 0,17624E=06	0.19100E+08	RC0 C.18191E-05	PC1 C,17624E=06 U,21167E=05 U,23634F=04	0.19100F-08 0.45947E-07 0.11774F-05
2 0 50 50 50 50	PLANAR RCO 0,18191F=05 0,23148E=04 0,27275E=03 0,14066E=02 0,47006E=02	RC1 0,17624E=06 0,21167E=05 0,23634E=04 0,14904E=03 0,68420E=03	0,19100E+08 0,45947E+07 0,11774E+05 0,18276E+04 0,18713E+03	RC0 C,18191E-05 C,23148E-04 C,27275E-03 C,14066E-02 C,47006E-02	FC1 C,17624E=06 C,2167E=05 C,23634F=04 C,14904E=03 C,66420E=03	0,19100F-08 0,45947E-07 0,11774E-05 0,18776E-04 0,18713E-03
2 0 50 50 50 50 50 50 50 50 50	PLANAR RC0 0,18191F-05 0,23148E=04 0,27275F-03 0,14066F-02 0,47006F-02 0,41092E=02 0,76447F=02	RC1 0,17624E-06 0,21167E-05 0,23634E-04 0,14904E-03 0,68420E-03 0,11166E-02 0,29635E-02	0,19100E+08 0,45947E+07 0,11774E+05 0,18276E+04 0,18713E+03 0,84077E+03 0,34940E+02	RC0 C,18191E-05 C,23148E-04 O,27275E-03 C,14066E-02 C,47006E-02 C,41092E-02 C,76447E-02	FC1 C,17024E-06 C,21167E-05 C,23034F-04 C,14904E-03 C,64420E-03 C,11166E-02 C,24035E-02	0,19100F-08 0,45947F-07 0,11774F-05 0,18776F-04 0,18776F-04 0,84677F-03 0,84677F-03 0,34940F-02
2 0 50 50 50 50 50 50 50 50 50 50 50 50 5	PLANAR RCO 0,18191F=05 0,23148E=04 0,27275E=03 0,14066E=02 0,41092E=02 0,76447E=02 0,76447E=02 0,12128E=01 0,16784E=01	RC1 0,17624E=06 0,21167E=05 0,23634E=04 0,14904E=03 0,68620E=03 0,11166E=02 0,29635E=02 0,66259E=02 0,12216E=01	0,19100E+08 0,45947E+07 0,11774E+05 0,18276E+04 0,18713E+03 0,84077E+03 0,34940E+02 0,11552E+01 0,29608E+01	RC0 C,18191E=05 C,23148E=04 C,27275E=03 C,1406E=02 C,47006E=02 C,41092E=02	FC1 C,17024E=06 C,21167E=05 C,23034F=04 C,14904E=03 C,66420E=03 C,11166E=02	0,19100F=08 0,45947E=07 0,11774E=05 0,18776E=04 0,18776E=03 0,84677E=03 0,34940F=02 0,11552E=01
2 0 50 50 50 50 50 50 50 50 50 50 50 50 5	PLANAR RCO 0,18191F=05 0,23148E=04 0,7275F=03 0,14066E=02 0,47006F=02 0,47006F=02 0,41092E=02 0,76447F=02 0,12128F=01	RC1 0,17624E=06 0,21167E=05 0,23634E=04 0,14904E=03 0,68420E=03 0,11166E=02 0,29635E=02 0,66259E=02	0,19100E+08 0,45947E+07 0,11774E+05 0,18276E+04 0,18713E+03 0,84077E+03 0,34940E+02 0,11552E+01 0,29408E+01 0,62349E+01	RC0 C, 18191E-05 C, 23146E-04 O, 27275E-03 C, 1406E-02 C, 4706E-02 C, 41092E-02 C, 76447E-02 C, 1212E-01 C, 16764E-01 C, 19214E-01	FC1 C,17024E-06 U,21167E-05 U,23034F-04 U,14904E-03 U,66420E-03 U,11166E-02 U,24035E-02 U,24035E-02 U,60259E-02 U,12216E-01 U,17902E-01	0,19100F=08 0,45947F=07 0,11774F=05 0,18776F=04 0,18773F=03 0,84677F=03 0,34940F=02 0,11552F=01 0,25600E=01 0,25600E=01
2 0 50 50 50 50 50 50 50 50 50 50 50 50 5	PLANAR RC0 0,18191F=05 0,23148E=04 0,27275E=03 0,14066E=02 0,47006E=02 0,47006E=02 0,47092E=02 0,76447F=02 0,12128E=01 0,16784E=01 0,19214E=01	RC1 0,17624E=06 0,21167E=05 0,23634E=04 0,14904E=03 0,68420E=03 0,11166E=02 0,29635E=02 0,66259E=02 0,12216E=01 0,17902E=01	0,19100E+08 0,45947E+07 0,11774E+05 0,18276E+04 0,18713E+03 0,84077E+03 0,34940E+02 0,11552E+01 0,29608E+01	RC0 C,18191E=05 C,23148E=04 C,27275E=03 C,1406E=02 C,4706E=02 C,41092E=02 C,76447E=02 C,12128E=01 C,16784E=01	FC1 C,17024E-06 C,21167E-05 C,23034E-04 C,14904E-03 C,66420E-03 C,11166E-02 C,24635E-02 C,24635E-02 C,12216E-01	0,19100F=08 0,45947F=07 0,11774F=05 0,18776F=04 0,18773F=03 0,84677F=03 0,34940F=02 0,11552F=01 0,25600E=01 0,25600E=01
2 0 50 50 50 50 50 50 50 50 50 50 50 50 5	PLANAR RC0 0,18191F=05 0,23148E=04 0,27275E=03 0,14066E=02 0,47006E=02 0,47006E=02 0,47092E=02 0,76447F=02 0,12128E=01 0,16784E=01 0,19214E=01	RC1 0,17624E=06 0,21167E=05 0,23634E=04 0,14904E=03 0,68620E=03 0,11166E=02 0,29635E=02 0,6259E=02 0,17902E=01 0,21317E=01	0,19100E+08 0,45947E+07 0,11774E+05 0,18276E+04 0,18713E+03 0,84077E+03 0,34940E+02 0,11552E+01 0,62349E+01 0,62349E+01 0,10387E 00	RC0 C,18191E-05 C,23148E-04 C,27275E-03 C,1406E-02 C,4706E-02 C,41092E-02 C,76447E-02 C,1228E-01 C,16784E-01 C,19214E-01 C,17886E-01	FC1 C,17024E-06 C,21167E-05 C,23034E-04 C,14904E-03 C,66420E-03 C,11166E-02 C,24035E-02 C,24035E-02 C,12216E-01 U,17902E-01 O,21317E-01	0,19100F=08 0,45947E=07 0,11774E=05 0,18776E=04 0,18713E=03 0,84677E=03 0,34940F=02 0,11552F=01 0,25600E=01 0,25600E=01 0,25600E=01
2 0 50 50 50 50 50 50 50 50 50 50 50 50 5	PLANAR RCO 0,18191F=05 0,23148E=04 0,27275E=03 0,14066E=02 0,47006F=02 0,47006F=02 0,47006F=02 0,247F=02 0,12128F=01 0,16784F=01 0,16784F=01 0,17886E=01	RC1 0,17624E=06 0,21167E=05 0,25634E=04 0,14904E=03 0,68420E=03 0,11166E=02 0,29635E=02 0,6259E=02 0,12216E=01 0,17902E=01 0,21317E=01 HEAT TRAFSFER	0,19100E+08 0,45947E+07 0,11774E+05 0,18276E+04 0,18713E+03 0,34940E+02 0,11552E+01 0,62349E+01 0,62349E+01 0,10387E 00 CDEFF, AHI	RC0 C.18191E-05 C.23148E-04 O.27275E-03 C.14046E-02 C.47006E-02 C.47092E-02 C.41092E-02 C.76447E-02 C.12128E-01 C.1676&E-01 C.1676&E-01 C.17886E-01 C.17886E-01 FRICTION	FC1 C.17024E-06 C.21167E-05 C.23034F-04 C.14904E-03 C.66420E-03 C.11166E-02 C.2595E-02 C.2595E-02 C.12216E-01 C.17902E-01 C.21317E-01	0,19100F=08 0,45947E=07 0,11774F=05 0,18776F=04 0,18713E=03 0,34940F=02 0,11552F=01 0,2500E=01 0,2500E=01 0,25000E=01 0,25000E=01
2 0 50 50 50 50 50 50 50 50 50 50 50 50 5	PLANAR RC0 0,18191F-05 0,23148E+04 0,27275F+03 0,14066F+02 0,41092E+02 0,76447F+02 0,16784E+01 0,10784E+01 0,19214E+01 0,17886E+01 0,17886E+01 RC0 0,16660F 00	RC1 0,17624E=06 0,21167E=05 0,23634E=04 0,14904E=03 0,68620E=03 0,11166E=02 0,20635E=02 0,66259E=02 0,12216E=01 0,17902E=01 0,21317E=01 HEAT TRAMSFER RC1 0,10701E C0	0,19100E+08 0,45947E+07 0,11774E+05 0,18276E+04 0,18713E+03 0,34940E+02 0,11552E+01 0,62549E+01 0,62549E+01 0,62549E+01 0,10387E 00 COEFF, AU RC2 0,28186E 00	RC0 C,18191E-05 C,23148E-04 C,27275E-03 C,1406E-02 C,4706E-02 C,41092E-02 C,76447E-02 C,1228E-01 C,16784E-01 C,19214E-01 C,17886E-01	FC1 C,17024E-06 C,21167E-05 C,23034E-04 C,14904E-03 C,66420E-03 C,11166E-02 C,24035E-02 C,24035E-02 C,12216E-01 C,12216E-01 C,12317E-01 FACTUR (TRANS) PC1 C,74013E-02	0,19100F=08 0,45947E=07 0,11774E=05 0,18776E=04 0,18713E=03 0,84677E=03 0,34940F=02 0,11552F=01 0,25600E=01 0,25600E=01 0,25600E=01
2 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RC0 0,18191F=05 0,23148E=04 0,27275E=03 0,44066E=02 0,47006E=02 0,41092E=02 0,76447E=02 0,16784E=01 0,16784E=01 0,17886E=01 0,17886E=01	RC1 0.17624E=06 0.21167E=05 0.25634E=04 0.14904E=03 0.68420E=03 0.11166E=02 0.29635E=02 0.66259E=02 0.12216E=01 0.17902E=01 0.21317E=01 HEAT TRAFSFER RC1 0.10701E C0 0.10884E 00	0,19100E+08 0,45947E+07 0,11774E+05 0,18276E+04 0,18713E+03 0,34940E+02 0,11552E+01 0,62349E+01 0,62349E+01 0,62349E+01 0,10387E 00 COEFF, AHI RC2 0,25568E 00	RCO C.18191E-05 C.23148E-04 O.27275E-03 C.14046E-02 C.47006E-02 C.47006E-02 C.41092E-02 C.76447E-02 C.16764E-01 C.16764E-01 C.17886E-01 C.17886E-01 FRICTION RCO O.43654E-02 O.44443E-02	FC1 C.17024E-06 C.21167E-05 C.23034F-04 C.14904E-03 C.66420E-03 C.11166E-02 C.29035E-02 C.66259E-02 C.12216E-01 U.17902E-01 O.21317E-01 FACTUR (TRANS) PC1 U.74013E-02 U.75165E-02	0,19100F=08 0,45947E=07 0,11774F=05 0,18776F=04 0,18713F=03 0,34940F=02 0,11552F=01 0,25600E=01 0,25600E=01 0,25600E=01 0,25600E=01 FORMED) RC2 0,73750E=02 0,74407E=02
2 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RC0 0,18191F=05 0,23148E=04 0,27275E=03 0,14066E=02 0,47006E=02 0,41092E=02 0,76447E=02 0,1228E=01 0,16784E=01 0,19214E=01 0,17886E=01 RC0 0,16660F 00 0,16754E 00 0,16469E 00 0,17049E 00	RC1 0,17624E=06 0,21167E=05 0,23634E=04 0,14904E=03 0,68620E=03 0,11166E=02 0,29635E=02 0,12216E=01 0,17902E=01 0,21317E=01 HEAT TRANSFER RC1 0,10701E C0 0,10884E 00 0,11303E 00	COEFF, AUD COEFF, AUD COEFF, CO CO CO CO CO CO CO CO CO CO	RC0 C, 18191E-05 C, 23148E-04 O, 27275E-03 C, 1406E-02 C, 47006E-02 C, 41092E-02 C, 76447E-02 C, 12128E-01 C, 16784E-01 C, 19214E-01 C, 19214E-01 C, 17886E-01 FRICTION RC0 O, 43654E-02 C, 45106E-02 C, 45762E-02	FC1 C,17024E-06 C,2107E-05 C,23034F-04 C,14904E-03 C,66420E-03 C,24635E-02 C,24635E-02 C,24635E-02 C,12216E-01 U,17902E-01 V,17902E-01 V,21317E-01 FACTUR (TRANS) FC1 C,74013E-02 U,75460E-02 U,7605E-02 U,76035E-02	0,19100F-08 0,45947E-07 0,11774E-05 0,18776E-04 0,18713E-03 0,84677E-03 0,34940E-02 0,11552E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01
2 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	PLANAR RCO 0,18191F-05 0,23148E-04 0,27275E-03 0,14066E-02 0,41092E-02 0,41092E-02 0,76447E-02 0,12128E-01 0,16784E-01 0,16786E-01 RCO 0,16660F 00 0,16654E 00 0,17886F 00 0,17649E 00 0,17520F 00 0,17515F 00	RC1 0,17624E=06 0,21167E=05 0,23634E=04 0,14904E=03 0,68420E=03 0,11166E=02 0,29635E=02 0,66259E=02 0,12216E=01 0,17902E=01 0,21317E=01 HEAT TRANSFER RC1 0,10701E C0 0,10884E 00 0,11086E 00 0,11503E 00 0,11503E 00	COEFF, Aut RC2 COEFF, Aut COEFF, CO COCCACACACACACACACACACACACACACACACACACA	RC0 C, 18191E-05 C, 23148E-04 O, 27275E-03 C, 1406E-02 C, 47006E-02 C, 41092E-02 C, 76447E-02 C, 12128E-01 C, 16784E-01 C, 19214E-01 C, 17886E-01 FRICTION RC0 C, 43654E-02 O, 44643E-02 C, 45106E+02	FC1 C.17024E-06 C.21167E-05 C.23034F-04 C.14904E-03 C.68420E-03 C.11166E-02 C.24035E-02 C.24035E-02 C.12216E-01 U.17902E-01 U.21317E-01 FACTUR (TRANS) PC1 U.74013E-02 U.75865E-02 U.70860E-02	0,19100F-08 0,45947E-07 0,11774E-05 0,18776E-04 0,18713E-03 0,84677E-03 0,34940E-02 0,11552E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,73750E-02 0,74407E-02 0,74532E-02
2 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RC0 0,18191F=05 0,2314bE=04 0,27275E=03 0,14066E=02 0,41092E=02 0,41092E=02 0,76447E=02 0,16784E=01 0,16784E=01 0,17886E=01 RC0 0,16660F 00 0,16754E 00 0,17649E 00 0,17815F 00 0,17815F 00 0,17815F 00	RC1 0,17624E=06 0,21167E=05 0,23534E=04 0,14904E=03 0,68620E=03 0,11166E=02 0,29635E=02 0,12216E=01 0,17902E=01 0,21317E=01 HEAT TRANSFER RC1 0,10701E C0 0,11086E 00 0,11086E 00 0,11503E C0 0,11745E C0	0,19100E+08 0,45947E+07 0,11774E+05 0,18276E+04 0,18715E+03 0,34940E+02 0,11552E+01 0,29408E+01 0,62349E+01 0,10387E 00 COEFF, AU: RC2 0,28186E 00 0,23735E 00 0,22373E 00 0,22373E 00 0,22373E 00 0,22373E 00 0,22373E 00 0,22373E 00 0,22771E 00 0,21214E 00 0,21946E 00	RC0 C, 18191E-05 C, 23148E-04 O, 27275E-03 C, 1406E-02 C, 47006E-02 C, 41092E-02 C, 76447E-02 C, 12128E-01 C, 16784E-01 C, 19214E-01 C, 17886E-01 FRICTION RC0 O, 43654E-02 O, 44443E-02 C, 45762E-02 C, 49761E-02 C, 49761E-0	FC1 C.17024E-06 C.21167E-05 C.23034F-04 C.14904E-03 C.66420E-03 C.66420E-03 C.24635E-02 C.24635E-02 C.12216E-01 C.12216E-01 C.12216E-01 C.12216E-01 C.12216E-01 C.12216E-01 C.12216E-01 C.12216E-01 C.12216E-01 C.12216E-02 C.12216E-02 C.75460E-02	0,19100F-08 0,45947E-07 0,11774E-05 0,18776E-04 0,18776E-03 0,84677E-03 0,3640F-02 0,11552E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-02 0,73750E-02 0,74407E-02 0,76119E-02 0,77356E-02 0,78532E-02 0,78532E-02 0,78532E-02 0,78532E-02 0,80303E-02
2 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RCO 0,18191F-05 0,23148E-04 0,27275E-03 0,14066E-02 0,41092E-02 0,41092E-02 0,76447E-02 0,12128E-01 0,16784E-01 0,16784E-01 0,17886E-01 RCO 0,16660F 00 0,16754E 00 0,17654E 00 0,17520F 00 0,17520F 00 0,17520F 00 0,19438E 00 0,21526F 00 0,23541F 00	RC1 0.17624E=06 0.21167E=05 0.25634E=04 0.14904E=03 0.68420E=03 0.11166E=02 0.29635E=02 0.66259E=02 0.12216E=01 0.17902E=01 0.21317E=01 HEAT TRANSFER RC1 0.10701E CO 0.10884E 00 0.11086E 00 0.11086E 00 0.11086E 00 0.11676E CO 0.11745E CO 0.11903E 00 0.12667F CO	COEFF, Aut RC2 COEFF, Aut RC2 COEFF, CC COEFF, CC COEFF, CC COEFF, CC COEFF, CC COEFF, CC COEFF, CC COEFF, CC CC COEFF, CC CC CC CC CC CC CC CC CC CC	RC0 C.18191E-05 C.23148E-04 O.27275E-03 C.14046E-02 C.47006E-02 C.47006E-02 C.47092E-02 C.76447E-02 C.12128E-01 C.16784E-01 C.16784E-01 C.17886E-01 C.17886E-01 FRICTION RC0 O.43654E-02 O.44445E-02 C.45706E-02 C.4570E-02 C.4970E-02 C.4976E-02 O.64397E-02 O.64397E-02 O.64397E-02 O.64397E-02 O.64397E-02	FC1 C.17624E-06 C.21167E-05 C.23034E-04 C.14904E-03 C.66420E-03 C.11166E-02 C.259E-02 C.259E-02 C.12216E-01 C.12216E-01 C.12216E-01 C.12216E-01 C.12216E-01 FACTUR (TRANS) FACTUR (TRANS) RC1 C.74013E-02 C.75165E-02 C.75165E-02 C.75165E-02 C.7545E-02 C.7545E-02 C.7545E-02 C.7545E-02 C.7545E-02 C.7545E-02 C.7545E-02 C.80728E-02 C.80728E-02 C.80728E-02 C.10237E-01	0,19100F=08 0,45947E=07 0,11774F=05 0,18776F=04 0,18776F=03 0,36940F=02 0,11552F=01 0,25600E=01 0,25600E=01 0,25600E=01 0,25600E=01 0,25600E=01 0,25600E=01 0,25600E=01 0,25600E=01 0,73750F=02 0,74407F=02 0,74407F=02 0,77356F=02 0,74407F=02 0,77356F=02 0,74407F=02 0,747F=02 0,747F=0
2 0 50 50 50 50 50 50 50 50 50 50 50 50 5	PLANAR RCO 0,18191F=05 0,23148E=04 0,27275E=03 0,14066E=02 0,41092E=02 0,41092E=02 0,76447E=02 0,12128E=01 0,16784E=01 0,19214E=01 0,17886E=01 RCO 0,16660F 00 0,16754E 00 0,17520F 00 0,17815F 00 0,19438F 00 0,21520F 00 0,21520F 00	RC1 0,17624E=06 0,21167E=05 0,23634E=04 0,14904E=03 0,68620E=03 0,11166E=02 0,29635E=02 0,6259E=02 0,12216E=01 0,17902E=01 0,21317E=01 HEAT TRAMSFER RC1 0,10701E CO 0,10884E 00 0,110886E 00 0,110886E 00 0,11503E CO 0,11676E CO 0,11676E CO 0,11903E CO	COEFF, All RC2 0,237736 0,11776 0,11776 0,11776 0,187135 0,3496 0,840775 0,3496 0,2496 0,11522 0,11522 0,11522 0,11522 0,2496 0,10387 0,00 0,23735 0,23735 0,237735 0,22771 0,22771 0,02771 0,207710 0,207710 0,207710 0,207710 0,2077	RC0 C, 18191E-05 C, 23148E-04 C, 27275E-03 C, 1406E-02 C, 47006E-02 C, 4706E-02 C, 41092E-02 C, 76447E-01 C, 16784E-01 C, 19214E-01 C, 19214E-01 C, 17886E-01 FRICTION RC0 C, 43654E-02 C, 45762E-02 C, 45762E-02 C, 45762E-02 C, 45762E-02 C, 45762E-02 C, 556042E-02 C, 56042E-02 C, 56042E-0	FC1 C.17624E-06 C.21167E-05 C.23034F-04 C.14904E-03 C.68420E-03 C.11166E-02 C.24035E-02 C.24035E-02 C.12216E-01 U.17902E-01 U.17902E-01 U.21317E-01 FACTUR (TRANS) FC1 U.74013E-02 U.75465E-02 U.75465E-02 U.75465E-02 U.75455E-02 U.75455E-02 U.75455E-02 U.75455E-02 U.75455E-02 U.75455E-02 U.75455E-02 U.87655E-02 U.87655E-02 U.1027E-01 C.11173E-01	0,19100F-08 0,45947E-07 0,11774E-05 0,18776E-04 0,18776E-03 0,84677E-03 0,34940F-02 0,11552E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,73750E-02 0,74407E-02 0,76119E-02 0,76136E-02 0,7853EE-02 0,78555EE-02 0,78555EE-02 0,78555EE-02 0,78555EE-02 0,78555EE-02 0,78555EE-02 0,78555EE-02 0,78555EE-02 0,78555EE-02 0,78555EE-02 0,78555EE-02 0,785555EE-02 0,785555EE-02 0,785555EE-02 0,785555EE-02 0,78555555555555555555555
2 50 50 50 50 50 50 50 50 50 50 50 50 50	PLANAR RC0 0,18191F-05 0,2314bE-04 0,27275E-03 0,14066E-02 0,41092E-02 0,41092E-02 0,76447E-02 0,12128E-01 0,16784E-01 0,16786E-01 0,17886E-01 RC0 0,16660F 00 0,16754E 00 0,17649E 00 0,17520F 00 0,17515F 00 0,21526F 00 0,21526F 00 0,21526F 00 0,23541F 00 0,25491F 00	RC1 0,17624E=06 0,21167E=05 0,23634E=04 0,14904E=03 0,68620E=03 0,11166E=02 0,29635E=02 0,2216E=01 0,17902E=01 0,21317E=01 HEAY TRANSFER RC1 0,10701E C0 0,10884E 00 0,11503E 00 0,11676E C0 0,12667E C0 0,12667E C0	0,19100E+08 0,45947E+07 0,11774E+05 0,18276E+04 0,18713E+03 0,84677E+03 0,34940E+02 0,11552E+01 0,29408E+01 0,62349E+01 0,10387E 00 COEFF, AHI RC2 0,28186E 00 0,25568E 00 0,22573E 00 0,225774E 00 0,225774E 00 0,22474E 00 0,22474E 00 0,22474E 00 0,22464E 00 0,22464E 00 0,224320E 00	RC0 C, 18191E-05 C, 23148E-04 O, 27275E-03 C, 1406E-02 C, 47006E-02 C, 41092E-02 C, 76447E-02 C, 12128E-01 C, 16784E-01 C, 19214E-01 C, 19214E-01 C, 17886E-01 FRICTION RC0 O, 43654E-02 O, 44443E-02 C, 43762E-02 C, 49791E-02 C, 49791E-02 O, 56042E+02 O, 56042E+02 O, 56042E+02 O, 56054E-02 C, 76451E+02	FC1 C.17624E-06 C.21167E-05 C.23034E-04 C.14904E-03 C.66420E-03 C.11166E-02 C.259E-02 C.259E-02 C.12216E-01 C.12216E-01 C.12216E-01 C.12216E-01 C.12216E-01 FACTUR (TRANS) FACTUR (TRANS) RC1 C.74013E-02 C.75165E-02 C.75165E-02 C.75165E-02 C.7545E-02 C.7545E-02 C.7545E-02 C.7545E-02 C.7545E-02 C.7545E-02 C.7545E-02 C.80728E-02 C.80728E-02 C.80728E-02 C.10237E-01	0,19100F-08 0,45947E-07 0,11774E-05 0,18776E-04 0,18776E-03 0,36940F-02 0,11552E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,25600E-01 0,73756E-02 0,74407E-02 0,74407E-02 0,77356E-02 0,7832E-02 0,7832E-02 0,80303E-02 0,80303E-02 0,96151E-02 0,12664E-01

## APPENDIX X

# EXPECTED FREQUENCY DISTRIBUTIONS OF TEMPERATURE

HISTRAND output for peak fuel and graphite temperatures of the peak rated channel (Tables 4/1, 5/1)

EXPECTED FREQUENCY IN REGION BELOW	X= 750.0	0.0
EXPECTED FREQUENCY IN INTERVAL BELOW		0.0
	770.0	0.0
	780.0	0.0
	790.0	0.0 0.0
	810.0	0.0
	820.0	0.1
	830.0	0.1
	840.0	0.2
	850.0	0.4
	860.0	0.7
	870.0	1.1
	880.0	1.8
	890.0	2.0
	900.0	3.9
	910.0	5.4
	920.0	7.5
	930.0	10.0
	. 940.0	13.1
	950.0	. 10.8
	960.0	21.3
	970.0	26.6
	980.0	32.7
	990.0	39.7
	1000.0	47.8
	1010.0	57.1
	1020.0	67.9
	1030.0	80.3
	1040.0	94.9
	1050.0	111.9
	1060.0	131.8
	1070.0	154.5
	1080.0	179.8
	1090.0	206.9
	1100.0	234.2
	1110.0	259.5
	1130.0	295.2
	1140.0	300.9
	1150.0	296.0
	1100.0	282.4
	1170.0	259.3
	1180.0	229.5
	1190.0	175.5
	1200.0	160.4
	1210.0	120.0
	1220.0	90.2
	1230.0	70.4
	1240.0	49.5
	1250.0	33.0
	1200.0	21.9
	1270.0	13.7
	1280.0	8.3
	1290.0	4.8
	1300.0	2.7
	1310.0	1.5
	1320.0	0.3
	1330.0	0.4
	1340.0	0.2
EXPECTED FREQUENCY IN REGION ABOVE	1350.0 X= 1350.0	0.1
EALECTED TREQUENCY IN REGION ADOVE	V- 1330.0	0.1

AX-2

# TNPG EXPECTED FREQUENCY DISTRIBUTION OF TW1;

EXPECTED FREQUENCY IN REGION BELOW X=	650.0	0.0
EXPECTED FREQUENCY IN INTERVAL BELOW X=	660.0	0.0
ENTERTED TREQUENCT IN THTERTRE DELON A	670.0	0.0
	680.0	0.0
·	690.0	0.1
	700.0	0.2
the second s	710.0	0.5
	720.0	0.9
	730.0	1.5
and the second	740.0	2.5
	750.0	4.0
e7.	760.0	5.8
	770.0	8.2
	780.0	11.1
	790.0	14.5
	800.0	18.5
	810.0	23.1
	820.0	28.3
	830.0	34.4
	840.0	41.5
	850.0	49.8
	860.0	59.8
	870.0	71.8
and the second	880.0	86.5
	890.0	104.6
	900.0	127.0
	910.0 920.0	187.0
	930.0	224.2
The second	940.0	263.8
	950.0	301.9
	960.0	333.4
and the second s	970.0	353.1
	980.0	356.8
	990.0	343.0
	1000.0	312.9
	1010.0	270.4
	1020.0	221.2
	1030.0	171.1
	1040.0	125.2
	1050.0	86.5
	1060.0	56.5
	1070.0	34.8
MELL TANK AND PERSON AND AND AND AND AND AND AND AND AND AN	1080.0	20.3
	1090.0	11.1
the second s	1100.0	5.7
the second s	1110.0	2.8
	1120.0	1.3
and the second se	1130.0	0.5
	1140.0 1150.0	0.2
EXPECTED FREQUENCY IN REGION ABOVE X=	1150.0	0.1
EXPLOTED FREQUENCE IN REGION ADDVC X-	1150.0	

AX-3

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# TNPG EXPECTED FREQUENCY DISTRIBUTION OF TW2;

EXPECTED FREQUENCY IN REGION BELOW X=		0.0
EXPECTED FREQUENCY IN INTERVAL BELOW X=	650.0	0.0
EXPECTED PREQUENCY IN INTERVAL BELUW X=	660.0	0.0
	670.0	0.1
	680.0	0.1
	690.0	0.3
The second	700.0	0.6
	710.0	1.1
	720.0	1.9
	730.0	3.0
	740.0	4.7
	750.0	6.8
	760.0	9.6
	770.0	12.8
	780.0	16.5
	790.0	20.8
	800.0	25.6
	810.0	31.2
	820.0	37.8
	830.0	45.6
	840.0	55.0
	850.0	66.2
	860.0	79.5
	870.0	95.2
	880.0	113.7
	890.0	135.4
	900.0	160.9
	910.0	190.3
	920.0	223.0
	930.0	256.9
	940.0	288.6
	950.0	314.0
	960.0	328.9
	970.0	330.5
	980.0	317.8
	990.0	292.2
	1000.0	256.9
	1010.0	216.2
	1020.0	174.3
	1030.0	134.7
	1040.0	99.8
	1050.0	70.8
	1060.0	48.1
	1070.0	31.2
	1080.0	19.3
	1090.0	11.4
	1100.0	6.3
	1110.0	3.3
	1120.0	1.7
	1130.0	0.8
	1140.0	0.3
	A A T U B U	0.00
	1150.0	0.1

AX-4

# TNPG EXPECTED FREQUENCY DISTRIBUTION OF TW3:

						0.0
	FREQUENCY			X =	600.0	0.0
EXPECTED	FREQUENCT	TIN TINIE	RVAL BELOW	~-	610.0	0.0
					620.0	0.0
					630.0	0.0
					640.0	0.1
					660.0	0.2
					670.0	0.5
					680.0	1.0
					690.0	1.9
					700.0	3.5
					710.0	5.8
					720.0	8.7
					730.0	12.3
					740.0	16.4
					750.0	20.7
					760.0	25.4
					770.0	30.8
					780.0	37.4
					790.0	45.7
					800.0	56.0
					810.0	68.4
					820.0	82.8
			Same and		830.0	99.2
					840.0	118.0
					850.0	140.3
					860.0	168.0
					870.0	202.3
					880.0	242.4
					890.0	284.5
					900.0	322.4
					920.0	348.8 358.1
					930.0	348.2
					940.0	321.0
					950.0	281.5
					960.0	235.6
					970.0	188.9
					980.0	145.6
					990.0	108.0
					1000.0	77.1
					1010.0	52.8
					1020.0	34.5
					1030.0	21.4
					1040.0	12.5
					1050.0	6.9
					1060.0	3.5
					1070.0	1.6
					1080.0	0.7
					1090.0	0.3
	IT OF THE OW		Ton Longitur		1100.0	0.1
EXPECTED	FREQUENCY	IN REG	TON AGOVE	X =	1100.0	0.1

AX-5

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