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An Improved Version of the SAGAPØ Code for the Thermofluiddynamic Analysis of Gas Cooled Fuel Element Bundles

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An Improved Version of the SAGAPØ Code for the Thermo-fluiddynamic Analysis of Gas Cooled Fuel Element Bundles

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Summary

The SAGAPØ Code, developed at the Karlsruhe Nuclear Center, was improved at General Atomic Company in San Diego, California (USA).
The modifications introduced at General Atomic are summarized in this paper.

Furthermore, the meaning of the new variables defined in CØMMØN BLØCKS is also explained. A complete listing of the new version of the code is included in Appendix. Finally, the results of a parametric study performed at General Atomic with SAGAPØ are summarized in this paper.

SAGAPØ-2: Eine verbesserte Version des Rechenprogramms SAGAPØ für die thermo- und fluiddynamische Analyse von gasgekühlten Brennelementbündeln

Zusammenfassung

Das im Kernforschungszentrum Karlsruhe entwickelte Rechenprogramm SAGAPØ wurde bei General Atomic Company in San Diego, California (USA), verbessert.

Die bei General Atomic eingeführten Änderungen werden in dieser Arbeit zusammengefaßt.

Außerdem wird hier auch die Bedeutung der in "CØMMØN BLØCKS" neu definierten Variablen erklärt. Eine Liste der neuen Version des Codes ist im Anhang enthalten.

Schließlich werden die Ergebnisse einer bei General Atomic mit SAGAPØ durchgeführten Parameterstudie in dieser Arbeit zusammengefaßt.

Contents

1. Introduction

The development of the computer code SAGAPØ for the thermo-fluiddynamic analysis of gas cooled fuel element bundles was started at the Karlsruhe Nuclear Center (KfK) in 1974. In 1977 two KFK-EUR papers were published /1,2/. The first one deals with the description of the physical models and the mathematical procedures applied in the code, while the second one is a guide for the users, which contains information about the structure of the code and the organization of input and output, and a complete listing.

In August 1977, a copy of SAGAPØ was given to General Atomic Company (GA) in San Diego, California (USA), as a result of the Collaboration Program signed by KfK and GA.

At GA, the structure of SAGAPØ was improved considerably, with the main purposes of allowing both a higher flexibility of the code and the capability of simplified procedures also, faster and cheaper than those of /1,2/ and, thus, very useful in the first phase of an optimization process for the thermofluiddynamic design of gas cooled rod bundles. Furthermore, some small errors contained in the version of SAGAPØ of /2/ were also corrected /3/.

These modifications, partly necessary to allow the calculations for the GCFR-Benchmarks II and III /4,5/ performed with SAGAPØ at GA, are described in detail in GA Internal Reports /3/ and are summarized in this paper.

In order to allow the mentioned modifications in SAGAPØ, some new CØMMØN BLØCKS were defined, referring mostly to new variables (new data), the values of which must be provided in BLØCK DATA. The meaning of these new variables is described accurately in this paper. It must be noticed that the main extensions for the input of SAGAPØ refer to the data which must be provided in BLØCK DATA by means of DATA statements, while only one modification concerns the data to be punched on cards (see below, variable NSEL).

A complete listing of the new version of SAGAPØ (SAGAPØ-2) is contained in Appendix.

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In order to provide some useful advices to the users of the code , this paper also contains a summary of the results of a parametric study carried out at GA to investigate the effects on results and calculation time of (A) sub-subchannel subdivision, (B) central subchannel subdivision, (C) axial section subdivision, (D) use of "hot" or "cooled" geometric dimensions, and (E) method for approximating the energy increments. Finally some remarks about laminar calculations are also included in this work.

2. Improvements in the structure of SAGAPØ

The main improvements in the structure of SAGAPØ refer to:

(A) The allowed bundle symmetry sections;

(B) The allowed shroud shapes;

(C) The procedure for the choice of the gas coolant;

(D) The correct introduction of gravitation effects for turbulent flow;

(E) The procedures of the subroutine AXSEC for the Nusselt number correction profiles due to spacer effects;

(F) The introduction of spacer effect on turbulent mixing.

The modifications concerning these and some more, less important, improvements are described in the following paragraphs, while the changes allowing simplified SAGAPØ calculations are discussed separately in Chapter 3.

2.1 Bundle symmetry sections

In case of hexagonal bundles, with the original version of SAGAPØ described in /2/, it is possible to perform calculations only for (1) the whole bundle flow section, or (2)a half of it, or (3) 1/12th, the type of the symmetry section being fixed by the value of the input parameter NSEL (see /1/, Par.3.1, 9th card). In that version of SAGAPØ, automatic procedures are included to establish indexing and connections of rods, channels and subchannels, and to compute the subchannel and channel flow areas and equivalent diameters.

In order to allow Benchmark III calculations, for which 1/6th of the bundle flow section had to be considered (see /5/), an extension of the SAGAPØ procedures became necessary. It was thought to be better to introduce a general procedure valid for all other symmetry sections, different from those previously allowed, instead of limiting the modifications to the case of 1/6th. Since the case of symmetry sections different from 1/1, 1/2 and 1/12 is not very frequent, it was decided to introduce, for the other sections, a procedure similar to that already used in /2/ for the 12-rod bundles, in which connections and indexing are provided in input*).

It must be pointed out that only symmetry sections can be computed with SAGAPØ, while other codes, like, for example CØBRA*GCFR /6/ can analyze separatly any portion of the bundle flow section**). However, this is not a big limitation for SAGAPØ. In fact, the analysis for non-symmetric sections is useful only in the first phase of an optimization process for the bundle geometry. For example, to optimize the shroud profile for a bundle with a large number of rods, it is convenient to limit the analysis to the most external rows of channels***), for some inital runs, in order to avoid useless expensive calculations. However, approximate calculations for a reduced number of channels can be carried out with SAGAPØ also, by defining a "fictitious" bundle which includes the interesting channels (see Fig.1).

2.2 Shroud shape

The SAGAPØ code was developed with the purpose of modelling - with the best possible accuracy - bundles having angular corner channels and blocking triangles with straight sides and base angles of 30^{o} in the wall channels (see /2/ and Fig.2).

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*) A description of the necessary new input variables is given in Par. 4.2.

**) However, the input preparation is considerably more complicated for CØBRA*GCFR than for SAGAPØ (see /2,6/).

***) Assumed to be disconnected from the more interior channels.

Therefore, to allow SAGAPØ calculations for bundles with a different shroud profile, since the most important condition to be respected refers to the flow areas of corner and wall channels (which must be the real ones), it is necessary to assume modified values for the distances between the centers of the external rods and the shroud*) and for the height of the blocking triangles, such that the flow areas of both corner and wall channels remain unchanged (see Fig.3).

This procedure was applied at the time of the calculations performed for the design of the shroud dimensions of the BR-2 12-rod bundle fuel element, having rounded corner channels (contrary to the 12-rod bundle calibration elements investigated experimentally in the Institute of Neutron Physics and Reactor Engineering of KfK /2,7/).

However, with such a procedure, not exact hydraulic diameters were assumed in the calculations, for both corner and wall channels**). In fact, if the shroud profile is modified in the way previously described, shroud wetted perimeter values different from the real ones are assumed automatically in SAGAPØ.

At the time of Benchmark III calculations /3,5/ due to the complicated shape of the AGATHE bundle to be computed (see Fig.3), an improvement of the SAGAPØ procedures became necessary to allow an accurate analysis***).

The calculations showed that, in normal situations, sufficiently correct results could be obtained by simply introducing correction factors for the hydraulic diameters in the axial momentum equations****) (see /3/ and Par.4.2.2. in this work).

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*) These distances must be all equal to one another, for all external channels.

**) The assumption of not correct hydraulic diameters has an effect on both pressure drop and mass flow and temperature distributions.

***) For the AGATHE bundle, the assumed wetted perimeters corresponding to the modified shroud were 3% too high for corner channels and 3% too low for wall channels.

****) The effect on the friction factors due to slightly incorrect values at the shroud wetted perimeters is negligible /3/.

2.3 Choice of the gas coolant

In SAGAPØ, the equations for the gas properties (i.e. density, dynamic viscosity, specific heat at constant pressure and thermal conductivity) are included in separate FUNCTIØNS (RHØ, ETA, CP and KAPPA, respectively). In the original version of the code /2/ these FUNCTIØNS could only contain the equations for one gas. For example, in the listing of /2/, they refer to helium, which is the coolant used up to now in most gas cooled rod bundle experiments carried out at KfK.

If calculations have to be performed with the version of SAGAPØ of /2/ for a bundle cooled by another gas, the cited FUNCTIØNS of /2/ must simply be replaced by others containing the appropriate set of equations for that gas. At the time of Benchmark III calculations, for which the coolant was CO_2 /5/, in order to allow an even easier use of SAGAPØ, the FUNCTIØNS RHØ, CP, ETA and KAPPA were modified in such a way as to contain the equations for various gases (now up to 4), the gas to be considered being fixed by the input value of the new option IGAS (see Par.4.2.2). The equations for CO_2 /5/ and for helium /8,9/ are already included; those for up to two more gases can be easily introduced.

2.4 Effects of gravitation

A method to allow taking into account the contribution of gravitation to the axial momentum equations in case of laminar flow, was introduced in SAGAPØ in June 1977 (see /2/ and also /3,10/), when it was noticed that gravitation may be important for light gases like helium, also, in case of low Reynolds number values*). It must be pointed out that the applicability of the method of /2/ is limited to the case of laminar flow. In fact, convergence problems occured when it was tried to take into account gravitation, with that procedure, for turbulent flow, also**). These

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*) Gravitation was not included yet in the mathematical model of SAGAPØ described in /1/, as also mentioned in /2/.

**) For gases like CO_2, heavier than helium gravitation is not negligible in case of turbulent flow, also (at low Reynolds numbers).

convergence problems were due to the procedures used for the sub-subchannel analysis /3/.

In order to overcome the convergence problems in case of turbulent flow the method of /2/ was modified at GA. For this purpose, Eqn. (I.55) of /1/, still used in /2/, was changed into:

$$\Delta p = - \left(\frac{\tilde{\bar{m}}_x - \xi_x}{A_x}\right)^2 \left[\frac{\lambda_x \Delta X}{2 D_x \rho_x}\right] + \Delta p_{grav_x}, \tag{1}$$

Δp_{grav_x} being the contribution of gravitation, computed as:

$$\Delta p_{grav_x} = \text{IGRAV}\ \rho_x\ \Delta X.^{*)} \tag{2}$$

Thus, in Eqns. (I.78), (I.94) and (I.95) of /1/ the terms $|\Delta p|$ are now replaced by:

$$|\Delta p - \text{IGRAV}\ \rho_{ia,b}\ \Delta X|. \tag{3}$$

However, Eqns. (I.66), (I.69) and (I.7o) of /1/, used for the calculation of the friction factors of the two portions of the wall subchannels, of the subchannels and of the channels, respectively, are still kept unchanged, although, rigorously, they should be modified, also. This was obtained assuming, for example for (I.66) of /1/:

$$\sum_{i=1}^{Li} \frac{A_i \sqrt{|\Delta p - \Delta p_{grav_i}|}}{\sqrt{\frac{\bar{\lambda}_i \Delta x}{2 D_i \bar{\rho}_i}}} \cong \sqrt{|\Delta p - \Delta p_{grav_{jsc}}|} \sum_{i=1}^{Li} \frac{A_i}{\sqrt{\frac{\bar{\lambda}_i \Delta x}{2 D_i \bar{\rho}_i}}}, \tag{4}$$

which should not be a severe approximation. Applying a similar approximation for the calculation of the whole bundle friction factor from the channel values, also, one obtained exactly the original equation (I.71) of /1/.**)

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*) About IGRAV see Par. 4.2.2

**) In /2/ Eqn. (I.71) of /1/ was modified, according to the first method, introduced at KfK, for taking into account gravitation /3/.

2.5 Modification in the subroutine AXSEC

As described in /2/, the subroutine AXSEC establishes, for each axial portion of the bundle, the subdivision into axial sections and the correction profiles for the Nusselt numbers, due to the spacer effect. This subroutine was considerably improved at GA (see Flow Chart of Fig.4). In fact, in SAGAPØ-2, the following limitations, present in the version of AXSEC of /2/, are removed:

(A) Impossibility of taking into account the spacer effect on the Nusselt numbers in the axial sections downstream a spacer, for a calculation step starting after the middle section of that spacer (in case of calculations carried out in more than one run).

(B) Impossibility of taking into account any eventual influence on the Nusselt numbers in the first sections of an axial portion, if it is due to the last spacer in the preceeding axial portion.

(C) Impossibility of modelling the case of two spacers so close to each other, that no region with undisturbed temperature profiles exists between them.

(D) Impossibility of performing correct calculations in case of spacers which middle section is less than WSP/2*) distant from the inlet section of the containing axial portion, or - in case of calculations carried out in more than one run - from the section at which the calculation step starts.

(E) Impossibility of assuming in input values for the length of the axial sections in the unheated axial portions, such that more than one spacer is contained in one section.**)

(F) Impossibility of neglecting the spacer effect on the Nusselt numbers.

The elimination of limitations (A) and (D) was quite important, because calculations in two or more steps are very useful and often necessary, especially for bundles with a large number of

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*) WSP is the spacer width.

**) In case of unheated portions, all sections have equal lengths in SAGAPØ and SAGAPØ-2.

rods (the allowed maximum calculation time for day-time runs is limited on all computers).

The necessity of eliminating limitation (E) became obvious, after the parametric study carried out at GA with SAGAPØ /3/ had shown that considerably longer axial sections can be used than those previously assumed in the calculations, especially for unheated sections (see Par.5.2).

Finally, limitation (F) was eliminated in order to allow simplified fast procedures, also (see Par. 3.1).

2.6 Spacer effect on turbulent mixing

In the original version of SAGAPØ of /2/, no enhancement of the turbulent mixing rates W^T could be considered in the spacer regions. However, the spacers affect certainly the turbulent mixing (in fact, their effect on the Nusselt numbers is due to increased mixing). Thus some modifications were made in the code, assuming that the correction factor for the turbulent mixing rate exchanged between two flow zones due to the spacer effect is proportional to the arithmetic average of the correction factors for the Nusselt numbers of the two flow zones*), i.e., for the flow zones 1 and 2, that:

$$\frac{W_{12}^{T}}{W_{12}^{TO}} = CY \left[0.5 \left(\frac{Nu_1}{Nu_1^O} + \frac{Nu_2}{Nu_2^O} \right) - 1 \right] + 1, \qquad (5)$$

where W^{TO} and Nu^O are the turbulent mixing rates and the Nusselt numbers, respectively, in case of no spacer effect, and the value of the constant CY must be provided in input (see Par.4.2.2). Calculations carried out for Benchmark III have shown that the assumption of CY = 1 instead of CY = 0 (which means no enhancement), brings only small changes for the mass flow and temperature

*) For the channels, the correction factor for the Nusselt number of each channel is assumed to be the average of the correction factors for the contained subchannels.

profiles outside the regions of spacer influence*), while the effects at axial locations near the spacers are more important, although not very large /3/.

2.7 Further improvements in SAGAPØ

Some more improvements were introduced in SAGAPØ, besides those described above in detail. They refer to:

The temperature correction for the Nusselt numbers of smooth walls

This correction is now:

$$CT = (T_W/T_G)^{-CØTW}, \qquad (6)$$

with CØTW = input value and T_G = inlet temperature T_E or = bulk temperature T_B, depending on the input value of the variable ITECØ (see Par.4.2.2), instead of (A):

$$CT = (T_W/T_E)^{-0.2} \qquad (7)$$

for the rods, according to /11/, and (B):

$$CT = (T_W/T_B)^{-0.5} \qquad (8)$$

for the shroud, according to /12/**).

This modification allows correct calculations with SAGAPØ for gases for which (7) and (8) are not valid, like, for example, for CO_2 /13/***)(which was the coolant for Benchmark III /5/). Furthermore, the use of the same equation for both rod and shroud is more correct.

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*) Although $W^T = W^{TO}$ at axial locations where no spacer effect is present, the mass flow and temperature profiles are slightly affected by the spacer effect there, also, because the enhancement of turbulent mixing in the region of spacer influence changes (with respect to the case of CY=0) the values of the mass flow rates and gas temperatures of the streams leaving these regions.

**) Erroneously, in /1/ it is said that Eqn.(7) is used in the SAGAPØ version of /2/ for the shroud Nusselt numbers, also. However, in case of not large film drops, the use of (7) or (8) is practically equivalent.

***) Eqns.(7),(8) are valid for gases like helium and air /10,11/.

The calculation of wall temperatures in case of heat losses through the shroud

Contrary to the original version of SAGAPØ /2/, SAGAPØ-2 allows a sufficiently correct calculation of the shroud temperatures in case of heat losses through the shroud walls, also, by computing these temperatures with the same equations already used in /2/ for heated shroud walls /1/. Consequently, the superposition principle is now applied, in case of heat losses, also, for the correction of the rod temperatures of the external channels /1/.

The use of the equations valid in case of heated shroud, which are not completely correct for cooled shroud, is possible because the heat losses are normally not very large in practical situations.

The procedures of the subroutine TLINE

In SAGAPØ-2, the procedure for the determination of the zero shear stress line position - $\tau=0$ - is now optimized for all sub-subchannel subdivisions, while in /2/ this procedure becomes slower and slower, by decreasing the number of sub-subchannels per 30^{o} to less than 10.

The procedures for the solution of the energy equations

In the new version of subroutines BALA, SUBBAL and RECCA2, the requirement of a precision lower than 10^{-4} is now allowed on the gas temperatures, in case of difficult convergence in the iterative loop ITERM for the solution of the energy equations. This allows overcoming local convergence problems, for example in case of spacer pressure drop coefficients which are very different in adjacent flow zones.

Furthermore the option has been introduced of calculating the energy increment within an axial section as:

$$\dot{m}_I \Delta h \qquad (9)$$

(Δh = enthalpy increment, $\dot{m}_I$ = mass flow rate entering the axial section), besides as:

$$\dot{m}_{av}\Delta h \qquad (10)$$

($\dot{m}_{av}$ = average mass flow rate in the axial sections) /1,2/, in order to allow an easier comparison between the results of SAGAPØ and those of CØBRA*GCFR (in CØBRA*GCFR, Eqn. (9) is used*)).

The sizes of the bundles which can be considered

In SAGAPØ-2 the maximum dimensions of some variables are larger than in the version of /2/. This was done to allow Benchmark III calculations /3,5/. With the new version of the code it is possible to compute bundles with a maximum of 37 rods, but only for symmetry sections with not more than 42 channels (not more than 18 external channels).**). Furthermore a maximum number of 4 spacers can be now assumed for an axial portion (against 3 spacers in /2/).

3. New options for simplified SAGAPØ-2 calculations

Besides the improvements described in Chapter 2, some more modifications have been introduced in SAGAPØ, in order to allow options for simplified calculations. These modifications refer to:

(A) The possibility of neglecting the spacer effect on Nusselt numbers

(B) The possibility of avoiding the subchannel calculation and/ or the calculation of the two portions of the wall subchannels.

In this way it is possible, with SAGAPØ-2, to carry out calculations faster and cheaper than those allowed with the more correct procedures of /1,2/ (which, obviously, can still be used in SAGAPØ-2). These simplified procedures are very useful, for example, in the first phase of an optimization process for the thermofluiddynamic design of gas-cooled rod bundles.

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*) see /3,6/ and Par. 5.5 in this work.

**) i.e. up to a half of a complete 37 rod bundle can be computed. Like in /2/, calculations for the whole bundle flow section can be carried out only for a 7, a 12, or a 19 rod bundle (see /3/).

The simplified procedures now allowed in SAGAPØ-2 are described in the next paragraphs.

3.1 Spacer effect on Nusselt numbers

In SAGAPØ-2 the following procedures are possible about the spacer effect on the Nusselt numbers:

- to take into account the effect of all spacers, completely (i.e. including the eventual effect of the last spacer of an axial portion on the Nusselt numbers in the first axial sections of the next axial portion),
- to take into account, for each axial portion, only the effect of the spacers contained in it (like in /2/),
- to neglect the effect of all spacers.

The advantage of neglecting the spacer effect is that a much less fine subdivision into axial sections can be assumed in this way, and, consequently, faster calculations can be carried out.*)

It must be noticed that, if the spacer effect on the Nusselt numbers is neglected, that on the turbulent mixing is neglected, also (see Eqn. (5)). However, as previously pointed out, this last effect is small, especially at a certain distance from the spacers.

The choice of the procedure to be used is fixed by the input values of the variables IDISP1 and IDISP2, the meaning of which is described in Par. 4.2.2.

3.2 Subdivision of the bundle flow section

Before describing the new options for the subdivision of the bundle flow section, it is useful to remember briefly the procedures in the original version of SAGAPØ /2/ for this subdivision and to make some remarks.

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*) However, this is not true any more, if too long sections are assumed, such that convergence problems occur (see /3/ and Par. 5.2 in this work).

3.2.1 Subdivision in the original version of SAGAPØ

As described in detail in /1,2/, in the original version of SAGAPØ the bundle flow section is subdivided as follows (see Fig.5):

(A) subdivision into channels (central, wall, corner),

(B) subdivision of central and wall channels into subchannels,

(C) subdivision of wall subchannels into two portions,

(D) subdivision of corner channels, central subchannels and portions of wall subchannels into sub-subchannels.

In the iterative calculation procedure, the mass flow rates and the temperatures are computed first for the channels (channel calculation), then, in a second step, separately for each channel*), the subchannel mass flow rates and temperatures are computed (subchannel calculation), then, in a third step, separately for each wall subchannel**), the calculation for the two portions of the wall subchannels is performed, and, finally, the sub-subchannel calculation is carried out.

The next two paragraphs contain some remarks about the subchannel calculation and the calculation of the two portions of the wall subchannels, which are the steps which can be eliminated in SAGAPØ-2, by means of the new simplified procedures.

3.2.2 Remarks about the subchannel calculation

While the subdivision into channels applies in the other thermo-fluiddynamic codes, like CØBRA*GCFR /6/ and SCRIMP /14/, that of the channels into subchannels is commonly not used in those codes, at least for central channels /5,6/. Moreover, with CØBRA*GCFR and SCRIMP, also in case of a subdivision of the channels, all the flow zones defined in this way are considered as separate channels, which continuity, energy and axial momentum equations are solved all together (because the simplified procedure of SAGAPØ cannot be applied in those codes).

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*) By use of a simplified method in which each subchannel is assumed to be connected with the other subchannel of the same channel and with the adjacent channels (not the subchannels!) connected to the containing channel /1/.

**) With a procedure similar to that used for the channels /1/.

In our opinion, the subchannel calculation is important, for central channels also, especially in case of differently heated rods, mainly because, in order to apply the temperature profile integration method for calculating Stanton numbers /1,2/, it is necessary to define for each rod the flow zone in which the profiles must be integrated and to compute for this flow zone both mass-flow rate and gas temperature. Furthermore, especially for the wall channels, as already happened for Benchmark II calculations /4/, it is not unusual that the spacer pressure drop coefficients are rather different in the subchannels of the same channel.

The only problem in performing a correct subchannel calculation lies in the evaluation of the mixing coefficients for the turbulent exchange between two subchannels of the same channel, i.e. the quantities /1,3,15/:

$$c = c_1\, c_2, \tag{11}$$

where c_1 is the ratio between the real eddy diffusivity-e- (average for the two subchannels), and a reference eddy diffusivity-$e^{(R)}$- defined as:

$$e^{(R)} = \frac{u^*D}{20}, \tag{12}$$

and c_2 is the correction factor for the temperature gradient in the transverse direction at the boundary between the subchannels:

$$c_2 = \left| \left(\frac{\partial T}{\partial y}\right)_{\text{av, at boundary}} \Big/ \frac{\Delta T}{\delta} \right|, \tag{13}$$

ΔT being the difference between the bulk temperatures of the two subchannels and δ the distance between their centers of gravity).

While the c_2 values in case of turbulent exchanges between channels are rather larger than 1 due to the restriction of the flow area at the gaps between channels, in case of turbulent exchange between subchannels*), the c_2 values should be very close to 1, because the boundary between two subchannels is not a gap, and, thus, at the boundary, the temperature profiles in the direction normal to the boundary do not present any increase of the slope /3/.

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*) And also between the two portions of the wall subchannels (see next paragraph).

Therefore, the only difficulty remains in the determination of the quantities c_1, which can be evaluated by means of eddy diffusivity measurements. Furthermore, thermofluiddynamic experiments in bundles with not equally heated rods - as soon as they will be carried out - will also probably give some indication about the c-values.

Anyway, although in the calculations performed up to now all c values for the exchange between subchannels*) have been assumed equal to 1**), the assumption of values different from 1 for these coefficients is not a problem, both for SAGAPØ and for SAGAPØ-2, because the c values are provided in input***).

The other objection-referring to the subdivision of central channels into three subchannels - that the zero shear and zero heat flux lines ($\tau=0$ and $\dot{Q}''=0$) do never lie exactly on the channel symmetry lines****) (especially in case of differently heated rods) and, consequently, the assumed integration zones for the profiles are not exactly the ones they should be, is not well grounded, at least for turbulent flow*****).
In fact, for turbulent flow:

A) the velocity profile - and, thus, the exchange of momentum through the assumed subchannel boundary - has a small influence on the temperature profile (see /1,3/),

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*) And also between the two portions of the wall subchannels (see next paragraph)

**) Because no experimental information was available about the c_1 values and because the available experimental tests referred to the case of equally heated rods.

***) Different c values can be assumed for the different types of subchannels (and for the two portions of the wall subchannels also; see next paragraph). As pointed out in /2/ these c values must be punched in the 21st data card.

****) If the zero shear and zero heat flux lines are exactly coincident with the channel symmetry lines, there would be no exchange between subchannels.

*****) It must be pointed out that this objection would concern CØBRA and SCRIMP also, because, there also, the symmetry lines are assumed as outer boundaries for the integrations, for turbulent flow. In case of laminar flow, while there is no problem about the c coefficients (because no turbulent mixing exists, i.e. c=0), the exact determination of the position of the maximum velocity and temperature lines may be more important (however, it has not been investigated, yet).

B) due to the flat shape of the temperature profile, it is not very important to assess the exact position of the zero heat flux line*)**).

3.2.3 Remarks about the calculation for the two portions of of the wall subchannels

The necessity of the subdivision of the wall subchannels into two portions (due to the fact that a complete wall subchannel cannot be considered to be equivalent either to a sector of a whole annulus or to a sector of the inner portion of an annulus /1,3/) is now generally accepted /3,4,5,6/. However, the procedure used in SAGAPØ is still different from those applied up to now in CØBRA*GCFR and SCRIMP, /6,14/. In fact:

A) in SAGAPØ the two central portions of the two subchannels of a wall channel are computed separately, while in CØBRA* GCFR and SCRIMP they are combined in a <u>sole channel</u>,
B) the simplified procedure of SAGAPØ is not used in the other codes (similar to the case of the subchannels),
C) while in SAGAPØ the position of the line separating the two portions is computed, this position is assumed in input for CØBRA*GCFR and SCRIMP.

As in the case of the subchannel calculation, a problem for the correct analysis in the two portions of the wall subchannels lies in the determination of the mixing factors for the turbulent exchange between the two portions. However, in this case also, the considerations made in Par. 3.2.2 are still valid.

3.2.4 New options for simplified calculations

Although, for the reasons explained in the preceeding paragraphs, we think that both the subchannel calculation and the calculation of the two portions of the wall subchannels are important, options for simplified and faster procedures, in which one or both of the mentioned steps are eliminated, have been introduced in SAGAPØ-2.

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*) This, however, only in case that the surfaces are all smooth or all rough, like in central channels.

**) An analytical approach for justifying this rather obvious statement is contained in /3/.

More precisely, in SAGAPØ-2, the following procedures are possible:

- to perform all calculation steps, i.e. for channels, subchannels and portion of wall subchannels (like in /2/),
- to perform the calculation for channels, wall subchannels and portion of wall subchannels, avoiding the central subchannel calculation,
- to perform the calculation for channels and wall subchannels, avoiding both central subchannel calculation and calculation for the two portions of the wall subchannels,
- to perform the calculation for channels and central subchannels, avoiding both wall subchannel calculation and calculation of the two portions,
- to perform only the channel calculation, avoiding the other steps.

In case that central and/or wall subchannel calculation steps are eliminated, the mass flow rate and gas temperature distributions are assumed to be uniform inside each central and/or wall channel (see subroutine SUBBAL). In a similar way, in case that the calculation step for the two portions of the wall subchannels is eliminated, the mass flow rate and the gas temperature distributions are assumed to be uniform inside each wall subchannel (see again subroutine SUBBAL). It must be noticed that, for structural reasons, it is not possible to avoid the wall subchannel calculation, without eliminating the calculation for the two portions (see subroutine SUBBAL). The choice of the procedure to be used is fixed by the input values of the variables IDIV1 and IDIV2, the meaning of which is described in Par. 4.2.2..

4. Remarks for the users of SAGAPØ-2

4.1 General remarks

The modifications of the structure of SAGAPØ, allowing both the improved and the simplified procedures described in the preceeding chapters, have been introduced in such a way as to complicate as less as possible the use and the understanding of the code, with respect to its original version /2/.

No new subprograms have been introduced, with respect to /2/. In order to avoid changes in the argument listings of the various subprograms, CØMMØN BLØCKS have been defined for those new variables which are present in more than one subprogram. The use of some CØMMØN BLØCKS which were already defined in some subprograms in /2/, has been extended to other subprograms. Furthermore, the sizes of some CØMMØN BLØCKS have been increased (see Par. 2.7). To minimize the differences between the input preparation of SAGAPØ-2 and that of SAGAPØ /2/, all new data are provided in SAGAPØ-2 by means of DATA statements in BLØCK DATA, by the definition of new CØMMØN BLØCKS. In this way, only one modification was necessary in the part of the input concerning data cards. This modification, however, does not modify the order of variables and cards (see below).

Only one modification was made in the output, concerning the printing of the turbulent mixing coefficient values, which were not printed in /2/.

In the next paragraphs the modifications for input, output and CØMMØN BLØCKS will be presented. For the topics which are not discussed in this chapter, the considerations made in /2/ are still valid.

4.2 Extensions in the input

4.2.1 Data on cards

The only modification concerning the preparation of the data cards refers to the meaning of the variable NSEL (see /2/, 9th card), fixing which bundle symmetry section has to be computed. Moreover, this modification refers only to the code version for hexagonal bundles. In fact, while in /2/ the possible values for NSEL, in case of hexagonal bundles, were:

NSEL = 1 (whole bundle flow section)
NSEL = 2 (a half)
NSEL = 3 (1/12th),

in SAGAPØ-2 the value:

NSEL = 4

is also allowed, which corresponds to the case that a symmetry section different from the previous ones is assumed (see Par.2.1).

4.2.2 BLØCK DATA

A first difference, concerning BLØCK DATA, between SAGAPØ-2 and the old version of the code /2/, is that the same number of data must now be provided both in the version for hexagonal bundles and in that for the 12-rod bundles, while in /2/ the values of the following variables, concerning indexing and connections, had to be provided only in the version for 12-rod bundles:

NPIN, JPIN (CØMMØN BLØCK/HEA6/)
NTYP (CØMMØN BLØCK/IND3/)
NER,NIS (CØMMØN BLØCK/IJ1/).*)

In SAGAPØ-2, values for these variables must be provided in BLØCK DATA, in case of hexagonal bundles, also. This is due to the procedure used in case of NSEL=4, which is not as automatic as those for NSEL=1,2 or 3, but is similar to those already used in /2/ for the 12-rod bundles (see Par.2.1). It must be noticed that, in case of NSEL≠4 also, input values must be provided for NPIN, JPIN, NTYP and NER (because of the features of BLØCK DATA), which, however will not be used in the calculations (thus all 1's or 0's can be assumed).

Moreover, the new data described below must be provided in BLØCK DATA for SAGAPØ-2 (both in the version for hexagonal bundles and in that for the 12-rod bundles).

1) CØMMØN BLØCK /ENEØP/

IENE = 1 if Eqn.(10) is applied for the energy balance
IENE = 2 if Eqn. (9) is applied for the energy balance.

2) CØMMØN BLØCK /GAAG1/

FCØPW1 (3)

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*) see /2/ for the meaning of these variables.

FCØPW1 (ITYP) $= \left(\frac{\text{real total wetted perimenter}}{\text{assumed total wetted perimeter}}\right)$ for channels and subchannels of type ITYP (ITYP=1: central; ITYP=2: wall; ITYP=3: corner).*)

3) CØMMØN BLØCK /GAAGT/

FCØPWT

FCØPWT $= \left(\frac{\text{real total wetted perimenter}}{\text{assumed total wetted perimeter}}\right)$ for the whole bundle flow section.*)

4) CØMMØN BLØCK /GASD1/

NSTØT

NSTØT = total number of channels in the assumed bundles symmetry section.

5) CØMMØN BLØCK /GASD2/

RAPPAI (42,3)

RAPPAI (NS,M) = ratio between the flow area of the Mth subchannel of channel NS (in the considered bundle symmetry section) and the flow area of the entire subchannel (i.e. as defined in the whole bundle flow section).**)

6) CØMMØN BLØCK /GASD3/

FSYMM

FSYMM = ratio between the area of the entire bundle flow section and that of its considered symmetry section.

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*) These variables have been introduced to be able to perform a correct analysis in case of shroud profiles different from that originally allowed in SAGAPØ (see Par.2.2). Obviously FCØPW1 (1) must be equal to 1, because a modification of the shroud profile does not affect the wetted perimeter in central channels.

**) For Benchmark III calculations (1/6th of a 37 rod bundle) /5/ the RAPPAI values were 0.5 for the corner channels and 1 for the other channels.

7) CØMMØN BLØCK /GASD4/

IGAS

IGAS = 1 for helium coolant

IGAS = 2 for CO_2 coolant

IGAS = 3 } for two more coolants, which equations are
IGAS = 4 } not included yet

(see Par. 2.3).

8) CØMMØN BLØCK /IDISPA/

IDISP1

IDISP1 = 1 if, for an axial portion, the effect on the Nusselt numbers due to the spacers contained in it must be taken into account;

IDISP1 = 2 if the effect of all spacers must be neglected

(see Par. 3.1).

9) CØMMØN BLØCK /IDISPB/

IDISP2

IDISP2 = 1 if the eventual effect of the last spacer of an axial portion on the Nusselt numbers in the first axial sections of the next axial portion must be taken into account;

IDISP2 = 2 if this effect must be neglected

(see Par. 3.1).

10) CØMMØN BLØCK /ISMØ/

CØTW

CØTW = exponent of the ratio $1/(T_W/T_G)$ for the temperature correction for the Nusselt numbers of smooth walls

(see Par. 2.7, Eqns,(6)-(8)).

11) CØMMØN BLØCK /ISMØ1/

ITECØ

ITECØ = 1 if, in Eqn.(6), T_G = inlet gas temperature T_E;

ITECØ = 2 if, in Eqn.(6), T_G = bulk temperature T_B

(see Par. 2.7).

12) CØMMØN BLØCK /ISUP/

IQLIN = 1 if, in case of non-adiabatic shroud walls Eqns. (II.52)-(II.63) or Eqns. (IV.60)-(IV.64), (IV.78)-(IV.83) of /1/ (for turbulent flow or laminar flow, respectively) must be applied for calculating shroud temperatures and for correcting rod temperatures (Superposition Principle).

IQLIN = 2 if the mentioned equations must not be applied (see Par. 2.7).

13) CØMMØN BLØCK /MART5/*)

NSTR

NSTR = number of central channels in the assumed bundle symmetry section.

14) CØMMØN BLØCK /MIXS1/

CY

CY = factor for the enhancement of turbulent mixing due to spacer effect, for the exchange between channels (see Eqn.(5), Par.2.6).

15) CØMMØN BLØCK /SUBDI/

IDIV1, IDIV2

IDIV1 = 1 if the subchannel calculation is required for all channels;
IDIV1 = 2 if it is required only for wall channels;
IDIV1 = 3 if it is required only for central channels,**)
IDIV1 = 4 if it is not required, neither for central channels channels, nor for wall channels.**)

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*) /MART5/ is <u>not</u> a new CØMMØN BLØCK. In /2/ it was already defined in the main program and in subroutine ENFRCØ.

**) As mentioned in Par.3.2.4, in case of IDIV1=3 or=4, the calculation of the two portions of the wall subchannels is automatically <u>not</u> performed.

IDIV2 = 1 if the calculation for the two portions of the wall subchannels is required;
IDIV2 = 2 if it is not required.

It must finally be noticed that, for 12-rod bundles and - in case of NSEL ≠ 4 - for hexagonal bundles also, any value can be provided in BLØCK DATA for the variables of CØMMØN BLØCKS /GASD1/, /GASD2/, /GASD3/ and /MART5/, because the real values, for these situations, are then evaluated by the code.

4.3 Extension in the output

The only extension in the output of SAGAPØ-2, with respect to /2/, is the printing of the Ingesson mixing coefficients YH (I1,I2) /15/ for the turbulent exchange between all connected channels I1 and I2, computed with the equation:

$$YH(I1,I2) = 1.14 \left(\frac{\sum\limits_{N_{I1}} \frac{\Delta A}{A'} + \sum\limits_{N_{I2}} \frac{\Delta A}{A'}}{N_{I1} + N_{I2}} \right)^{0.5} \left(\frac{A_R}{\bar{A}} \right)^2 \qquad (14)$$

(N_{I1}, N_{I2} are the numbers of gaps for channels I1, I2; the areas ΔA, A', A_R and $\bar{A}$ are defined in Fig.6).*)

The YH values are printed by the subroutine INGE, immediately after the spacer blockage factors (see 4.1.8 in /2/).

4.4 CØMMØN BLØCKS

4.4.1 New CØMMØN BLØCKS

Many of the new CØMMØN BLØCKS have been defined to introduce the new input variables, the meaning of which has already been described in Par.4.2.2. Anyway, in order to provide here a presentation similar to that used in the original users' guide /2/, the complete list of the new CØMMØN BLØCKS is included in this paragraph, together with the lists of the subprograms in which the single CØMMØN BLØCKS are defined. However, the des-

*) This equation was not included, by mistake, neither in /1/ nor in /2/. It must be remembered the real channel mixing coefficients used in the code are obtained by multiplying the YH coefficients by the input factor PCØRR (see 3.1 21st card in /2/).

cription of the meaning of the new input variables will be not repeated here.

1) CØMMØN /ENEØP/ IENE

IENE is defined in BLØCK DATA and used in BALA, RECCA2 and SUBBAL.

2) CØMMØN /GAAG1/ FCØPW1 (3)

The FCØPW1 values are defined in BLØCK DATA and used in ANGCA1, BALA, RECCA1 and SUBBAL.

3) CØMMØN /GAAG2/ FCØPW2 (18,2)

FCØPW2 (III,M) = $\frac{\text{real total wetted perimeter}}{\text{assumed total wetted perimeter}}$ for the wall portion of the Mth subchannel of the IIIth external channel.

The FCØPW2 values are computed in subroutine RECCA1, in case of wall subchannels; in case of corner channels, they are set equal to FCØPW1 (3) (see CØMMØN BLØCK /GAAG1/) in subroutine ANGCA1. The FCØPW2 values are then used in RECANG and RECCA2.

4) CØMMØN /GAAGT/ FCØPWT

FCØPWT is defined in BLØCK DATA and is used in the main program.

5) CØMMØN /GAGR/ DPSI

DPSI = $\Delta p_{av}/|\Delta p_{av}|$ (Δp_{av} = average channel pressure drop). The variable DPSI was introduced to allow the new procedure for taking into account gravitation. Its value is defined in the main program. DSPI is then used in CEWA, RECANG and RECCA1.

6) CØMMØN /GAMAR/ CXX

CXX = factor for the cross-flow exchange between channels, depending on the type of the assumed bundle symmetry section.

The variable CXX was introduced to correct a small error present in /2/. CXX is defined in TMCF for the energy exchange, or in UA for the momentum exchange, and is used in CF1.

7) CØMMØN /GASD1/ NSTØT

The CØMMØN BLØCK /GASD1/ is present only in BLØCK DATA and in the main program. The input value of NSTØT defined in BLØCK DATA is used in SAGAPØ-2 only in case of NSEL=4 (see Par.4.2.1). Otherwise, this input value is not used and the real value of NSTØT is computed, like in /2/, in subroutine INDEX.

8) CØMMØN /GASD2/ RAPPAI (42,3)

The RAPPAI values defined in BLØCK DATA, are used in the subroutines HEATI and INQUA (versions for hexagonal bundles) only in case of NSEL=4 (see Par.4.2.1).

9) CØMMØN /GASD3/ FSYMM

FSYMM is defined in BLØCK DATA and is used in TØTGEØ (version for hexagonal bundles) only in case that NSEL=4 (see Par. 4.2.1).

10) CØMMØN /GASD4/ IGAS

IGAS is defined in BLØCK DATA and is used in CP, ETA, KAPPA and RHØ.

11) CØMMØN /IDISPA/ IDISP1

IDISP1 is defined in BLØCK DATA and is used in AXSEC.

12) CØMMØN/ IDISPB/ IDISP2

IDISP2 is defined in BLØCK DATA and is used in the main program.

13) CØMMØN /ISMØ/CØTW

CØTW is defined in BLØCK DATA and is used in RTSI and TELIN.

14) CØMMØN /ISMØ1/ ITECØ

ITECØ is defined in BLØCK DATA and is used in RTSI and TELIN.

15) CØMMØN /ISUP/ IQLIN

IQLIN is defined in BLØCK DATA and is used in RTRI, RTSI and TEMLAM.

16) CØMMØN /MIXS1/ CY

CY is defined in BLØCK DATA and is used in BALA.

17) CØMMØN /MIXS2/ CCY

CCY = factor for the enhancement of turbulent mixing due to spacer effect, for the exchange between subchannels of the same channel and between the two portions of wall subchannels (see Eqn.(5), Par.2.6).

In SAGAPØ-2 CCY is set equal to CY in BALA.*) It is used in RECCA2 and SUBBAL.

18) CØMMØN /PRSPA/ DISTOO

DISTOO = distance from the inlet section of an axial portion, or from the section at which the calculation is started (in case of calculations carried out in more than one step), to the middle section of the last preceeding spacer (the sign of DISTOO is negative).

The variable DISTOO has been introduced to allow the improvements of the subroutine AXSEC for the spacer effects on Nusselt numbers. The value of DISTOO is set equal to 10^{-7} at the beginning of the main program. Then, for the first axial portion, the appropriate value is evaluated in the main program, in case that the calculation step starts after the bundle inlet (if spacers are present in the bundle part computed in the preceeding step). For the succeeding axial portions the appropriate DISTOO values are evaluated only

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*) If required, a more sophisticated correlation between CCY and CY can be easily introduced in the code.

in case of IDISP2 =1 (see CØMMØN BLØCK/IDISPB/), otherwise the value 10^{-7} is kept. DISTOO is used in AXSEC.*)

19) CØMMØN /SECIN/ KK

KK = index of the axial section
The variable KK has been defined to allow introducing the spacer effect on turbulent mixing without changing any argument list. The value of KK is set equal to that of K (index of the axial section) in the subroutine BALA (K is an argument for BALA). Then KK is used in SUBBAL and RECCA2 (for which K is not an argument).

20) CØMMØN /SUBDI/ IDIV1,IDIV2

IDIV1 and IDIV2 are defined in BLØCK DATA and are used in SUBBAL.

4.2.2 Extensions for existing CØMMØN BLØCKS

The use of some CØMMØN BLØCKS, which were already defined in some subprograms in /2/, has been extended to other subprograms in SAGAPØ-2. The subprograms are also mentioned, in which they are now used.

1) CØMMØN /GEN2/ A (42)

Now used in the version of INGE for hexagonal bundles, also, besides in the main program, BALA, ENFRCØ, INLCØN, INQUA, KAPCØR, NØRMT, RECCA1, RECCA2, SUBBAL, TMCF and TRICA1.

2) CØMMØN /GRAV/ IGRAV

Now used in CEWA, RECANG and RECCA1, also, besides in BLØCK DATA, main program, BALA, SUBBAL and RECCA2.

3) CØMMØN /GRID2/ YY(100,42,3)**)

Now used in BALA, RECCA2 and SUBBAL also, besides in AXSEC, CEWA, RECANG, SUBDH and WALLTE.

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*) For the meaning of the variables see Par.5.77 in /2/

**) In the list of CØMMØN BLØCKS presented in Par.5.77 of /2/ it is erroneously written that /GRID2/ contains the variable DIST (7), also. On the contrary, this variable belongs to /GRID1/, together with the variable EPSISC (42,3,3).

4) CØMMØN /HEA1/ Q(37)*)

Now used in the version of HEA1 for hexagonal bundles, also, besides in the main program and in HEATR.

5) CØMMØN /HEA6/ NPIN(42),JPIN(42,3)

Now used in the version of BLØCK DATA and INQUA for hexagonal bundles and in TMCF and UA, also, besides in the version of HEATI for hexagonal bundles, in the version of BLØCK DATA for 12-rod bundles, in AXSEC, BALA, ENFRCØ, ENTFR, INLCØN, NØRMT, SIMLA1, SUBBAL, SUBCØN, SUBDH, TBFUN, TMPUN, TWFUN and WALLTE.

6) CØMMØN /IND3/ NTYP(42)

Now used the versions of BLØCK DATA and HEATI for hexagonal bundles, also, besides in the version of INDEX for hexagonal bundles, in the version of BLØCK DATA for 12-rod bundles, in the main program, in BALA, CØNNIJ, ENFRCØ, INGE, INLCØN, INQUA, KAPCØR, NØRMT, RECCA2, SIMLA1, SUBBAL, SUBCØN, TBFUN, TEMLAM, TMCF, TMPUN, TWFUN, UA and WALLTE.

7) CØMMØN /IJ1/ NER(42),NIS(42,3)

Now used in the version of BLØCK DATA for hexagonal bundles, also, besides in CØNNIJ, in the version of BLØCK DATA for 12-rod bundles, in the main program, in BALA, INGE, RECCA2, SUBBAL, SUBCØN, TMCF and UA.

8) CØMMØN /MART5/ NSTR

Now used in both versions of BLØCK DATA, also, besides in the main program and in ENFRCØ.

4.4.3 CØMMØN BLØCKS with increased sizes

In order to allow performing Benchmark III calculations /5/, the sizes for some CØMMØN BLØCKS have been increased (see Par. 2.7). These CØMMØN BLØCKS are listed below, with the

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*) Note that the sizes of this CØMMØN BLØCK have also been increased.

sizes of /2/ and the new ones. For the meaning of the variables see Par. 5.77 in /2/.

CØMMØN BLØCK /GRID/:

CSPAC (42,3) → CSPAC (42,4)

CØMMØN BLØCK /GRIDWC/:

EPSWC (18,2,2,3) → EPSWC (18,2,2,4)
CSPWC (18,2,2,3)   CSPWC (18,2,2,4)

CØMMØN BLØCK /GRIDO/:

CSPSC (42,3,3) → CSPSC (42,3,4)

CØMMØN BLØCK /GRID1/:

EPSISC (42,3,3), DIST(7) → EPSISC(42,3,5)*),DIST(7)

CØMMØN BLØCK /GRID6/:

EPSIC (42,3) → EPSIC (42,4)

CØMMØN BLØCK /GRID8/:

PGDPSC (42,3,3) → PGDPSC (42,3,4)

CØMMØN BLØCK /HEA1/:

Q(19) → Q(37)

CØMMØN BLØCK /HEA2/:

QQ(2,12),QQO → QQ(3,18),QQO

CØMMØN BLØCK /HEA7/:

IDPIN(2,12) → IDPIN (3,18)

CØMMØN BLØCK /IND2/:

NØT (3,18) → NØT (4,30)

CØMMØN BLØCK /IND4/:

NUM3(3),...,NUM36(3) → NUM3(4),...,NUM36(4)

Furthermore the dimensions of some variables, defined in the main program by means of DIMENSIØN statements, had also to be increased /3/.

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*) The variable EPSISC must be dimensional for a number of spacers equal to the real one + 1, to allow the possibility (introduced at GA /3/) of taking into account the effect on the Nusselt numbers of an axial portion, due to the last spacer of the preceeding axial portion.

5. Some advises about input parameters

A parametric study, based on the data of Test 1 of Benchmark II /3,4/, was carried out at GA with the purpose of investigating the effect on results and calculation time of the following parameters:

A) Sub-subchannel subdivision

B) Axial section subdivision

C) Central subchannel subdivision

D) Use of hot or cold dimensions

E) Method for approximating the energy increments.

The results of this parametric study, which are discussed in detail in /3/, are summarized in the first four paragraphs of this chapter, with the purpose of providing some useful information to the users of the code.

Finally, in the last paragraph, some advises are given about parameters useful in laminar calculations.

5.1 Sub-subchannel subdivision

The parametric study carried out at GA had shown that, if the purpose of the SAGAPØ-calculations is only to predict average subchannel friction factors and pin and shroud temperatures - and not to assess local azimuthal pin temperature profiles*) - the sub-subchannel subdivision can be avoided for the central subchannels, the corner channels and the central portion of the wall subchannels, and can be reduced for the wall portion of the wall subchannels**). In this way the SAGAPØ-results for

*) One of the aims in developing SAGAPØ - at least in the first development phase - was to try to assess a method for the prediction of the azimuthal pin temperature profiles inside each subchannel, also /1,3,16/. Especially for this aim, a very fine subdivision of the flow section into sub-subchannels was necessary. A simplified method for evaluating local azimuthal pin temperature profiles was proposed in /16/ (and the possibility of using it is still kept in SAGAPØ), but this method could not be further investigated /3/.

**) It must be noticed that the assumption of a not too fine subdivision of the wall portion of the wall subchannels is also necessary to obtain convergence in case flow regimes near the boundary between hydraulically smooth flow and rough flow /3/.

average subchannel friction factors and pin and shroud temperatures are only slightly modified (Figs. 7-10); on the contrary the calculation time decreases strongly (of a factor of 2 for case 1 of Benchmark II, see Fig.11).

In conclusion we advise to use, for the normal calculations with SAGAPØ-2, the following values for the parameters defining the sub-subchannel subdivision (see 3.1, 9th card in /2/):

NSC3OC = 1*)
NSC3OA = 1
NSC3OW = 3 or 4 (normally)**)

5.2 Axial section subdivision

The effect of the axial section subdivision on results and calculation time was also investigated at GA. Most of the calculations were carried out by neglecting the spacer effect on Nusselt numbers. This allowed assuming equal lengths for all axial sections over each axial portion. This parametric study was performed by varying the value of the input parameters XDE1, which defines the approximate desired length of the axial sections where no spacer effect on Nusselt numbers is present (in terms of XDE1 times the equivalent diameter D_C of central channels; see 3.1, 19th card, in /2/). As a reference the case of $XDE1_O$=2.5 was taken, which was the value assumed in the calculations previously performed at KfK /1/. This parametric study showed that, normally, the number of axial sections does not need to be very large (no important changes in the results could be noticed for case 1 of Benchmark II - except for the corner channel with the largest solidity, and, for the other channels, near the spacers, see Figs.7-10). However in case of too long axial sections (for XDE1 > $3 \cdot XDE1_O$ in case of the

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*) In the original version of SAGAPØ /2/, due to a small error, occurring in RECCA1 for NSC3OC=1, if the angle for the central portion of the wall subchannels is smaller than $\pi/6$, the assumptions of NSC3OC=1 is not always possible /3/.

**) The value of NSC3OW which can be used depends on the shape of the wall channels also. For Benchmark II calculations /3,4/ the minimum value at which convergence could be reached was 3, while it was 4 for Benchmark III calculations /3, 5/.

investigated test), there is no systematic decrease of the computation time, due to the increase of the local convergence problems (which are solved by halving the length of some axial sections, thus increasing the number of nodes) and the results are more affected by the axial subdivision (see Fig.11). Of course, the choice of the XDE1 values depends on the value of the equivalent diameter D_c: in case of Benchmark III calculations /3,5/ a value XDE1=10 could be assumed, because of the smaller value of D_c with respect to Benchmark II calculations. Similar considerations are valid for the parameters XDE2, defining the axial section subdivision in the regions of spacer effect on Nusselt numbers (see 3.1, 19th and 20th cards in /2/), in case that the spacer effect is taken into account. However, the choice of the values for XDE2 also depends on the distribution of the spacer blockages in adjacent flow zones. Furthermore larger values of XDE2 can be assumed if a detailed description of the pin temperature profiles near spacers is not required. For example, for Benchmark III, XDE2=8 (i.e. the maximum allowed value; see /2/) was assumed for the rough part (since the pin temperatures had to be computed only at axial levels far from the spacers, in the rough part), while XDE2=2 was assumed for the smooth part (the axial level was in the spacer region, for the smooth part).

5.3 Central subchannel subdivision

The modification described in Par.3.2.4 allowed investigating the effects of the central subchannel subdivision. As it could be forseen, in case that the central subchannel calculation is not performed (IDIV1=2, IDIV2=1, see Par.4.2.2) the only effect is that the central subchannel pin temperatures are equal to the average values of the pin temperatures obtained with the central subchannel calculation. The effect on the calculation time, for case 1 of Benchmark II, is shown by Fig.11: the calculation time is normally less in case that the central subchannel calculation is not performed, partly because a calculation step is eliminated (see subroutine SUBBAL) and partly because less convergence problems normally occur in this case (however, there is an exception for XDE1=7.5). Anyway, for those XDE1 values which can be assumed without considerably affecting the results (i.e. up to XDE1=5÷7.5 for the case of

Fig.11),it can be concluded that it is worth to always perform the central subchannel calculation, because the required calculation time is not much larger (if at all).

5.4 Use of hot or cold dimensions

Both for Benchmark II /4/ and for Benchmark III /5/, the calculations were carried out both with cold and with hot dimensions, in order to investigate the effect of the thermal expansion of the bundle geometric dimensions /3/. The results of these calculations show that the thermal expansion affects the pin temperatures only slightly, while the pressure drop is not affected (see Fig.7-10)*).

Anyway, since the correction for the thermal expansion is performed automatically by the code, it is worth to apply at least the correction corresponding to the inlet temperature (which does not require any increase of the calculation time).

5.5 Approximation of the energy increment

In the original version of SAGAPØ /1,2/ the energy increments in the various flow zones could only be computed with Eqn.(10), which represents - in our opinion - the most correct approximation of the differential increment $\dot{m}$ dh. The introduction of the possibility of using Eqn.(9) (applied in CØBRA) instead of Eqn.(10) (see Par.2.7 and 4.2.2) allowed evaluating the differences in the results due to the use of the two equations /3/. As it could be easily forseen, it was found that, in case of not large variation of the mass flow rate (i.e. always in sections far from the spacers, and also in regions near spacers, if the spacer profiles are not very different for adjacent flow zones), the use of the two equations is practically equivalent for the calculation of mass flow and temperature distributions. On the contrary, not negligible differences (up to 20°C) for the temperature values corresponding to the use of the two different

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*) These Figures refer to Benchmark II calculations. Similar effects of thermal expansion could be noticed for Benchmark III calculations, also /3/.

equations were found, especially in spacer regions, for adjacent flow zones with very different spacer resistances. Furthermore, it was noticed that the use of Eqn.(9) brings more convergence problems than that of Eqn.(10). Due to this and due to the fact that, as pointed out above, Eqn.(10) is more correct, we suggest to go on using Eqn.(10) in SAGAPØ-2 also, which means to assume IENE=1 in BLØCK DATA (see Par.4.2.2, CØMMØN BLØCK /ENEØP/).

5.6 Some parameters for laminar calculations

As pointed out in previous papers /1,2,10/, calculations are possible with SAGAPØ for laminar flow also, although heat conduction and radiation - which are very important in case of laminar flow - are not yet included. For the introduction of these two effects, which are neglected in SAGAPØ-2 also, a third version of the code is under preparation at the Institute of Neutron Physics and Reactor Engineering of the Karlsruhe Nuclear Center. In the meanwhile, if it is necessary to carry out laminar calculations with SAGAPØ or SAGAPØ-2, some remarks are useful for the users, concerning the simplified procedures which can be applied in the codes for laminar calculations in order to avoid convergence problems (see Par.4.6.2 in /1/). For the 19 rod bundle investigated in /1/, the convergence problems, occurring in the energy balances if the simplified procedure of /1,2/ is not applied, were due to the much larger friction in the corner channels with respect to that in the wall channels and to the fact that conduction effects could not be taken into account. In fact, due to the much larger friction, the bulk and pin temperatures computed in the corner channels are much higher than those in the wall channels, if conduction is neglected, and furthermore, the differences between the velocity and temperature values in corner channels and those in wall channels increase more and more over the bundle length, because the laminar friction factors are proportional to the wall temperatures of the corresponding channels /1/*).

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*) In fact, $\lambda = K/Re_W \sim \nu_W \sim (T_W)^{1.66}$ for helium.

Since the experimental results for the investigated laminar test did not show any systematic difference between the pin temperatures in the corner and in the wall channels (which is certainly a consequence of conduction in the azimuthal direction), the possibility of assuming average values of the coefficients $\frac{K}{D^2} = \frac{\lambda Re_w}{D^2}$ for some adjacent <u>external</u> channels was introduced in the code**).

The index NS1 of the external channel at which this simplified procedure starts to be applied, together with the index NS2 of the external channel at which it ends to be applied must be provided in BLØCK DATA (see Par.3.3, CØMMØN BLØCK /MART2/ in /2/). If the simplified procedure has not to be applied, NS1=NS2=0 must be assumed /2/.

Moreover, correction factors were derived in /1/, to be used for the Nusselt numbers and the dimensionless shroud temperatures in case that the described simplified procedure is used for the K-values. These correction factors were obtained "considering that the average wall temperatures in the whole external channel (corner + wall), corresponding to the assumption of equal K/D^2 values for corner and wall channels, are smaller than those corresponding to the real K/D^2 values, because the wall temperatures must be averaged by means of the wetted perimeters" (cited from /1/, Par.4.6.3). Using these correction factors a very good agreement was obtained in /1/ between measured and computed temperatures for the external channels, also.

However, this so good agreement was only the result of coincidences, as shown with a more correct analysis performed later /10,17/. In particular it was thought that, if the measured pin temperatures are practically equal for wall and corner channel channels (due to conduction in the azimuthal direction in the rods) their bulk temperatures cannot differ very much from each other, also, and thus, at least for the investigated test, it is better not to use any correction factor for Nusselt numbers and dimensionless

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*) In case of equal values for the bulk temperatures and for the coefficients K/D^2, the friction pressure drops are equal for both corner and wall channels.

shroud temperatures.*) Thus, the option ISIMPL was introduced in the codes, which allows to apply the simplified procedure described in Par.4.6.2 of /1/ without correcting the Nusselt numbers and the dimensionless shroud temperatures (case of ISIMPL=1, see CØMMØN BLØCK /SIMLAM/, 3rd note of Pag 136 in /2/).

Furthermore, the option IEXAV was also introduced in the code, which allows the assumption of an average rod temperature value and an average shroud temperature value for all external channels, instead of the single subchannel values (case of IEXAV=2, see CØMMØN BLØCK /EXAVTW/, 2nd note of Pag 162 in /2/).

Calculations performed at GA have shown that, if IEXAV=2 is assumed, no convergence problems occur for laminar calculations, also in case that the simplified procedure described Par.4.6 of /1/ is not applied. This should confirm the expectation that the convergence problems occurring in case of laminar flow are due to the fact that conduction effects are neglected in the present versions of the code.

In conclusion for laminar calculations with SAGAPØ or SAGAPØ-2 we suggest to assume:

ISIMPL = 1
IEXAV = 2
NS1 = NS2 = O,

except for the case of unequally heated rods, where better results can probably be obtained with:

ISIMPL =1
IEXAV = 1
NS1 = index of the first external channel
NS2 = index of the last external channel.

Acknowledgement:

The author wishes to thank Dr. K. Rehme, Mr. S. Cevolani and Mr. J. Marek for their friendly help in writing this paper. He is grateful to the GA Personnel - and especially to Dr. R.H. Simon, Dr. G.B. Melèse D'Hospital, Dr. G. Schlueter and Dr. C.B. Baxi - for their great collaboration during his stay at San Diego.

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*) The agreement between the measured pin temperatures and the pin temperature values computed with this later analysis, was reasonable (although worse than that obtained in /1/). Moreover, the results indicate that a better agreement should be obtained, after the introduction of conduction and radiation.

Nomenclature

A. Latin letter symbols

A	= Flow area
$A', \bar{A}, A_R, \Delta A$	= Areas for turbulent mixing (Fig.6)
c, c_1, c_2	= Turbulent mixing coefficients (Eqns.(11)-(13))
CØTW	= Coefficient for the temperature correction for Nusselt numbers of smooth walls (Equ. (6))
CT	= Temperature correction factor for Nusselt numbers of smooth walls (Eqns.(6)-(8))
$CY = \frac{W^T}{W^{TO}}$	= Spacer correction factor for turbulent mixing (Eqn.(5))
D	= Hydraulic diameter
D_c, DETC	= Hydraulic diameter for central channels
e	= Eddy diffusivity
$e^{(R)}$	= Reference eddy diffusivity
$\Delta h, dh$	= Enthalpy increment per unit mass flow rate
IGRAV	= Gravitation coefficient for the axial momentum equations (Equ.(2))
II	= Index of the last spacer of the preceeding axial sections + 1
ISPAC	= Spacer index
k	= Coolant thermal conductivity
$K = \lambda Re_W$	= Geometric constant for laminar friction factors
L_i	= Number of sub-subchannels in a portion of wall subchannel
MSPAC	= Number of spacer in an axial portion
$\dot{m}$	= Mass flow rate
N	= Number of gaps for a channel
NSC30A	= Numbers of sub-subchannels per 30° in corner channels
NSC30C	= Number of sub-subchannels per 30° in central subchannels and central portions of wall subchannels
NSC30W	= Number of sub-subchannels per 30° in the wall portion of the wall subchannels
$Nu = \frac{\alpha D}{k}$	= Nusselt number
$Nu^o = \frac{\alpha^o D}{k}$	= Nusselt number for fully developed flow
Δp	= Pressure drop

$\dot{Q}''$	= Heat flux
$Re = \frac{\rho u D}{\mu}$	= Reynolds number
$Re_W = \frac{\rho_W u D}{\mu}$	= Reynolds number with gas properties computed at wall temperature
T	= Temperature
T_B	= Bulk temperature
T_E	= Inlet temperature
T_G	= T_B or = T_E (Eqn. (6))
T_W	= Wall temperature
u	= Coolant velocity
$u^* = u\sqrt{\frac{\lambda}{8}}$	= Friction velocity
W^T	= (Turbulent mixing rate) × c_2
W^{TO}	= W^T for fully developed flow
WSP	= Spacer width
Δx	= Axial section length
x^*_{sp}	= (Distance from the inlet section of a spacer)/ D_c
XDE1,XDE2	= (Desired axial section lengths)/D_c
Y_{sp}	= Nu/Nu^o
YH	= Ingesson mixing coefficients (Eqn. (14))

B. <u>Greek letter symbols</u>

α	= Heat transfer coefficient
α^o	= α for fully developed flow
δ	= Distance between two centers of gravity
λ	= Friction factor
μ	= Coolant dynamic viscosity
ν	= Coolant kinematic viscosity
ξ	= Contribution of cross-flow, turbulent mixing and density variation to the axial momentum equations
ρ	= Coolant density
τ	= Shear stress

C. <u>Subscripts</u>

a	= Zone outside τ=0
av	= Average
b	= Zone inside τ=0
B	= Bulk
C	= Central channel

E	= Bundle inlet
G	= Gas
grav	= Gravitation
i	= Sub-subchannel index
I	= Axial section inlet
j	= Index of the portion of wall subchannel
(R)	= Reference
SC	= Subchannel index
W	= Wall
X	= Channel, or subchannel, or portion of wall subchannel, or sub-subchannel.

D. Special signs

–	= Average
•	= Per unit time
"	= Per unit surface

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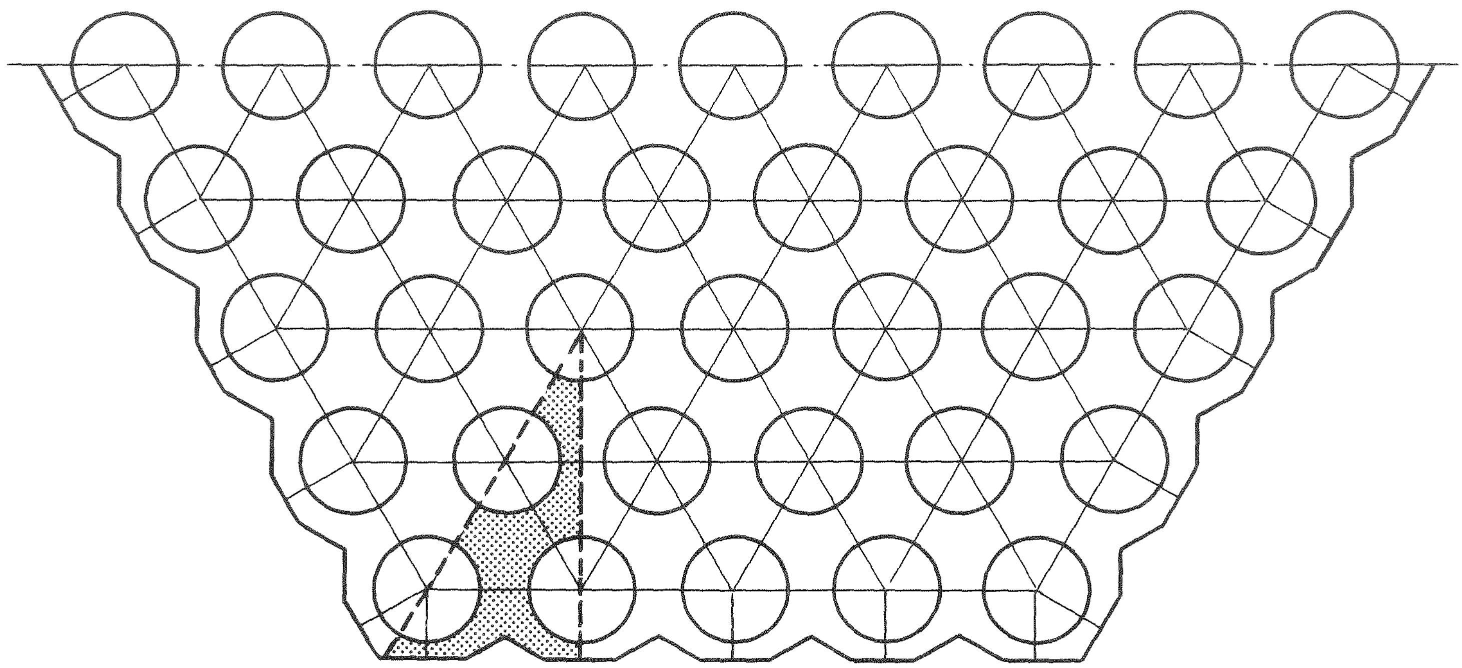


Fig.1: Definition of a "fictitious bundle" (1/12th) in the first phase of an optimazation process for the design of the shroud dimensions

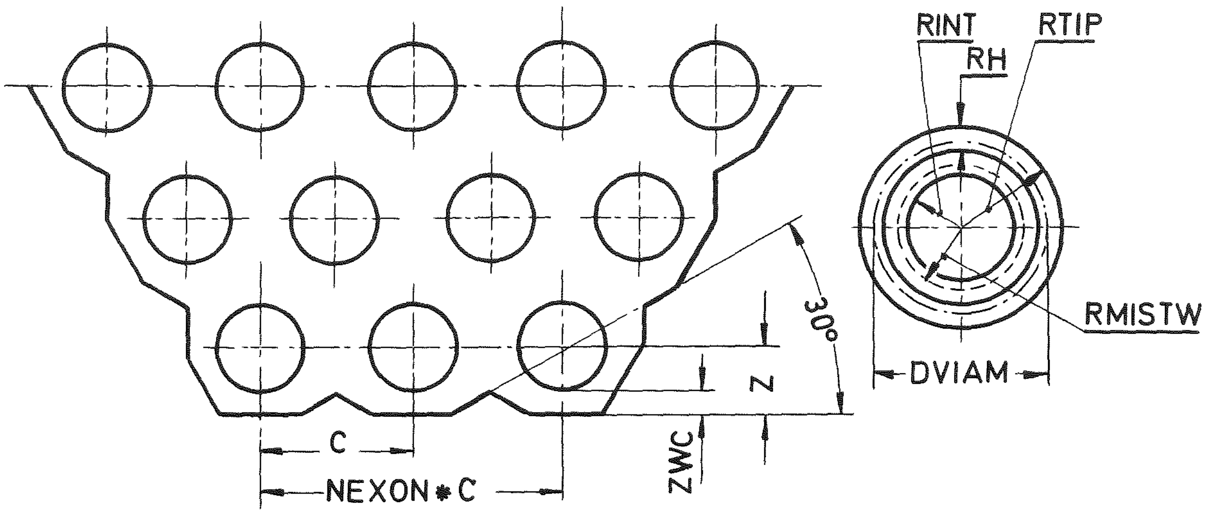


Fig.2: Geometric parameters needed by SAGAPØ as input information for the definition of the flow section geometry (for the symbology see also Par.3.1 in /2/).

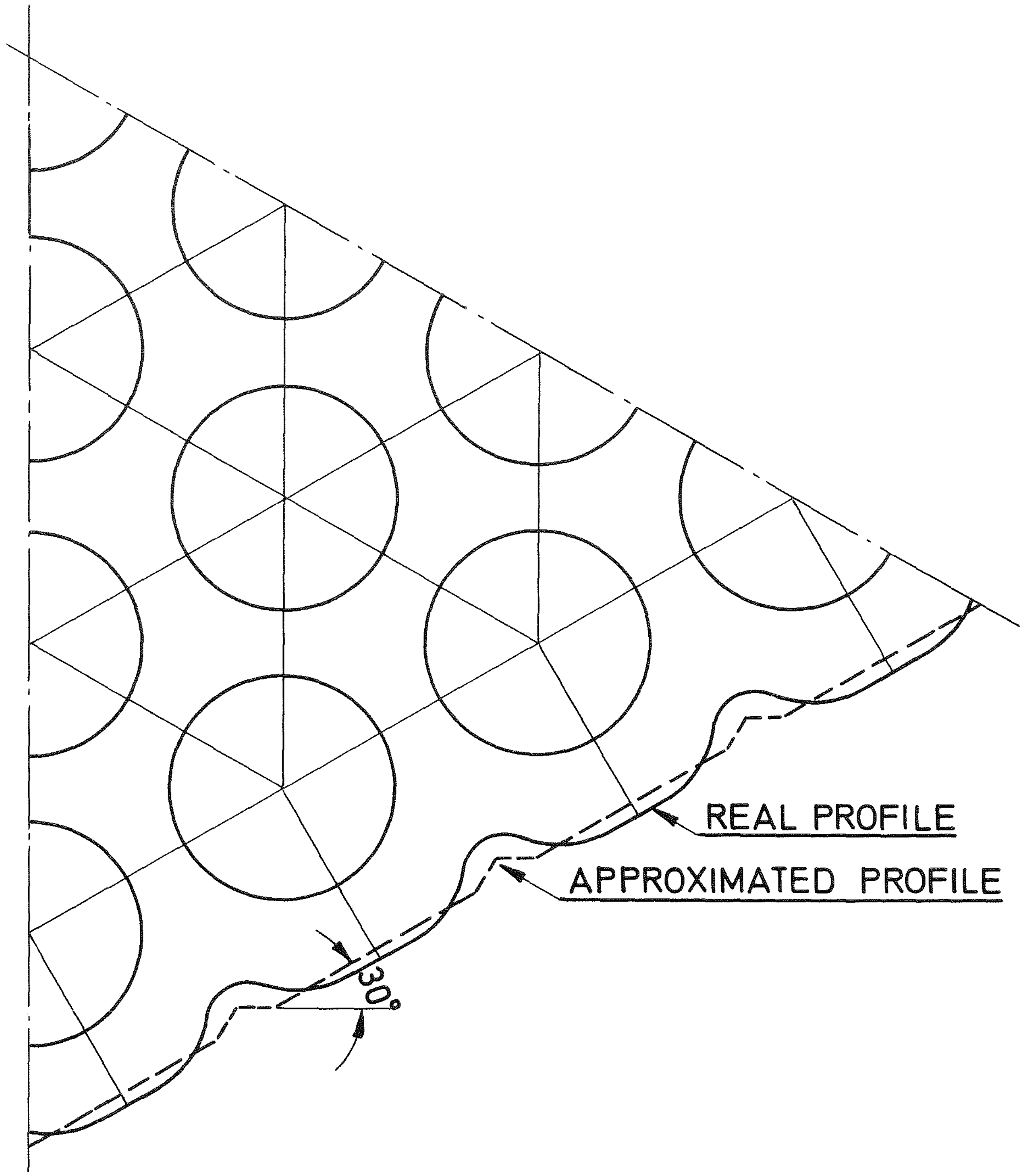


Fig.3: Approximation of the shroud shape

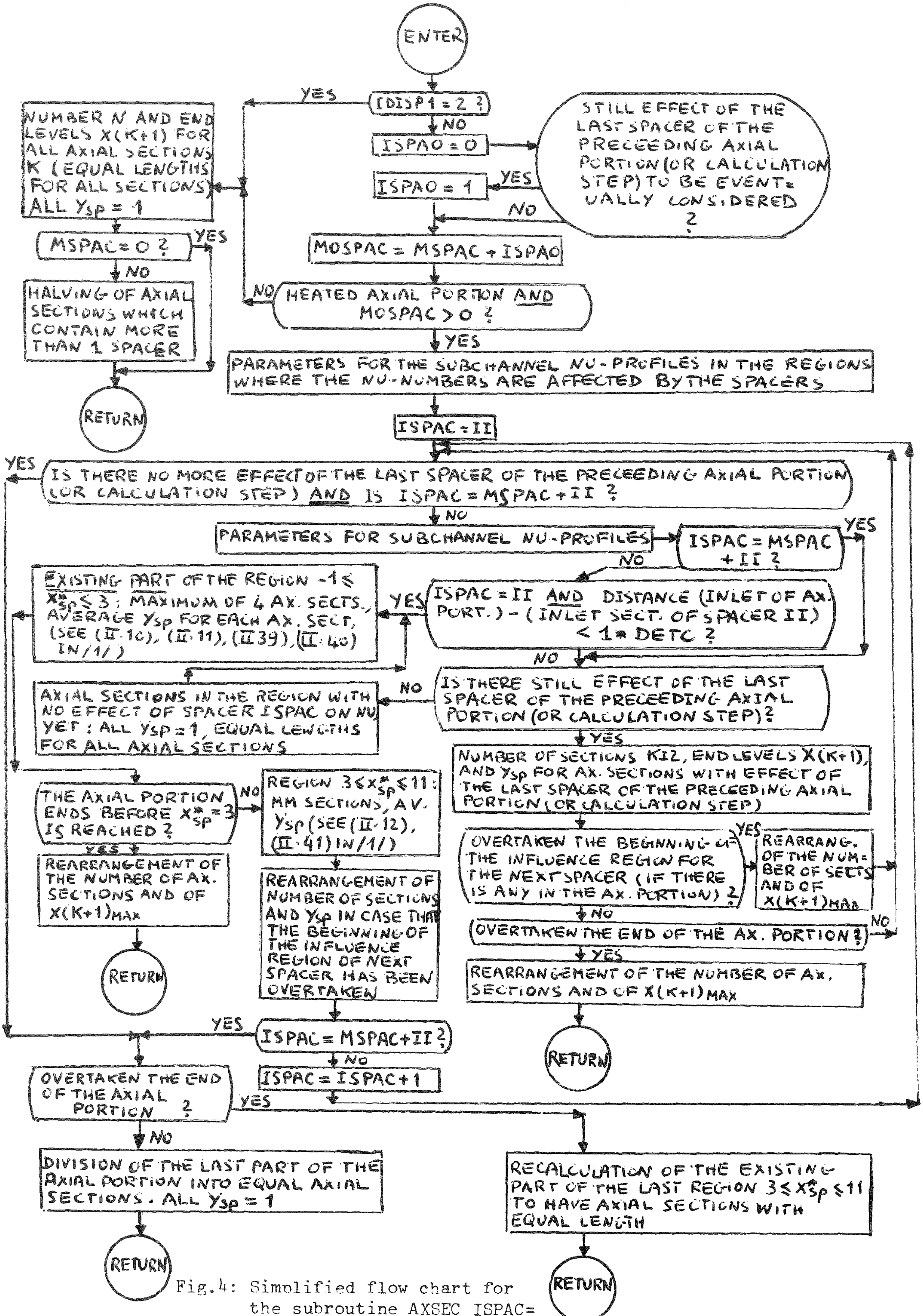
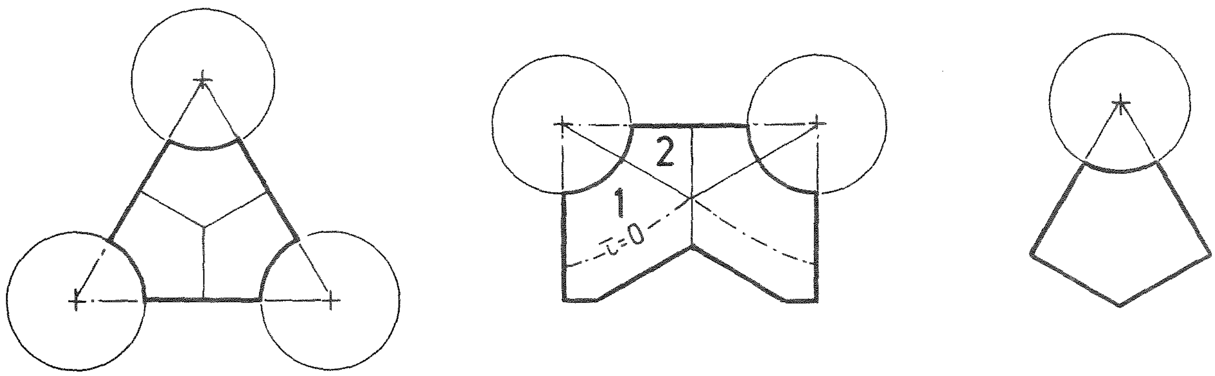


Fig.4: Simplified flow chart for the subroutine AXSEC ISPAC= spacer index /2/.

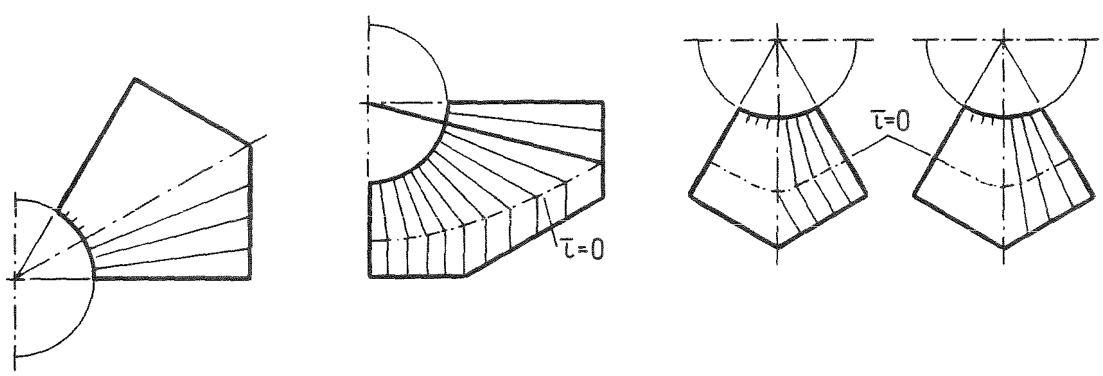


central channels and subchannels

wall channels and subchannels
1=wall portion
2=central portion

corner channels (no subdivision into subchannels)

Fig.5a: Subdivision into subchannels and portions of wall subchannels.



Subdivision of the central subchannels

Subdivision of the wall subchannels

1.st step 2.nd step
subdivision of the corner channels

Fig.5b: Subdivision into sub-subchannels.

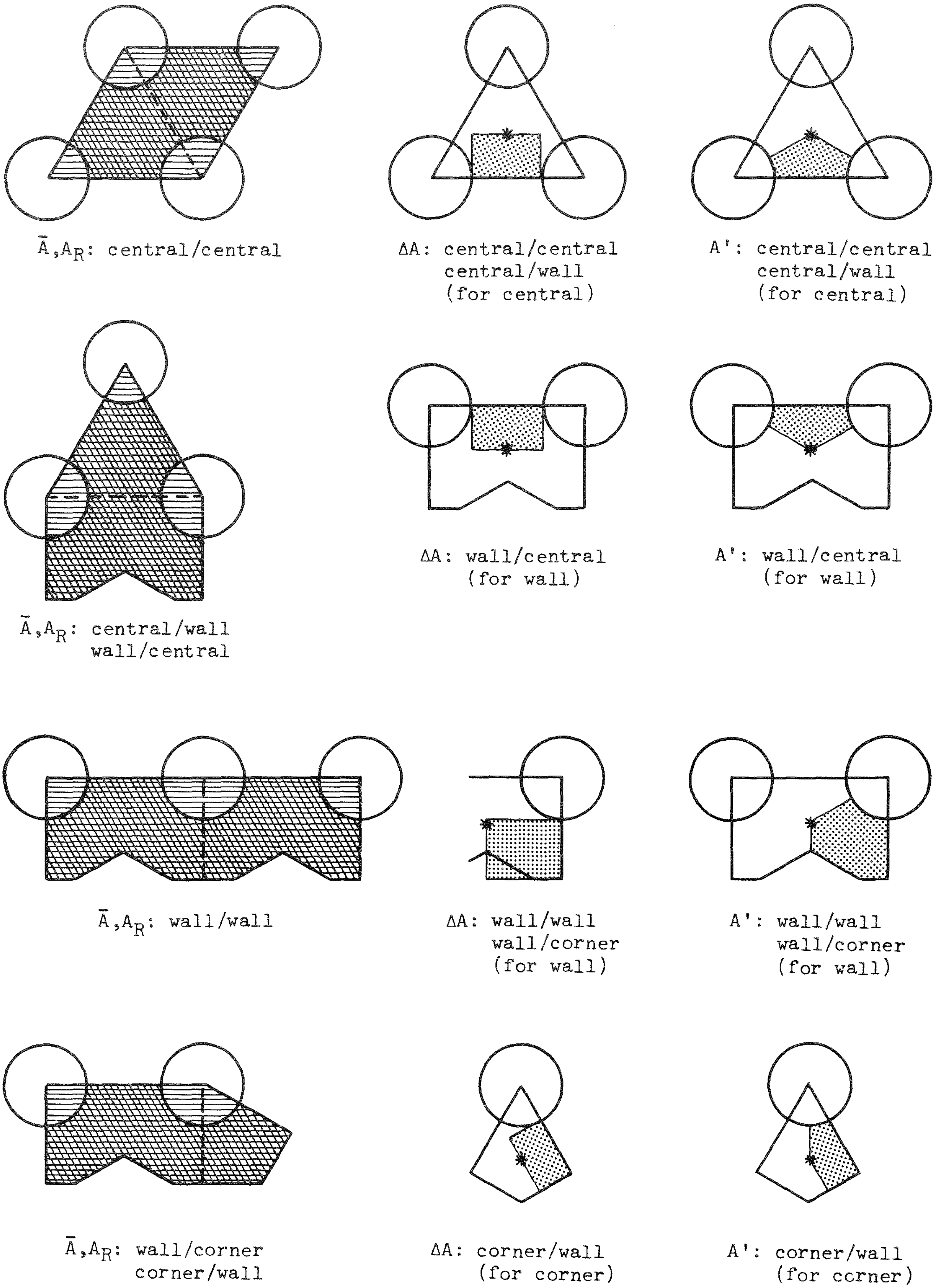


Fig.6: "Mixing areas" for Eqn.14

* = center of gravity ▤ = A_R ▧ = $\bar{A}$

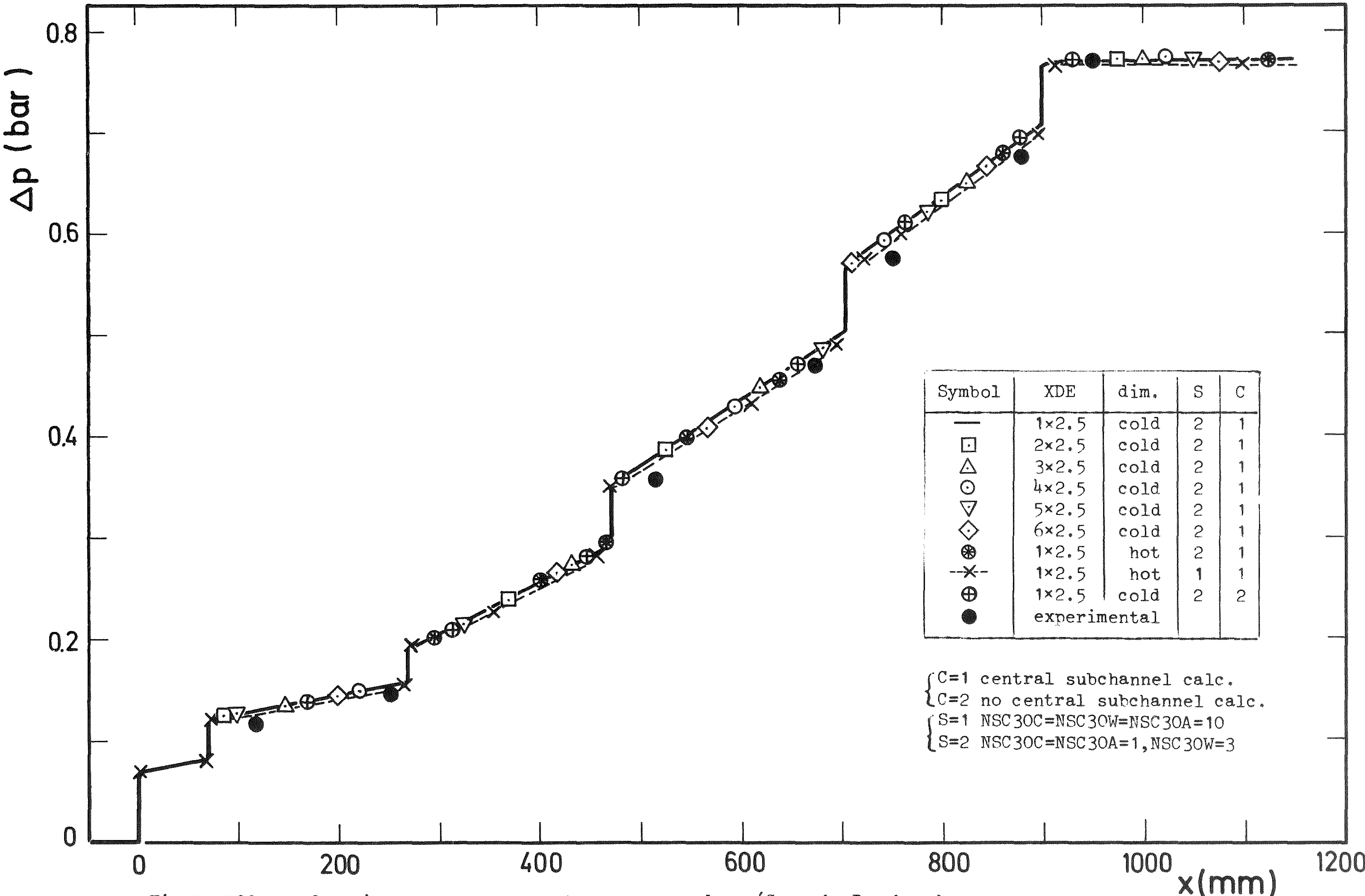


Fig.7: Effect of various parameters on the pressure drop (Case 1, Benchmark Meeting II Calculations)

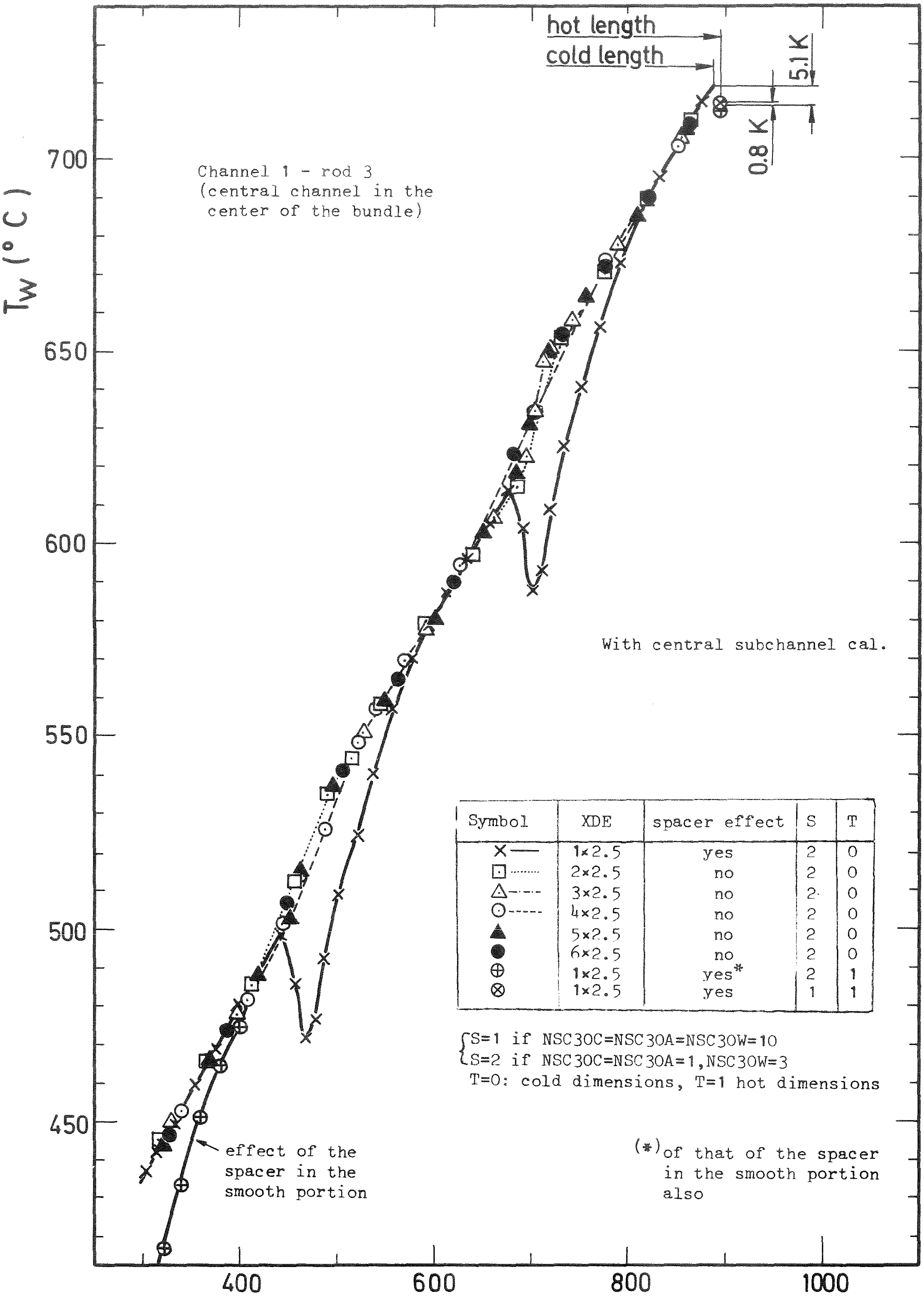


Fig.8: Effect of various parameters on the pin temperature of a central channel (Case 1, Benchmark Meeting II Calculations)

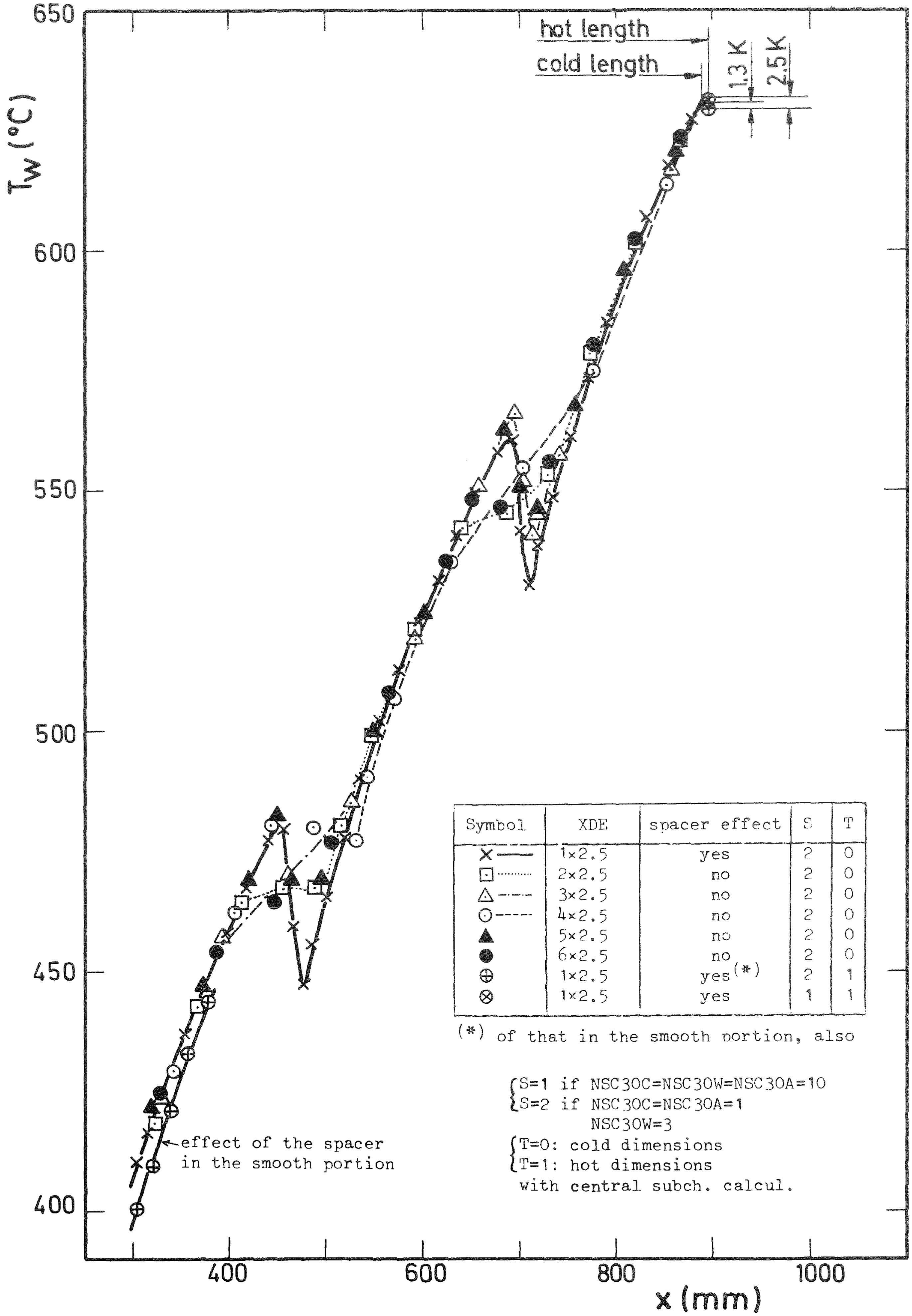


Fig.9: Effect of various parameters on the pin temperature of a wall channel (Case 1, Benchmark Meeting II calculations)

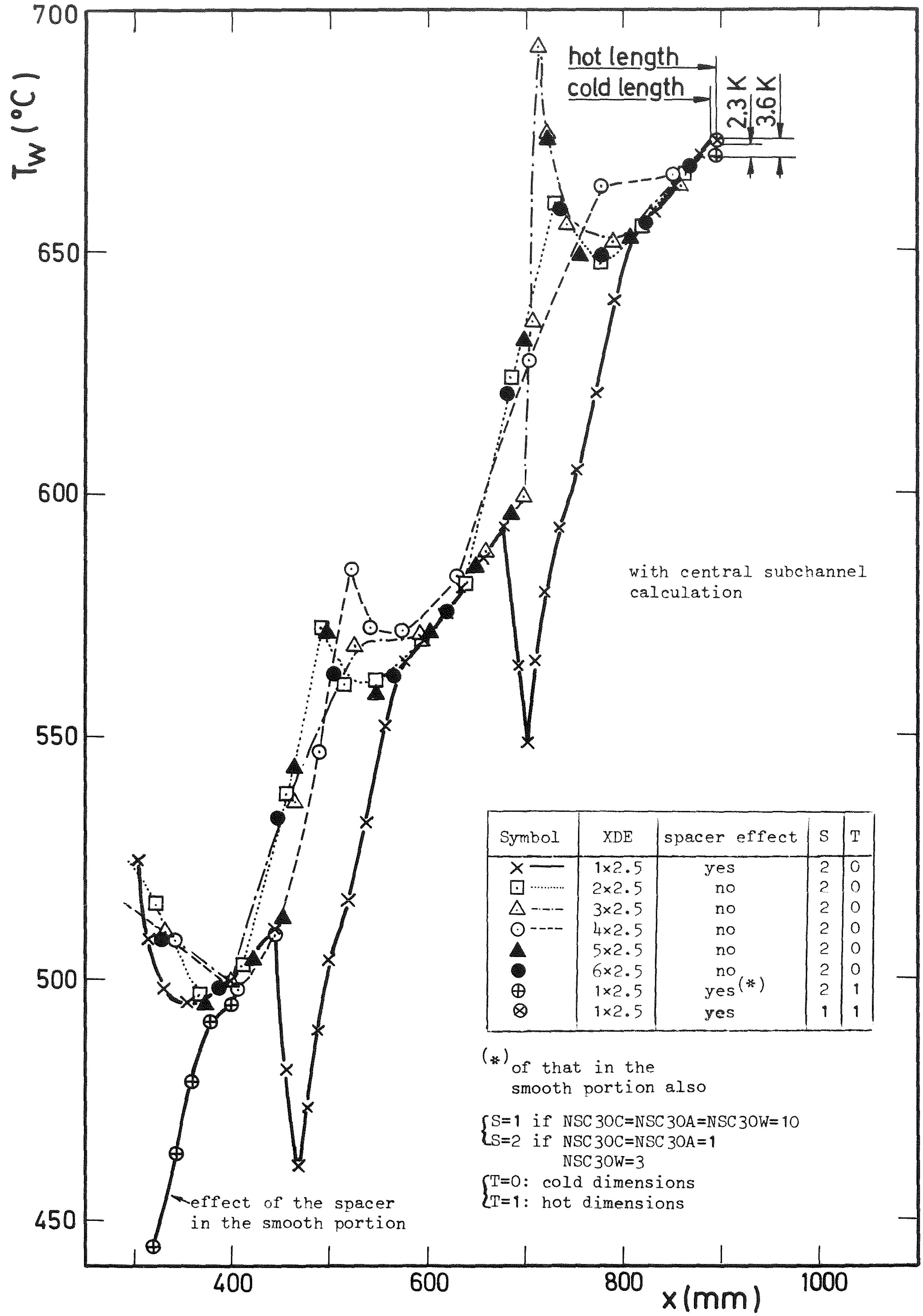


Fig. 10: Effect of various parameters on the pin temperature for the corner channel with the largest blockage (Case 1, Benchmark Meeting II calculations)

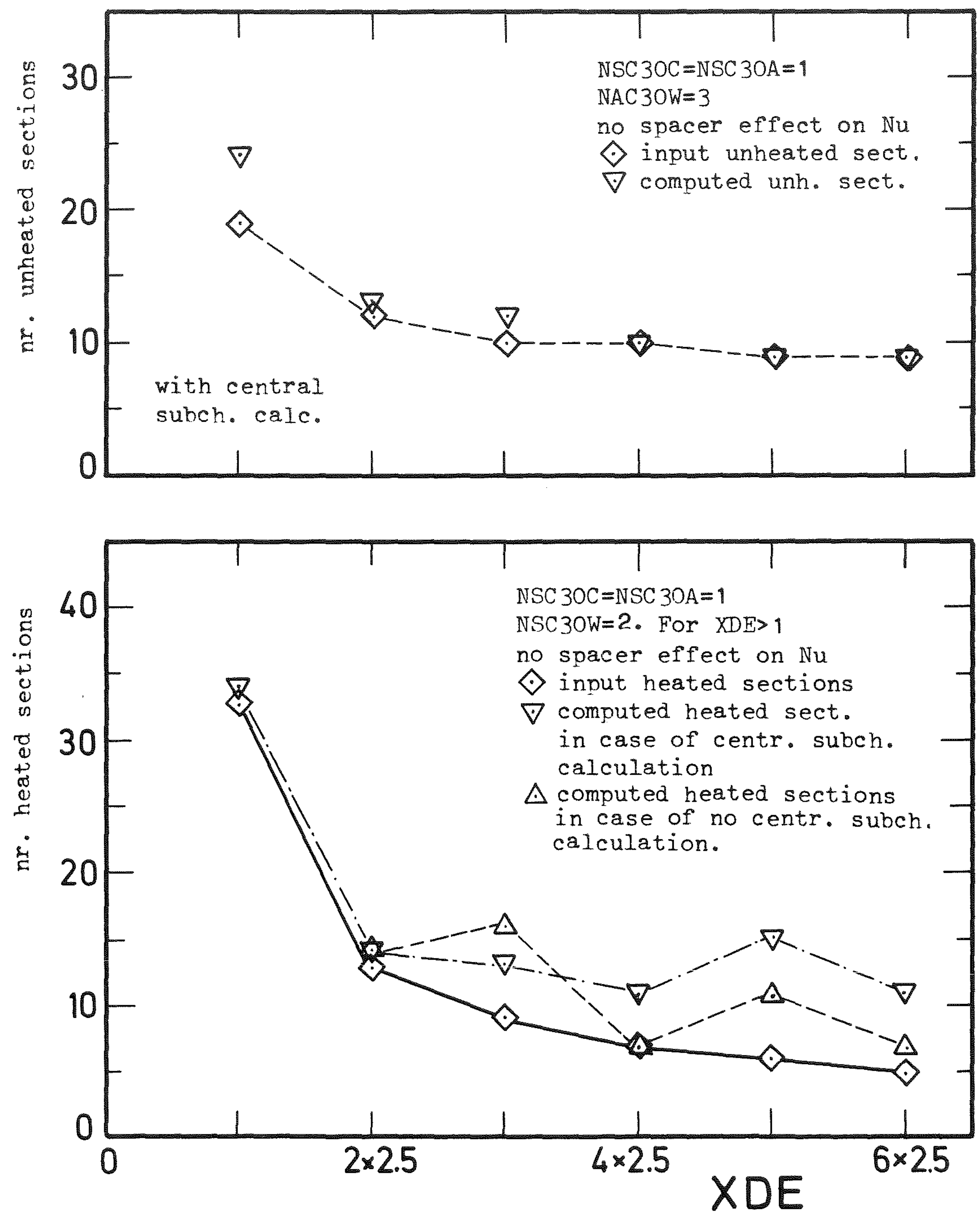


Fig.11a: Effect of various parameters on calculation time for case 1 of Benchmark Meeting II calculations. (UNIVAC computer of GA)

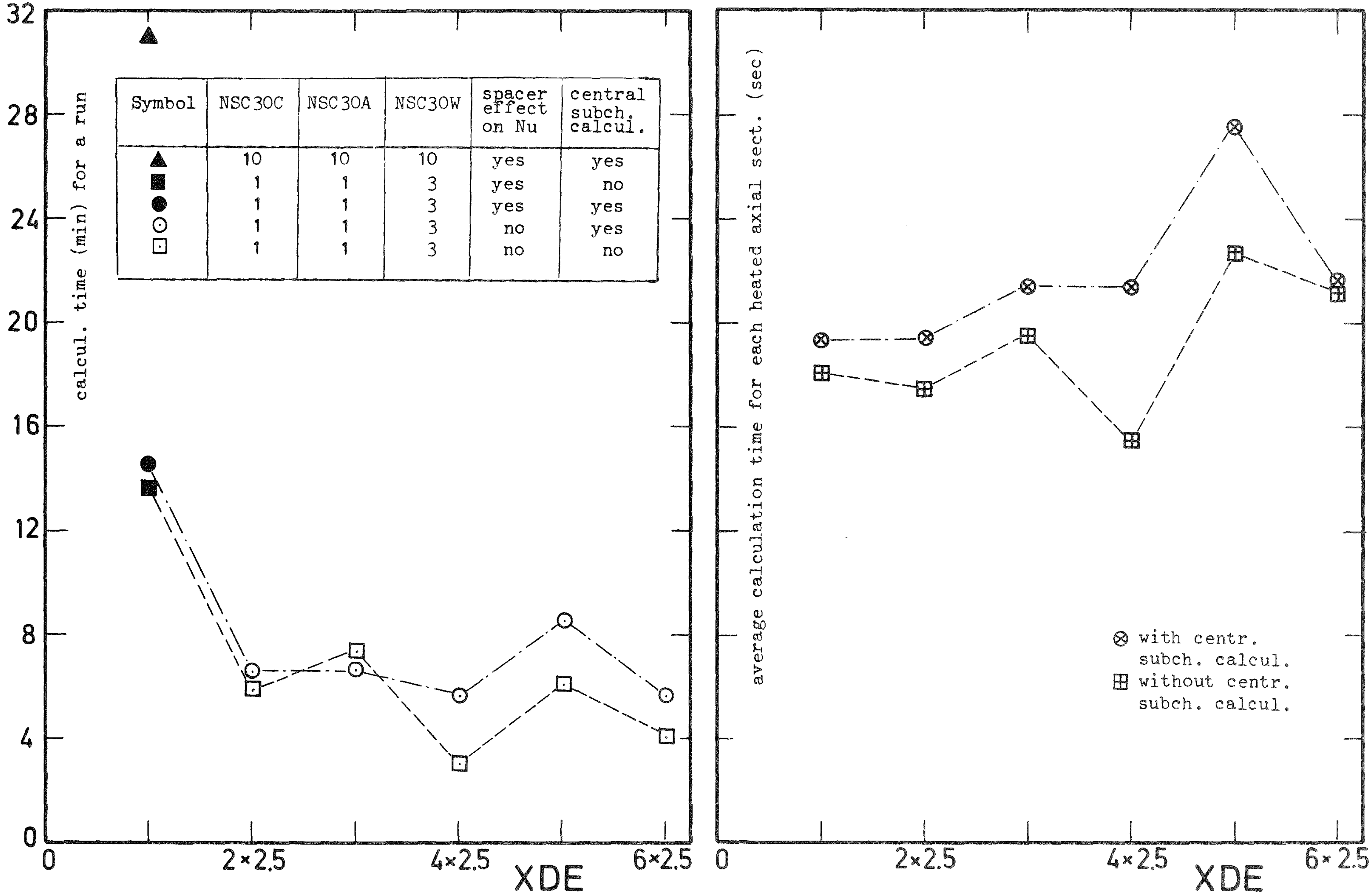


Fig.11b: Effect of various parameters on calculation time for case 1 of Benchmark Meeting II calculations. (UNIVAC computer of GA)

Appendix

Listing of SAGAPØ-2

```
C     A. MARTELLI                                                        000000
C     ***********                                                        000000
C                                                                        000000
C                                                                        000000
C                                                                        000000
C     =================================================================000000
C     S A G A P O                                                        000000
C                                                                        000000
C     A COMPUTER CODE FOR THE THERMO-FLUIDDYNAMIC ANALYSIS OF GAS COOLED000000
C     BUNDLES OF PARTLY SMOOTH AND PARTLY ROUGHENED RODS IN STEADY STATE000001
C     CONDITIONS                                                         000001
C     =================================================================000001
C                                                                        000001
C                                                                        000001
C     THE CODE HAS BEEN WRITTEN IN FORTRAN IV FOR THE COMPUTER IBM 370- 000001
C     168 OF THE KARLSRUHE NUCLEAR CENTER                                000001
C     DESCRIPTION OF THE PHYSICAL MODEL: KFK 2436-EUR 5508D              000001
C     USER'S GUIDE: KFK 2483-EUR 5510E                                   000001
C                                                                        000001
C                                                                        000002
C     MAIN PROGRAM                                                       000002
C     ------------------------------------------------------------------ 000002
C     THE MAIN PROGRAM  READS MOST OF THE INPUT DATA, PRINTS AND PUNCHS 000002
C     MOST OF THE COMPUTED RESULTS,PERFORMS SOME SIMPLE CALCULATIONS     000002
C     AND ORGANIZES ALL THE CALCULATIONS OF SAGAPO                       000002
C                                                                        000002
      REAL LENGTH,LAMBDM,MFLOW,MA,MSCH ,MI,MO,MEC,LAM ,MEA1,LAM1,MM2     000002
     1     ,MSCH1,LAMSCH,MSCHB,MSCHB1,LAMBDA(100),MAV,MAWC,MSCWC1,LAMWC,000002
     2     NDE1,NDE2,KAPPA                                               000002
      REAL*8 TITLE(4,7)/'INITIAL ','UNHEATED',' SMOOTH ','PART',         000003
     1       'FIRST HE','ATED SMO','OTH PART',' ','FIRST UN',            000003
     2       'HEATED R','OUGH PAR','T','ROUGH PA','RT (HEAT',            000003
     3       'ED OR UN','HEATED)','LAST  UN','HEATED R','OUGH PAR','T', 000003
     4       'SECOND H','EATED SM','OOTH PAR','T','LAST UNH','EATED SM',000003
     5       'OOTH PAR','T'/                                             000003
      DIMENSION PGDPT(4),EPSIT(4),CSPT(4),DPBAR(100),PBAR(100),         000003
     1          T(100),RHOET(100),ETABT(100),UBT(100),REBT(100),P(100), 000003
     2          GRI(42,3,7),IRGRI(42,3),GRIP(42,3,7),XDE1(7),XDE2(7),    000003
     3          QPIN(37),XLAM1(7),NSPAC(7),PLEN(7),VDIAM(7),FAREL(7),    000003
     4          CIPA(7),ZIPA(7),TWTIPA(7),TBTIPA(7),TBPIPA(7),WSP(7),    000004
     5          PLENC(7),RHIPA(3),ACW(45),DECW(45),MEC(45),              000004
     6          AA1(30),DEA1(30),MEA1(30),RMISTW(7),RINT(7),             000004
     7          HPLUS1(42,3),HPLUS2(42,3),TWA(42,3),QPLUSA(42,3),        000004
     8          PRBA (42,3),XSTART(7),XEND(7),AMASST(42,3)               000004
     9          ,AMASSB(42,3),TEMPBA(42,3),YDHA(42,3),TEMPTA(42,3)       000004
      DIMENSION INDSP(100),NEXPR(7 ),PEX(10),XEXPR(10),NEXTW(7 ),       000004
     1          XEXTW(3),TWTH(42,3,3),TWP(42,3),DELTIO(18,2,90),         000004
     2          GRI1(18,2,7),GRI2(18,2,7),YODHA(42,3),                   000004
     3          X2DPRQ(7),NDPRQ(7),QDCOI(7),QLDCOI(7),QDCO(7,7),         000004
     4          QLDCO(7,7),XPRQ(3),BICT(42,3),TWINF(42,3),QSECT(3)       000005
      COMMON/GRIDWC/EPSWC(18,2,2,4),CSPWC(18,2,2,4)/CORRE/QHRDAR,QRMDAR 000005
     1      ,QLAMR/QPAR1/QDEV/QPAR2/QLINM,QLDEV/QPAR3/PERL(3)            000005
     2      /CORR/SIGMA(42),PHI(42),SBMNS/IDISPB/IDISP2                  000005
     3      /CORR1/SIGMAI(42,3),PHII(42,3)/CORR2/CHI(18,2,2),PSI(18,2,2)000005
     4      /GEN1/LAM(42)/GEN4/TEMP(42)/GEN2/A(42)/GEN5/DE(42)           000005
     5      /GEN3/MI(42)/GEN6/MO(42)/HEA1/Q(37)/HEA5/QQ(42,3)            000005
     6      /GRID/CSPC(42,4)/GRIDD/CSPSC(42,3,4)/GASD1/NSTOT             000005
     7      /GRID1/EPSISC(42,3,5),DIST(7 )/GRID3/X(100)                  000005
     8      /GRID6/EPSIC(42,4)/GRID7/PGDPC(42,4)/GRID8/PGDPSC(42,3,4)    000005
     9      /IND3/NTYP(42)/GEO2/ATOT,DETOT,ASEC/GEO0/ACH(3)/GAGR/DPSI    000006
      COMMON/GEO5/ATC,DETC,ATW,DETW,ATA,DETA,AAC,AAW,AAA                 000006
     1      /HB3/TEMP2(42)/MOB1/MM2(42)/ MO34/WCF(42)                    000006
     2      /MOB2/UAV(42) /MOB5/TAV(42)/MO36/MAV(42)/MOB8/DPNS(42)       000006
     3      /MOB24/WI(42,3)/SUB2/TSCH(42,3),MSCH(42,3)                   000006
     4      /HEA6/NPIN(42),JPIN(42,3)/SUB1/ASCH(42,3)                    000006
     5      /SUB6/TSCH1(42,3)/SUB5/LAMSCH(42,3)/SUB8/MSCH1(42,3)         000006
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     6       /SUB20/PRCVI(18,2)/SUB22/TW(42,3)                            000006
     7       /SUB23/HPLUSB(42,3),HPLUSW(42,3),QPLUS(42,3),PR3  (42,3)     000006
     8       ,YODH(42,3)/IJ1/NER(42),NIS(42,3)/MART/ITCORR /DAT/PIG       000006
     9       /CCLAM1/CCLAMB/CCLAM2/COLAMA/SUB21/TTSCHA(18,2),TTSCHB(18,2)000007
      COMMON/DAT1/D0,C1,C2,C3,C4,C5,C16,C17,C18,C19/PRSPA/DIST00         000007
     1       /DAT2/C6,C7,C8,C9,C10,C11,C12,C13,C14,C15/DAT4/NDEST,NDEEND 000007
     2       /DAT6/IRHPL/DAT7/CNLSS(2)/WAC01/XMSCHB(18,2),XMSCHA(18,2)   000007
     3       /WCSE2/MSCWC1(18,2,2)/WCSE3/LAMWC(18,2,2)/WCSE7/MAWC(18,2,2)000007
     4       /WCSE6/ASCWC1(18,2,2)/WCSE5/TSCWC1(18,2,2)                  000007
     5       /WCSE8/ASCHWC(18,2,2)/WCSE9/TAVWC(18,2,2)/WCSE1/DEWC(18,2,2)000007
     6       ,PPWWCC(18,2,2)/WCSE12/TWWC(18,2,2)/GRAV/IGRAV              000007
     7       /PARTB/TEMPB(42,3),XMASSB(42,3),YOH(42,3)/INITL/XMHE        000007
     8       /WSSCH/T1SSC1(18,2),T2SSC1(18,2),T1SSC2(18,2),T2SSC2(18,2)  000007
     9       /WSSCHO/TBSSC1(42,3),TWSSC1(42,3),TBSSC2(42,3),TWSSC2(42,3) 000008
      COMMON/WSSCH1/DELTIE(18,2,90),DTIEAV(18,2)/WSSCH2/TIO(18,2,90)     000008
     1       /IROSMO/IRH/SUBLA/CLASUB/SHROUD/TLINER(18,2)/QSHR/QALIN     000008
     2       /INPAR/IPA/LAMIN3/F1ATIP(42),F1DTIP(42)/LAMIN4/F2ATIP(42,3),000008
     3       F2DTIP(42,3)/LAMIN5/RTIP(7)/LAMINO/I2TIP(42,3)/MART5/NSTR   000008
     4       /GAAGT/FCCPWT                                               000008
      EXTERNAL RTRI,RTSI                                                 000008
C                                                                        000008
C     ........................................................... 000008
C                                                                        000008
C   1-READ AND WRITE INPUT DATA                                          000009
C                                                                        000009
      TIME0=0.                                                           000009
      TIME1=ZEIT(TIME0)                                                  000009
      DIST00=-1.E07                                                      000009
      PEXOUT=0.                                                          000009
      COLAMB=1.                                                          000009
      SQ3=SQRT(3.)                                                       000009
      PIG=3.141593                                                       000009
    1 FORMAT(8I10)                                                       000009
    2 FORMAT(8F10.5)                                                     000010
      READ(5,1)NEXCCN,NRODS,NSPACT,NSPAC                                 000010
      READ(5,2)C,Z,ZWC,RH,FLEN,VDIAM                                     000010
      READ(5,2)AREFB,RMISTW,RINT,RTIP                                    000010
      READ(5,1)NDVQ,NSEL,NSC30C,NSC30W,NSC30A                            000010
      READ(5,2)PE,PE1,TE,TE1,MFLCW,XLAM1                                 000010
      READ(5,2)COLAMA                                                    000010
      READ(5,1)IPAST,IPAEND,IREAD1                                       000010
      READ(5,2)STLEN                                                     000010
      READ(5,1)INDPR,INDQ                                                000010
      READ(5,1) NEXPRT,NEXPR                                             000011
      READ(5,1) NEXTWT,NEXTW                                             000011
      READ(5,1)ITCM,ITC1,ITC2,MSUBCH                                     000011
      READ(5,2)XDE1,XDE2                                                 000011
      READ(5,2)FT,PCORR,CTU1,CTU2,CTU3                                   000011
      READ(5,2)TWPRCF,TCPRCF                                             000011
      READ(5,2)CINL,CCUT                                                 000011
      READ(5,2)FAREL                                                     000011
      READ(5,2)TWTIPA,TBTIPA,TEPIPA                                      000011
      IF(NEXPRT.GT.0)READ(5,2)(XEXPR(I),PEX(I),I=1,NEXPRT),PEXOUT        000011
      IF(NEXTWT.GT.0)READ(5,2)(XEXTW(I),I=1,NEXTWT)                      000012
      IF(NDVQ.EQ.1)GOTO 3                                                000012
      READ(5,2)(QPIN(I),I=1,NRODS)                                       000012
      GOTO 5                                                             000012
    3 READ(5,2)QPIN(1)                                                   000012
      DO 4 I=1,NRODS                                                     000012
    4 QPIN(I)=QPIN(1)                                                    000012
    5 CONTINUE                                                           000012
      READ(5,2)QLINMT                                                    000012
      IF(INDQ.EQ.1)GOTO 3800                                             000012
      DO 3799 I=1,NRODS                                                  000013
 3799 QPIN(I)=QPIN(I)/4.186                                              000013
      QLINMT=QLINMT/4.186                                                000013
```

```
3800  CONTINUE                                                           000013
      READ(5,1)NDPRQT,NDPRQ                                              000013
      IF(NDPRQT.EQ.0)GOTO 3716                                           000013
      READ(5,2)(X2DPRQ(I),I=1,NDPRQT)                                    000013
      READ(5,1)NQDCO                                                     000013
        READ(5,4001)((QDCO(I,J),J=1,NQDCO),I=1,NDPRQT)                   000013
        READ(5,4001)((QLDCO(I,J),J=1,NQDCO),I=1,NDPRQT)                  000013
4001 FORMAT(6E12.5)                                                      000014
3716 CONTINUE                                                            000014
     HEALEN=PLEN(2)+PLEN(4)+PLEN(6)                                      000014
     TOTLEN=PLEN(1)+PLEN(3)+PLEN(5)+PLEN(7)+HEALEN                       000014
     IF(ABS(PE/PE1-1.).GT.1.E-05)CINL=0.                                 000014
     PEO=PE1                                                             000014
     IF(INDPR.EQ.1)GOTO 6529                                             000014
     PE=PE/0.980665                                                      000014
     PEO=PE1/0.980665                                                    000014
6529 CONTINUE                                                            000014
     PEBAR=PE*0.980665                                                   000015
     PEOBAR=PEO*0.980665                                                 000015
     WRITE(6,6)NRODS,PEO,PEOBAR,TE1,MFLOW,C,Z,ZWC,TOTLEN,HEALEN          000015
   6 FORMAT(1H1,5X,I4,' RODS BUNDLE :'//5X,'INLET PRESSURE=',F10.7,' KG000015
    1/SQCM   =',F10.7,' BARS'                                            000015
    1       /5X,'INLET TEMPERATURE=',F10.2,' C'/5X,'TOTAL MASS FLOW RATE000015
    2=',F12.6,' G/SEC'///5X,'GEOMETRY AT 20 DEGREES : '//                000015
    3                                      5X,'ROD PITCH=',F10.6,' CM'/ 000015
    45X,'DISTANCE CENTER OF ROD - EXAGONAL WALL=',F10.6,' CM'/5X,        000015
    5'ZWC=',F10.7,' CM'//5X,                                             000015
    6  'TOTAL LENGTH=',F10.3,' CM'/5X,'HEATED LENGTH=',F10.3,' CM'/5X,  000016
    7'LENGTH AND VOL. DIAMETERS FOR THE EXISTING PARTS :')               000016
     DO 972 IPA=1,7                                                      000016
     IF(PLEN(IPA).LE.1.E-06)GOTO 972                                     000016
     WRITE(6,971)IPA,PLEN(IPA),IPA,VDIAM(IPA)                            000016
 971 FORMAT(5X,'LENGTH(',I1,')=',F10.6,' CM',5X,'VOL. DIAM.(',I1,')=',  000016
    1    F10.6,' CM')                                                    000016
 972 CONTINUE                                                            000016
     IF(PLEN(4).GT.1.E-06)                                               000016
    *WRITE(6,980)RH,                                                     000016
    1             C16,C17,C4,C5,C0,C1,C2,C3,               C6,C7,C8,C9  000017
    2,C10,C11,C13,C14,C15                                                000017
 980 FORMAT(///////5X,'HEIGHT OF ROUGHNESS (RH) =',F8.5,' CM'/5X,        000017
    1'G(H+) * ((R2-R1)/RH*',F6.3,')**',F6.3,' / (PR**',F6.3,'*((TW+273.000017
    215)/(TB+273.15))**',F6.3,')=' /5X,'=',F6.3,'*(HW+)**',F6.3,'+',F9.3000017
    3,'/(HW+)**' ,F6.3///5X,                                             000017
    5 'R(H+)=(', F6.3,'+', F7.1,'/(HW+)**', F6.3,')**', F6.3,'+',F6.3, 000017
    6'*LN(RH/(',F6.3,'*(R0-R1))'/12X,'+',F6.3,'/(HW+)**',F6.3,'*((TW+27000017
    73.16) /(TB1+273.16)-1)**',F6.3//)                                   000017
     WRITE(6,3727)QLINMT,(I,QPIN(I),I=1,NRODS)                           000017
3727 FORMAT(//5X,'MAXIMUM POWER FROM THE LINER:'//5X,'Q MAX=',E15.5,     000018
    1  ' CAL/SEC*CM'                                                     000018
    2       ///5X,'MAXIMUM POWER OF RODS:'//(5X,'Q MAX(',I4,')=',E15.5,000018
    3  ' CAL/SEC*CM'))                                                   000018
     IF(NDPRQT.EQ.0)GOTO 3730                                            000018
     WRITE(6,3731)                                                       000018
3731 FORMAT(//5X,'COEFFICIENTS FOR THE POLYNOMIAL PROFILES OF THE ROD P000018
    1OWER ( 0 TAKEN AT THE BEGINNING OF THE ACTUAL PART ):'/)            000018
     DO 3729 I=1,NDPRQT                                                  000018
3729 WRITE(6,3728)X2DPRQ(I),(QDCO(I,J),J=1,NQDCO)                        000018
3728 FORMAT(/5X,'AS FAR AS X =',F10.6,' CM :'/(5X,8E15.5))               000019
     WRITE(6,3733)                                                       000019
3733 FORMAT(//5X,'COEFFICIENTS FOR THE POLYNOMIAL PROFILE OF THE LINER 000019
    1POWER ( 0 TAKEN AT THE BEGINNING OF THE ACTUAL PART ):'/)           000019
     DO 3732 I=1,NDPRQT                                                  000019
3732 WRITE(6,3728)X2DPRQ(I),(QLDCO(I,J),J=1,NQDCO)                       000019
3730 CONTINUE                                                            000019
     ............................................................... 000019
                                                                         000019
```

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C    2-INDEXING AND CONNECTIONS FOR THE CHANNELS                           000019
C                                                                          000020
      CALL INDEX(NSEL,NEXCON,NSTR,NSTOT,NROM1)                             000020
      NSPER=NSTOT-NSTR                                                     000020
C     ............................................................         000020
C                                                                          000020
C    3-READ AND WRITE INPUT DATA                                           000020
C                                                                          000020
      IF(NSPACT.EQ.0)GOTO 7                                                000020
      READ(5,2)WSPO,(DIST(I),I=1,NSPACT)                                   000020
      WRITE(6,970)WSPO,(I,DIST(I),I=1,NSPACT)                              000020
  970 FORMAT(//5X,'SPACERS (AT 20 DEGREES):'//5X,'WIDTH=',F10.6,' CM'//    000021
     1(5X,'DIST(',I2,')=',F10.3,' CM'))                                    000021
      WRITE(6,83)                                                          000021
      DO 11 I=1,NSPACT                                                     000021
       READ(5,981)((GRI(NS,J,I   ),J=1,3),NS=1,NSTOT)                      000021
      READ(5,981)((GRIP(NS,J,I   ),J=1,3),NS=1,NSTOT)                      000021
      READ(5,981)((GRI1(K,J,I   ),J=1,2),K=1,NSPER)                        000021
      READ(5,981)((GRI2(K,J,I   ),J=1,2),K=1,NSPER)                        000021
   11 CONTINUE                                                             000021
      READ(5,982)((IRGRI(NS,J),J=1,3),NS=1,NSTOT)                          000021
  981 FORMAT(6F10.5)                                                       000022
  982 FORMAT(6I10)                                                         000022
    7 CONTINUE                                                             000022
      READ(5,2)TIMEPU                                                      000022
      READ(5,1)IPUNCH                                                      000022
C     ............................................................         000022
C                                                                          000022
C    4-CORRECTION OF THE INPUT DIMENSIONS TO TAKE INTO ACCOUNT THE         000022
C      THERMAL EXPANSION OF THE BUNDLE STRUCTURE                           000022
C                                                                          000022
      SPLENO=0.                                                            000023
      NEXPRP=0                                                             000023
      NEXTWP=0                                                             000023
      NSPACP=0                                                             000023
      NDPRQP=0                                                             000023
      DO 882 IPA=1,7                                                       000023
      EXFTBP=1.+EXPCL(TBPIPA(IPA))*(TBPIPA(IPA)-20.)                       000023
      EXFTWT =1.+EXPCO(TWTIPA(IPA))*(TWTIPA(IPA)-20.)                      000023
      IF(NEXPR(IPA).EQ.0)GOTO 1010                                         000023
      IEXPR1=NEXPRP+1                                                      000023
      IEXPR2=NEXPRP+NEXPR(IPA)                                             000024
      NEXPRP=IEXPR2                                                        000024
      DO 1009 IEXPR=IEXPR1,IEXPR2                                          000024
 1009 XEXPR(IEXPR)=(XEXPR(IEXPR)-SPLENO)*EXFTBP                            000024
 1010 CONTINUE                                                             000024
      IF(NEXTW(IPA).EQ.0)GOTO 1012                                         000024
      IEXTW1=NEXTWP+1                                                      000024
       IEXTW2=NEXTWP+NEXTW(IPA)                                            000024
      NEXTWP=IEXTW2                                                        000024
      DO 1011 IEXTW=IEXTW1,IEXTW2                                          000024
 1011 XEXTW(IEXTW)=(XEXTW(IEXTW)-SPLENO)*EXFTWT                            000025
 1012 CONTINUE                                                             000025
      IF(NDPRQ(IPA).EQ.0)GOTO 1015                                         000025
      IDPRQ1=NDPRQP+1                                                      000025
      IDPRQ2=NDPRQP+NDPRQ(IPA)                                             000025
      NDPRQP=IDPRQ2                                                        000025
      DO 1014 IDPRQ=IDPRQ1,IDPRQ2                                          000025
      CALL MODFQD(IDPRQ,NDPRQT,NQDCC,QQCO,EXFTWT)                          000025
      CALL MODFQD(IDPRQ,NDPRQT,NQDCC,QLDCO,EXFTWT)                         000025
 1014 X2DPRQ(IDPRQ)=(X2DPRQ(IDPRQ)-SPLENO)*EXFTWT                          000025
 1015 CONTINUE                                                             000026
      IF(NSPAC(IPA).EQ.0)GOTO 882                                          000026
      ISPAC1=1+NSPACP                                                      000026
      ISPAC2=NSPACP+NSPAC(IPA)                                             000026
      NSPACP=ISPAC2                                                        000026
```

```
      WSP(IPA)=WSP0*(1.+EXPCC(TBTIPA(IPA))*(TBTIPA(IPA)-20.))          000026
      DO 881 ISPAC=ISPAC1,ISPAC2                                       000026
  881 DIST(ISPAC)=(DIST(ISPAC)-SPLENO)*EXFTBP                          000026
  882 SPLENO=SPLENO+PLEN(IPA)                                          000026
      EXCON=NEXCON                                                     000026
      DO 983 IPA=1,7                                                   000027
      EXFTBP=1.+EXPCL(TBPIPA(IPA))*(TBPIPA(IPA)-20.)                   000027
      EXFTWT =1.+EXPCO(TWTIPA(IPA))*(TWTIPA(IPA)-20.)                  000027
      PLENO(IPA)=PLEN(IPA)                                             000027
      PLEN(IPA)=PLEN(IPA)*EXFTBP                                       000027
      RMISTW(IPA)=RMISTW(IPA)*EXFTWT                                   000027
      RINT  (IPA)=RINT  (IPA)*EXFTWT                                   000027
      RTIP  (IPA)=RTIP  (IPA)*EXFTWT                                   000027
      VDIAM(IPA)=VDIAM(IPA)*EXFTWT                                     000027
      CIPA(IPA)=C*(1.+EXPCC(TBTIPA(IPA))*(TBTIPA(IPA)-20.))            000027
      ZIPA(IPA)=(Z+EXCON*C*SQ3*0.5)*EXFTBP-EXCON*CIPA(IPA)*SQ3*0.5     000028
  983 CONTINUE                                                         000028
      SPLEN=0.                                                         000028
      NEXPRP=0                                                         000028
      NSPACP=0                                                         000028
      NDPRQP=0                                                         000028
      DO 885 IPA=1,7                                                   000028
      IF(NEXPR(IPA).EQ.0)GOTO 1020                                     000028
      IEXPR1=NEXPRP+1                                                  000028
      IEXPR2=NEXPRP+NEXPR(IPA)                                         000028
      NEXPRP=IEXPR2                                                    000029
      DO 1019 IEXPR=IEXPR1,IEXPR2                                      000029
 1019 XEXPR(IEXPR)=XEXPR(IEXPR)+SPLEN                                  000029
 1020 CONTINUE                                                         000029
      IF(NSPAC(IPA).EQ.0)GOTO 885                                      000029
      ISPAC1=1+NSPACP                                                  000029
      ISPAC2=NSPACP+NSPAC(IPA)                                         000029
      NSPACP=ISPAC2                                                    000029
      DO 884 ISPAC=ISPAC1,ISPAC2                                       000029
  884 DIST(ISPAC)=DIST(ISPAC)+SPLEN                                    000029
  885 SPLEN=SPLEN+PLEN(IPA)                                            000030
      DO 8 IPA=1,7                                                     000030
      IF(PLEN(8-IPA).LE.1.E-06)GOTO 8                                  000030
      IPAM=8-IPA                                                       000030
      GOTO 9                                                           000030
    8 CONTINUE                                                         000030
    9 CONTINUE                                                         000030
      PLEN(IPAM)=SPLEN                                                 000030
      IPA1=IPAM-1                                                      000030
      DO 10 IPA=1,IPA1                                                 000030
      PLEN(IPA)=PLENO(IPA)*(1.+EXPCC(TWTIPA(IPA))*(TWTIPA(IPA)-20.))   000031
      PLEN(IPAM)=PLEN(IPAM)-PLEN(IPA)                                  000031
   10 CONTINUE                                                         000031
      DO 886 IPA=3,5                                                   000031
      IF(PLEN(IPA).LE.1.E-06)GOTO 886                                  000031
      RHIPA(IPA-2)=RH*(1.+EXPCC(TWTIPA(IPA))*(TWTIPA(IPA)-20.))        000031
  886 CONTINUE                                                         000031
      SPLEN=0.                                                         000031
      NEXTWP=0                                                         000031
      DO 1013 IPA=1,7                                                  000031
      IF(NDPRQ(IPA).EQ.0)GOTO 1017                                     000032
      IDPRQ1=NDPRQP+1                                                  000032
      IDPRQ2=NDPRQP+NDPRQ(IPA)                                         000032
      NDPRQP=IDPRQ2                                                    000032
      DO 1016 IDPRQ=IDPRQ1,IDPRQ2                                      000032
 1016 X2DPRQ(IDPRQ)=X2DPRQ(IDPRQ)+SPLEN                                000032
      X2DPRQ(IDPRQ2)=X2DPRQ(IDPRQ2)*1.1                                000032
 1017 CONTINUE                                                         000032
      IF(NEXTW(IPA).EQ.0)GOTO 1022                                     000032
      IEXTW1=NEXTWP+1                                                  000032
       IEXTW2=NEXTWP+NEXTW(IPA)                                        000033
```

```
      NEXTWP=IEXTW2
      DO 1021 IEXTW=IEXTW1,IEXTW2
 1021 XEXTW(IEXTW)=XEXTW(IEXTW)+SPLEN
 1022 CONTINUE
 1013 SPLEN=SPLEN+PLEN(IPA)
      UNHLE=PLEN(1)+PLEN(3)
C     ***************************************************************
C
C   5-REARRANGEMENT OF THE GEOMETRIC AXIAL DATA IF THE CALCULATION DOES
C     NOT START AT THE BUNDLE INLET
C
      ISTAIN=1
      SPLEN=0.
      IPAST1=IPAST-1
      NEXPRS=0
      NEXTWS=0
      NSPACS=0
      NDPRQS=0
      IF(IPAST1.EQ.0)GOTO 2222
      DO 6532 IPA=1,IPAST1
      SPLEN=SPLEN+PLEN(IPA)
      PLEN(IPA)=0.
      NEXPRT=NEXPRT-NEXPR(IPA)
      NEXPRS=NEXPRS+NEXPR(IPA)
      NEXPR(IPA)=0
       NEXTWT=NEXTWT-NEXTW(IPA)
      NEXTWS=NEXTWS+NEXTW(IPA)
      NEXTW(IPA)=0
      NDPRQT=NDPRQT-NDPRQ(IPA)
      NDPRQS=NDPRQS+NDPRQ(IPA)
      NDPRQ(IPA)=0
      NSPACT=NSPACT-NSPAC(IPA)
      NSPACS=NSPACS+NSPAC(IPA)
       NSPAC(IPA)=0
 6532 CONTINUE
      IF(IPAST.EQ.4)AREFB=AREFB*(PLEN(4)+SPLEN-STLEN)/PLEN(4)
 2222 CONTINUE
      PLEN(IPAST)=PLEN(IPAST)+SPLEN-STLEN
      IF(ABS(STLEN-SPLEN).GT.1.E-04)ISTAIN=2
      IF(NEXPRT.EQ.0)GOTO 6534
      IEXPR1=0
      DO 6533 I=1,NEXPRT
      XEXPR(I)=XEXPR(I+NEXPRS)-STLEN
      IF(XEXPR(I).LE.0.)IEXPR1=IEXPR1+1
 6533 PEX(I)=PEX(I+NEXPRS)
      NEXPR(IPAST)=NEXPR(IPAST)-IEXPR1
       NEXPRT=NEXPRT-IEXPR1
      IF(NEXPRT.EQ.0)GOTO 6534
      DO 973 I=1,NEXPRT
      XEXPR(I)=XEXPR(I+IEXPR1)
  973 PEX(I)=PEX(I+IEXPR1)
 6534 CONTINUE
      IF(NEXTWT.EQ.0)GOTO  6536
      IEXTW1=0
      DO 6535 I=1,NEXTWT
      XEXTW(I)=XEXTW(I+NEXTWS)-STLEN
      IF(XEXTW(I).LE.0.)IEXTW1=IEXTW1+1
 6535 CONTINUE
      NEXTW(IPAST)=NEXTW(IPAST)-IEXTW1
      NEXTWT=NEXTWT-IEXTW1
      IF(NEXTWT.EQ.0)GOTO 6536
      DO 974 I=1,NEXTWT
  974 XEXTW(I)=XEXTW(I+IEXTW1)
 6536 CONTINUE
      IF(NDPRQT.EQ.0)GOTO 6539
      IDPRQ1=0
```

```
      DO 6540 I=1,NDPRQT                                                000039
      X2DPRQ(I)=X2DPRQ(I+NDPRQS)-STLEN                                  000039
      IF(X2DPRQ(I).LE.0.)IDPRQ1=IDPRQ1+1                                000039
      DO 6540 IQDCO=1,NQDCO                                             000040
      QDCO(I,IQDCO)=QDCO(I+NDPRQS,IQDCO)                                000040
      QLDCO(I,IQDCO)=QLDCO(I+ NDPRQS,IQDCO)                             000040
 6540 CONTINUE                                                          000040
      NDPRQ(IPAST)=NDPRQ(IPAST)-IDPRQ1                                  000040
      NDPRQT=NDPRQT-IDPRQ1                                              000040
      IF( NDPRQT.EQ.0)GOTO  6539                                        000040
      DO 976 I=1,NDPRQT                                                 000040
      X2DPRQ(I)=X2DPRQ(I+IDPRQ1)                                        000040
      DO 976 IQDCO=1,NQDCO                                              000040
      QDCO(I,IQDCO)=QDCO(I+IDPRQ1,IQDCO)                                000041
      QLDCO(I,IQDCO)=QLDCO(I+IDPRQ1,IQDCO)                              000041
  976 CONTINUE                                                          000041
 6539 CONTINUE                                                          000041
      IF(NSPACS.NE.0)DISTOO=DIST(NSPACS)-STLEN                          000041
      NSPA00=NSPACT+1                                                   000041
      IF(NSPACS.GT.NSPA00)NSPA00=NSPACS                                 000041
      IF(NSPACT.EQ.0 .AND. NSPACS.EQ.0)GOTO 6538                        000041
      ISPAC1=0                                                          000041
      DO 6537 I=1,NSPA00                                                000041
      IF(I.GT.NSPACT)GOTO 2006                                          000042
      DIST(I)=DIST(I+NSPACS)-STLEN                                      000042
      IF(DIST(I).LE.0.)ISPAC1=ISPAC1+1                                  000042
      IF(DIST(I).LE.0.)DISTOO=DIST(I)                                   000042
 2006 CONTINUE                                                          000042
      DO 2000 NS=1,NSTCT                                                000042
      DO 2001 J=1,3                                                     000042
      IF(NSPACS.GT.0)GRIOO=GRI(NS,J,I)                                  000042
      IF(I.LE.NSPACT)GRI(NS,J,I)=GRI(NS,J ,I+NSPACS)                    000042
      IF(I.LE.NSPACT .AND. I.GE.NSPACS .AND. NSPACS.GT.0)GRI(NS,J,I+1)= 000042
     =GRIOO                                                             000043
      IF(I.GT.NSPACT .AND. I.GE.NSPACS .AND. NSPACS.GT.0)GRI(NS,J,NSPACT000043
     ++1)=GRIOO                                                         000043
      IF(I.LE.NSPACT)GRIP(NS,J,I)=GRIP(NS,J,I+NSPACS)                   000043
 2001 CONTINUE                                                          000043
      IF(NS.LE.NSTR .OR. I.GT.NSPACT)GOTO 2000                          000043
      NSW=NS-NSTR                                                       000043
      DO 2002 J=1,2                                                     000043
      GRI1(NSW,J,I)=GRI1(NSW,J,I+NSPACS)                                000043
 2002 GRI2(NSW,J,I)=GRI2(NSW,J,I+NSPACS)                                000043
 2000 CONTINUE                                                          000044
 6537 CONTINUE                                                          000044
      NSPAC(IPAST)=NSPAC(IPAST)-ISPAC1                                  000044
      NSPACT=NSPACT-ISPAC1                                              000044
      NSPA00=NSPACT+1                                                   000044
      IF(ISPAC1.GT.NSPA00)NSPA00=ISPAC1                                 000044
      IF(NSPACT.EQ.0 .AND. ISPAC1.EQ.0)GOTO 6538                        000044
       DO 977 I=1,NSPA00                                                000044
      DO 2003 NS=1,NSTCT                                                000044
      DO 2004 J=1,3                                                     000044
      IF(ISPAC1.GT.0)GRIOO=GRI(NS,J,I)                                  000045
      IF(I.LE.NSPACT)GRI(NS,J,I)=GRI(NS,J,I+ISPAC1)                     000045
      IF(I.GE.ISPAC1 .AND. ISPAC1.GT.0 .AND. I.LE.NSPACT)GRI(NS,J,I+1)= 000045
     =GRIOO                                                             000045
      IF(I.GE.ISPAC1 .AND. ISPAC1.GT.0 .AND. I.GT.NSPACT)GRI(NS,J,      000045
     *NSPACT+1)=GRIOO                                                   000045
      IF(I.GT.NSPACT)GOTO 2004                                          000045
      GRIP(NS,J,I)=GRIP(NS,J,I+ISPAC1)                                  000045
 2004 CONTINUE                                                          000045
      IF(NS.LE.NSTR .OR. I.GT.NSPACT)GOTO 2003                          000045
      NSW=NS-NSTR                                                       000046
      DO 2005 J=1,2                                                     000046
      GRI1(NSW,J,I)=GRI1(NSW,J,I+ISPAC1)                                000046
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 2005 GRI2(NSW,J,I)=GRI2(NSW,J,I+ISPAC1)                               000046
 2003 CONTINUE                                                         000046
      IF(I.LE.NSPACT)DIST(I)=DIST(I+ISPAC1)                            000046
  977 CONTINUE                                                         000046
 6538 CONTINUE                                                         000046
      HEALEN=PLEN(2)+PLEN(4)+PLEN(6)                                   000046
      UNHLE1=PLEN(1)+PLEN(3)                                           000046
      TOTLEN=UNHLE1+HEALEN+ PLEN(5)+PLEN(7)                            000047
      HRDAR=RH/AREFB                                                   000047
      IF(PLEN(4).GT.1.E-06)FCCRLA=ALOG(RTIP(4)/(RTIP(4)-RHIPA(2)))/    000047
     /                     (2.*PIG*PLEN(4))                            000047
C     ............................................................... 000047
C                                                                      000047
C   6-INITIALIZATION OF VARIABLES                                      000047
C                                                                      000047
      GLINMT=GLINMT*HEALEN                                             000047
      DO 3734 I=1,NRCDS                                                000047
 3734 QPIN(I)=QPIN(I)*HEALEN                                           000048
      ANCE=NSC30C                                                      000048
      ANWA=NSC30W                                                      000048
      ANCC=NSC30A                                                      000048
      ALFACE=PIG/(6.*ANCE)                                             000048
      ALFAWA=PIG/(6.*ANWA)                                             000048
      ALFACC=PIG/(ANCC*6.)                                             000048
      NSC90=3*NSC30W                                                   000048
      NSC45=NSC30C/2+1+NSC30C                                          000048
      L=1                                                              000048
      T(1)=TE                                                          000049
      P(1)=PE                                                          000049
      PBAR(1)=PEBAR                                                    000049
      X(1)=0.                                                          000049
      XDEST=NDEST                                                      000049
      XDEEND=NDEEND                                                    000049
      TO=TE                                                            000049
      PO=PE                                                            000049
      INLET=1                                                          000049
      ISPAC=1                                                          000049
      II=1                                                             000050
      HH=0.                                                            000050
      IEXPR1=1                                                         000050
      IEXTW1=1                                                         000050
      IEXTWC=1                                                         000050
      IDPRQ=1                                                          000050
      SPRLEN=0.                                                        000050
      IRHPL=1                                                          000050
C     ............................................................... 000050
C                                                                      000050
C     7- LOOP IPA :  A SUBDIVISION OF RODS INTO SEVEN POSSIBLE DIFFERENT000051
C        PARTS IS MADE ( BUT ONLY FIVE TOGETHER ARE SUPPOSED TO EXIST : 000051
C        1) SMOOTH UNHEATED+SMOOTH HEATED+ROUGH+SMOOTH HEATED+SMOOTH    000051
C           UNHEATED                                                   000051
C        2) SMOOTH UNHEATED+ROUGH UNHEATED+ROUGH HEATED+ROUGH UNHEATED+ 000051
C           SMOOTH UNHEATED)                                           000051
C                                                                      000051
C     IPA=1 : INITIAL UNHEATED SMOOTH PART                             000051
C     IPA=2 : FIRST HEATED SMOOTH PART                                 000051
C     IPA=3 : FIRST UNHEATED ROUGH PART                                000051
C     IPA=4 : ROUGH PART (HEATED OR UNHEATED))                         000052
C     IPA=5 : LAST UNHEATED ROUGH PART                                 000052
C     IPA=6 : SECOND HEATED SMOOTH PART                                000052
C     IPA=7 : LAST UNHEATED SMOOTH PART                                000052
C                                                                      000052
      DO 8888 IPA=1,7                                                  000052
      IF(IPA.EQ.IPAEND+1)CALL TYPUN(NSTOT,NSTR,T(L),P(L),PBAR(L),      000052
     *TE1,PEO,PEOBAR,INDPR,MFLOW,IPA,IPAEND,2,XLAM1,X(L)+STLEN,&742)   000052
      IF(PLEN(IPA)  .LE.1.E-06)GOTO 8888                               000052
```

```
        SPLENG=SPRLEN                                                   000052
      IF(IPA.EQ.IPAST)SPLENG=SPLEN-STLEN                                000053
      C=CIPA(IPA)                                                       000053
      Z=ZIPA(IPA)                                                       000053
      D=VDIAM(IPA)                                                      000053
      LENGTH=PLEN(IPA)                                                  000053
      LAM1=XLAM1(IPA)                                                   000053
      MSPAC=NSPAC(IPA)                                                  000053
      NDE1=XDE1(IPA)                                                    000053
      NDE2=XDE2(IPA)                                                    000053
      FREL=FAREL(IPA)                                                   000053
      ZWCIPA=ZWC     *(1.+EXPCC(TBPIPA(IPA))*(TBPIPA(IPA)-20.))         000054
      POBAR=PO*0.980665                                                 000054
      WRITE(6,991)(TITLE(I,IPA),I=1,4),C,Z,ZWCIPA,D,LENGTH,MSPAC,TO,PO  000054
     1,POBAR                                                            000054
  991 FORMAT(1H1,5X,4A8///5X,'C=',F10.6,' CM'/5X,'Z=',F10.6,' CM'/5X,   000054
     1'ZWC=',F10.6,' CM'/ 5X,'VEL. DIAMETER=',F10.6,' CM'/5X,'PART LENGT000054
     2H='  ,F10.5,' CM'/5X,'NUMBER OF SPACERS=',I3//5X,'INLET CONDITIONS000054
     3 :'/5X,'INLET AVERAGE TEMPERATURE=',F7.2,' C'/5X,'INLET PRESSURE='000054
     4,F10.7,' KG/SQCM    =',F10.7,' BARS'/////)                        000054
      IF(MSPAC.EQ.0)GOTO 968                                            000054
      ISPAC2=ISPAC+MSPAC-1                                              000055
      WRITE(6,967)WSP(IPA),(I,DIST(I),I=ISPAC,ISPAC2)                   000055
  967 FORMAT(5X,'SPACERS (DISTANCES ARE EVALUATED FROM THE BUNDLE ENTRAN000055
     1CE) :'/5X,'WIDTH=',F10.6,' CM'/(5X,'DIST(',I2,')=',F10.3,' CM'))  000055
      WRITE(6,83)                                                       000055
  968 CONTINUE                                                          000055
      C2=C*0.5                                                          000055
      EM1=C2-ZWCIPA*SQ3                                                 000055
      X(1)=HH                                                           000055
      DDD=HH+LENGTH                                                     000055
      SUR=PIG*D*LENGTH                                                  000056
      IF(IPA.EQ.5)IRHPL=2                                               000056
      GOTO(993,994,993,994,993,994,993),IPA                             000056
  993 PLDHL=0.                                                          000056
      GOTO 995                                                          000056
  994 PLDHL= PLEN(IPA)/HEALEN                                           000056
  995 CONTINUE                                                          000056
      GOTO(996,996,997,997,997,996,996),IPA                             000056
  996 IRH=1                                                             000056
      CLASUB=1.0576                                                     000056
      XMAXNU=1.6                                                        000057
      CHSLNU=2./3.                                                      000057
      GOTO 998                                                          000057
  997 IRH=2                                                             000057
      CLASUB=1.                                                         000057
      XMAXNU=1.                                                         000057
      CHSLNU=.5                                                         000057
      RH=RHIPA(IPA-2)                                                   000057
      WRITE(6,990)RH                                                    000057
  990 FORMAT(///5X,'HEIGHT OF ROUGHNESS=',F10.7,' CM'////)              000057
  998 CONTINUE                                                          000058
      CONST=CNUSS(IRH)                                                  000058
      QTOT=0.                                                           000058
      DO 992 I=1,NRODS                                                  000058
      Q(I)=QPIN(I)*PLDHL                                                000058
  992 QTOT=QTOT+Q(I)                                                    000058
C                                                                       000058
C     ......................................................            000058
C                                                                       000058
C   8-SUBROUTINES HEATI,TOTGEO,INGUA, KAPCOR                            000058
C                                                                       000059
      CALL HEATI(NSTOT,NSTR,NSEL,NEXCON,IPA)                            000059
      CALL TOTGEO(NSEL,D,C,Z,PIG,NEXCON,NRODS,WW,WA,ZA,EM1,PERLT,       000059
     *RTIP(IPA))                                                        000059
      QLINM=QLINMT*PLDHL/PERLT                                          000059
```

```
      CALL INCUA(NSEL,NSTCT,NEXCCN,ATC,ATW,ATA,DETC,DETW,DETA)          000059
      CALL KAPCOR(NSTCT,NSTR)                                           000059
C     ................................................................. 000059
C                                                                       000059
C   9-DEFINITICN OF THE RECICNS WHERE INDISTURBED FLOW IS ASSUMED AND   000059
C     EVALUATICN OF THE SPACER PARAMETERS                               000060
C                                                                       000060
      DXST =XDEST*DETC                                                  000060
      DXEND=XDEEND*DETC                                                 000060
      XSTART(1)=X(1)+DXST                                               000060
      XEND(MSPAC+1)=X(1)+LENGTH-DXEND                                   000060
      IMSPAC=ISPAC1+NSPACS                                              000060
      IF(IMSPAC.EQ.0  .OR. IPA.NE.IPAST)GOTO 7007                       000060
      DO 7002 NS=1,NSTCT                                                000060
      NP=NPIN(NS)                                                       000060
      DO 7002 J=1,NP                                                    000061
      DO 7002 M=1,NP                                                    000061
      IF(IRGRI(NS,J).EQ.JPIN(NS,M))EPSISC(NS,M,MSPAC+1)=GRI(NS,J,NSPACT+000061
     +1)                                                                000061
 7002 CCNTINUE                                                          000061
 7007 CCNTINUE                                                          000061
      IF(IPA.EQ.IPAST .CR. II.EQ.1)GCTO 7009                            000061
      DO 7008 NS=1,NSTOT                                                000061
      NP=NPIN(NS)                                                       000061
      DO 7008 J=1,NP                                                    000061
      DO 7008 M=1,NP                                                    000062
      IF(IRGRI(NS,J).EQ.JPIN(NS,M))EPSISC(NS,M,MSPAC+1)=GRI(NS,J,II-1)  000062
 7008 CCNTINUE                                                          000062
 7009 CCNTINUE                                                          000062
      IF(MSPAC.EQ.0)GCTO 12                                             000062
      JSP=MSPAC+ISPAC-1                                                 000062
      IPAFD=1                                                           000062
      DO 4430 I=ISPAC,JSP                                               000062
      I1SPAC=I-ISPAC+1                                                  000062
      IPAFD=IPAFD+1                                                     000062
      XSTART(IPAFD)=DIST(I)+DXST+WSP(IPA)*0.5                           000063
      XEND(IPAFD-1)=DIST(I)-WSP(IPA)*0.5-DXEND                          000063
      PGDPT(I1SPAC)=0.                                                  000063
      EPSIT(I1SPAC)=0.                                                  000063
      DO 5601 NS=1,NSTOT                                                000063
      PGDPC(NS,I1SPAC)=0.                                               000063
      EPSIC(NS,I1SPAC)=0.                                               000063
      NP=NPIN(NS)                                                       000063
      DO 5600 J=1,NP                                                    000063
      DO 5599 M=1,NP                                                    000063
      IF(IRGRI(NS,J).NE.JPIN(NS,M))GCTO 5599                            000064
      EPSISC(NS,M,I1SPAC)=GRI(NS,J,I)                                   000064
      PGDPSC(NS,M,I1SPAC)=GRIP(NS,J,I)                                  000064
      EPSIC(NS,I1SPAC)=EPSIC(NS,I1SPAC)+EPSISC(NS,M,I1SPAC)*ASCH(NS,M)  000064
      PGDPC(NS,I1SPAC)=PGDPC(NS,I1SPAC)+PGDPSC(NS,M,I1SPAC)*4.*ASCH(NS, 000064
     *M)/DE(NS)                                                         000064
      IF(NTYP(NS).NE.2)GOTC 56CC                                        000064
      NSW=NS-NSTR                                                       000064
      EPSWC(NSW,M,1,I1SPAC)=GRI1(NSW,M,I)*EPSISC(NS,M,I1SPAC)           000064
      EPSWC(NSW,M,2,I1SPAC)=GRI2(NSW,M,I)*EPSISC(NS,M,I1SPAC)           000064
      GOTC 56CC                                                         000065
 5599 CCNTINUE                                                          000065
 5600 CCNTINUE                                                          000065
      EPSIT(I1SPAC)=EPSIT(I1SPAC)+EPSIC(NS,I1SPAC)                      000065
      PGDPT(I1SPAC)=PGDPT(I1SPAC)+PGDPC(NS,I1SPAC)                      000065
      EPSIC(NS,I1SPAC)=EPSIC(NS,I1SPAC)/A(NS)                           000065
      PGDPC(NS,I1SPAC)=PGDPC(NS,I1SPAC)*DE(NS)*0.25/A(NS)               000065
 5601 CCNTINUE                                                          000065
      EPSIT(I1SPAC)=EPSIT(I1SPAC)/ASEC                                  000065
      PGDPT(I1SPAC)=PGDPT(I1SPAC)*DETCT*0.25/ASEC                       000065
      CSPT(I1SPAC)=GRIFUN(EPSIT(I1SPAC))                                000066
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      DO 5602 NS=1,NSTOT                                                000066
      CSPC(NS,I1SPAC)=GRIFUN(EPSIC(NS,I1SPAC))                          000066
      NP=NPIN(NS)                                                       000066
      DO 5602 M=1,NP                                                    000066
      CSPSC(NS,M,I1SPAC)=GRIFUN(EPSISC(NS,M,I1SPAC))                    000066
      IF(NTYP(NS).NE.2)GOTO 975                                         000066
      NSW=NS-NSTR                                                       000066
      CSPWC(NSW,M,1,I1SPAC)=GRIFUN(EPSWC(NSW,M,1,I1SPAC))               000066
      CSPWC(NSW,M,2,I1SPAC)=GRIFUN(EPSWC(NSW,M,2,I1SPAC))               000066
  975 CONTINUE                                                          000067
 5602 CONTINUE                                                          000067
      WRITE(6,960)I,EPSIT(I1SPAC)                                       000067
  960 FORMAT(//  5X,'SPACER NR.',I5,5X,'EPSILON TOT.=',F10.7)           000067
      DO 964 NS=1,NSTOT                                                 000067
      NP=NPIN(NS)                                                       000067
      WRITE(6,961)NS,EPSIC(NS,I1SPAC),(JPIN(NS,M),NS,M,                 000067
     *EPSISC(NS,M,I1SPAC),M=1,NP)                                       000067
  961 FORMAT(/5X,'CHANNEL NR.',I5,5X,'EPSILON=',F10.7/                  000067
     1  5X,'SUBCHANNELS:'/(5X,'ROD NR.',I5,') EPSILON(',I5,',',I2,')=', 000067
     2  F10.7))                                                         000068
  964 CONTINUE                                                          000068
      WRITE(6,83)                                                       000068
 4430 CONTINUE                                                          000068
   12 CONTINUE                                                          000068
C                                                                       000068
C     ............................................................... 000068
C   10-SUBROUTINES INGE AND CEWACO                                      000068
C                                                                       000068
      CALL INGE(NEXCON,NSEL,NSTR,NSTOT,C,Z,D,ATC,ATW,ATA,PIG,PCORR,CTU1,000068
     *CTU2,DETC,DETW,EM1)                                               000069
      CALL CEWACO(NSC30C,NSC45,12,ALFACE,D,C2,AAC,DETC,MFLOW,ATOT,ACW,  000069
     *            DECW,MEC)                                             000069
      CALL CEWACO(NSC30A,NSC30A,3,ALFACC,D,ZA,AAA,DETA,MFLOW,ATOT,AA1,  000069
     *            DEA1,MEA1)                                            000069
      MA=MFLOW/ATOT                                                     000069
      PROV1=MA*DETOT                                                    000069
      PROV2=-1.E-03*MA**2/980.665                                       000069
C     ............................................................... 000069
C                                                                       000069
C   11-INLET MASS FLOW RATES AND TEMPERATURES ;EVALUATION OF PRESSURE   000070
C      LOSS AT THE BUNDLE INLET                                         000070
C                                                                       000070
      IF(INLET.NE.1)GOTO 4435                                           000070
      CALL INLCON(NSTOT,MFLOW,ATOT,TE,IREAD1,NSTR)                      000070
      PI=PE                                                             000070
      DO 4432 I=1,10                                                    000070
      PO=PE+CINL*PROV2/RHO(PI,TE)*0.5                                   000070
      IF(ABS(PO/PI-1.).LE.1.E-06)GOTO 4434                              000070
 4432 PI=PO                                                             000070
      WRITE(6,4433)PO,PI                                                000071
 4433 FORMAT(1H1,5X,'CALCULATION STOPS : PO=',F10.7,'  ; PI=',F10.7)    000071
      STOP                                                              000071
 4434 CONTINUE                                                          000071
      DPE=PO-PE                                                         000071
      DPEBAR=DPE*0.980665                                               000071
      WRITE(6,1333)DPE,DPEBAR,CINL                                      000071
 1333 FORMAT(///130('*')//5X,                                           000071
     *              'PRESSURE LOSS DUE TO ENTRANCE=',F10.7,' KG/SQCM  =',000071
     *F10.7,' BARS ( CINL=',F4.2,')'//)                                 000071
      INLET=2                                                           000072
      DPBAR(1)=PEOBAR-PEBAR-DPEBAR                                      000072
      IF(STLEN.GT.1.E-06 .OR. IFUNCH.EQ.2)GOTO 4435                     000072
      WRITE(1,1)NSPACT                                                  000072
      IF(NSPACT.GT.0)WRITE(1,6069)(DIST(I),I=1,NSPACT)                  000072
      XLTOT=0.                                                          000072
      WRITE(1,1)IPA                                                     000072
```

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      WRITE(1,6069)XLTCT,CPEAR(1)                                        000072
 4435 CONTINUE                                                           000072
C     ............................................................... 000072
C                                                                        000073
C   12-EVALUATICN OF SECTICN LENGTHS AND CORRECTICN FACTORS FOR NUSSELT  000073
C                                                                        000073
      CALL AXSEC(NDE1,NDE2,CETC,WSP(IPA),CCNST,DDD,II,HH,MSPAC,LENGTH,N,000073
     *IPA,QTCT,NSTCT,XMAXNU,CHSLNU)                                      000073
      WRITE(6,14)LENGTH,N,FREL                                           000073
   14 FCRMAT(///130('*')///                                              000073
     *       5X,'TOTAL LENGTH=',F7.2,1X,'CM',5X,'NUMBER OF SECTIONS=',I3000073
     *,5X,'FREL=' ,F10.4///)                                             000073
C     ............................................................... 000073
C                                                                        000074
C   13-INITIALIZATICN CF VARIABLES                                       000074
C                                                                        000074
      T(1)=T0                                                            000074
      P(1)=P0                                                            000074
      PBAR(1)=P0*0.980665                                                000074
      NSEFD=0                                                            000074
      IPAFD=1                                                            000074
      TM=0.                                                              000074
      PM=0.                                                              000074
      LAMBDM=0.                                                          000075
      REM=0.                                                             000075
      UM=0.                                                              000075
      DELTAX=0.                                                          000075
      TWTC=0.                                                            000075
      TBTC=0.                                                            000075
      TBPC=0.                                                            000075
       NSTR1=NSTR+1                                                      000075
      DO 5636 NS=NSTR1,NSTCT                                             000075
      NP=NPIN(NS)                                                        000075
      DO 5636 M=1,NP                                                     000076
      TLINER(NS-NSTR,M)=TSCH1(NS,M)                                      000076
      IF(ISTAIN.EQ.2)GOTO 978                                            000076
      DO 5634 JWC=1,2                                                    000076
 5634 TSCWC1(NS-NSTR,M,JWC)=TSCH1(NS,M)                                  000076
  978 CONTINUE                                                           000076
      DO 5635 I=1,NSC90                                                  000076
      DELTIO(NS-NSTR,M,I)=0.                                             000076
 5635 TIC(NS-NSTR,M,I)=0.                                                000076
 5636 CONTINUE                                                           000076
      IF(IRH.NE.2)GOTO 4439                                              000077
      DO 4438 NS=1,NSTOT                                                 000077
      NP=NPIN(NS)                                                        000077
      DO 4438 M=1,NP                                                     000077
      HPLUS1(NS,M)=0.                                                    000077
      HPLUS2(NS,M)=0.                                                    000077
      TWA(NS,M)=0.                                                       000077
      QPLUSA(NS,M)=0.                                                    000077
      PRBA (NS,M)=0.                                                     000077
      YDH(NS,M)=0.                                                       000077
      YODH(NS,M)=0.                                                      000078
      TEMPB(NS,M)=TE                                                     000078
      XMASSB(NS,M)=1.                                                    000078
      YODHA(NS,M)=0.                                                     000078
      YDHA(NS,M)=0.                                                      000078
      TEMPBA(NS,M)=0.                                                    000078
      AMASSB(NS,M)=0.                                                    000078
      TEMPTA(NS,M)=0.                                                    000078
      AMASST(NS,M)=0.                                                    000078
 4438 CONTINUE                                                           000078
 4439 CONTINUE                                                           000079
C                                                                        000079
C     ............................................................... 000079
```

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C  14-THE AXIAL LOOP STARTS (K=INDEX OF THE AXIAL SECTION )             000079
C                                                                       000079
      K1=1                                                              000079
      NSUBDH=0                                                          000079
 8503 CONTINUE                                                          000079
      DO 9999 K=K1,N                                                    000079
C                                                                       000079
      TIME2=ZEIT(TIME1)                                                 000080
      IF(TIME2.GT.TIMEPU)CALL TMFUN(NSTOT,NSTR,T(K),P(K),PBAR(K),      000080
     *TE1,PEO,PEOBAR,INDPR,MFLOW,IPA,IPAEND,2,XLAM1,X(K)+STLEN,&742)    000080
C                                                                       000080
      ASECLA=ASEC                                                       000080
      DETOLA=DETOT                                                      000080
      L=K+1                                                             000080
      H=X(L)-X(K)                                                       000080
      QDEV=0.                                                           000080
      QLDEV=0.                                                          000080
      INDPRQ=1                                                          000081
      IF(NDPRQ(IPA).EQ.0)GOTO 3702                                      000081
      XPRQ(1)=X(K)-SPLENG                                               000081
      IF(X(L).LT.X2DPRQ(IDPRQ))GOTO 1018                                000081
      XPRQ(2)=X2DPRQ(IDPRQ)-SPLENG                                      000081
      INDPRQ=2                                                          000081
 1018 XPRQ(INDPRQ+1)=X(L)-SPLENG                                        000081
      DO 3402 IQDEV=1,INDPRQ                                            000081
      IQDEV1=IQDEV+1                                                    000081
      IIQDEV=IDPRQ+IQDEV-1                                              000081
      DO 3401 IQDCO=1,NQDCO                                             000082
      QDCOI(IQDCO)=QDCO(IIQDEV,IQDCO)                                   000082
 3401 QLDCOI(IQDCO)=QLDCO(IIQDEV,IQDCO)                                 000082
      QDEV=FQDEV(QDCOI,NQDCO,XPRQ(IQDEV),XPRQ(IQDEV1))+QDEV             000082
 3402 QLDEV=FQDEV(QLDCOI,NQDCO,XPRQ(IQDEV),XPRQ(IQDEV1))+QLDEV          000082
      QDEV=QDEV/H                                                       000082
      QLDEV=QLDEV/H                                                     000082
 3702 CONTINUE                                                          000082
      QALIN=QLINM*QLDEV/LENGTH                                          000082
      DO 6670 NS=NSTR1,NSTOT                                            000082
      NP=NPIN(NS)                                                       000083
      DO 6670 M=1,NP                                                    000083
 6670 DTIEAV(NS-NSTR,M)=0.                                              000083
      XM=(X(L)+ X(K))*0.5+STLEN                                         000083
      XMHE=XM-UNHLE                                                     000083
      IF(NSUBDH.EQ.0)WRITE(6,8504)                                      000083
 8504 FORMAT(1H1)                                                       000083
      WRITE(6,15)K,H,XM                                                 000083
   15 FORMAT(    5X,'AXIAL SECTION NR.',I4,5X,'( SECTION LENGTH=',F10.5,000083
     *'; HEIGHT=',F10.5,' )')                                           000083
      H1=H/LENGTH                                                       000084
      DELTAH=(QTOT*QDEV+QLINM*PERLT*QLDEV)*H1/MFLOW                     000084
      RHO1=RHO(P(K),T(K))                                               000084
      IF(NSPACT.EQ.0)GOTO 16                                            000084
      IF(X(K).LT.DIST(ISPAC))GOTO 4437                                  000084
      IF(IPAFD.LE.MSPAC)IPAFD=IPAFD+1                                   000084
      IF(ISPAC.EQ.NSPACT)GOTO 16                                        000084
      ISPAC=ISPAC+1                                                     000084
 4437 CONTINUE                                                          000084
      IF(X(L).LT.DIST(ISPAC))GOTO 16                                    000084
      INDSP(K)=2                                                        000085
      I1SPAC= ISPAC-II+1                                                000085
      WRITE(6,4440)ISPAC                                                000085
 4440 FORMAT(1H+,80X,'SPACER NR.',I3,' IS PRESENT',24('.')/5X,21('-'))  000085
      IF(K.EQ.1)GOTO 8500                                               000085
      GOTO 17                                                           000085
   16 INDSP(K)=1                                                        000085
      SBMNS=MFLOW/ATOT*ASEC                                             000085
      WRITE(6,4441)                                                     000085
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 4441 FORMAT(1H+,78X,50('.')/5X,21('-'))                                  000085
   17 CONTINUE                                                            000086
      DO 4444 NS=1,NSTCT                                                  000086
      SIGMA(NS)=0.                                                        000086
      PHI(NS)=0.                                                          000086
      NP=NPIN(NS)                                                         000086
      DO 4443 M=1,NP                                                      000086
      MSCH(NS,M)=MSCH1(NS,M)                                              000086
      TSCH(NS,M)=TSCH1(NS,M)                                              000086
      IF(K.GT.1 .AND. NSUBCH.EQ.0)TWF(NS,M)=TW(NS,M)                      000086
      SIGMAI(NS,M)=0.                                                     000086
      PHII(NS,M)=0.                                                       000087
      IF(NS.LE.NSTR)GOTO 4443                                             000087
      DO  4442 JWC=1,2                                                    000087
      CHI(NS-NSTR,M,JWC)=1.                                               000087
      PSI(NS-NSTR,M,JWC)=1.                                               000087
 4442 CONTINUE                                                            000087
 4443 CONTINUE                                                            000087
 4444 CONTINUE                                                            000087
      ITGLT=0                                                             000087
      DELTAP=0.                                                           000087
      T(L)=DELTAH/CP(P(K),T(K))+T(K)                                      000088
      PBT=P(K)                                                            000088
C     ............................................................. 000088
C                                                                         000088
C  15-THE LOOP ITCORR STARTS                                              000088
C                                                                         000088
      DO 49 ITCORR=1,ITCM                                                 000088
      IF(INDSP(K).EQ.2 .AND. ITCORR.GT.2)GOTO 45                          000088
C                                                                         000088
      LAMBDA(K)=LAM1                                                      000088
      DDDCT=0.                                                            000089
C*****CALCULATION OF DELTAP AND DELTAT FOR THE WHOLE BUNDLE FLOW SECT.*  000089
      DO 4448 ITTE1=1,10                                                  000089
      TL=T(L)                                                             000089
      TBT=(T(L)+T(K))*0.5                                                 000089
      DO 4445 ITTE2=1,10                                                  000089
      TBT1=TBT                                                            000089
      TBT=DELTAH/CP(PBT,TBT)*0.5+T(K)                                     000089
      IF(ABS(TBT/TBT1-1.).LE.1.E-04)GOTO 4447                             000089
 4445 CONTINUE                                                            000089
      WRITE(6,4446)TBT,TBT1                                               000090
 4446 FORMAT(1H1,'CALCULATION STOPS: ITTE2=10 ; TBT=',E15.7,5X,'TBT1=',   000090
     *    E15.7)                                                          000090
      STOP                                                                000090
 4447 CONTINUE                                                            000090
       T(L)=DELTAH/CP(PBT,TBT)+T(K)                                       000090
      DO 18 ITPR=1,10                                                     000090
      DP=DELTAP                                                           000090
      PBT=P(K)+0.5*DP                                                     000090
      P(L)=P(K)+DP                                                        000090
      RHOBT(K)=RHO(PBT,TBT)                                               000091
      RHO2=RHO(P(L),T(L))                                                 000091
      DEL1RT=(RHO1-RHO2)/RHOBT(K)**2                                      000091
      DECORR=DETOLA/FCOPWT                                                000091
      DELTAP=PROV2*(LAMBDA(K)*H/(2.*RHOBT(K)*DECORR)+DEL1RT)*(ASEC/       000091
     /ASECLA)**2+IGRAV*RHOBT(K)*H*0.001                                   000091
      ETABT(K)=ETA(PBT,TBT)                                               000091
      REBT(K)=PROV1/ETABT(K)*DETCLA/DETOT*ASEC/ASECLA                     000091
      IF(INDSP(K).EQ.2)DELTAP=DELTAP+PROV2*(CSPT(I1SPAC)+DSPDPF(EPSIT(    000091
     1 I1SPAC),DETCLA,LAMBDA(K),WSP(IPA),PGDPT(I1SPAC),REBT(K),4))/       000091
     2  RHOBT(K)                                                          000092
      PLL=P(K)+DELTAP                                                     000092
      IF(ABS(PLL/P(L)-1.).LE.1.E-05)GOTO 20                               000092
   18 CONTINUE                                                            000092
      WRITE(6,19)K,ITCORR,DP,DELTAP                                       000092
```

```
   19 FORMAT(1H1,5X,'CALCULATION STEPS: ITPR=10 FOR SECTION',I4,2X,'(ITC000092
     *ORR=',I2,') DP=',E20.5,5X,'AND DELTAP=',E20.5)                   000092
      STOP                                                             000092
   20 CONTINUE                                                         000092
       T(L)=DELTAH/CP(PBT,TBT)+T(K)                                    000092
      IF(ABS(T(L)/TL-1.).LE.1.E-04)GOTO 4450                           000093
 4448 CONTINUE                                                         000093
      WRITE(6,4449)T(L),TL                                             000093
 4449 FORMAT(1H1,5X,'CALCULATION STEPS: ITTE1=10 ; T(L)=',E15.7,5X,    000093
     *    'TL=',E15.7)                                                 000093
      STOP                                                             000093
 4450 CONTINUE                                                         000093
      UBT(K)=MA/RHOBT(K)/100. *ASEC/ASECLA                             000093
      PROV=REBT(K)*ETABT(K)*SQRT(ABS(LAMBDA(K))*0.125/RHOBT(K))        000093
      SQDPG=SQRT(ABS(DELTAP)*980665.)                                  000093
      SQDPGF=SQRT(ABS(DELTAP-IGRAV*RHOBT(K)*H*0.001)*980665.)          000094
      IF(ITCORR.EQ.1)DPSI=DELTAP/ABS(DELTAP)                           000094
      SIGMST=(SQRT(ABS(DELTAP-IGRAV*RHOBT(K)*H*0.001)*980665.)-SQDPG)/ 000094
     /SQRT(LAMBDA(K)*H/(2.*DETCLA*RHOBT(K)))                           000094
      IF(INDSP(K).EQ.2)GOTO 45                                         000094
C     ................................................................ 000094
C                                                                      000094
C     FOR SECTIONS WITHOUT SPACERS: SUB-SUBCHANNEL CALCULATION         000094
C                                                                      000094
      DO 6671 NS=NSTR1,NSTOT                                           000094
      NP=NPIN(NS)                                                      000095
      DO 6671 M=1,NP                                                   000095
      DO 6671 I=1,NSC90                                                000095
 6671  DELTIE(NS-NSTR,M,I)=DELTIO(NS-NSTR,M,I)-DTIEAV(NS-NSTR,M)       000095
      ASECLA=0.                                                        000095
      DETCLA=0.                                                        000095
      DO 29 NS=1,NSTOT                                                 000095
      IF(ITCORR.EQ.1)SIGMA(NS)=SIGMST                                  000095
      IF(NTYP(NS).EQ.3)GOTO 25                                         000095
      NP=NPIN(NS)                                                      000095
      DDDDNS=0.                                                        000096
      TNS=0.                                                           000096
      AMNS=0.                                                          000096
      DO 24 M=1,NP                                                     000096
      IF(ITCORR.EQ.1)SIGMAI(NS,M)=SIGMST                               000096
      IF(NTYP(NS).EQ.2)GOTO 22                                         000096
C                                                                      000096
C*****SUB-SUBCHANNEL CALCULATION FOR THE CENTRAL CHANNELS************* 000096
C                                                                      000096
      CALL TRICAL(K,NS,NSC300,IRH,PROV,PBT,RH,ACW,DECW,MEC,AAC,DETC,DET000096
     *T,H1,ALFACE,H,M,P(K),P(L),SQDPG,TE1,SUR,D,AMT,DDDD,ATSCH,&8500,C) 000097
      AMSCH=AMT*ASCH(NS,M)/AAC                                         000097
      GOTO 23                                                          000097
C                                                                      000097
   22 CONTINUE                                                         000097
C*****SUB-SUBCHANNEL CALCULATION FOR THE WALL CHANNELS**************** 000097
      CALL RECCAL(K,NS,NSC90,NSC45,IRH,PROV,PBT, RH,H1,ALFAWA,ACW,DECW,M000097
     *EC,AAW,DETW,ATOT,DETOT,MFLOW,WW,D,C,M,NSTR,H,P(K),P(L),SQDPG,TE1, 000097
     *     SUR,AMT,DDDD,ATSCH,CTU3,EM1,&8500,ALFACE)                   000097
      NSW=NS-NSTR                                                      000097
      IF(K.GT.1)GOTO 4455                                              000098
      DO 4451 JWC=1,2                                                  000098
      IF(IREAD1.EQ.1 .OR. ISTAIN.EQ.1)MSCWC1(NSW,M,JWC)=MSCH1(NS,M)/ASCH000098
     *(NS,M)*ASCHWC(NSW,M,JWC)/F2ATIP(NS,M)                            000098
 4451 ASCWC1(NSW,M,JWC)=ASCHWC(NSW,M,JWC)                              000098
 4455 CONTINUE                                                         000098
      AMSCH=AMT                                                        000098
   23 CONTINUE                                                         000098
      DDDDNS=DDDDNS+AMSCH/AMT*DDDD+ASCH(NS,M)*(SIGMAI(NS, M)-SIGMA(NS))/000098
     *SQDPGF                                                           000098
      AMNS=AMNS+AMSCH                                                  000099
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   24 TNS=TNS+ATSCH*AMSCH                                                000099
      TNS=TNS/AMNS                                                       000099
      RHCNS=RHC(PBT,TNS)                                                 000099
      LAM(NS)=((A(NS)/DDDDNS)**2)*2.*DE(NS)*RHCNS/H *F1ATIP(NS)**2*      000099
     *F1DTIP(NS)                                                         000099
      GOTO 28                                                            000099
C                                                                        000099
C*****SUB-SUBCHANNEL CALCULATICN FOR THE CORNER CHANNELS***************** 000099
   25 CONTINUE                                                           000099
      IF(ITCORR.EQ.1)SIGMAI(NS,1)=SIGMST                                 000100
      CALL ANGCAL(K,NS,NSC30A,IRH,PROV,PBT,RH,H1,ALFACO,AA1,AAA,DETA,DET000100
     *UT,D,WA,NSTR,H,P(K),P(L),SCDPG,TE1,SUR,    AMT,DDDDNS,&8500,AMAT,  000100
     2AMBT)                                                              000100
      AMNS=AMT*ASCH(NS,1)/AAA                                            000100
      XMSCHA(NS-NSTR,1)=AMAT*ASCH(NS,1)/AAA                              000100
      XMSCHB(NS-NSTR,1)=AMBT*ASCH(NS,1)/AAA                              000100
      DDDDNS=DDDDNS*ASCH(NS,1)/AAA                                       000100
      LAM(NS)=LAMSCH(NS,1)                                               000100
   28 CONTINUE                                                           000100
      ASECLA=ASECLA+A(NS)*F1ATIP(NS)                                     000101
       DETOLA=DETOLA+A(NS)/DE(NS)*F1ATIP(NS)/F1DTIP(NS)                  000101
      MO(NS)=2.*AMNS-MI(NS)                                              000101
      DDDDT=DDDDT+DDDDNS                                                 000101
   29 CONTINUE                                                           000101
      DETOLA=ASECLA/DETOLA                                               000101
C     ................................................................. 000101
C                                                                        000101
C  16-NEW VALUE FOR THE WHOLE BUNDLE FRICTION FACTOR                     000101
C                                                                        000101
      IF(              ITCORR.EQ.1)GOTO 43                               000102
      DDDDT=DDDDT*(MFLOW*ASEC)/(SBMNS*ATOT)                              000102
      LAM1=((ASECLA/DDDDT)**2-DEL1RT)*2.*DETOLA*RHCBT(K)/H               000102
      DPSI= DPAV/ABS(DPAV)                                               000102
C     ................................................................. 000102
C                                                                        000102
C  17-CONVERGENCE TEST FOR THE LOOP ITCORR                               000102
C                                                                        000102
   45 CONTINUE                                                           000102
      IF(ITCORR.LE.ITC2)GOTO 48                                          000102
      DELAM=ABS(LAMBDA(K)/LAM1-1.)                                       000103
      IF(.NOT.(DELAM.LE.1.E-04 .OR. (DELAM.LE.1.E-03 .AND. ITCORR.GT.    000103
     *   ITC1) .OR. (DELAM.LE.1.E-02 .AND. ITCORR.GT.(ITC1+5))))GOTO 48  000103
C     ................................................................. 000103
C                                                                        000103
C  18-CONVERGENCE HAS BEEN REACHED: PRINT AND PUNCH RESULTS FOR SECT. K 000103
C                                                                        000103
      WRITE(6,46)                                                        000103
     *  T(L),    P(L),PBT,DELTAP,LAMBDA(K),ITCORR,ITGL,ITGLT,ITERM,FREL 000103
   46 FORMAT(/5X,'T 2=',F10.4,5X,'P 2=',F10.6,5X,'P AV=',F10.6,5X,       000103
     * 'DELTAP=',F11.8,5X,'LAMBDA=',F7.5/5X,'( ITCORR=',I2,              000104
     *        5X,' ITGL=',I5,5X,'ITGL1=',I5,5X,'ITERM=',I5,5X,           000104
     *  'FREL=',F5.2,' )'///     5X,'CHANNEL',9X,'OUTLET MASS',8X,'AVERA000104
     *GE MASS',7X,'OUTLET TEMP.',8X,'AVERAGE TEMP.',7X,'PRESSURE LOSS'/)000104
      WRITE(6,81)(NS,MM2(NS),MAV(NS),TEMP2(NS),TAV(NS),DPNS(NS),         000104
     *  NS=1,NSTOT)                                                      000104
   81 FORMAT(I12,5E20.8)                                                 000104
      WRITE(6,83)                                                        000104
      DO 80 NS=1,NSTOT                                                   000104
      WRITE(6,78)NS,UAV(NS),NS,WCF(NS)                                   000104
      IF(INDSP(K).EQ.1)WRITE(6,79)NS,MO(NS),NS,LAM(NS)                   000105
   78 FORMAT(5X,'UAV(',I3,')=',E13.5,10X,'WCF(',I3,')=',E12.3)           000105
   79 FORMAT(1H+,T70,'MO(',I3,')=',F10.2,10X,'LAM(',I3,')=',F10.5)       000105
   80 CONTINUE                                                           000105
      WRITE(6,83)                                                        000105
   83 FORMAT(/ )                                                         000105
      DO 85 NS=1,NSTOT                                                   000105
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```
      NI=NER(NS)                                                        000105
      WRITE(6,84)(M,NS,NIS(NS,M),WT(NS,M),M=1,NI)                       000105
   84 FORMAT(3(5X,I2, ') WT(',I4,',',I4,')=',E12.3))                    000105
   85 CONTINUE                                                          000106
      XLTOT=X(L)+STLEN                                                  000106
       PBAR(L)=P(L)*0.980665                                            000106
      DPBAR(L)=PEOBAR-PBAR(L)                                           000106
      IF(IPUNCH.EQ.1)WRITE(1,1)IPA                                      000106
      IF(IPUNCH.EQ.1)WRITE(1,6069)XLTOT,DPBAR(L)                        000106
C     ................................................................. 000106
C                                                                       000106
C  19-CORRECTION OF THE COMPUTED SURFACE PIN TEMPERATURES FOR THE BIOT  000106
C     EFFECT AND FOR THE RADIAL POSITION OF THE THERMOCOUPLES           000106
C                                                                       000107
      IF( QTOT.LE.1.E-06)GOTO 50                                        000107
      DO 53 NS=1,NSTOT                                                  000107
      NSW=NS-NSTR                                                       000107
      NP=NPIN(NS)                                                       000107
      DO 51 M=1,NP                                                      000107
      TWINF(NS,M)=TW(NS,M)                                              000107
      IF(QQ(NS,M).LT.1.E-06)GOTO 51                                     000107
      QHRDAR=QQ(NS,M)*QDEV*HRDAR                                        000107
      RVOL=D*0.5                                                        000107
      IF(I2TIP(NS,M).EQ.1 .AND. IPA.EQ.4)RVOL=RTIP(4)-RH                000108
      FCORTW=((RVOL**2-RMISTW(IPA)**2)*0.5+RINT(IPA)**2*ALOG(RMISTW(IPA)000108
     */RVOL))/((RVOL**2-RINT(IPA)**2)*SUR)*RVOL                         000108
      QRMDAR=QQ(NS,M)*QDEV*FCORTW                                       000108
      IF(IPA.EQ.4)QLAMR=QQ(NS,M)*QDEV*FCORLA                            000108
      CALL CORRTE(TW(NS,M),TSCH(NS,M),PBT,    NS,M,0,BIOT(NS,M),TWINF(NS,000108
     *M))                                                               000108
      CALL CORRTE(TWSSC1(NS,M),TBSSC1(NS,M),PBT,    NS,M,1,BIOTI1,TWINF1)000108
      CALL CORRTE(TWSSC2(NS,M),TBSSC2(NS,M),PBT,    NS,M,2,BIOTI2,TWINF2)000108
      IF(NTYP(NS).NE.2)GOTO 51                                          000108
      DO 3721 JWC=1,2                                                   000109
       CALL CORRTE(TWWC(NSW,M,JWC),TAVWC(NSW,M,JWC),PBT,    NS,M,JWC,BIOT000109
     *WC,TWINWC)                                                        000109
 3721 CONTINUE                                                          000109
   51 CONTINUE                                                          000109
   53 CONTINUE                                                          000109
      WRITE(6,86)                                                       000109
   86 FORMAT(                            //5X,'CHANNEL',3(2X,'ROD',4X,'TEMP000109
     *ERATURE',5X,'HEAT POWER')/)                                       000109
      IF(IPUNCH.EQ.1)WRITE(1,6069)XM                                    000109
      DO 88 NS=1,NSTOT                                                  000110
      NP=NPIN(NS)                                                       000110
      DO 3723 M=1,NP                                                    000110
 3723 QSECT(M)=QQ(NS,M)*QDEV*H1                                         000110
      WRITE(6,87)NS,(JPIN(NS,M),TW(NS,M),QSECT(M),M=1,NP)               000110
   87 FORMAT(I12,3(I5,2E15.5))                                          000110
      IF(IPUNCH.EQ.1)WRITE(1,6069)(TW(NS,M),M=1,NP)                     000110
      IF(NS.LE.NSTR)GOTO 88                                             000110
      NSW=NS-NSTR                                                       000110
      IF(IPUNCH.EQ.1)WRITE(1,6069)(TLINER(NSW,M),M=1,NP)                000110
 6069 FORMAT( 3E15.5)                                                   000111
   88 CONTINUE                                                          000111
      GOTO 50                                                           000111
C     ................................................................. 000111
C                                                                       000111
C  20-CALCULATION IN THE CHANNELS, IN THE SUBCHANNELS AND IN THE TWO    000111
C     PORTIONS OF THE WALL SUBCHANNELS                                  000111
C                                                                       000111
   48 CONTINUE                                                          000111
      CALL BALA(K,NSTOT,INDSP(K),ASECLA,H,LENGTH,P(K),P(L),PBT,FREL,FT, 000111
     *ITCORR,ITCM,DPAV,ITERM,ITGL,88500,WSP(IPA),I1SPAC)                000112
      ITGLT=ITGLT+ITGL                                                  000112
      CALL SUBBAL(NSTOT,NSTR,INDSP(K),H,LENGTH,D,PIG,P(K),P(L),PBT,FREL,000112
```

```
     *FT,ITCORR,DPAV,&8500,WSP(IPA),IISPAC)
      CALL NORMT(NSTCT,NSTR,TBT,ATOT,ASEC,MFLOW)
      IF(IRH.EQ.1 .AND. QTCT.GT.1.E-06)CALL WALLTE
     *         (K,NSTCT,NSTR,RH,SUR,C,PIG, TE1 ,PBT,&8500,RTSI)
      IF(IRH.EQ.2 .AND. QTCT.GT.1.E-06)CALL WALLTE
     *         (K,NSTCT,NSTR,RH,SUR,C,PIG, TE1 ,PBT,&8500,RTRI)
      NS1=NSTR+1
      DO 64 NS=NS1,NSTOT
      NP=NPIN(NS)
      NSTYP=NTYP(NS)
      NSW=NS-NSTR
      DO 7034 M=1,NP
      GOTO(7033,7033,7032),NSTYP
 7032 PROVI(NSW,M)=MSCH(NS,M)*DE(NS )/ASCH(NS,M)*SQRT(LAMSCH(NS,M)*0.125
     */RHO(PBT,TSCH(NS,M)))
      GOTO 7034
 7033 PROVI(NSW,M)=MAWC(NSW,M,1)*DEWC(NSW,M,1)/ASCHWC(NSW,M,1)*
     *SQRT(LAMWC(NSW,M,1)*C.125/RHO(PBT,TAVWC(NSW,M,1)))
 7034 CONTINUE
   64 CONTINUE
   49 CONTINUE
C     ..............................................................
C
C  21-END OF THE LOOP ITCORR
C
      WRITE(6,56)ITCM,LAMBDA(K),LAM1,DELTAP,DPAV
   56 FORMAT(1H1,'CALCULATION STEPS: ITCORR=',I2/5X,'( LAMBDA=',E15.7,5X
     *,'LAM1=',E15.7,5X,'DELTAP=',E15.7,5X,'DPAV=',E15.7,' )')
      STOP
C     ..............................................................
C
C  22-DEFINITION OF THE INLET VALUES OF CHANNEL AND SUBCHANNEL
C     VARIABLES FOR THE NEXT AXIAL SECTION; SUBSEQUENT ADDITIONS FOR
C     AVERAGE VALUES OF VARIABLES
C
   50 CONTINUE
      NSUBDH=0
      INDTW=1
      PBAR(L)=P(L)*C.980665
      DO 100 NS=1,NSTOT
      TEMP(NS)=(2.*MAV(NS)*TAV(NS)-MI(NS)*TEMP (NS))/MM2(NS)
      MI(NS)=MM2(NS)
      NP=NPIN(NS)
      DO 97 M=1,NP
      PMSCH1=MSCH1(NS,M)
      MSCH1(NS,M)=2.*MSCH(NS,M)-MSCH1(NS,M)
      TSCH1(NS,M)=(2.*MSCH(NS,M)*TSCH(NS,M)-PMSCH1*TSCH1(NS,M))/MSCH1(NS
     *,M)
      IF(NTYP(NS).NE.3 .OR. INDSP(K).EQ.2)GOTO 6647
      DO 6646 I=1,NSC90
 6646 DELTIO(NS-NSTR,M,I)=(TIC(NS-NSTR,M,I)-TSCH1(NS,M))*TCPRCF
 6647 CONTINUE
      IF(QQ(NS,M).GT.1.E-06)GOTO 5633
      TW(NS,M)=TSCH(NS,M)
      TEMPB(NS,M)=TSCH(NS,M)
      BIOT(NS,M)=0.
      TWINF(NS,M)=TSCH(NS,M)
 5633 CONTINUE
      IF(K.EQ.1 .OR. NEXTW(IPA).EQ.0)GOTO 1180
      IF(X(K).GT.XEXTW(IEXTWC).AND.X(K-1).LE.XEXTW(IEXTWC))GOTO 1181
      IF(K.EQ.N .AND. X(N+1).GT.XEXTW(IEXTWC) .AND. X(N).LE.XEXTW(IEXTWC
     *))GOTO 1181
      GOTO 1180
 1181 TWTH(NS,M,IEXTWC)=(TW(NS,M)-TWP(NS,M))/(X(K+1)-X(K-1))*2.*(XEXTW(
     *IEXTWC)-0.5*(X(K)+X(K-1)))+TWP(NS,M)
      INDTW=2
```

```
 1180 CONTINUE
      IF(NTYP(NS).NE.2)GOTO 97
      NSW=NS-NSTR
      DO 95 JWC=1,2
      PMSCWC=MSCWC1(NSW,M,JWC)
      MSCWC1(NSW,M,JWC)=2.*MAWC(NSW,M,JWC)-PMSCWC
      TSCWC1(NSW,M,JWC)=(2.*MAWC(NSW,M,JWC)*TAVWC(NSW,M,JWC)-PMSCWC*
     *   TSCWC1(NSW,M,JWC))/MSCWC1(NSW,M,JWC)
      ASCWC1(NSW,M,JWC)=ASCHWC(NSW,M,JWC)
   95 CONTINUE
      IF(INDSP(K).EQ.2)GOTO 97
      DO 6648 I=1,NSC90
 6648 DELTIO(NSW,M,I)=(TIO(NSW,M,I)-TSCWC1(NSW,M,1))*TWPRCF
   97 CONTINUE
  100 CONTINUE
      IF(INDTW.EQ.2 .AND. IEXTWC.LT.NEXTWT)IEXTWC=IEXTWC+1
      IF( INDPRQ.EQ.2 .AND. IDPRQ.LT.NDPRQT)IDPRQ=IDPRQ+1
      TWTC=TWFUN(NRODS,NSTOT,PIC,AAC,AAA)*H+TWTC
      TBPC=TBFUN(NSTR,NSTOT)*H+TBPC
      TBTC=TBT*H+TBTC
      IF(X(K).LT.XSTART(IPAFD) .OR. X(L).GT.XEND(IPAFD))GOTO 103
      NSEFD=NSEFD+1
      TM=TM+TBT*H
      PM=PM+PBT*H
      LAMBDM=LAMBDM+LAMBDA(K)*H
      REM=REM+REBT(K)*H
      UM=UM+UBT(K)*H
      DELTAX=DELTAX+H
      IF(IRH.EQ.1)GOTO 103
      DO 9899 NS=1,NSTOT
      NP=NPIN(NS)
      DO 9899 M=1,NP
      HPLUS1(NS,M)=HPLUS1(NS,M)+HPLUSB(NS,M)*H
      HPLUS2(NS,M)=HPLUS2(NS,M)+HPLUSW(NS,M)*H
      QPLUSA(NS,M)=QPLUSA(NS,M)+QPLUS(NS,M)*H
      PRBA (NS,M)=PRBA (NS,M)+PRB (NS,M)*H
      TWA(NS,M)=TWA(NS,M)+TW(NS,M)*H
      YOHA(NS,M)=YOHA(NS,M)+YOH(NS,M)*H
      YODHA(NS,M)=YODHA(NS,M)+YODH(NS,M)*H
      AMASSB(NS,M)=AMASSB(NS,M)+XMASSB(NS,M)*H
      TEMPBA(NS,M)=TEMPBA(NS,M)+TEMPB(NS,M)*XMASSB(NS,M)*H
      AMASST(NS,M)=AMASST(NS,M)+MSCH(NS,M)*H
      TEMPTA(NS,M)=TEMPTA(NS,M)+TSCH(NS,M)*MSCH(NS,M)*H
 9899 CONTINUE
  103 CONTINUE
C     ...............................................................
C
C  23-PRINT SUBCHANNEL VARIABLES
C
      WRITE(6,83)
      DO 8887 NS=1,NSTOT
      NTYPNS=NTYP(NS)
      NP=NPIN(NS)
      NSW=NS-NSTR
      WRITE(6,8885)NS
 8885 FORMAT(5X,'CHANNEL NR.',I5)
      DO 8887 M=1,NP
      IF(QQ(NS,M).GT.1.E-06)SCNUSS=QQ(NS,M)*QDEV*DE(NS)*F2DTIP(NS,M)/
     /(SUR*(TWINF(NS,M)-TSCH(NS,M))*KAPPA(PBT,TSCH(NS,M)))*D*0.5/
     /RTIP(IPA)
      SCREB=MSCH(NS,M)*DE(NS)*F2DTIP(NS,M)/(ASCH(NS,M)*F2ATIP(NS,M)*
     *ETA(PBT,TSCH(NS,M)))
      SCREW=SCREB*ETA(PBT,TSCH(NS,M))*RHO(PBT,TWINF(NS,M))/(ETA(PBT,
     *TWINF(NS,M))*RHO(PBT,TSCH(NS,M)))
      QLINSC=QLINM*QLDEV*PERL(NTYPNS)*ASCH(NS,M)/ACH(NTYPNS)*H1
      WRITE(6,8886)M,JPIN(NS,M),MSCH1(NS,M),TSCH1(NS,M),LAMSCH(NS,M)
```

```
     *,SCREB,SCREW                                                      000125
 8886 FORMAT(5X,I2,'-(ROD NR.',I4,')',T27,'OUT. MASS',F10.6,T52,'OUT. TE000125
     1MP.=',F7.2,T75,'LAMBDA=',F10.5,T99,'REB=',F7.0,T112,'REW=',F7.0)  000125
      WRITE(6,3725)QLINSC                                               000125
 3725 FORMAT(T27,'Q LINER=',E15.5)                                      000125
      IF(IRH.EQ.2 .AND. QTOT.GT.1.E-06 .AND. I2TIP(NS,M).NE.1)          000126
     *                            WRITE(6,3724)BIOT(NS,M)               000126
 3724 FORMAT(1H+,T52,'BIOT=',F10.5)                                     000126
      IF(QTOT.GT.1.E-06)WRITE(6,3722) TWINF(NS,M)                       000126
 3722 FORMAT(1H+,                     T75,'TW INF.=',F10.2)             000126
      IF(QTOT.GT.1.E-06 .AND. NTYP(NS).NE.1)WRITE(6,3740)TLINER(NSW,M)  000126
 3740 FORMAT(1H+,T99,'T  AT LINER=',F10.2)                              000126
        IF(INDSP(K).EQ.2)GOTO 91                                        000126
      IF(IRH.EQ.1 .OR. I2TIP(NS,M).EQ.1)GOTO 3726                       000126
      RHPLM=RHPLUS(HPLUSB(NS,M),TW(NS,M),TE1 ,QPLUS(NS,M),HPLUSW(NS,M), 000126
     *TEMPB(NS,M),YODH(NS,M))                                           000127
      WRITE(6,8883)HPLUSB(NS,M),HPLUSW(NS,M),RHPLM                      000127
 8883 FORMAT(T27,'HB+ =',E12.5,T52,'HW+ =',E12.5,T75,'R( H+ )=',E12.5)  000127
      IF(QQ(NS,M).LE. 1.E-06)GOTO 91                                    000127
      GHPLM=GHPLUS(HPLUSW(NS,M),TW(NS,M),TSCH(NS,M),PRB (NS,M),YDH(NS,M)000127
     1,10000.,0.)                                                       000127
      TWDTEM=(TW(NS,M)+273.16)/(TE+273.16)                              000127
      TWDTBM=(TW(NS,M)+273.16)/(TSCH(NS,M)+273.16)                      000127
      PHIM=GHPLM/(PRB (NS,M)**O4 * TWDTBM**O5)*(O16*YDH(NS,M))**O17     000127
      WRITE(6,94)GHPLM,SCNUSS      ,TWDTBM,TWDTEM,YDH(NS,M),O4,O5,O16,  000127
     1     O17,PHIM                                                     000128
   94 FORMAT(1H+,T99,'G( HW+ )=',E12.5/T27,'NU =',E13.6,T52,'TW/TB=',E13000128
     1.5,T75,'TW/TE=',E13.5,T99,'Y/RH=',E13.5/T27,'G( HW+ )/( PR**',F4.2000128
     2,' * (TW/TB)**',F4.2,' ) * (',F6.3,'*Y/RH)**',F6.3,' =',E13.6)    000128
 3726 IF(QQ(NS,M).LE.1.E-06)GOTO 91                                     000128
      IF(IRH.EQ.1 .OR. I2TIP(NS,M).EQ.1)WRITE(6,4242)SCNUSS             000128
 4242 FORMAT(1H+,T52,'NU =',E13.6)                                      000128
      WRITE(6,6685)TBSSC1(NS,M),TWSSC1(NS,M),TBSSC2(NS,M),TWSSC2(NS,M)  000128
 6685 FORMAT(T27,'TBSSCH(1)=',F7.2,T52,'TWSSCH(1)=',F7.2,T75,'TBSSCH(N)=000128
     1',F7.2,T99,'TWSSCH(N)=',F7.2)                                     000128
      IF(NTYP(NS).EQ.1)GOTO 91                                          000129
      WRITE(6,6640)TTSCHA(NSW,M),TTSCHB(NSW,M),TEMPB(NS,M)              000129
 6640 FORMAT(T27,'TA=',F7.2,T52,'TB=',F7.2,T75,'TBC=',F7.2)             000129
      IF(NTYP(NS).EQ.2)WRITE(6,6644)TWWC(NSW,M,1),TWWC(NSW,M,2)         000129
 6644 FORMAT(T27,'TW(1)=',F7.2,T52,'TW(2)=',F7.2)                       000129
      WRITE(6,6645)T1SSC1(NSW,M),T2SSC1(NSW,M),T1SSC2(NSW,M),           000129
     *               T2SSC2(NSW,M)                                      000129
 6645 FORMAT(T27,'T1SSCH(1)=',F7.2,T52,'T2SSCH(1)=',F7.2,T75,'T1SSCH(N)=000129
     1',F7.2,T99,'T2SSCH(N)=',F7.2)                                     000129
   91 CONTINUE                                                          000129
      IF(NTYP(NS).NE.2)GOTO 8887                                        000130
      WRITE(6,90)(JWC,MSCWC1(NSW,M,JWC),JWC,TSCWC1(NSW,M,JWC),JWC,ASCWC1000130
     *(NSW,M,JWC),JWC,LAMWC(NSW,M,JWC),JWC=1,2)                         000130
   90 FORMAT(T27,'MOUT(',I1,')=',E13.6,T52,'TOUT(',I1,')=',E13.6,T75,   000130
     1      'AREA(',I1,')=',E13.6,T99,'LAMBDA(',I1,')=',E13.6)          000130
 8887 CONTINUE                                                          000130
 9999 CONTINUE                                                          000130
      GOTO 8499                                                         000130
C     .............................................................     000130
C                                                                       000130
C  24-POINT REACHED IN THE CASE OF CONVERGENCE PROBLEMS (LOOP K ENDS    000131
C     AT LABEL 9999)                                                    000131
 8500 CONTINUE                                                          000131
      NSUBDH=NSUBDH+1                                                   000131
      IF(NSUBDH.LE.MSUBDH)GOTO 8502                                     000131
      WRITE(6,8501)MSUBDH                                               000131
 8501 FORMAT(//' STOP DUE TO REACHED MAXIMUM NUMBER OF SUBDIVISIONS FOR 000131
     *AXIAL PITCH: NSUBDH=',I2)                                         000131
      STOP                                                              000131
C                                                                       000131
 8502 CALL SUBDH(N,K,K1,NSTC1)                                          000132
```

```
      GOTO 8503                                                         000132
C     ............................................................... 000132
C                                                                       000132
C  25-VALUES OF VARIABLES FOR THE WHOLE BUNDLE FLOW SECTION            000132
C                                                                       000132
 8499 CONTINUE                                                          000132
      DEPTOT=P(L)-P(1)                                                  000132
      WRITE(6,8889)                                                     000132
 8889 FORMAT(1H1,4X,'VARIABLES FOR THE WHOLE BUNDLE'/5X,30('-')////     000132
     *  5X,'A) INLET VALUES OF TEMPERATURE AND PRESSURE'//5X,'SECTION NR000133
     *.' ,T26,'HEIGHT (CM)',T43,'TEMPERATURE ( C)',T63,'PRESSURE (KG/SQC000133
     *M)',T86,'PRESSURE (BARS)'/)                                       000133
      WRITE(6,8890)(I,X(I),T(I),P(I),PBAR(I),I=1,L)                     000133
 8890 FORMAT(7X,I3,15X,F9.4,13X,F7.2,11X,F9.5,12X,F9.5)                 000133
      WRITE(6,8891)                                                     000133
 8891 FORMAT(/////5X,'B) VALUES AVERAGED OVER AXIAL SECTIONS'//5X,'SECTI000133
     *ON NR.',T23,'DENSITY (G/CCM)',T41,'VISCOSITY(G/CM*SEC)',T64,'VELOC000133
     *ITY (M/SEC)',T85,'REYNOLDS NR.',T99,'FRICTION FACTOR'/)           000133
      WRITE(6,8892)(I,RHOBT(I),ETABT(I),UBT(I),REBT(I),LAMBDA(I),I=1,N) 000133
 8892 FORMAT(7X,I3,17X,F7.5,12X,F9.7,12X,F7.3,11X,F9.2,6X,F7.5)         000134
      WRITE(6,8878)DEPTOT                                               000134
 8878 FORMAT(///5X,'TOTAL PRESSURE DROP=',F9.6,' KG/SQCM')              000134
C     ............................................................... 000134
C                                                                       000134
C  26-EVALUATION AND PRINTING OF AVERAGE VALUES OF VARIABLES FOR THE    000134
C     REGIONS WHERE INDISTURBED FLOW IS ASSUMED                         000134
C                                                                       000134
      IF(NSEFD.EQ.0)GOTO 8897                                           000134
      TM=TM/DELTAX                                                      000134
      PM=PM/DELTAX                                                      000135
      PMBAR=PM*0.980665                                                 000135
      LAMBDM=LAMBDM/DELTAX                                              000135
      RHOM=RHO(PM,TM)                                                   000135
      ETAM=ETA(PM,TM)                                                   000135
      REM=REM/DELTAX                                                    000135
      UM=UM/DELTAX                                                      000135
      WRITE(6,8893) TM,PM,PMBAR,RHOM,ETAM,UM,REM,LAMBDM                 000135
 8893 FORMAT(////5X,'C) TOTAL MEAN VALUES AVERAGED IN PARTS WHERE UNDIST000135
     *URBED FLOW IS SUPPOSED'//                5X,'TEMPERATURE',T22,'=',F9.000135
     *2,' C'/5X,'PRESSURE',T22,'=',F9.4,' KG/SQCM   =',F9.4,' BARS'     000136
     *                                    /5X,'DENSITY',T22,'=',000136
     *  F9.5,' G/CCM'/5X,'VISCOSITY',T22,'=',F9.7,' G/CM*SEC'/5X,       000136
     *'VELOCITY',T22,'=',F9.3,' M/SEC'/5X,'REYNOLDS NR.',T22,'=',F9.2/5X000136
     *    ,'FRICTION FACTOR',T22,'=',F9.5//)                            000136
      IF(IRF.EQ.1)GOTO 8897                                             000136
      WRITE(6,83)                                                       000136
      DO 8876 NS=1,NSTOT                                                000136
      NP=NPIN(NS)                                                       000136
      DO 8874 M=1,NP                                                    000136
      IF(I2TIP(NS,M).EQ.1)GOTO 8897                                     000137
      WRITE(6,8885)NS                                                   000137
      HPLUS1(NS,M)=HPLUS1(NS,M)/DELTAX                                  000137
      HPLUS2(NS,M)=HPLUS2(NS,M)/DELTAX                                  000137
      QPLUSA(NS,M)=QPLUSA(NS,M)/DELTAX                                  000137
      PRBA (NS,M)=PRBA (NS,M)/DELTAX                                    000137
      TWA(NS,M)=TWA(NS,M)/DELTAX                                        000137
      YDHA(NS,M)=YDHA(NS,M)/DELTAX                                      000137
      YODHA(NS,M)=YODHA(NS,M)/DELTAX                                    000137
      TEMPTA(NS,M)=TEMPTA(NS,M)/AMASST(NS,M)                            000137
      TEMPBA(NS,M)=TEMPBA(NS,M)/AMASSB(NS,M)                            000138
      RHPLA=RHPLUS(HPLUS1(NS,M),TWA(NS,M),TEL,QPLUSA(NS,M),HPLUS2(NS,M),000138
     1TEMPBA(NS,M),YODHA(NS,M))                                         000138
      WRITE(6,8875)M,JPIN(NS,M),HPLUS1(NS,M),HPLUS2(NS,M),RHPLA         000138
 8875 FORMAT(5X,I2,'-(ROD NR.',I4,')',T27,'HB+ =',E12.5,T52,'HW+ =',E12.000138
     15,T75,'R( H+ )=',E12.5)                                           000138
      IF(GQ(NS,M).LE.1.E-06)GOTO 8874                                   000138
```

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      TWDTEA=(TWA(NS,M)+273.16)/(TE+273.16)                              000138
      TWDTBA=(TWA(NS,M)+273.16)/(TEMPTA(NS,M)+273.16)                    000138
      GHPLA=GHPLUS(HPLUS2(NS,M),TWA(NS,M),TEMPTA(NS,M),PRBA (NS,M),      000138
     1YDHA(NS,M),10000.,0.)                                              000139
      PHIA=GHPLA/(PRBA (NS,M)**O4 * TWDTBA**O5)*(O16*YDHA(NS,M))**O17    000139
      WRITE(6,94)GHPLA,GPLUSA(NS,M),TWDTBA,TWDTEA,YDHA(NS,M),O4,O5,O16,  000139
     1O17,PHIA                                                           000139
 8874 CONTINUE                                                           000139
 8876 CONTINUE                                                           000139
 8897 CONTINUE                                                           000139
C     ...............................................................   000139
C                                                                        000139
C  27-COMPARISON BETWEEN THE INPUT AND THE COMPUTED AVERAGE              000139
C     TEMPERATURES OF THE GAS, OF THE SHROUD AND OF THE PINS IN THE      000140
C     AXIAL PORTION                                                      000140
C                                                                        000140
      TWTC=TWTC/LENGTH                                                   000140
      TBTC=TBTC/LENGTH                                                   000140
      TBPC=TBPC/LENGTH                                                   000140
      WRITE(6,69) TWTIPA(IPA),TWTC,TBTIPA(IPA),TBTC,TBPIPA(IPA),TBPC     000140
   69 FORMAT(///5X,'COMPARISON OF INPUT TEMPERATURES WITH COMPUTED VALUE000140
     1S'//T17,'INPUT',T26,'COMPUTED'/5X,'TWTIPA',2F11.2/5X,'TBTIPA',2F11000140
     2.2/5X,'TBPIPA',2F11.2)                                             000140
C     ...............................................................   000141
C                                                                        000141
C  28-COMPARISON BETWEEN THE EXPERIMENTAL AND THE COMPUTED PRESSURE      000141
C     LOSSES                                                             000141
C                                                                        000141
      IF(NEXPR(IPA).GT.0 .OR. NEXTW(IPA).GT.0)WRITE(6,1023)              000141
 1023 FORMAT(////5X,'COMPARISON WITH EXPERIMENTAL RESULTS'/5X,36('-')//)000141
      IF(NEXPR(IPA).EQ.0)GOTO 1040                                       000141
      GOTO (1069,1070),INDPR                                             000141
 1069 WRITE(6,1072)                                                      000141
      GOTO 1071                                                          000142
 1070 WRITE(6,1073)                                                      000142
 1071 CONTINUE                                                           000142
 1072 FORMAT(5X, '1) PRESSURES (KG/SQCM)'//)                             000142
 1073 FORMAT(5X, '1) PRESSURES (BARS)'//)                                000142
      IEXPR2=IEXPR1+NEXPR(IPA)-1                                         000142
      K1=1                                                               000142
      DO 1037 IEXPR=IEXPR1,IEXPR2                                        000142
      DO 1024 K=K1,N                                                     000142
      K2=K                                                               000142
      IF(XEXPR(IEXPR).GE.X(K) .AND. XEXPR(IEXPR).LT.X(K+1))GOTO 1025     000143
 1024 CONTINUE                                                           000143
      GOTO 1040                                                          000143
 1025 K1=K2                                                              000143
      IF(INDSP(K).EQ.2)GOTO 1026                                         000143
      KK=K2                                                              000143
      GOTO 1027                                                          000143
 1026 KK=K2-1                                                            000143
      IF(KK.EQ.0)KK=2                                                    000143
 1027 CONTINUE                                                           000143
      GOTO (1028,1029),INDPR                                             000144
 1028 PR1=P(KK)                                                          000144
      PR2= P(KK+1)                                                       000144
      GOTO 1030                                                          000144
 1029  PR1=PBAR(KK)                                                      000144
      PR2=PBAR(KK+1)                                                     000144
 1030 PTH=(PR2-PR1)/(X(KK+1)-X(KK))*( XEXPR(IEXPR)-X(KK))+PR1            000144
      DPEX=PEX(IEXPR)-PE1                                                000144
      DPTH=PTH-PE1                                                       000144
      PTMPEX=PTH-PEX(IEXPR)                                              000144
      DPERR=(DPTH-DPEX)/DPEX*100.                                        000145
      WRITE(6,1031)IEXPR,XEXPR(IEXPR),PEX(IEXPR),DPEX,PTH,DPTH,PTMPEX,   000145
     *DPERR                                                              000145
```

```
 1031 FORMAT(5X,I2,')HEIGHT=',F10.5,' CM',5X,'P EX.=',F10.5,5X,'P EX.-PE000145
     *1=',F10.7,5X,'P TH.=',F10.5,5X,'P TH.-PE1=',F10.7/33X,'P TH.-P EX.000145
     *=',F10.7,5X,'(DP TH.-DP EX.)/DP EX. *100 =',F7.3/)               000145
 1037 CONTINUE                                                          000145
 1040 CONTINUE                                                          000145
C     ............................................................... 000145
C                                                                       000145
C  29-PRINT OF THE PIN TEMPERATURES AT SPECIAL AXIAL POSITIONS          000145
C                                                                       000146
      IF(NEXTW(IPA).EQ.0)GOTO 1060                                      000146
      WRITE(6,1041)                                                     000146
 1041 FORMAT(///5X,'2) COMPUTED ROD TEMPERATURES ( C)'//)               000146
      IEXTW2=IEXTW1+NEXTW(IPA)-1                                        000146
      DO 1050 IEXTW=IEXTW1,IEXTW2                                       000146
      WRITE(6,1045)IEXTW,XEXTW(IEXTW)                                   000146
      DO 1044 NS=1,NSTOT                                                000146
      NP=NPIN(NS)                                                       000146
      WRITE(6,1046)(M,NS, JPIN(NS,M),TWTH(NS,M,IEXTW),M=1,NP)           000147
 1044 CONTINUE                                                          000147
 1045 FORMAT(/5X,I2,')HEIGHT=',F10.5,' CM'/)                            000147
 1046 FORMAT(3(5X,I2,') TW TH.(',I5,',',I5,')=',F10.3,' C'))            000147
 1050 CONTINUE                                                          000147
 1060 CONTINUE                                                          000147
C     ............................................................... 000147
C                                                                       000147
C  30-STARTING VALUES OF VARIABLES FOR THE NEXT AXIAL PORTION           000147
C                                                                       000147
      IF(X(L).GT.DIST(ISPAC) .AND. ISPAC.NE.NSPACT)ISPAC=ISPAC+1        000148
      TO=T(L)                                                           000148
      PO=P(L)                                                           000148
      DPBAR(1)=DPBAR(L)                                                 000148
      II=II+NSPAC(IPA)                                                  000148
      IEXPR1=IEXPR1+NEXPR(IPA)                                          000148
      IEXTW1=IEXTW1+NEXTW(IPA)                                          000148
      SPRLEN=SPRLEN+PLEN(IPA)                                           000148
      HH=SPRLEN                                                         000148
      IF(II.GT.1 .AND. IDISP2.EQ.1)DISTOO=DIST(II-1)-SPRLEN             000148
      IF(NDPRQ(IPA).GT.0)IDPRQ=IDPRQ+1                                  000149
      ISTAIN=1                                                          000149
 8888 CONTINUE                                                          000149
C     ............................................................... 000149
C                                                                       000149
C  31-END OF THE LOOP IPA; CALCULATION OF THE PRESSURE RECOVERY AT THE  000149
C     OUTLET OF THE BUNDLE                                              000149
C                                                                       000149
      DEPOUT=-COUT*PROV2/RHO2*0.5                                       000149
      POUT=PO+DEPOUT                                                    000149
      POBAR=POUT*0.980665                                               000150
      WRITE(6,8896)DEPOUT,POUT,POBAR,COUT                               000150
 8896 FORMAT(////5X,'PRESSURE RECAPTURE DUE TO EXIT=',F7.5,' KG/SQCM',5X000150
     *    ,'PRESSURE OUTSIDE=',F10.5,' KG/SQCM   =',F10.5,' BARS  ( COUT=000150
     *',F4.2,' )')                                                      000150
      DPOBAR=PEOBAR-POBAR                                               000150
      IF(IPUNCH.EQ.1)WRITE(1,6069)DPOBAR                                000150
      IF(PEXOUT.LE.1.E-06)STOP                                          000150
      IF(INDPR.EQ.2)POUT=POBAR                                          000150
      DPEX=PEXOUT-PE1                                                   000150
      DPTH=POUT-PE1                                                     000151
      DPERR=( DPTH-DPEX)/DPEX*100.                                      000151
      WRITE(6,1008)PEXOUT,DPTH,DPEX,DPERR                               000151
 1008 FORMAT(/5X,'EXP. PRESSURE OUTSIDE=',F10.5/5X,'P TH.-PE1=',F10.7/5X000151
     *,'P EX.-PE1=',F10.7/5X,'(DP TH.- DP EX.)/DP EX.*100=',F6.3)       000151
  742 STOP                                                              000151
      END                                                               000151
C                                                                       000000
C                                                                       000000
```

```
C
C
C
C
C
      FUNCTION AKA(R1DR2,PHI)
C     ------------------------------------------------------------------
C     AKA COMPUTES THE ADDITIONAL FRICTION IN THE LAMINAR HYDRODYNAMIC
C     ENTRANCE LENGTH
C
      IF(PHI.GT.0.002)GOTO 1
      AKA=132.53*PHI/R1DR2**0.013
      RETURN
    1 IF(PHI.GE.0.01755)GOTO 2
      A=0.7932+0.3421*ALOG(PHI)
      GOTO 4
    2 IF(PHI.GE.0.05)GOTO 3
      A=-0.05033+0.1322*ALOG(PHI)
      GOTO 4
    3 IF(PHI.GT.0.1)GOTO 5
      A=-0.4463
    4 B=-0.205*PHI**0.44362
      AKA=EXP(A)*R1DR2**B
      RETURN
    5 AKA=0.64/R1DR2**0.0738
      RETURN
      END
C
C
C
C
      FUNCTION BETAF(P,W,ZWC)
C     ------------------------------------------------------------------
C     BETAF EVALUATES THE PARAMETER BETA FOR THE DETERMINATION OF THE
C     SEPARATION LINE DEFINING THE TWO PORTIONS OF THE WALL SUBCHANNELS
C     IN THE LAMINAR CALCULATIONS
C     THE FOLLOWING EQUATION IS EXACTLY VALID AT ZWC=0, 1.2<P/D,W/D<1.5)
C
      BETAF=( 3.77165-2.0795*P)+(-1.71935+1.2139*P)*W
      RETURN
      END
C
C
C
C
      SUBROUTINE CEWACC(N,NN,NTYP,ALFA,D,X,AT,DET,MFLOW,ATOT,AREA,DE,ME)
C-----------------------------------------------------------------------
C     SUBROUTINE CEWACC EVALUATES GEOMETRICAL  PARAMETERS AND INLET MASS
C     FLOW RATES FOR 'CENTRAL-TYPE' AND CORNER SUB-SUBCHANNELS.
C
      REAL MFLOW,ME
      DIMENSION AREA(NN),DE(NN),ME(NN)
      COMMON/CEN1/G(45)/ANG1/RR2(30),ALF12(30)/ANG2/PER(30)
      PEROD=ALFA*D*0.5
      ARROD=PEROD*0.25*D
      E1=0.
      DO 3 I=1,NN
      AI=I
      E2=X*TAN(ALFA*AI)
      DELTAF=E2-E1
      AREA(I)=X*DELTAF*0.5-ARROD
      DE(I)=4.*AREA(I)/PEROD
      IF(NTYP.EQ.3)GOTO 1
      EPS=SQRT(1.+DE(I)/D)
      G(I)=GSTAR(EPS)
      GOTO 2
```

```
  1 PER(I)=DELTAE
    RR2(I)=SQRT(D**2+DE(I)*D)*0.5
     ALF12(I)=D*0.5/RR2(I)
    DE(I)=4.*AREA(I)/(PERCC+PER(I))
  2 CONTINUE
    ME(I) =MFLOW*AREA(I)/ATOT
  3 E1=E2
    IF(NTYP.EQ.3)GOTO 5
    WRITE(6,4)
  4 FORMAT(////130('*')/////
   *          5X,'GEOMETRY OF CENTRAL CHANNELS (REFERENCE TO 1/6)'//)
    GOTO 7
  5 WRITE(6,6)
  6 FORMAT(////130('*')////5X,'GEOMETRY OF ANGULAR CHANNELS (REFERENCE
   * TO 1/2)'//)
  7 CONTINUE
    WRITE(6,8)AT,DET
  8 FORMAT(5X,'TOTAL FLOW AREA=',F5.2,1X,'SQCM',5X,'TOTAL EQUIVALENT D
   *IAMETER=',F4.1,1X,'CM'//)
    WRITE(6,9)
  9 FORMAT(5X,'SECTION NR.',5X,'FLOW AREA (SQCM)',4X,'EQUIV. DIAMETER(
   *CM)'/)
    WRITE(6,10)(I,AREA(I),DE(I),I=1,N)
 10 FORMAT(7X,I3,15X,F7.5,17X,F5.3)
    RETURN
    END
C
C
C
C
    SUBROUTINE CORRTE(TW,TB,PB,     NS,M,I,BICT,TWINF)
C----------------------------------------------------------------------
C     CORRTE CORRECTS THE COMPUTED TEMPERATURES FOR THE BIOT EFFECT AND
C     THE POSITION OF THE THERMOCOUPLE INSIDE THE CANNING
C
    COMMON/IROSMC/IRH/BIDE/IBIDE/CORRE/QHRDAR,QRMDAR,QLAMR/LAMINO/
   1         I2TIP(42,3)
    REAL KMET,KINF,KAPPA
    TWINF=TW
    IF(IRH.EQ.1)GOTO 100
C
C     ONLY FOR ROUGHENED RODS
    IF(I2TIP(NS,M).NE.1)GOTO 9
C     ...................................................................
C     FOR ROUGHENED RODS AND LAMINAR FLOW
C
    TW=TW+QLAMR/KAPPA(PB,TW)
    GOTO 100
C     ...................................................................
C     FOR ROUGHENED RODS AND TURBULENT FLOW
C
  9   TWBI=TWINF
    DTWINF=TW-TB
    DO 10 IT=1,10
    TWP=TW
    IF(IBIDE.EQ.1)TWBI=TW
    BICT=QHRDAR/((TWBI -TB) *KMET(TWBI))
    TW=DTWINF/KINF(BICT)+TB
    IF(ABS(TWP/TW-1.).LE.1.E-04)GOTO 13
 10 CONTINUE
    WRITE(6,12)NS,M,I,BICT,TWP,TW
 12 FORMAT(1H1,5X,'CALCULATION STOPS IN SUBROUTINE CORRBI: NS=',I5,' M
   *=',I2,' I=',I3/5X,'BICT=',E15.5,5X,'TWP=',E15.5,5X,'TW=',E15.5)
    STOP
C
 13 IF(QRMDAR.LE.1.E-06)TW=DTWINF/EINF(BIDT)+TB
```

```
 ..................................................................
   FOR SMOOTH AND ROUGHENED RODS, TURBULENT AND LAMINAR FLOW

100 TW=TWCTEP(QRMDAR,TW)
   RETURN
   END




   SUBROUTINE CRFL1(ITGL,DPJAV,FREL,AJT,JMAX,AJ,MJ,DPJ,WCFJ,WCF1J,
  *EP1J)
---------------------------------------------------------------------
   CRFL1 EVALUATES THE CROSS FLOW SOLUTIONS

   REAL MJ
   DIMENSION AJ(JMAX),MJ(JMAX),DPJ(JMAX),WCFJ(JMAX),WCF1J(JMAX),
  *EP1J(JMAX)
   IF(ITGL-2)1,3,5
 ..................................................................
   FIRST ITERATION : ASSUMED WCFJ(J)=0

 1 CONTINUE
   DO 2 J=1,JMAX
   WCFJ(J)=0.
 2 WCF1J(J)=0.
   RETURN
 ..................................................................
   SECOND ITERATION : ASSUMED WCFJ(J)=-0.5*(DPJ(J)-DPJ AV)*
                                     MJ(J)/DPJ(J)

 3 CONTINUE
   WCFJT=0.
   DO 4 J=1,JMAX
   EP1J(J)=DPJ(J)-DPJAV
   WCFJ(J)=-0.5*EP1J(J)*MJ(J)/DPJ(J)
 4 WCFJT=WCFJT+WCFJ(J)
   GOTO 7
 5 CONTINUE
 ..................................................................
   ITGL>2: WCFJ(J) ARE OBTAINED BY USE OF THE TANGENT METHOD

   WCFJT=0.
   DO 6 J=1,JMAX
   EPJ=DPJ(J)-DPJAV
   IF(ABS(EP1J(J)-EPJ).LT.1.E-20)GOTO 6
   WCFJP=WCFJ(J)
   WCFJ(J)=WCFJP-FREL*EPJ*(WCFJP-WCF1J(J))/(EPJ-EP1J(J))
   WCF1J(J)=WCFJP
   EP1J(J)=EPJ
 6 WCFJT=WCFJT+WCFJ(J)
 7 CONTINUE
 ..................................................................
   NORMALIZATION OF THE WCF(J): THEIR SUMMATION MUST BE =0

   WCFJT=WCFJT/AJT
   DO 8 J=1,JMAX
 8 WCFJ(J)=WCFJ(J)-WCFJT*AJ(J)
   RETURN
   END




   FUNCTION CSFUN(IRH,REAI,SQ8LIA,SQ3LI3,QA)
---------------------------------------------------------------------
```

```
C     CSFUN COMPUTES THE FACTOR CS=AS/2.5 FOR THE VELOCITY PROFILE
C     IN THE ZONES OUTSIDE THE TAU=0 LINE (IN THE CASE OF SMOOTH
C     RODS CSFUN=1)
C
      COMMON/COLAM2/COLAMA
      IF(IRF.EQ.2)GOTO 1
      CSFUN=1.
      RETURN
    1 PROV=SQRT(1.056+0.005*(SQ8LIA/SQ8LI3)**2)
      SQ8LIA=ABS(SQ8LIA)
      SQ8LIA=(2.5*ALOG(REAI/(SQ8LIA*PROV))+5.5*COLAMA-5.699)     /PROV
      SQ8LIA=ABS(SQ8LIA)
      CSFUN=(SQ8LIA-5.5*COLAMA)/(2.5*ALOG(REAI/SQ8LIA)-GA)
      RETURN
      END
C
C
C
C
      SUBROUTINE DDCNNE(TWO,TBT,GHPL,RODR2,R1DR2,YDH,R2MRDH,FF,T2,T1,TE)
C-----------------------------------------------------------------------
C     DDCNNE EVALUATES THE TEMPERATURES T1 AND T2 OF THE TWO REGIONS OF
C     CORNER CHANNELS AND OF THE 'WALL PART' OF WALL SUBCHANNELS
C
      RODR22=RODR2**2
      R1DR22=R1DR2**2
      F1=1.-RODR22
      F2=1.-R1DR22
      F3=RODR22-R1DR22
      T2=TWO-FF*(GHPL+2.5/F1*(F2*ALOG(YDH+R2MRDH)-F3*ALOG(YDH)-0.5*(1.+
     +2.*R1DR2-RODR22-2.*R1DR2*RODR2)))
      T1=F2/F3*TBT-F1/F3*T2
      IF(T1.GE.TE .AND. T2.GE.TE)RETURN
C
      T2=TE
      T1=F2/F3*TBT-F1/F3*T2
      RETURN
      END
C
C
C
C
      FUNCTION EINF(BIOT)
C     EINF EVALUATES THE E INFINITE VALUE
C-----------------------------------------------------------------------
C
      COMMON/BIDAT1/BI4,BI5,BI6,BI7,BI8,BI9,BI10
      IF(BIOT.GT.BI4)GOTO 1
      EINF=BI5+BI6*BIOT+BI7*BIOT**2
      RETURN
    1 EINF=BI8+BI9*BIOT+BI10*BIOT**2
      RETURN
      END
C
C
C
C
      SUBROUTINE ENFRCO
C     ------------------------------------------------------------------
C     ENFRCO COMPUTES AN AVERAGE GAMMA VALUE FOR THE LAMINAR
C     CALCULATIONS IF WALL AND CORNER CHANNELS ARE COMPUTED TOGETHER
C
      REAL LAM,LAMSCH,LAMWC
      COMMON/MART5/NSTR
      COMMON/SUB5/LAMSCH(42,3)/GEN1/LAM(42)/GEN2/A(42)/GEN5/DE(42)
     1      /LAMIN1/AKAPPA(42)/LAMIN2/FATIP(3),FDTIP(3)/INO3/NTYP(42)
```

```
     2      /MART2/NS1,NS2/HEA6/NPIN(42),JPIN(42,3)/GAMCO/CGAMMA(13)
     3      /WCSE3/LAMWC(18,2,2)
      P=0.
      PP=0.
      DO 100 NS=NS1,NS2
      ITYP=NTYP(NS)
      ADDK=A(NS)*FATIP(ITYP)*(DE(NS)*FDTIP(ITYP))**2/AKAPPA(NS)
      P=P+ADDK
  100 PP=PP+ADDK/CGAMMA(NS-NSTR)
      P=P/PP
      DO 120 NS=NS1,NS2
      ITYP=NTYP(NS)
      PDCG=P/CGAMMA(NS-NSTR)
      LAM(NS)=LAM(NS)*PDCG
      NP=NPIN(NS)
      DO 120 M=1,NP
      LAMSCH(NS,M)=LAMSCH(NS,M)*PDCG
      IF(ITYP.EQ.3)GOTO 120
      DO 110 JWC=1,2
  110 LAMWC(NS-NSTR,M,JWC)=LAMWC(NS-NSTR,M,JWC)*PDCG
  120 CONTINUE
      RETURN
      END
C
C
C
C
      SUBROUTINE ENTRFR(K,I,ITYP,R1,RO,R2,NS,III,JJJ,DE,A,M,P,TB,LAMLAM)
C     ------------------------------------------------------------------
C     ENTRFR COMPUTES THE GAMMA FACTORS TO CORRECT THE FRICTION FACTORS
C     IN THE HYDRODYNAMIC ENTRANCE REGION
C
      REAL M,LAMLAM
      COMMON/GRID3/X(100)/RETEM/TNY/LAMIN1/AKAPPA(42)/GAMCO/CGAMMA(13)
     1      /ENTR1/CKAPPA(2),DEA(2),GAMMA(2),WGAMMA(2),A1/HEA6/NPIN(42),
     2      JPIN(42,3)
      RE=M*DE/(A*RHO(P,TB))*RHO(P,TNY)/ETA(P,TNY)
      IF(ITYP.EQ.1 .OR. I.EQ.2)CALL NEWTON(RO,R1,R2)
      R1DR2=R1/R2
      RODR1=RO/R1
      DEA(I)=2.*(R2-R1)
      CKAPPA(I)=FKAPPA(R1DR2)
      DKAPPA=AKAPPA(NS)
      IF(I.EQ.2)DKAPPA=     CKAPPA(RODR1)
      REA=RE*DEA(I)/DE
      IF(ITYP.EQ.1 .OR. I.EQ.2)REA=REA*DKAPPA/CKAPPA(I)*(DEA(I)/DE)**3
      PHIDX=4./(DEA(I)*REA)
      PHIA1=PHIDX*X(K)
      PHIA2=PHIDX*X(K+1)
      AKA1=AKA(R1DR2,PHIA1)
      AKA2=AKA(R1DR2,PHIA2)
      GAMMA(I)=1.+4./CKAPPA(I)*(AKA2-AKA1)/(PHIA2-PHIA1)
      IF(ITYP.EQ.2)GOTO 10
      LAMLAM=LAMLAM*GAMMA(1)
      IF(ITYP.EQ.3)CGAMMA(III)=GAMMA(1)
      RETURN
C     ..................................................................
C     ONLY FOR THE WALL SUBCHANNELS
C
   10 A1=A
      IF(I.EQ.1)RETURN
      C1=A1*DEA(1)**2/CKAPPA(1)
      C2=A*DE**2/DKAPPA
      WGAMMA(JJJ)=(C1+C2)/(C1/GAMMA(1)+C2/GAMMA(2))
      LAMLAM=LAMLAM*WGAMMA(JJJ)
      IF(JJJ.LT.NPIN(NS))RETURN
```

```
      CGAMMA(III)=0.
      NP=NPIN(NS)
      DO 20 JJ=1,NP
   20 CGAMMA(III)=CGAMMA(III)+WGAMMA(JJ)
      CGAMMA(III)=CGAMMA(III)/FLOAT(NP)
      RETURN
      END
C
C
C
C
      FUNCTION EXPCL(T)
C     ------------------------------------------------------------------
C     EXPCL COMPUTES THE EXPANSION COEFFICIENTS FOR THE CORRECTION OF
C     THE GEOMETRICAL DIMENSIONS OF THE LINER
C
      COMMON/EXDAT1/EX4(7),EX5(7),EX6(7)/INPAR/IPA
      EXPCL=EX4(IPA)+EX5(IPA)*T+EX6(IPA)*T**2
      RETURN
      END
C
C
C
C
      FUNCTION EXPCO(T)
C-----------------------------------------------------------------------
C     EXPCO COMPUTES THE EXPANSION COEFFICIENTS FOR THE CORRECTION OF TH
C     GEOMETRICAL DIMENSIONS OF THE RODS
C
      COMMON/EXDAT/ EX1(7),EX2(7),EX3(7) /INPAR/IPA
      EXPCO=EX1(IPA)+EX2(IPA)*T+EX3(IPA)*T**2
      RETURN
      END
C
C
C
C
      FUNCTION FKAPPA(R)
C     ------------------------------------------------------------------
C     FKAPPA EVALUATES THE KAPPA VALUES FOR THE CORNER CHANNELS AND THE
C     WALL PORTION OF THE WALL SUBCHANNELS ( VALIDITY FOR CORNER CHANNE-
C     LS 1.2< W/D <1.5)
C
      FKAPPA=62.146*(1.-R)**2/(1.+R**2+(1.-R**2)/ALOG(R))
      RETURN
      END
C
C
C
C
      FUNCTION FQDEV(A,N,X1,X2)
C-----------------------------------------------------------------------
C     FQDEV INTEGRATES THE PROFILES OF POWER
C
      DIMENSION A(N)
      FQDEV=0.
      X1AI=0.
      DO 10 I=1,N
      AI=I
      IF(X1.GT.0.)X1AI=X1**AI
   10 FQDEV=FQDEV+A(I)*(X2**AI-X1AI)
      RETURN
      END
C
C
C
```

```
C
      FUNCTION GHPLUS(HPLUSW,TW,TBT,PR,YDH,REW,R2MROH)
C-----------------------------------------------------------------------
C     GHPLUS EVALUATES THE FUNCTION G(H+)=G(HW+,PRANDTL,TW/TB,Y/RH)
C
      COMMON/DAT1/A1,A2,A3,A4,A5,A6,A7,A8,A9,A10
      GHPL  =(A1*HPLUSW**A2+A3/HPLUSW**A4)
      IF(GHPL.LE.A9)GHPL=A10
      GHPLUS=GHPL*PR**A5*((TW+273.16)/(TBT+273.16))**A6/(A7*(YDH+R2MROH)
     *)**A8
      RETURN
      END
C
C
C
C
      FUNCTION GKAPPA(X)
C     ------------------------------------------------------------------
C     GKAPPA EVALUATES THE KAPPA VALUES FOR THE CENTRAL SUBCHANNELS AND
C     THE CENTRAL PORTIONS OF THE WALL SUBCHANNELS ( VALIDITY FOR THE
C     CENTRAL CHANNELS AT 1.2< P/D <1.5)
C
      GKAPPA=54.237*(X**2-1.)**3*X**0.342/ABS(3.*X**4-4.*X**2-4.*X**4*
     *ALOG(X)+1.)
      RETURN
      END
C
C
C
C
      FUNCTION GRIFUN(EPS)
C     ------------------------------------------------------------------
C     GRIFUN EVALUATES THE COEFFICIENT KO/2=(KI+KO)/2 FOR THE LOCAL
C     PRESSURE LOSSES AT THE INLET AND AT THE OUTLET OF A SPACER
C
      GRIFUN     =0.5*(EPS*0.5+EPS**2)/(1.-EPS)**2
      RETURN
      END
C
C
C
C
      FUNCTION GSTAR(EPS)
C-----------------------------------------------------------------------
C     GSTAR EVALUATES THE FUNCTION G(EPSILON)
C
      COMMON/SUBLA/CLASUB
      GSTAR=(3.75*CLASUB+1.25*EPS)/(1.+EPS)+2.5*ALOG(2.*(EPS+1))
      RETURN
      END
C
C
C
C
      SUBROUTINE INLCON(NSTOT,MFLOW,ATOT,TE,IREAD1,NSTR)
C-----------------------------------------------------------------------
C     SUBROUTINE INLCON  FIXES THE INLET CONDITIONS FOR MASS FLOW RATES
C     AND BULK TEMPERATURES OF THE CHANNELS AND THE SUBCHANNELS AND FOR
C     THE BULK TEMPERATURES OF THE TWO PORTIONS OF THE WALL SUBCHANNELS
C
      REAL MFLOW,MI,MSCH1,MSCWC1,MSCH
      COMMON/IND3/NTYP(42)/SUB2/TSCH(42,3),MSCH(42,3)/SUB22/TW(42,3)
     1        /GEN2/A(42)/GEN3/MI(42)/GEN4/TEMP(42)
     2        /HEA6/NPIN(42),JPIN(42,3)
     3        /SUB1/ASCH(42,3)/SUB6/TSCH1(42,3)/SUB8/MSCH1(42,3)
     4        /WCSE2/MSCWC1(18,2,2)/WCSE5/TSCWC1(18,2,2)
```

```
      IF(IREAD1.EQ.2)GOTO 3
C     ..................................................................
C     IREAD1=1 MEANS UNIFORM DISTRIBUTIONS
C
      DO 2 NS=1,NSTOT
      MI(NS)=MFLOW*A(NS)/ATOT
      TEMP(NS)=TE
      NP=NPIN(NS)
      DO 1 M=1,NP
      MSCH1(NS,M)=MFLOW*ASCH(NS,M)/ATOT
      TSCH1(NS,M)=TE
      IF(NTYP(NS).NE.2)GOTO 1
      DO 6 JWC=1,2
    6 TSCWC1(NS-NSTR,M,JWC)=TE
    1 CONTINUE
    2 CONTINUE
      GOTO 1000
C     ..................................................................
C     IREAD1=2 MEANS NON-UNIFORM DISTRIBUTIONS
C
    3 CONTINUE
      READ(5,4)(MI(NS),TEMP(NS),NS=1,NSTOT)
      DO 5 NS= 1,NSTOT
      NSW=NS-NSTR
      NP=NPIN(NS)
      READ(5,4)(MSCH1(NS,M),TSCH1(NS,M),M=1,NP)
      IF(NTYP(NS).EQ.2)READ(5,4)((MSCWC1(NSW,M,JWC),TSCWC1(NSW,M,JWC),
     *  JWC=1,2),M=1,2)
    4 FORMAT(8F10.5)
    5 CONTINUE
 1000 CONTINUE
      DO 1001 NS=1,NSTOT
      NP=NPIN(NS)
      DO 1001 M=1,NP
      MSCH(NS,M)=MSCH1(NS,M)
      TSCH(NS,M)=TSCH1(NS,M)
      TW(NS,M)=TSCH(NS,M)
 1001 CONTINUE
      RETURN
      END
C
C
C
C
      SUBROUTINE KAPCOR(NSTOT,NSTR)
C     ------------------------------------------------------------------
C     KAPCOR COMPUTES THE KAPPA VALUES FOR THE LAMINAR CALCULATIONS
C     (IF IKAPPA=1, OTHERWISE SAVES THE VALUES OF BLOCK DATA) AND
C     CORRECTS THE KAPPA VALUES OF THE CORNER AND WALL CHANNELS IF IT IS
C      DESIRED TO HAVE THERE ABOUT THE SAME VALUE OF (LAMBDA/EQ. DIAM.)
C
      COMMON/LAMIN2/FATIP(3),FCTIP(3)/IND3/NTYP(42)/GEN2/A(42)/GEN5/
     1      DE(42)/INPAR/IPA/LAMINK/BKAPPA(7,3)/LAMIN1/AKAPPA(42)
     2      /MART2/NS1,NS2/WALLCO/WFCO1(18,2),WFCO(18,2)/WALLKA/AKAWC(2)
     3      /WAKA1/IKAPPA
      AKAWC(1)=BKAPPA(IPA,2)
      AKAWC(2)=BKAPPA(IPA,2)
      IF(IKAPPA.EQ.1)CALL SELAWA
      DO 5 NS=1,NSTOT
      IF(NS.LE.NSTR)GOTO 3
      DO 4 I=1,2
      WFCO (NS-NSTR,I)=1.
    4 WFCO1(NS-NSTR,I)=1.
    3 ITYP=NTYP(NS)
    5 AKAPPA(NS)=BKAPPA(IPA,ITYP)
      IF(NS1.EQ.0 .AND. NS2.EQ.0)GOTO 35
```

```
      IF(NS1.GT.NSTR .AND. NS2.LE.NSTCT)GOTO 9
      WRITE(6,6)NS1,NS2
    6 FORMAT(1H1,5X,'STOP BECAUSE NS1=',I5,' AND NS2=',I5)
      STOP
C
    9 AT=0.
      PP=0.
      DO 10 NS=NS1,NS2
      ITYP=NTYP(NS)
      ATIP=A(NS)*FATIP(NS)
      PP=PP+ATIP*(DE(NS)*FDTIP(ITYP))**2/BKAPPA(IPA,ITYP)
   10 AT=AT+ATIP
      PP=AT/PP
      DO 20 NS=NS1,NS2
      ITYP=NTYP(NS)
   20 AKAPPA(NS)=(DE(NS)*FDTIP(ITYP))**2*PP
   35 CONTINUE
      DO 29 NS=1,NSTCT
      ITYP=NTYP(NS)
   29 WRITE(6,30)NS,AKAPPA(NS),BKAPPA(IPA,ITYP)
   30 FORMAT(     5X,'CHANNEL',I5,' : USED KAPPA=',F10.3,' (INPUT KAPPA='
     *        ,F10.3,')')
      RETURN
      END
C
C
C
C
      REAL FUNCTION KINF(BICT)
C-----------------------------------------------------------------------
C     KINF EVALUATES THE K INFINITE VALUE
C
      COMMON/BIDAT/BI1,BI2,BI3
      KINF=BI1+BI2*BICT+BI3*BICT**2
      RETURN
      END
C
C
C
C
      REAL FUNCTION KMET(TW)
C     KMET EVALUATES THE CONDUCTIVITY OF THE PIN CANNING
C-----------------------------------------------------------------------
C
      COMMON/DATKM/D1(7),D2(7) /INPAR/IPA
      KMET=D1(IPA)+D2(IPA)*TW
      RETURN
      END
C
C
C
C
      SUBROUTINE MODFQD(I,NI,NJ,A,EXF)
C     MODFQD COMPUTES THE COEFFICIENTS A OF THE INTEGRAL PROFILES OF
C     POWER
C----------------------------------------------------------------------
C
      DIMENSION A(7,7)
      DO 10 J=1,NJ
      AJ=J
   10 A(I,J)=A(I,J)/(AJ*EXF**AJ)
      RETURN
      END
C
C
C
```

```
C
      SUBROUTINE NEWTCN(R0,R1,R2)
C     ------------------------------------------------------------------
C     NEWTON FINDS R2 IN THE LAMINAR CALCULATIONS OF THE CENTRAL
C     SUBCHANNELS AND THE CENTRAL PORTIONS OF THE WALL SUBCHANNELS
C     BY MEANS OF THE NEWTON ITERATION METHOD
C
      R2P=2.*R0-R1
      A=-0.5/R0**2
      B=-ALOG(R1)+0.5*(R1/R0)**2
      C=2.*A
      DO 10 IT=1,20
      F=ALOG(R2P)+A*R2P**2+B
      DF=1./R2P+C*R2P
      R2=R2P-F/DF
      IF(ABS(R2/R2P-1).LE.1.E-04)GOTO 20
   10 R2P=R2
      WRITE(6,15)R2
   15 FORMAT(/5X,'STOP IN SUBROUTINE NEWTON ; R2=',E15.5)
      STOP
   20 RETURN
      END
C
C
C
C
      SUBROUTINE NORMT(NSTOT,NSTR,TBT,ATOT,ASEC1,MFLOW)
C-----------------------------------------------------------------------
C     NORMT NORMALIZES THE CHANNEL TEMPERATURES TO THE TOTAL BULK
C     TEMPERATURE,THE SUBCHANNEL TEMPERATURES TO THE TEMPERATURE OF THE
C     CONTAINING CHANNELS. IT NORMALIZES ALSO THE VALUES OF THE
C     TEMPERATURES OF THE TWO PORTIONS OF THE WALL SUBCHANNELS TO THE
C     TEMPERATURE OF THE CONTAINING WALL SUBCHANNELS
C
      REAL MAV,MSCH,MAWC,MFLOW
      DIMENSION A(42),ASCH(3)
      COMMON/GEN2/AZ(42)/SUB1/ASCHZ(42,3)/SUB2/TSCH(42,3),MSCH(42,3)
     1       /IND3/NTYP(42)/FEA6/NPIN(42),JPIN(42,3)/MOB5/TAV(42)
     2       /MOB6/MAV(42)/WCSE7/MAWC(18,2,2)/WCSE8/ASCHWC(18,2,2)
     3       /WCSE9/TAVWC(18,2,2)/LAMIN3/F1ATIP(42),F1DTIP(42)/LAMIN4/
     4       F2ATIP(42,3),F2DTIP(42,3)
      DEH=TBT*MFLOW*ASEC1/ATOT
      ASEC=0.
      DO 10 NS=1,NSTOT
      A(NS)=AZ(NS)*F1ATIP(NS)
      ASEC=ASEC+A(NS)
   10 DEH=DEH-TAV(NS)*MAV(NS)
      DEHA=DEH/ASEC
      DO 11 NS=1,NSTOT
   11 TAV(NS)=TAV(NS)+DEHA*A(NS)/MAV(NS)
      DO 5 NS=1,NSTOT
      NP=NPIN(NS)
      SHSCH=0.
      DO 1 M=1,NP
    1 SHSCH=SHSCH+MSCH(NS,M)*TSCH(NS,M)
      DEH=MAV(NS)*TAV(NS)-SHSCH
      DO 4 M=1,NP
      RAPPA=ASCH(M)/A(NS)
      TSCH(NS,M)=TSCH(NS,M)+DEH*RAPPA/MSCH(NS,M)
      IF(NTYP(NS).NE.2)GOTO 4
      NSW=NS-NSTR
      SHWC=0.
      DO 2 JWC=1,2
    2 SHWC=SHWC+MAWC(NSW,M,JWC)*TAVWC(NSW,M,JWC)
      DEHWC=MSCH(NS,M)*TSCH(NS,M)-SHWC
      DO 3 JWC=1,2
```

```
      RAPPA=ASCHWC(NSW,M,JWC)/ASCH(M)
    3 TAVWC(NSW,M,JWC)=TAVWC(NSW,M,JWC)+DEHWC*RAPPA/MAWC(NSW,M,JWC)
    4 CONTINUE
    5 CONTINUE
      RETURN
      END
C
C
C
C
      FUNCTION RELAM(A,C,P,TB,TW,M,TLINER,ITYP,R1DR2L,PH1DPH)
C     ------------------------------------------------------------------
C     RELAM COMPUTES THE LAMINAR REYNOLDS NUMBERS FOR THE CALCULATION
C     OF THE SUBCHANNEL FRICTION FACTORS
C
      REAL M
      COMMON/INPAR/IPA/LAMIN5/RTIP(7)/DAT/PIG/QPAR3/PERL(3)/MART/ITCORR
     1       /RETEM/TNY
      TL=TLINER
      IF(IPA/2*2.NE.IPA .OR. ITCORR.EQ.1)TW=TB
      RENU =M*C /(A*RHO(P,TB))
      TNY=TW
      IF(ITYP.NE.1 .AND. IPA/2*2.EQ.IPA .AND. ITCORR.GT.1)
     *             TNY=TNU(TW,TL,ITYP,PERL(ITYP),PIG,RTIP(IPA))
      RELAM=RENU *RHO(P,TNY)/ETA(P,TNY)
      RETURN
      END
C
C
C
C
      FUNCTION RHPLUS(HPLUSB,TW,TB,QPLUS,HPLUSW,TB1,YDH)
C-----------------------------------------------------------------------
C
C     RHPLUS EVALUATES THE FUNCTION R(H+)
C     IRHPL=1 : R(H+)=R(HW+)+CONST/(HW+)**CONST*(TW/TB1-1)**CONST+
C                       +CONST*ALOG(HR/(0.01*(RO-R1)))
C     IRHPL=2 : R(H+)=R(HB+) (FOR THE LAST UNHEATED ROUGH PART)
C
      COMMON/DAT2/B1,B2,B3,B4,B5,B6,B7,B8,B9,B10/TRANS/RHTU,RHSM
     1       /DAT6/IRHPL
      CORRTW=0.
      GOTO(1,2),IRHPL
    1 HPLUS=HPLUSW
      CTW=(TW+273.16)/(TB1+273.16)-1.
      IF(CTW.GT.0.)CORRTW=CTW**B10
      GOTO 3
    2 HPLUS=HPLUSB
    3 RHPL  =(B1+B2/HPLUS**B3)**B4+B5*ALOG(1./(YDH*B6))+B8/HPLUS**B9*
     * CORRTW
      RHTU=RHPL
      RHSM=5.5+2.5*ALOG(HPLUSB)
C
C     IF R(H+) TURB. >RHSM THE FLOW IS "HYDRAULICALLY SMOOTH"
C
      IF(RHPL.GT.RHSM)RHPL=RHSM
      RHPLUS=RHPL
      RETURN
      END
C
C
C
C
      SUBROUTINE RNU(HPLUSW,TWI,LAMIB,REI,PRI,TBT,YDH,R1DR2,R2MROH,U1DU,
     *REW,YYI,NUI,GHPL)
C-----------------------------------------------------------------------
```

```
C     RNU EVALUATES NUSSELT NUMBER IN THE ROUGH PART
C
      REAL LAMIB, NUI
      GHPL=GHPLUS(HPLUSW,TWI,TBT,PRI,YDH,REW,R2MROH)
      FF=GHPL+2.5*ALOG(YDH+R2MROH)-(1.25+3.75*R1DR2)/(1.+R1DR2)
      STI=SQRT(LAMIB*0.125)*U1EL/FF
      NUI=STI*REI*PRI*YYI
      RETURN
      END
C
C
C
C
      SUBROUTINE SELAWA
C     ------------------------------------------------------------------
C     SELAWA COMPUTES THE KAPPA VALUES FOR THE SUBCHANNELS AND THE TWO
C     KAPPA VALUES FOR THE TWO PORTIONS OF THE WALL SUBCHANNELS IN THE
C     LAMINAR CALCULATIONS
C
      COMMON /LAMIN6/ANGLAM/WALLKA/AKAWC(2)/WAKAO/P,W,Z,ZWC,A,PW
     1       /LAMINK/BKAPPA(7,3)/INPAR/IPA
      BKAPPA(IPA,1)=GKAPPA(1.050075*P)
      BKAPPA(IPA,3)=FKAPPA(0.476156/Z)
      ALFA=ATAN(2.*(Z-ZWC)/P)
        BETA=BETAF(P,W,ZWC)
      ALFAB=ALFA*BETA
      ANGLAM=TAN(ALFAB)/TAN(ALFA)
      A2=P**2*TAN(ALFAB)*0.125-0.125*ALFAB
      PW2=ALFAB*0.5
      A1=A-A2
      PW1=PW-PW2
      R=SQRT((1.570796-ALFAB)/(4.*Z*P-P**2*TAN(ALFAB)-6.928204*ZWC**2))
      X=P*SQRT(TAN(ALFAB)/ALFAB)
      AKAWC(1)=FKAPPA(R)
      AKAWC(2)=GKAPPA(X)
      BKAPPA(IPA,2)=A**3/(PW**2*(A2**3/(PW2**2*AKAWC(2))+A1**3/(PW1**2*
     *AKAWC(1))))
       RETURN
      END
C
C
C
C
      SUBROUTINE SIMLA1(TE,TI,TWI,TLI,NUI,TETAI,I,JJJ,TBEQ1,TBEQ2,II)
C     ------------------------------------------------------------------
C     SIMLA1 CORRECTS THE NUSSELT NUMBERS AND THE DIMENSIONLESS TEMPERAT
C     URES OF THE UNHEATED WALLS IN THE CORNER AND WALL CHANNELS IN THE
C     LAMINAR CALCULATIONS IF THE KAPPA VALUES HAVE BEEN CORRECTED IN
C     SUBROUTINE KAPCOR
C
      REAL NUI
      COMMON/HEA6/NPIN(42),JPIN(42,3)/IND3/NTYP(42)/QPAR3/PERL(3)
     1      /SUB1/ASCH(42,3)/GEOC/ACH(3)/MART2/NS1,NS2/INPAR/IPA
     2      /LAMINK/BKAPPA(7,3)/LAMIN1/AKAPPA(42)/WALLCC/WFC01(18,2),
     3      WFC0(18,2)/SUB2/TB(42,3),BMASS(42,3)/SIMLAM/ISIMPL
      IF(I.GT.NS1 .OR. JJJ.GT.1)GOTO 20
      TBAVR=0.
      TBAVL=0.
      PERLT=0.
      SANG=0.
      AVRAKR=0.
      AVRAKL=0.
      DO 10 NS=NS1,NS2
      NP=NPIN(NS)
      ITYP=NTYP(NS)
      DO 10 M=1,NP
```

```
      PERLSC=PERL(ITYP)*ASCH(NS,M)/ACH(ITYP)
      ANG=60.*FLOAT(7-2*ITYP)*ASCH(NS,M)/ACH(ITYP)
      SANG=SANG+ANG
      PERLT=PERLT+PERLSC
      RAKA=BKAPPA(IPA,ITYP)/AKAPPA(NS)
      RAKR=RAKA*ANG*WFCO(II,JJJ)
      RAKL=RAKA*PERLSC*WFCO1(II,JJJ)
      AVRAKR=AVRAKR+RAKR
      AVRAKL=AVRAKL+RAKL
      TBAVR=TBAVR+TB(NS,M)*RAKR
   10 TBAVL=TBAVL+TB(NS,M)*RAKL
      TBAVR=TBAVR/AVRAKR
      TBAVL=TBAVL/AVRAKL
      AVRAKR=AVRAKR/SANG
      AVRAKL=AVRAKL/PERLT
      TBEQ1=TE+(TBAVR-TE)*AVRAKR
      TBEQ2=TE+(TBAVL-TE)*AVRAKL
C     ...............................................................
C
      ENTRY SIMLA2(TI,TWI,TLI,NUI,TETAI,TBEQ1,TBEQ2)
   20 CO1=1.+(TBEQ1-TI)/(TWI-TI)
      CO2=1.+(TBEQ2-TI)/(TLI-TI)
      IF(ISIMPL.EQ.2)GOTO 1111
      CO1=1.
      CO2=1.
 1111 CONTINUE
      NUI=NUI/CO1
      TETAI=TETAI*CO2
      TWI=TI+(TWI-TI)*CO1
      TLI=TI+(TLI-TI)*CO2
      RETURN
      END
C
C
C
C
      FUNCTION SMFUN1(RHOI,ETAI,DETOT,PROV,I,KVIA ,REAI,DAI,SQ8LIA,RO,
     *G,CS)
C-----------------------------------------------------------------------
C     FUNCTION SMFUN1 EVALUATES SQRT(LAMBDA/8) FOR THE SMOOTH REGION OF
C     CORNER SUBCHANNELS (SECOND CALCULATION STEP) .
C
      COMMON/ANG1/R2(30),ALFA(30)/COLAM2/COLAMA
      BETA= RO/R2(I)
      G=(G*2.-8.1815+1.25*BETA)/(1.+BETA)
      IF(KVIA.EQ.1)GOTO 3
C     ...............................................................
C     AFTER THE FIRST ITERATION IN RECANG
C
      SMFUN1=(2.5*ALOG((R2(I)-RO)/DAI*REAI/SQ8LIA)-G)*CS+5.5*COLAMA
      RETURN
C     ...............................................................
C     AT THE FIRST ITERATION IN RECANG
C
    3 UAST2=SQRT((1.-BETA**2)/(1.-ALFA(I)))*PROV/(DETOT*SQRT(RHOI))
      SMFUN1=CS*(2.5*ALOG((R2(I)-RO)*RHOI/ETAI*UAST2)-G)+5.5*COLAMA
      RETURN
      END
C
C
C
C
      SUBROUTINE SUBDH(N,K,K1,NSTOT)
C-----------------------------------------------------------------------
C     SUBDH HALVES THE K.TH AXIAL SECTION IF CONVERGENCE PROBLEMS
C     OCCURRED IN IT
```

```
C
      COMMON/GRID2/YY(100,42,3)/GRID3/X(100)/HEA6/NPIN(42),JPIN(42,3)
C     ..................................................................
C     THE MAXIMUM VALUE OF THE AXIAL INDICES IS 100
C
      IF(N.LT.100)GOTO 2
      WRITE(6,3)
    3 FORMAT(1H1,5X,'NUMBER OF AXIAL SECTIONS BECOMES TOO BIG')
      STOP
C     ..................................................................
C
    2 CONTINUE
      NI=N-K
      N=N+1
      DO 10 I=1,NI
      II=N-I+1
      X(II+1)=X(II)
      X(II)=X(II-1)
      DO 1 NS=1,NSTOT
      NP=NPIN(NS)
      DO 1 M=1,NP
    1 YY(II,NS,M)=YY(II-1,NS,M)
   10 CONTINUE
      X(K+1)=(X(K)+X(K+2))*0.5
      DO 20 NS=1,NSTOT
      NP=NPIN(NS)
      DO 20 M=1,NP
   20 YY(K+1,NS,M)=YY(K,NS,M)
      K1=K
      WRITE(6,30)
   30 FORMAT(/130('*')//)
      RETURN
      END
C
C
C
C
      FUNCTION TIS(R1,R2,INU)
C-----------------------------------------------------------------------
C     TIS EVALUATES THE CORRECTION FACTOR FOR THE NUSSELT NUMBERS IN
C     THE REGION WHERE THE TEMPERATURE PROFILE IS NOT YET FULLY
C     DEVELOPED ( CASE OF TURBULENT FLOW )
C     INU=1 : FOR SMOOTH RODS
C     INU=2 : FOR ROUGH RODS
C     INU=3 : FOR SMOOTH LINER
C
      COMMON/INITL/X
      GOTO(1,2,3),INU
    1 TSI=0.86+0.3*(2.*(R2-R1)/X)**0.4*(R1/R2)**0.2
      GOTO 4
C
C     ******************************************************************
C     NO EQUATIONS ARE AVAILABLE AT THE MOMENT FOR THE INLET EFFECT IN
C     THE CASE OF ROUGHENED RODS: THUS, AT INU=2, TIS=1 IS IMPOSED
C     ******************************************************************
    2 TSI=1.
      GOTO 4
C
    3 TSI=0.86+0.54*(2.*(R2-R1)/X)**0.4*(1.+0.48*(R1/R2)**0.37)
C
C
    4 IF(TSI.LE.1.)TSI=1.
      TIS=TSI
      RETURN
      END
C
```

```
C
C
C
C
      FUNCTION TME(PBT,M1,M2,T1,T2,LAM1,LAM2,A1,A2,CTURB)
C-----------------------------------------------------------------------
C     TME EVALUATES THE MASS FLOW RATES PER UNIT LENGTH EXCHANGED DUE
C     TO TURBULENCE
C
      REAL M1,M2,LAM1,LAM2
      T12=(T1*M1+T2*M2)/(M1+M2)
      RHO12=RHO(PBT,T12)
      RHO1=RHO(PBT,T1)
      RHO2=RHO(PBT,T2)
      UAST12=(SQRT(LAM1*0.125)*M1/RHO1+SQRT(LAM2*0.125)*M2/RHO2)/(A1+A2)
      TME=CTURB*RHO12*UAST12
      RETURN
      END
C
C
C
C
      FUNCTION TNU(TW,TL,ITYP,PERL,PIG,RTIP)
C     ------------------------------------------------------------------
C     TNU EVALUATES THE TEMPERATURE AT WHICH REYNOLDS NUMBERS MUST
C     COMPUTED FOR THE CALCULATION OF LAMINAR FRICTION FACTORS
C
      LPIG=ITYP**2-ITYP
      PHR=RTIP*PIG/LPIG*2.
      TNU=(TL*PERL+TW*PHR)/(PERL+PHR)
      RETURN
      END
C
C
C
C
      FUNCTION TUBENU(REI,PRI)
C-----------------------------------------------------------------------
C     TUBENU EVALUATES THE NUSSELT NUMBER OF A TUBE WITH THE SAME REYNOL
C     AND PRANDTL NUMBERS AS THE ANNULAR SECTION WHOSE CROSS SECTIONAL F
C     AREA IS EQUAL TO THE ACTUAL AREA ( TURBULENT FLOW, SMOOTH RODS )
C
      A=1.07+900./REI-0.63/(1.+10.*PRI)
      FTU=1./(1.82*ALOG10(REI)-1.64)**2
      TUBENU=FTU*0.125*REI*PRI/(A+12.7*SQRT(FTU*0.125)*(PRI**(2./3.)-1.)
     *)
      RETURN
      END
      FUNCTION TURBWC(CTUB,E,PRAD,D,W,C,GAMMA,A1,A2,DE1,DE2,EM1)
C-----------------------------------------------------------------------
C     TURBWC EVALUATES THE GEOMETRIC CONSTANTS FOR THE TURBULENT
C     EXCHANGE BETWEEN THE TWO PORTIONS OF THE WALL SUBCHANNELS
C
      SINGAM=SIN(GAMMA)
      COSGAM=COS(GAMMA)
      PERSEP=PRAD-0.5*D
      Z=W-D*0.5
      EM2=C*0.5-EM1
      ZWC=EM2/SQRT(3.)
      A3=EM2*ZWC*0.5
      D3=D**3
      C2=C**2
      E2=E**2
      Z2=Z**2
      YB3=C*0.5-EM2/3.
      XB3=Z-ZWC/3.
```

```
      YB1=(0.25*(C2*(C.5*Z-E/3.)+D3*(SINGAM-1.)/6.)-YB3*A3)/A1
      XB1=(0.25*(C*(Z2-E2/3.)-D3*COSGAM)-XB3*A3)/A1
      YB2=(E*C2-D3*SINGAM*C.5)/(12.*A2)
      XB2=(E2*C-D3*(1.-COSGAM)*C.5)/(12.*A2)
      DE12=(A1+A2)/(A1/DE1+A2/DE2)
      DELTA=SQRT((YB1-YB2)**2+(XB1-XB2)**2)
      TURBWC=0.05*CTU3*PERSEP/DELTA*DE12
      RETURN
      END
C
C
C
C
      FUNCTION TWCTEP(QRMDAR,TW)
C-----------------------------------------------------------------------
C     TWCTEP CORRECTS THE COMPUTED ROD TEMPERATURE TO TAKE INTO ACCOUNT
C     THE POSITION OF THE THERMOCOUPLES INSIDE THE CANNING
C
      COMMON/DATKM/C1(7),C2(7)/INPAR/IPA
      D1=C1(IPA)
      D2=C2(IPA)
      TWCTEP=(-D1+SQRT(D1**2+2.*D2*(D1*TW+0.5*D2*TW**2+QRMDAR)))/D2
      RETURN
      END
C
C
C
C
      FUNCTION TWFUN(NRODS,NSTOT,PIG,AAC,AAA)
C-----------------------------------------------------------------------
C     TWFUN EVALUATES AN AVERAGE VALUE FOR ROD TEMPERATURES
C
      COMMON/IND3/NTYP(42)/HEA6/NPIN(42),JPIN(42,3)/SUB1/ASCH(42,3)
     1       /SUB22/TW(42,3)
      SANG=0.
      TWTIPA=0.
      DO 10 NS=1,NSTOT
      NP=NPIN(NS)
      ITYP=NTYP(NS)
      DO 10 M=1,NP
      GOTO(1,2,3),ITYP
    1 ANG=PIG/6.*ASCH(NS,M)/AAC
      GOTO 4
    2 ANG=PIG*0.25
      GOTO 4
    3 ANG=PIG/6.*ASCH(NS,1)/AAA
    4 SANG=SANG+ANG
      TWTIPA=TWTIPA+TW(NS,M)*ANG
   10 CONTINUE
      TWFUN=TWTIPA/SANG
      RETURN
      END
C
C
C
C
      SUBROUTINE TAU(I,AI,P,ALFA,D,W,RH,DET,PROV,IRH,DAI,DBI,PAI,F,
     *RHPL,TWI,TE,ITTEMP,QPLUS,ETAA,RHOA,ETAB,RHOB,ETAIW,RHOIW,BETA,EM1,
     *XC1,XC2,T1,*,CS)
C-----------------------------------------------------------------------
C     SUBROUTINE TAU EVALUATES POINTS OF THE LINE F=F(P) (F=0 FOR POINTS
C     ON THE TAU=0 LINE).
C
       COMMON/CALAM1/COLAMB/COLAM2/COLAMA/MART/ITCORR/REC1/PVERT(90)
     1       ,PRAD(90)/REC2/E(90)
C
```

```
      PVERT(I)=P*D*0.5
      PRAD(I)=PVERT(I)/COS(BETA)
      E(I)=PVERT(I) *TAN(BETA)
      IF(I.GT.1)GOTO 1
C     ................................................................
C     FIRST SUB-SUBCHANNEL
C
      ZAI=W-0.5*D-PVERT(1)
      DELTAE=E(1)
      DBI=2.*E(1)*P/ALFA-D
      GOTO 2
C     ................................................................
C     FOR THE I.TH SUB-SUBCHANNEL, IF I>1
C
    1 CONTINUE
      WW=W-((E(I)+E(I-1))*0.5-EM1)*XC1
      ZAI=WW-0.5*(D+PVERT(I)+PVERT(I-1))
      DELTAE=E(I)-E(I-1)
      DBI=2.*(PVERT(I-1)*TAN(BETA)-E(I-1))*P/ALFA-D
C     ................................................................
C     FOR ALL SUB-SUBCHANNELS
C
    2 DAI=4.*ZAI/XC2
      PAI=DELTAE*XC2
      ZBI=0.5*(SQRT(D**2+D*DBI)-D)
C
      IF(DAI.GT.0. .AND. DBI.GT.0.)GOTO 100
      WRITE(6,22)I,DAI,DBI,P,E(I),E(I-1),PVERT(I),PVERT(I-1),ITCORR
   22 FORMAT(5X,'STOP IN TAU : I=',I5,5X,'DAI=',E15.5,5X,'DBI=',E15.5
     1/5X,'P=',E15.5,5X,'E(I)=',E15.5,5X,'E(I-1)=',E15.5/5X,'PVERT(I)=',
     2E15.5,5X,'PVERT(I-1)=',E15.5,5X,'ITCORR=',I5)
      RETURN 1
C
  100 CONTINUE
      F0=2.5*ALOG(ZAI*PROV*SQRT(RHOA *DAI/DET**3)/ETAA )*CS+5.5*COLAMA
      IF(IRH.EQ.2)GOTO 3
C
C     IN THE CASE OF SMOOTH RODS
C
      F01=SQRT(DBI*RHOA/(DAI*RHOB))*(2.5*ALOG(ZBI*PROV*SQRT(RHOB*DBI/DET
     ***3)/ETAB)+5.5)
      GOTO 4
C
C     IN THE CASE OF ROUGHENED RODS
C
    3 HPLUSB=RH/DET*PROV/ETAB*SQRT(DBI/DET*RHOB)
      HPLUSW=RH*DET   *PROV/ETAIW*SQRT(DBI/DET*RHOIW)
      YDH=(SQRT(D**2+D*DBI)-D)*0.5/RH
      RHPL=RHPLUS(HPLUSB,TWI,TE,QPLUS,HPLUSW,T1,YDH)
      F01=SQRT(DBI*RHOA/(DAI*RHOB))*(2.5*ALOG(ZBI/RH)+RHPL)
C
C
    4 F=F0-F01
      RETURN
      END
C
C
C
C
      FUNCTION TBFUN(NSTR,NSICT)
C-----------------------------------------------------------------------
C     TBFUN EVALUATES THE MEAN LINER TEMPERATURE IN THE AXIAL SECTION
C
      COMMON/SHROUD/TLINER(18,2)/CPAR3/PERL(3)/IND3/NTYP(42)
     1        /HEA6/NPIN(42),JPIN(42,3)/SUB1/ASCH(42,3)/GEOO/ACH(3)
C
```

```
      NSTR1=NSTR+1                                                      001105
      TBPIPA=0.                                                         001106
      PERLT=0.                                                          001107
      DO 10 NS=NSTR1,NSTOT                                              001108
      NTYPNS=NTYP(NS)                                                   001109
      NP=NPIN(NS)                                                       001110
      DO 10 M=1,NP                                                      001111
      PERLSC=PERL(NTYPNS)*ASCH(NS,M)/ACH(NTYPNS)                        001112
      PERLT=PERLT+PERLSC                                                001113
   10 TBPIPA=TBPIPA+TLINER(NS-NSTR,M)*PERLSC                            001114
      TBFUN=TBPIPA/PERLT                                                001115
      RETURN                                                            001116
      END                                                               001117
C                                                                       001117
C                                                                       001117
C                                                                       001117
C                                                                       001117
      SUBROUTINE TMPUN(NSTOT,NSTR,TE,PE,PEBAR,TE1,PE1,PE1BAR,           001118
     *INDPR,MFLOW,IPAST,IPAEND,IREAC1,XLAM1,STLEN,*)                    001119
C                                                                       001120
C     TMPUN PUNCHS THE CARDS WHICH MUST BE CHANGED TO START A NEW       001121
C     CALCULATION STEP (PUNCHING UNITY=1)                               001122
C     THE ACTUAL CALCULATION STEP IS STOPPED BECAUSE THE ALLOWED        001123
C     CALCULATION TIME TIMEPL HAS BEEN ELAPSED  OR BECAUSE THE END      001124
C     OF THE AXIAL PORTION IPAEND (IPAEND<7) HAS BEEN OVERTAKEN         001125
C     ----------------------------------------------------------------- 001126
      REAL MFLOW,MI,MSCH1,MSCWC1                                        001127
      DIMENSION XLAM1(7)                                                001128
      COMMON/GEN3/MI(42)/GEN4/TEMP(42)/SUB6/TSCH1(42,3)/SUB8/MSCH1(42,3)001129
     1       /WCSE2/MSCWC1(18,2,2)/WCSE5/TSCWC1(18,2,2)/IND3/NTYP(42)   001130
     2       /HEA6/NPIN(42),JPIN(42,3)                                  001131
C                                                                       001132
C     10TH CARD:                                                        001133
      IF(INDPR.EQ.1)GOTO 1                                              001134
      PE=PEBAR                                                          001135
      PE1=PE1BAR                                                        001136
    1 WRITE(1,2)PE,PE1,TE,TE1,MFLOW,(XLAM1(I),I=1,3)                    001137
    2 FORMAT(8F10.5)                                                    001138
C                                                                       001139
C     13TH CARD                                                         001140
      WRITE(1,3)IPAST,IPAEND,IREAC1                                     001141
    3 FORMAT(3I10)                                                      001142
C                                                                       001143
C     14TH CARD                                                         001144
      WRITE(1,2)STLEN                                                   001145
C                                                                       001146
C     LAST BLOCK OF CARDS                                               001147
      WRITE(1,4)(MI(NS),TEMP(NS),NS=1,NSTOT)                            001148
      DO 5 NS=1,NSTOT                                                   001149
      NSW=NS-NSTR                                                       001150
      NP=NPIN(NS)                                                       001151
      WRITE(1,4)(MSCH1(NS,M),TSCH1(NS,M),M=1,NP)                        001152
      IF(NTYP(NS).EQ.2)WRITE(1,4)((MSCWC1(NSW,M,JWC),TSCWC1(NSW,M,JWC), 001153
     *                  JWC=1,2),M=1,2)                                 001154
    4 FORMAT(8F10.5)                                                    001155
    5 CONTINUE                                                          001156
      RETURN 1                                                          001157
      END                                                               001158
C                                                                       001158
C                                                                       001158
C                                                                       001158
C                                                                       001159
      SUBROUTINE TRICAL(K,NS,NN,IRH,PROV,P3,    RH,A,DE,MEC,AT,DET,DETOT,001159
     *H1,ALFA, H,M,PR1,PR2,SQDPG,TE,SUR,D,AMT,DDDD,ATSCH,*,C)           001160
C-----------------------------------------------------------------------001161
C     SUBROUTINE TRICAL CALCULATES FRICTION FACTORS AND APPROXIMATE     001162
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C     OUTLET MASS FLOW RATES AND TEMPERATURES FOR CENTRAL SUBCHANNELS
C
      REAL MEC,LAMSCH,KAPPA,LAMLAM,MSCH
      COMMON/SUB5/LAMSCH(42,3)/CEN1/C(45)/SUB1/ASCH(42,3)/INPAR/IPA
     1      /SUB6/TSCH1(42,3)/CORR1/SIGMAI(42,3),PHII(42,3)
     2      /LAMIN5/RTIP(7)/DAT/PIG/SUB23/HPLUSB(42,3),HPLUSW(42,3)
     3      ,SPLUS(42,3),PRB  (42,3),YODH(42,3)/HEA5/QQ(42,3)
     4      /WSSCHO/TBSSC1(42,3),TWSSC1(42,3),TBSSC2(42,3),TWSSC2(42,3)
     5      /LAMINO/I2TIP(42,3)/LAMIN1/AKAPPA(42) /LAMIN2/FATIP(3),
     6      FDTIP(3)/LAMIN3/F1ATIP(42),F1DTIP(42)/LAMIN4/F2ATIP(42,3),
     7      F2DTIP(42,3)/LAMIN7/F1PTIP/GEN2/ACHA(42)/SUB2/TSCH(42,3),
     8      MSCH(42,3) /SUB22/TW(42,3)/MART/ITCORR/LAMIN9/I3TIP(42,3)
      DIMENSION A(30),DE(30),MEC(30)
C
      IF(M.GT.1)GOTO 2998
      F1ATIP(NS)=0.
      F1PTIP=0.
 2998 CONTINUE
      I2TIP(NS,M)=I3TIP(NS,M)
      IF(                   I2TIP(NS,M).EQ.1)GOTO 2999
C     ..............................................................
C     ..............................................................
C     I3TIP#1: THE TURBULENT CALCULATION MUST BE PERFORMED
C
      TWIAV=0.
      AMT=0.
      TT=0.
      DDDD=0.
      HPLUS1=0.
      HPLUS2=0.
C     ..............................................................
C     SUB-SUBCHANNEL CALCULATIONS ( I = SUB-SUBCHANNEL INDEX )
C
      DO 1 I=1,NN
      AM1=MEC(I)
      AA=A(I)
      DD=DE(I)
      GG=G(I)
      CALL CEWA(K,NS,IRH,PFCV,F8,RH,AA,DD,GG,AM1,DETOT,H1,ALFA,I,M,H,PR1
     *,PR2,SQDPG,AMT,TT,DDDD,TE,SUR,1,III,HPLUS1,HPLUS2,TSCH1(NS,M),
     *SIGMAI(NS,M),PHII(NS,M),&777,D,TWI,TI,C)
      TWIAV=TWIAV+TWI*ALFA
      TBSSC2(NS ,M  )=TI
      TWSSC2( NS,M  )=TWI
      IF (I.GT.1) GOTO 1
      TBSSC1( NS,M  )=TI
      TWSSC1( NS,M  )=TWI
    1 CONTINUE
C     ..............................................................
C     ALL SUB-SUBCHANNELS HAVE BEEN COMPUTED; AVERAGE SUB-SUBCHANNEL
C     VARIABLES WILL BE NOW COMPUTED
C
       TWIAV=TWIAV*12./PIG
       ATSCH=TT/AMT
      RHOT=RHO(PB,ATSCH)
      LAMSCH(NS,M)=((AT/DDDD)**2)*2.*DET*RHOT/H
      I2TIP(NS,M)=0
      F2ATIP(NS,M)=1.
      F2DTIP(NS,M)=1.
      IF(I3TIP(NS,M).EQ.2)GOTO 3000
C     ..............................................................
C     I3TIP=3: THE LAMINAR CALCULATION MUST BE ALSO PERFORMED
C
      IF(ITCORR.GT.1)GOTO 2999
      MSCH(NS,M)=AMT*ASCH(NS,M)/AT
      TSCH(NS,M)=ATSCH
```

```
      TW(NS,M)=TWIAV
C     .................................................................
C     .................................................................
C     FOR I3TIP=1 OR I3TIP=3
C
 2999 CONTINUE
      RELA=RELAM(ASCH(NS,M)*FATIP(1),DET*FDTIP(1),PB,TSCH(NS,M),TW(NS,M)
     &             ,MSCH(NS,M),0.,1,0.,1.)
      LAMLAM=AKAPPA(NS)/RELA
      ROCEN=C*SQRT(SQRT(3.)/(2.*PIG))
      CALL ENTRER(K,1,1,RTIP(IFA),ROCEN,R2CEN,NS,III,M,DET*FDTIP(1),
     *              ASCH(NS,M)*FATIP(1),MSCH(NS,M),PB,TSCH(NS,M),LAMLAM)
      IF(                   I2TIP(NS,M).EQ.1)GOTO 2997
C     .................................................................
C     I3TIP=3: SAGAPO DECIDES WHETHER THE FLOW IS LAMINAR OR TURBULENT
C
      IF(LAMSCH(NS,M).GT.LAMLAM)GOTO 3000
C     THE FLOW IS LAMINAR
C
 2997 CONTINUE
      LAMSCH(NS,M)=LAMLAM
      DDDD=AT*FATIP(1)/SQRT(LAMLAM*H/(2.*DET*FDTIP(1)*
     *RHO(PB,TSCH(NS,M))))
      AMT=MSCH(NS,M)*AT/ASCH(NS,M)
      ATSCH=TSCH(NS,M)
      I2TIP(NS,M)=1
      F2ATIP(NS,M)=FATIP(1)
      F2DTIP(NS,M)=FDTIP(1)
      HPLUSB(NS,M)=1.
      HPLUSW(NS,M)=1.
      QPLUS(NS,M)=1.
      PRB  (NS,M)=1.
      YODH(NS,M)=1.
      TBSSC1( NS,M  )=TSCH(NS,M)
      TBSSC2(NS ,M  )=TSCH(NS,M)
      TWSSC1( NS,M  )=TW(NS,M)
      TWSSC2( NS,M  )=TW(NS,M)
C     .................................................................
C     FOR LAMINAR AND FOR TURBULENT FLOW ( HERE COMES THE CALCULATION
C     IN THE CASE OF TURBULENT FLOW )
C
 3000 CONTINUE
      F1ATIP(NS)=F1ATIP(NS)+ASCH(NS,M)/ACHA(NS)*F2ATIP(NS,M)
       F1PTIP=F1PTIP+ASCH(NS,M)/ACHA(NS) *F2ATIP(NS,M)/F2DTIP(NS,M)
      F1DTIP(NS)=F1ATIP(NS)/F1PTIP
      IF(IRH.EQ.1 .OR.     I2TIP(NS,M  ).EQ.1)RETURN
C     .................................................................
C     FOR TURBULENT FLOW AND ROUGHENED RODS
C
      HPLUSB(NS,M)=HPLUS1/AT
      HPLUSW(NS,M)=HPLUS2/AT
      CPT=CP(PB,ATSCH)
      QPLUS(NS,M)=QC(NS,M)*AT/(SUR*AMT*CPT*(TE+273.16))
      PRB  (NS,M)=ETA(PB,ATSCH)*CPT/KAPPA(PB,ATSCH)
      YODH(NS,M)=0.5*(SQRT(D**2+DET*D)-D)/RH
      RETURN
  777 RETURN 1
      END
C
C
C
C
      SUBROUTINE TLINE(I,AI,ITTEMP,NS,K,ALFA,D,W,RH,DET,PROV,IRH,CAI,DBI
     *,AAI,ABI,RHPL,G,TWI,TE,QPLUS,ETAA,RHOA,ETAB,RHOB,ETAIW,RHOIW,ANGT,
     *EM1,XC1,XC2,T1,*,CS)
C-----------------------------------------------------------------------
```

```
C      SUBROUTINE TLINE EVALUATES THE POSITION OF THE TAU=0 LINE FOR EACH
C      "WALL-TYPE" SUB-SUBCHANNEL
C
       COMMON/REC1/      PVERT(90),PRAD(90)/REC2/E(90)/REC3/P(90)
       NNN=20
       SSCHFA=19.0986*ALFA
       XIRH=IRH
       I1=I-1
 8400  IF(I.GT.1)GOTO 1
C      ..................................................................
C      STARTING POINT (F(P),P) FOR THE 1.ST SUB-SUBCHANNEL
C
       P1=1.0001-(W/D-1.)*0.39*(2.-XIRH)
       XX=0.39
       GOTO 2
C      ..................................................................
C      STARTING POINT (F(P),P) FOR THE I.TH SUB-SUBCHANNEL  ( I>1 )
C
     1 P1=P(I1) +0.08*(W/D-1.)*SSCHFA
       XX=-0.04*SSCHFA
C      ..................................................................
C      RESEARCH OF TWO CONSECUTIVE POINTS (F(P),P) AT WHICH F= FAI-FBI
C      HAS DIFFERENT SIGNS ( ITERATION LOOP ITAU1 )
C
     2 CONTINUE
       DO 4 ITAU1=1,NNN
       P2=P1+XX*(W/D-1.)
       CALL TAU(I,AI,P2,ALFA,D,W,RH,DET,PROV,IRH,DAI,DBI,PAI,F2,RHPL,TWI,
      *TE,ITTEMP,QPLUS,ETAA,RHOA,ETAB,RHOB,ETAIW,RHOIW,ANGT,EM1,XC1,XC2,
      2T1,&8500,CS)
       IF(ITAU1.EQ.1)GOTO 3
       IF(F1*F2.LE.0.)GOTO 6
     3 F1=F2
     4 P1=P2
C      ..................................................................
C      TWO CONSECUTIVE POINTS AT WHICH F =FAI-FBI HAS  DIFFERENT SIGNS
C      HAVE BEEN NOT FOUND : IT WILL BE TRIED TO START CLOSER TO THE RODS
C      ( IF IT HAS NOT YET BEEN TRIED AND IF IT IS I>1 )
C
       WRITE(6,5)I,ITTEMP,NS,K
     5 FORMAT(5X,'STOP IN TLINE IN LOOP ITAU1    FOR SUBCH.',I3,2X,'(ITTE
      *MP=',I2,')OF CHANNEL',I4,2X,'(AXIAL SECTION NR.',I4,')'/130('*'))
       IF(NNN.EQ.40)RETURN 1
       NNN=40
       IF(I.GT.2)I1=I-2
       GOTO 8400
C      ..................................................................
C      TWO CONSECUTIVE POINTS (F(P),P) HAVE BEEN FOUND, AT WHICH
C      F= FAI-FBI HAS  DIFFERENT SIGNS; THE VALUE OF P AT WHICH F=0 WILL
C      BE NOW RESEARCHED BY MEANS OF THE TANGENT METHOD ( ITERATION LOOP
C      ITAU2 )
C
     6 CONTINUE
       DO 8  ITAU2=1,30
       PP=P1-F1*(P2-P1)/(F2-F1)
       CALL TAU(I,AI,PP,ALFA,D,W,RH,DET,PROV,IRH,DAI,DBI,PAI,F ,RHPL,TWI,
      1TE,ITTEMP,QPLUS,ETAA,RHOA,ETAB,RHOB,ETAIW,RHOIW,ANGT,EM1,XC1,XC2,
      2T1,&8500,CS)
       IF(ABS(PP/P1-1.).LE.1.E-04 .OR. ABS(PP/P2-1.).LE.1.E-04) GOTO 10
       IF(F*F1.GE.0.)GOTO 7
       F2=F
       P2=PP
       GOTO 8
     7 F1=F
       P1=PP
     8 CONTINUE
```

```
C      ..................................................................
C      PROBLEMS IN FINDING THE POSITION OF THE TAU=0 LINE
C
       WRITE(6,9)I,ITTEMP,NS,K
     9 FORMAT(5X,'STOP  IN TLINE IN LOOP ITAU2    FOR SUBCH.',I3,2X,'(ITT
      *EMP=',I2,')OF CHANNEL',I4,2X,'(AXIAL SECTION NR.',I4,')')
  8500 RETURN 1
C      ..................................................................
C      THE POSITION OF THE TAU=0 LINE HAS BEEN FOUND FOR SUB-SUBCHANNEL I
C      SOME GEOMETRIC PARAMETERS WILL BE NOW COMPUTED
C
C
    10 PBI=ALFA*D*0.5
       AAI=CAI*PAI*0.25
       ABI=CBI*PBI*0.25
       P(I)=PP
       EPS=SQRT(1.+CBI/D)
       G=GSTAR(EPS)
       RETURN
       END
C
C
C
C
        SUBROUTINE WALLTE(K,NSTCT,NSTR,RH,SUR,D,PIG,TE,PBT,*,RTI)
C-----------------------------------------------------------------------
C      WALLTE ORGANIZES THE CALCULATION OF THE PIN AND OF THE SHROUD
C      TEMPERATURES
C
       REAL LAMSCH,LAMWC,LAMB,MSCH,MAWC
       COMMON/FEA5/QQ(42,3)/FEA6/NPIN(42),JPIN(42,3)/GEN5/DE(42)
     0        /LAMIN4/F2ATIP(42,3),F2DTIP(42,3)
     1        /SUB1/ASCH(42,3)/SUB2/TSCH(42,3),MSCH(42,3)
     2        /SUB3/ADAB(18,2),DETB(18,2)/SUB4/LAMB(18,2)
     3        /SUB5/LAMSCH(42,3)/SUB22/TW(42,3)/GRID2/YY(100,42,3)
     4        /WCSE1/DEWC(18,2,2),PHWC(18,2,2)/WCSE3/LAMWC(18,2,2)
     5        /WCSE7/MAWC(18,2,2)/WCSE8/ASCHWC(18,2,2)/WCSE9/TAVWC(18,2,2)
     6        /WCSE12/TWWC(18,2,2)/IND3/NTYP(42)/QPAR3/PERL(3)/GEOD/ACH(3)
     7        /WACO1/XMSCHB(18,2),XMSCHA(18,2)/SHROUD/TLINER(18,2)
     8        /PARTB/TEMPB(42,3),XMASSB(42,3),YDH(42,3)/EXAVTW/IEXAV
     9        /SUB21/TSCHA(18,2),TSCHB(18,2)/QPAR1/QDEV/IROSMO/IRH
C      ..................................................................
C      I=CHANNEL INDEX
C
       DO 11 I=1,NSTCT
       NP=NPIN(I)
       ITYP=NTYP(I)
       II=I-NSTR
C      ..................................................................
C      M=SUBCGANNEL INDEX
C
       DO 9 M=1,NP
       TW(I,M)=TSCH(I,M)
       QA=QQ(I,M)/SUR*QDEV
       GOTO(1,2,7),ITYP
C      ..................................................................
C--A) CENTRAL SUBCHANNELS
C
     1 CALL RTI (PBT,TSCH(I,M),MSCH(I,M),DE(I),ASCH(I,M),1.,LAMSCH(I,M),
      1         YY(K,I,M),QA,FACHE,TE,RH,I,II,M,JPIN(I,M),TW(I,M),1.,1,
      2   DE(I),D,YDH(I,M),&8500,F2ATIP(I,M),F2DTIP(I,M))
       TEMPB(I,M)=TSCH(I,M)
       XMASSB(I,M)=MSCH(I,M)
       GOTO 9
C      ..................................................................
C--B) WALL SUBCHANNELS
```

```
C
    2 TW(I,M)=0.
      DO 5 JWC=1,2
       TWWC(II,M,JWC)=TSCH(I,M)
      GOTO(3,4),JWC
C
C   -1-WALL TYPE PART
C
    3 RU1DRU=XMSCHB(II,M)*ADAB(II,M)/MAWC(II,M,1)
      CALL RTI (PBT,TAVWC(II,M,1),MAWC(II,M,1),DETB(II,M),ASCHWC(II,M,1)
     1         ,ADAB(II,M),LAMB(II,M),YY(K,I,M),QA,FACHE,TE,RH,I,II,M,
     2         JPIN(I,M),TWWC(II,M,1),RU1DRU,2,DEWC(II,M,1),D,XXXX,&8500
     3,1.,1.)
      GOTO 5
C
C   -2-CENTRAL TYPE PART
C
    4 CALL RTI (PBT,TAVWC(II,M,2),MAWC(II,M,2),DEWC(II,M,2),ASCHWC(II,M,
     1         2),1.,LAMWC(II,M,2),YY(K,I,M),QA,FACHE,TE,RH,I,II,M,JPIN
     2         (I,M),TWWC(II,M,2),1.,1,DEWC(II,M,2),D,XXXX,&8500,1.,1.)
C
    5 TW(I,M)=TW(I,M)+PHWC(II,M,JWC)*TWWC(II,M,JWC)
    6 CONTINUE
      TW(I,M)=TW(I,M)*4./(D*PIG)
      XMASSB(I,M)=XMSCHB(II,M)+MAWC(II,M,2)
      TEMPB(I,M)=(XMSCHB(II,M)*TSCHB(II,M)+MAWC(II,M,2)*TAVWC(II,M,2))/
     /XMASSB(I,M)
      IF (IRH.EQ.2)
     *YDH(I,M)=0.5*(SQRT(D**2+16./PIG*ASCH(I,M))-D)/RH
      GOTO 9
C     ...................................................................
C--C) CORNER CHANNELS
C
    7 RU1DRU=XMSCHB(II,1)*ADAB(II,1)/MSCH(I,1)
      CALL RTI (PBT,TSCH(I,1),MSCH(I,1),DETB(II,1),ASCH(I,1),ADAB(II,1),
     1         LAMB(II,1),YY(K,I,1),QA,FACHE,TE,RH,I,II,1,JPIN(I,1),
     2          TW(I,1),RU1DRU,3,DE(I),D,YDH(I,M),&8500,F2ATIP(I,1),
     3         F2DTIP(I,1))
      TEMPB(I,1)=TSCHB(II,1)
      XMASSB(I,1)=XMSCHB(II,1)
    9 CONTINUE
   11 CONTINUE
C     ...................................................................
C     IF AN AVERAGE VALUE IS DESIRED FOR THE PIN AND THE SHROUD
C     TEMPERATURES OF THE EXTERNAL CHANNELS
C
      IF(IEXAV.EQ.1)RETURN
      PERLT=0.
      PERRT=0.
      TLM=0.
      TWM=0.
      NSTR1=NSTR+1
      DO 20 I=NSTR1,NSTOT
      ITYP=NTYP(I)
      NP=NPIN(I)
      DO 20 M=1,NP
      PERLSC=PERL(ITYP)*ASCH(I,M)/ACH(ITYP)
      PERLT=PERLT+PERLSC
      PERRSC=1./NTYP(I)
      PERRT=PERRT+PERRSC
      TLM=TLM+TLINER(I-NSTR,M)*PERLSC
   20 TWM=TWM+TW(I,M)*PERRSC
      TLM=TLM/PERLT
      TWM=TWM/PERRT
      DO 30 I=NSTR1,NSTOT
      NP=NPIN(I)
```

```
      DO 30 M=1,NP
      TLINER(I-NSTR,M)=TLM
   30 TW(I,M)=TWM
      RETURN
 8500 RETURN 1
      END
C
C
C
C
      SUBROUTINE ANGCAL(K,NS,N,IRH,PRCV,PB,    RH,H1,ALFA,A,AT,DET,DETOT,
     *D,W,NSTR,H,PR1,PR2,SQEPG,TE,SUP,              AMT,DDDD,*, AMA,AMB)
C-----------------------------------------------------------------------
C     SUBROUTINE ANGCAL CALCULATES FRICTION FACTORS AND APPROXIMATE
C     OUTLET MASS FLOW RATES AND TEMPERATURES FOR CORNER CHANNELS
C
      REAL LAMSCH,LAMB,MSCH1,KAPPA,MSCH,LAMLAM
C
      DIMENSION A(30)
C
      COMMON /WACO1/  XMSCHE(18,2),XMSCHA(18,2)
      COMMON /DAT/    PIG
      COMMON /ANG2/   PA(30)
      COMMON /SUB1/   ASCH(42,3)
      COMMON /SUB2/   TSCH(42,3),MSCH(42,3)
      COMMON /SUB3/   ALAB(18,2),DETE(18,2)
      COMMON /SUB4/   LAMB(18,2)
      COMMON /SUB5/   LAMSCH(42,3)
      COMMON /SUB6/   TSCH1(42,3)
      COMMON /SUB8/   MSCH1(42,3)
      COMMON /INPAR/  IPA
      COMMON /SUB22/  TW(42,3)
      COMMON /SUB23/  HPLUSB(42,3),HPLUSW(42,3),
     *                QPLUS(42,3),PRB(42,3),YODH(42,3)
      COMMON /MART/   ITCORP
      COMMON /FEA5/   QQ(42,3)
      COMMON /LAMIN0/ I2TIP(42,3)
      COMMON /LAMIN1/ AKAPPA(42)
      COMMON /LAMIN2/ FATIP(3),FDTIP(3)
      COMMON /LAMIN3/ F1ATIP(42),F1DTIP(42)
      COMMON /LAMIN4/ F2ATIP(42,3),F2DTIP(42,3)
      COMMON /LAMIN5/ RTIP(7)
      COMMON /LAMIN9/ I3TIP(42,3)
      COMMON /WSSCH1/ DELTIE( 18,2,90),DTIEAV(18,2)
      COMMON /REC1/   PVERT(90),PRAD(90)
      COMMON /REC2/   E(90)
      COMMON /REC3/   P(90)
      COMMON /WSSCH/T1SSC1(18,2),T2SSC1(18,2),T1SSC2(18,2),T2SSC2(18,2)
      COMMON/WSSCH0/TBSSC1(42,3),TWSSC1(42,3),T3SSC2(42,3),TWSSC2(42,3)
      COMMON /SHROUD/ TLINER(18,2)
      COMMON /GAAG1/  FCOPW1(2)
      COMMON /GAAG2/  FCOPW2(18,2)
C
C
C
      III=NS-NSTR
      FCOPW2(III,1)=FCOPW1(3)
      DTIEAV(III,1)=0.
      I2TIP(NS,1)=I3TIP(NS,1)
      IF(                     I2TIP(NS,1).EQ.1)GOTO 2999
C     ----------------------------------------------------------------
C
C     I3TIP#1: THE TURBULENT CALCULATION MUST BE PERFORMED
C
      TWIAV=0.
      CS=1.
```

```
      AMAI=MSCH1(NS,1)/AT
      ANGT=0.
      AMT=0.
      TT=0.
      AMB=0.
      TTB=0.
      SRAMIB=0.
      DDDDA=0.
      DDDDB=0.
      ATB=0.
      HPLUSB(NS,1)=0.
      HPLUSW(NS,1)=0.
      TI=TSCH1(NS,1)
      DEPA=DETOT
C
      DO 3 I=1,N
      AI=I
      ANGT=ANGT+ALFA
C*****FIRST STEP: EVALUATION OF THE TAU=0 LINE AS FOR WALL CHANNELS****
      CALL RECANG(I,AI,NS,K,1,IRH,ALFA,AMA1,TI,PB,D,W,RH,DETOT,PROV,DAI
     *,DBI,AAI,ABI,GG,SSSA,SSSB,AMTI,3,H1,H,PR1,PR2,SQDPG,1,TE,SUR,TWI,
     *AMAI,TAI,AMBI,TBI,III,TSCH1(NS,1),TSCH(NS,1),HPLUS1,HPLUS2,ANGT,0.
     *,0.,1.,&777,DEPA,CS)
C*****SECOND STEP: SUBCHANNELS DEFINED WITH RADII FROM ROD CENTER******
      AAI=A(I)-ABI
      DAI=4.*AAI/PA(I)
      TI1=TI
      TAI1=TAI
      TBI1=TBI
      TW1=TWI
      CS1=CS
      CALL RECANG(I,AI,NS,K,2,IRH,ALFA,AMA1,TI1,PB,D,W,RH,DETOT,PROV,DA
     *I,DBI,AAI,ABI,GG,SSSA,SSSB,AMTI,3,H1,H,PR1,PR2,SQDPG,1,TE,SUR,TW1,
     *AMAI,TAI1,AMBI,TBI1,III,TSCH1(NS,1),TSCH(NS,1),HPLUS1,HPLUS2,ANGT,
     *0.,0.,1.,&777,DEPA,CS1)
      TWIAV=TWIAV+TW1*ALFA
      DTIEAV(III,1)=DTIEAV(III,1)+DELTIE(III,1,I)*AMTI
      AMT=AMT+AMTI
      TT=TT+AMTI*TI1
      AMB=AMB+AMBI
      RAMIB=AMTI*ABI/(AAI+ABI)
      SRAMIB=SRAMIB+RAMIB
      TTB=TTB+RAMIB*TBI1
      DDDDA=DDDDA+SSSA
      DDDDB=DDDDB+SSSB
      DDDD=DDDDA+DDDDB
      ATB=ATB+ABI
      IF(IRH.EQ.1)GOTO 3
      HPLUSB(NS,1)=HPLUSB(NS,1)+HPLUS1*ABI
      HPLUSW(NS,1)=HPLUSW(NS,1)+HPLUS2*ABI
    3 CONTINUE
C
C
       TWIAV=TWIAV*12./PIG
      DTIEAV(III,1)=DTIEAV(III,1)/AMT
       ATSCH=TT/AMT
      RHOT=RHO(PB,ATSCH)
      LAMSCH(NS,1)=((AT/DDDD)**2        )*2.*DET*RHOT/H
      ADAB(III,1)=AT/ATB
      DETB(III,1)=48.*ATB/(PIG*D)
      AMA=AMT-AMB
      TSCHB=TTB/SRAMIB
      RHOBT=RHO(PB,TSCHB)
      LAMB(III,1)=((ATB/DDDDB)**2        )*2.*DETB(III,1)*RHOBT/H
      I2TIP(NS,1)=0
      FLATIP(NS)=1.
```

```
      F1DTIP(NS)=1.
      F2ATIP(NS,1)=1.
      F2DTIP(NS,1)=1.
      IF(I3TIP(NS,1).EQ.2)GOTO 3000
C     ----------------------------------------------------------------
C
C     I3TIP=3: THE LAMINAR CALCULATION MUST BE ALSO PERFORMED
C
      IF(ITCORR.GT.1)GOTO 2999
      MSCH(NS,1)=AMT*ASCH(NS,1)/AT
      TSCH(NS,1)=ATSCH
      TW(NS,1)=TWIAV
C     ----------------------------------------------------------------
C
C     FOR I3TIP=1 OR I3TIP=3
C
 2999 CONTINUE
      R1DR2L=1./SQRT(1.+12.*AT*FATIP(3)/(PIG*RTIP(IPA)**2))
      RELA=RELAM(ASCH(NS,1)*FATIP(3),DET*FDTIP(3),PB,TSCH(NS,1),TW(NS,1)
     &             ,MSCH(NS,1),TLINER(III,1),3,R1DR2L,1.)
      LAMLAM=AKAPPA(NS)/RELA
      R2COR=RTIP(IPA)/R1DR2L
      CALL ENTRFR(K,1,3,RTIP(IPA),R2COR,R2COR,NS,III,1,DET*FDTIP(3),
     *              ASCH(NS,1)*FATIP(3),MSCH(NS,1),PB,TSCH(NS,1),LAMLAM)
      IF(                    I2TIP(NS,1).EQ.1)GOTO 2997
C     ----------------------------------------------------------------
C
C     I3TIP=3: SAGAPO DECIDES WHETHER THE FLOW IS LAMINAR OR TURBULENT
C
      IF(LAMSCH(NS,1).GT.LAMLAM)GOTO 3000
C     ----------------------------------------------------------------
C
C     THE FLOW IS LAMINAR
C
 2997 CONTINUE
      LAMSCH(NS,1)=LAMLAM
      DCDD=AT*FATIP(3)/SQRT(LAMLAM*H/(2.*DET*FDTIP(3)*
     *RHO(PB,TSCH(NS,1))))
      AMT=MSCH(NS,1)*AT/ASCH(NS,1)
      ATSCH=TSCH(NS,1)
      I2TIP(NS,1)=1
      F1ATIP(NS)=FATIP(3)
      F1DTIP(NS)=FDTIP(3)
      F2ATIP(NS,1)=FATIP(3)
      F2DTIP(NS,1)=FDTIP(3)
      HPLUSB(NS,1)=1.
      HPLUSW(NS,1)=1.
      QPLUS(NS,1)=1.
      PRB(NS,1)  =1.
      YODH(NS,1)=1.
      TBSSC1( NS,1  )=TSCH(NS,1   )
      T1SSC1(III,1  )=TSCH(NS,1   )
      T2SSC1(III,1  )=TSCH(NS,1   )
      TWSSC1( NS,1  )=TW(NS,1   )
      TBSSC2(NS ,1  )=TSCH(NS,1   )
      T1SSC2(III,1  )=TSCH(NS,1   )
      T2SSC2(III,1  )=TSCH(NS,1   )
      TWSSC2( NS,1  )=TW(NS,1   )
      ADAB(III,1)=2.
      AMA=AMT*0.5
      AMB=AMA
 3000 CONTINUE
C     ----------------------------------------------------------------
C
C     THE FLOW IS TURBULENT
C
```

```
      IF(IRH.EQ.1)RETURN
      IF(             I2TIP(NS,1  ).EQ.1)RETURN
C
      HPLUSB(NS,1)=HPLUSB(NS,1)/ATB
      HPLUSW(NS,1)=HPLUSW(NS,1)/ATB
      CPTB=CP(PB,TSCHB)
      QPLUS(NS,1)=QQ(NS,1)*ATB/(SUR*AMB*CPTB*(TE+273.16))
      PRB(NS,1)  =ETA(PB,ATSCH)*CP(PB,ATSCH)/KAPPA(PB,ATSCH)
      YODH(NS,1)=0.5*(SQRT(D**2+D*DETB(III,1))-D)/RH
      RETURN
  777 RETURN 1
      END
C
C
C
C
      SUBROUTINE AXSEC(NDE1,NDE2,DETC,WSP,CONST,DDD,II,HH,MSPAC,LENGTH,N
     *,IPA,QTOT,NSTOT,XMAXNU,CHSLNU)
C-----------------------------------------------------------------------
C     AXSEC EVALUATES SECTION LENGTHS AND CORRECTION FACTORS FOR NU.
C
      REAL LENGTH,NDE1,NDE2
C
      COMMON /HEA6/   NPIN(42),JPIN(42,3)
      COMMON /GRID1/  EPSISC(42,3,5),DIST(7)
      COMMON /GRID2/  YY(100,42,3)
      COMMON /GRID3/  X(100)
      COMMON /PRSPA/  DISTO
      COMMON /IDISPA/ IDISP1
C
      DIMENSION       B(42,3),        AA(42,3),SLOPE(42,3),YYM(3,42,3)
C
C
C
      X1=NDE1*DETC
      IF(IDISP1.EQ.2)GOTO 1040
      DE11W=11.*DETC-WSP*0.5
      ISPAO=0
      IF(-DISTO.LT.DE11W*0.999)ISPAO=1
      MOSPAC=MSPAC+ISPAO
      IF(MOSPAC.GT.0 .AND. IPA.EQ.IPA/2*2 .AND. QTOT.GT.1.E-06)GOTO 2
C***********************************************************************
C*****UNHEATED SMOOTH PART OR PART WITHOUT SPACERS OR IDISP1=2*********
C***********************************************************************
 1040 SEC=LENGTH/X1+1.
      N=SEC
      SEC=N
      H=LENGTH/SEC
      DO 1 K=1,N
      DO 100 NS=1,NSTOT
      NP=NPIN(NS)
      DO 100 M=1,NP
  100 YY(K,NS,M)=1.
    1 X(K+1)=X(K)+H
      IF(MSPAC.EQ.0)RETURN
      N1=N
 1044 III=II
      KO=1
 1045 CONTINUE
      DO 1046 K=KO,N
      IF(X(K).GT.DIST(III) .AND. III.LT.MSPAC)III=III+1
      IF(III+1.GT.MSPAC)GOTO 1046
      KK=K
      IF(X(K).LT.DIST(III) .AND. X(K+1).GT.DIST(III+1))GOTO 1047
 1046 CONTINUE
      GOTO 1049
```

```
 1047 N=N+1                                                              000022
      NK1=N-KK                                                           000022
      DO 1048 K=1,NK1                                                    000022
       K1=N-K+2                                                          000022
 1048 X(K1)=X(K1-1)                                                      000022
      X(KK+1)=X(KK)+(DIST(III)+DIST(III+1))*0.5                          000022
      KC=KK+1                                                            000022
      GOTO 1045                                                          000022
 1049 CONTINUE                                                           000022
      IF(N1.EQ.N)RETURN                                                  000022
      K1=N1+1                                                            000023
      DO 1050 K=K1,N                                                     000023
      DO 1050 NS=1,NSTOT                                                 000023
      NP=NPIN(NS)                                                        000023
      DO 1050 M=1,NP                                                     000023
 1050 YY(K,NS,M)=1.                                                      000023
      RETURN                                                             000023
C*********************************************************************** 000023
C*****HEATED PART WITH SPACERS: AXIAL STEPS FIT CORR. PROF. FOR NU***** 000023
C*********************************************************************** 000023
    2 CONTINUE                                                           000024
      ZETA1=2./(1.+XMAXNU)                                               000024
      JSPAC=MSPAC+II-1                                                   000024
C                                                                        000024
      AMM=8./NDE2+0.5                                                    000024
      MM=AMM                                                             000024
      BMM=MM                                                             000024
      NDE2=8./BMM                                                        000024
      X2=NDE2*DETC                                                       000024
C                                                                        000024
C     (NOTE THAT 8/NDE2 MUST BE AN INTEGER TO FIT CORR. PROF. FOR NU)    000025
      NPSEC=0                                                            000025
      K=0                                                                000025
      M1=NPSEC+1                                                         000025
      M2=M1+MM+3                                                         000025
      M3=M2+1                                                            000025
      JSPACO=JSPAC+1                                                     000025
      XXX1=1.E07                                                         000025
       XXX11=1.E07                                                       000025
      KLK=0                                                              000025
C                                                                        000026
C                                                                        000026
      DO 16 ISPAC=II,JSPACO                                              000026
      DELO=HH                                                            000026
      IF(ISPAC.LE.JSPAC)XXX1=DIST(ISPAC)-WSP*0.5-DETC                    000026
      IF(XXX1.LE.HH)DISTO=-1.E07                                         000026
 1020 I1SPAC=ISPAC-II+1                                                  000026
      IF(-DISTO.LE.DE11W*0.999)I1SPAC=MSPAC+1                            000026
      IF(-DISTO.GT.DE11W*0.999 .AND. ISPAC.EQ.JSPAC+1)GOTO 1030          000026
      DO 3 NS=1,NSTOT                                                    000026
      NP=NPIN(NS)                                                        000027
      DO 3 NN=1,NP                                                       000027
      B(NS,NN)=CONST*EPSISC(NS,NN,I1SPAC)**2                             000027
      YYM(1,NS,NN)=1.+0.75*ZETA1*B(NS,NN)                                000027
      YYM(2,NS,NN)=(1.+B(NS,NN)*0.5*(1.+ZETA1))*(XMAXNU-1.)+(2.-XMAXNU)*000027
     *(1.+0.5*B(NS,NN)*(1.+CHSLNU+(1.-CHSLNU)/(3.-XMAXNU)))               000027
      YYM(3,NS,NN)=1.+0.5*B(NS,NN)*(2.*CHSLNU+(1.-CHSLNU)/(3.-XMAXNU))   000027
      AA(NS,NN)=1.+CHSLNU*B(NS,NN)                                       000027
    3 SLOPE(NS,NN)=CHSLNU*B(NS,NN)*0.125/DETC                            000027
      IF(ISPAC.EQ.JSPAC+1)GOTO 4                                         000027
      IF(ISPAC.EQ.II .AND. HH.GE.XXX1)GOTO 11                            000028
    4 K=K+1                                                              000028
      L=K+1                                                              000028
      IF(K.NE.NPSEC+1)GOTO 10                                            000028
      IF(-DISTO.GT.DE11W*0.999)GOTO 1010                                 000028
C                                                                        000028
```

```
C*****EFFECT OF THE LAST SPACER PRECEDING THE POINT AT WHICH THE          000028
C      CALCULATION HAS BEEN STARTED (ADDED AT GA)                  *******000028
       X10=X(1)                                                           000028
       DELO=DE11W+DISTO+X10                                               000028
       DISTO=-1.E07                                                       000029
       XLL=DELO-8.*DETC                                                   000029
       X00=X10                                                            000029
       DO 1000 KI=1,MM                                                    000029
       X00=X00+X2                                                         000029
       KI2=KI                                                             000029
       IF(X00.GE.DELO*0.999)GOTO 1003                                     000029
 1000 CONTINUE                                                            000029
       MM1=MM+1                                                           000029
       MM2=MM+3                                                           000029
       DO 1001 KI=MM1,MM2                                                 000030
       X00=X00+DETC                                                       000030
       KI2=KI                                                             000030
       IF(X00.GE.DELO*0.999)GOTO 1003                                     000030
 1001 CONTINUE                                                            000030
       WRITE(6,1002)                                                      000030
 1002 FORMAT(1H1,5X,'ERROR IN AXSEC (DELO)')                              000030
       STOP                                                               000030
C                                                                         000030
 1003 L=KI2+1                                                             000030
       J=4                                                                000031
       X(L)=DELO                                                          000031
       DO 1008 KI1=1,KI2                                                  000031
       K=KI2+1-KI1                                                        000031
       IF(KI1-MM)1004,1004,1006                                           000031
 1004 X(K)=X(K+1)-X2                                                      000031
       DO 1005 NS=1,NSTOT                                                 000031
       NP=NPIN(NS)                                                        000031
       DO 1005 NN=1,NP                                                    000031
 1005 YY(K,NS,NN)=AA(NS,NN)-(X(K)+X2*0.5-XLL)*SLOPE(NS,NN)                000031
       GOTO 1008                                                          000032
 1006 X(K)=X(K+1)-DETC                                                    000032
       J=J-1                                                              000032
       DO 1007 NS=1,NSTOT                                                 000032
       NP=NPIN(NS)                                                        000032
       DO 1007 NN=1,NP                                                    000032
 1007 YY(K,NS,NN)=YYM(J,NS,NN)                                            000032
 1008 CONTINUE                                                            000032
       X(1)=X10                                                           000032
       DO 1013 KI1=1,KI2                                                  000032
       L=KI1+1                                                            000033
       K=L-1                                                              000033
       NPSEC=K                                                            000033
       IF(X(L).GT.XXX1)GOTO 1015                                          000033
       IF(X(L).GT.DDD)GOTO 1014                                           000033
 1013 CONTINUE                                                            000033
       GOTO 1020                                                          000033
C                                                                         000033
C      THE END OF THE AXIAL PORTION HAS BEEN OVERTAKEN                    000033
 1014 X(L)=DDD                                                            000033
       N=KI1                                                              000034
       RETURN                                                             000034
C                                                                         000034
C                                                                         000034
C      THE BEGINNING OF THE INFLUENCE REGION OF THE SUCCEEDING SPACER HAS000034
C      BEEN OVERTAKEN                                                     000034
 1015 X(L)=XXX1                                                           000034
       DELO=XXX1                                                          000034
       GOTO 1020                                                          000034
C                                                                         000034
C                                                                         000035
C*****AXIAL STEPS WHERE NO EFFECT OF SPACERS ON NU IS PRESENT********* 000035
```

```
 1010 CONTINUE                                                           000035
      DX=XXX1-DELD                                                       000035
      SEC=DX/X1+1.                                                       000035
      NSEC=SEC                                                           000035
      SEC=NSEC                                                           000035
      H=DX/SEC                                                           000035
      IF(ABS(DX).LE.1.E-05)NSEC=0                                        000035
      M1=NSEC+NPSEC+1                                                    000035
      M2=M1+MM+3                                                         000036
      M3=M2+1                                                            000036
      KLK=0                                                              000036
      XXX11=1.E07                                                        000036
      IF(ISPAC.LT.JSPAC)XXX11=DIST(ISPAC+1)-WSP*0.5-DETC                 000036
      IF(NSEC.EQ.0)GOTO 10                                               000036
    7 CONTINUE                                                           000036
      DO 8 NS=1,NSTOT                                                    000036
      NP=NPIN(NS)                                                        000036
      DO 8 NN=1,NP                                                       000036
    8 YY(K,NS,NN)=1.                                                     000037
      X(L)=X(K)+H                                                        000037
      GOTO 4                                                             000037
   10 IF(K-M1)7,11,13                                                    000037
   11 CONTINUE                                                           000037
C                                                                        000037
C****AXIAL STEPS (DIST(ISPAC)-WSP/2-DETC)-(DIST(ISPAC)-WSP/2+3*DETC) **  000037
      IF(ISPAC.EQ.II .AND. FF.GE.XXX1)K=L                                000037
      XXX2=X(K)-XXX1                                                     000037
C     XXX2#0 IF DETC > DISTANCE BETWEEN THE FIRST SPACER AND THE INLET   000037
C     OF THE PART                                                        000038
      XXX3=DETC-XXX2                                                     000038
      X(K+1)=X(K)+XXX3                                                   000038
      K=K-1                                                              000038
      M1=M1-1                                                            000038
      M2=M2-1                                                            000038
      M3=M3-1                                                            000038
      IF(XXX3.LE.1.E-03)GOTO 101                                         000038
      K=K+1                                                              000038
      M1=M1+1                                                            000039
      M2=M2+1                                                            000039
      M3=M3+1                                                            000039
      XXX3=0.                                                            000039
      DO 12 NS=1,NSTOT                                                   000039
      NP=NPIN(NS)                                                        000039
      DO 12 NN=1,NP                                                      000039
   12 YY(K,NS,NN)=1.+0.25*E(NS,NN)*(1.+XXX2/DETC)*ZETA1                  000039
  101 CONTINUE                                                           000039
      DO 60 J=1,3                                                        000039
      K=K+1                                                              000039
      L=K+1                                                              000040
      X(L)=X(K)+DETC+XXX3                                                000040
      IF(X(L).GT.X(K))GOTO 77                                            000040
      K=K-1                                                              000040
      XXX3=XXX3+DETC                                                     000040
      GOTO 60                                                            000040
   77 XXX3=0.                                                            000040
      DO 59 NS=1,NSTOT                                                   000040
      NP=NPIN(NS)                                                        000040
      DO 59 NN=1,NP                                                      000040
   59 YY(K,NS,NN)=YYY(J,NS,NN)                                           000041
      IF(X(L).GT.DDD)GOTO 61                                             000041
   60 CONTINUE                                                           000041
      LL=L                                                               000041
      GOTO 4                                                             000041
C                                                                        000041
C*****PART ENDS BEFORE (DIST(ISPAC)-WSP/2+3*DETC ) IS REACHED ********  000041
   61 CONTINUE                                                           000041
```

```
      X(L)=DDD                                                          000041
      N=K                                                               000041
      RETURN                                                            000042
C                                                                       000042
   13 IF(K.EQ.M3)GOTO 15                                                000042
C                                                                       000042
C*****AXIAL STEPS WHERE INFLUENCE OF SPACERS IS DECREASING************* 000042
      X(L)=X(K)+X2                                                      000042
      DO 14 NS=1,NSTOT                                                  000042
      NP=NPIN(NS)                                                       000042
      DO 14 NN=1,NP                                                     000042
   14 YY(K,NS,NN)=AA(NS,NN)-(X(K)+X2*0.5-X(LL))*SLOPE(NS,NN)            000042
      IF(X(L).GT.XXX11 .AND. KLK.EQ.0)KLK=K                             000043
      GOTO 4                                                            000043
   15 CONTINUE                                                          000043
C                                                                       000043
C     END OF INFLUENCE OF THE SPACER.                                   000043
      IF(KLK.NE.0)M2=KLK                                                000043
      IF(KLK.NE.0) X(KLK+1)=XXX11                                       000043
      K=M2                                                              000043
      NPSEC=M2                                                          000043
      HH=DIST(ISPAC)+CELLW                                              000043
      IF(KLK.NE.0)HH=XXX11                                              000044
      DELO=HH                                                           000044
   16 CONTINUE                                                          000044
C                                                                       000044
C     ALL SPACERS HAVE BEEN CONSIDERED.                                 000044
 1030 HH=DELO                                                           000044
      IF(HH.GT.DDD)GOTO 21                                              000044
C*****END OF SMOOTH OR ROUGH PART NOT YET REACHED********************** 000044
      DX=DDD-HH                                                         000044
      SEC=DX/X1+1.                                                      000044
      NSEC=SEC                                                          000045
      SEC=NSEC                                                          000045
      H=DX/SEC                                                          000045
      K1=K+1                                                            000045
      N=K+NSEC                                                          000045
      DO 20 K=K1,N                                                      000045
      L=K+1                                                             000045
      X(L)=X(K)+H                                                       000045
      DO 19 NS=1,NSTOT                                                  000045
      NP=NPIN(NS)                                                       000045
      DO 19 NN=1,NP                                                     000046
   19 YY(K,NS,NN)=1.                                                    000046
   20 CONTINUE                                                          000046
      RETURN                                                            000046
C                                                                       000046
C*****END OF SMOOTH OR ROUGH PART OVERTAKEN: CORRECTION TO FIT END POINT000046
   21 CONTINUE                                                          000046
      DX=DDD-X(LL)                                                      000046
      SEC=DX/X2+1.                                                      000046
      NSEC=SEC                                                          000046
      SEC=NSEC                                                          000047
      H=DX/SEC                                                          000047
      N=LL+NSEC-1                                                       000047
      DO 25 K=LL,N                                                      000047
      L=K+1                                                             000047
      X(L)=X(K)+H                                                       000047
      DO 24 NS=1,NSTOT                                                  000047
      NP=NPIN(NS)                                                       000047
      DO 24 NN=1,NP                                                     000047
   24 YY(K,NS,NN)=AA(NS,NN)-(X(K)+H*0.5-X(LL))*SLOPE(NS,NN)             000047
   25 CONTINUE                                                          000048
      RETURN                                                            000048
      END                                                               000048
C                                                                       000048
```

```
C
C
C
      SUBROUTINE BALA(K,NSTCT,INDSP,ASEC,H,LENGTH,PR1,PR2,PBT,    FREL,FT
     *,ITCORR,ITCM,DPAV,ITERM,ITGL,*,WSP,I1SPAC)
C-----------------------------------------------------------------------
C     SUBROUTINE BALA EVALUATES OUTLET MASS FLOW RATES AND TEMPERATURES
C
      REAL LAM,MI,M2,MAV,LENGTH,MAVCF,MAV1,MAV2,KAPPA
C
      DIMENSION WCF1(42),EP1(42),A(42),DE(42),
     1           TA(42),  RHCAV(42),RHC1(42),XMEM(42),I1TIP(42)
C
      COMMON/GECO/ACH(3)/HEA6/NPIN(42),JJRUD(42,3)/GRID/CSPAC(42,4)
     1       /CORR/SIGMA(42),PHI(42),SBMNS/LAMIN0/I2TIP(42,3)
     2       /IJ1/NER(42),NIS(42,3)/GEN1/LAM(42)/GEN2/AZ(42)/GEN3/MI(42)
     3       /GEN4/TEMP(42)/GEN5/DEZ(42)/LAMIN3/F1ATIP(42),F1DTIP(42)
     4       /IND3/NTYP(42)/MCE1/M2(42)/MOB2/UAV(42)/MOB8/DP(42)
     5       /MOB4/WCF(42)/MOB5/TAV(42)/MOB6/MAV(42)/MOB24/WT(42,3)
     6       /MOB26/RUAS(42)/TUR1/CTURB(42,3)/HB3/TEMP2(42)/HEA3/QT(42)
     7       /QPAR1/QDEV/QPAR2/QLINM,QLDEV/QPAR3/PERL(3)/GRID6/EPS(42,4)
     8       /GRID7/PGDP(42,4)/CCND1/CCOND(42,3)/MART2/NNSS1,NNSS2
     9       /GRAV/IGRAV/GAAG1/FCCPW1(3)
      COMMON/ENEOP/IENE/MIXS1/CY/MIXS2/CCY/SECIN/KK/GRID2/YY(100,42,3)
C     ..................................................................
C     APPROXIMATE METHOD FOR THE LAMINAR CALCULATIONS
C
      KK=K
      CCY=CY
      IENFR=1
      DO 1001 NS=1,NSTCT
      NP=NPIN(NS)
      DO 1000 JJJ=1,NP
      IF(I2TIP(NS,JJJ).EQ.0 .OR. NTYP(NS).EQ.1)GOTO 1000
      IENFR=2
 1000 CONTINUE
 1001 CONTINUE
      IF(NNSS1.NE.0 .AND. NNSS2.NE.0 .AND. IENFR.EQ.2)CALL ENFRCO
C
      DO 400 NS=1,NSTCT
      RHO1(NS)=RHO(PR1,TEMP (NS))
      NP=NPIN(NS)
C
C     THE FLOW AREAS AND THE EQUIVALENT DIAMETERS ARE BASED ON THE TIP
C     DIAMETER OF THE RODS IN THE CASE OF LAMINAR CALCULATIONS
C     I1TIP(NS)=0 FOR TURBULENT FLOW; I1TIP(NS)=1 FOR LAMINAR FLOW
C
      I1TIP(NS)=0
      A(NS)=AZ(NS)*F1ATIP(NS)
      DE(NS)=DEZ(NS)*F1DTIP(NS)
      DO 399 JJJ=1,NP
  399 I1TIP(NS)=I1TIP(NS)+I2TIP(NS,JJJ)
C
      DO 400 M=1,3
      WT(NS,M)=0.
  400 CONTINUE
      XX=1./980665.
C     ..................................................................
C     ITERATION ON THE RELAXATION FACTOR (LOOP ITFREL)
C
      DO 999 ITFREL=1,98
      IVIA=1
C     ..................................................................
C     CALCULATION OF THE PRESSURE LOSSES (LOOP ITGL)
C
      DO 15 ITGL=1,70
```

```
C*****EVALUATION OF CROSS-FLOW SOLUTIONS**********************************
      CALL CRFL1(ITGL,DPAV,PPEL,ASEC,NSTOT,A,MI,DP,WCF,WCF1,EP1)
      DO 1  NS=1,NSTOT
      M2(NS)=MI(NS)-H*WCF(NS)
      MAV(NS)=(M2(NS)+MI(NS))*0.5
      TA(NS)=TEMP(NS)
    1 CONTINUE
      IF(ITGL.GT.1  .AND. IVIA.EQ.1)GOTO 9
C     ......................................................................
C     CALCULATION OF THE AVERAGE GAS TEMPERATURES (LOOP ITERM)
C
      XPREC=1.E-04
      DO 7 ITERM=1,20
      DO 3 NS=1,NSTOT
      NP=NPIN(NS)
      YYNS=0.
      DO 1002 JJJ=1,NP
 1002 YYNS=YYNS+YY(K,NS,JJJ)
      YYNS=YYNS/FLOAT(NP)-1.
      THEX=0.
      CONHE=0.
      NI=NER(NS)
      NTYPNS=NTYP(NS)
      ACH1=ACH(NTYPNS)
      MAV1=MAV(NS)*ACH1/AZ(NS)
      DO 2 M=1,NI
      J=NIS(NS,M)
      NP=NPIN(J)
      YYJ=0.
      DO 1003 JJJ=1,NP
 1003 YYJ=YYJ+ YY(K,J,JJJ)
      YYJ=YYJ/FLOAT(NP)-1.
      YYNSJ=(YYNS+YYJ)*CCY*0.5+1.
      NTYPJ=NTYP(J)
      ACH2=ACH(NTYPJ)
      MAV2=MAV(J)*ACH2/AZ(J)
      IF(TA(NS).LE.0. .OR. TA(NS).GT.3000. .OR. TA(J).LE.0. .OR. TA(J)
     *.GT.3000.)GOTO 302
      WT(NS,M)=TME(PBT,MAV1,MAV2,TA(NS),TA(J),LAM(NS),LAM(J),ACH1,ACH2,
     *CTURB(NS,M))*YYNSJ
      IF(I1TIP(NS).NE.0 .OR. I1TIP(J).NE.0)WT(NS,M)=0.
      TANSJ=(TA(NS)*MAV1+TA(J)*MAV2)/(MAV1+MAV2)
      CONHE=CONHE-(TA(NS)-TA(J))*CCOND(NS,M)*(KAPPA(PBT,TA(NS))+KAPPA
     *(PBT,TA(J)))
    2 THEX=THEX-(TA(NS)-TA(J))*WT(NS,M)*CP(PBT,TANSJ)
      IF(ITGL.GT.1)GOTO 101
      CFHEX=0.
      GOTO 102
  101 CONTINUE
      DO 303 LS=1,NSTOT
      IF(M2(LS).LE.0.)GOTO 302
  303 CONTINUE
      CALL TMCF(NS,NI,TACF,MAVCF,MAV1)
      TANSCF=(TA(NS)*MAV1+TACF*MAVCF)/(MAV1+MAVCF)
      CFHEX=WCF(NS)*(TA(NS)-TACF)*CP(PBT,TANSCF)
  102 XXMAV=MAV(NS)
      XXM2=M2(NS)
      IF(IENE.EQ.2)XXMAV=MI(NS)
      IF(IENE.EQ.2)XXM2=XXMAV
      TEMP2(NS)=TEMP(NS)+H/(XXMAV*CP(PBT,TA(NS)))*((QT(NS)*QDEV+QLINM*
     *PERL(NTYPNS)*AZ(NS)/ACH1*GLDEV)/LENGTH+THEX+CFHEX+CONHE)
      PHI(NS)=(THEX+CFHEX+CONHE)*H/AZ(NS)
      TAV(NS)=(XXM2*TEMP2(NS)+MI(NS)*TEMP(NS))*0.5/XXMAV
    3 CONTINUE
      IF(ITGL.EQ.1)GOTO 9
      IF(ITERM.GT.10)XPREC=1.E-03
```

```
      IF(ITERM.GT.15)XPREC=1.E-02                                       000061
      DO 4 NS=1,NSTOT                                                   000061
      IF(ABS(TAV (NS)/TA(NS)-1.).GT.XPREC)GOTO 5                        000061
    4 CONTINUE                                                          000061
      GOTO 9                                                            000061
    5 CONTINUE                                                          000061
      DO 6 NS=1,NSTOT                                                   000061
    6 TA(NS)=TAV(NS)                                                    000061
    7 CONTINUE                                                          000061
C     ................................................................. 000061
C     END OF LOOP ITERM                                                 000062
C                                                                       000062
       WRITE(6,8)ITGL,ITCORR,(TAV(NS),NS=1,NSTOT)                       000062
    8 FORMAT(    5X,'   CHANNEL CALCULATION STOPS IN LOOP ITERM AT ITGL=000062
     $',I6,/5X ,'ITCORR=',I5/5X,'TEMPERATURES='/(8E15.5))               000062
      RETURN 1                                                          000062
C     ................................................................. 000062
C     CALCULATION OF PRESSURE LOSSES FOR CHANNELS                       000062
C                                                                       000062
    9 CONTINUE                                                          000062
      DO 10 NS=1,NSTOT                                                  000063
      RHOAV(NS)=RHO(PBT,TAV(NS))                                        000063
   10 UAV(NS)=MAV(NS)/(A(NS)*RHOAV(NS))                                 000063
      DPAV=0.                                                           000063
      SMA=0.                                                            000063
      DO 13 NS=1,NSTOT                                                  000063
      TMOEX=0.                                                          000063
      NI=NER(NS)                                                        000063
      NTYPNS=NTYP(NS)                                                   000063
      ACH1=ACH(NTYPNS)                                                  000063
      DO 11 M=1,NI                                                      000064
      J=NIS(NS,M)                                                       000064
      TMOEX=TMOEX-(UAV(NS)-UAV(J))*WT(NS,M)                             000064
   11 CONTINUE                                                          000064
      TMOEX=FT*TMOEX/A(NS)*H                                            000064
      IF(ITGL.GT.1)GOTO 103                                             000064
      CFMOEX=0.                                                         000064
      GOTO 104                                                          000064
  103 UCFAV=UA(NS,NI,ACH1,1)                                            000064
      CFMOEX=(2.*UAV(NS)-UCFAV)*WCF(NS)/A(NS) *H                        000064
  104 CONTINUE                                                          000065
      XMEM(NS)=LAM(NS)*H/(2.*DE(NS)*RHOAV(NS))*FCOPW1(NTYPNS)           000065
      RE=MAV(NS)*DE(NS)/(A(NS)*ETA(PBT,TAV(NS)))                        000065
      IF(INDSP.EQ.2)XMEM(NS)=XMEM(NS)+(CSPAC(NS,I1SPAC)+DSPDPF(EPS(NS,I1000065
     *SPAC), DE(NS),LAM(NS),WSP,PGDP(NS,I1SPAC),RE,NTYP(NS)))/RHOAV(NS) 000065
   12 DP(NS)=XX*(-(MAV(NS)/A(NS))**2*(XMEM(NS)-(RHO(PR2,TEMP2(NS))-RHO1(000065
     *NS))/RHOAV(NS)**2)+TMOEX+CFMOEX+IGRAV*RHOAV(NS)*980.665*H)        000065
      DPAV=DPAV+DP(NS)*MI(NS)                                           000065
      SMA=SMA+MI(NS)                                                    000065
   13 CONTINUE                                                          000065
      DPAV=DPAV/SMA                                                     000066
C     ................................................................. 000066
C     TEST OF CONVERGENCE FOR THE CHANNEL PRESSURE LOSSES               000066
C                                                                       000066
      DO 14 NS=1,NSTOT                                                  000066
      IF(ABS(DP(NS)/DPAV-1.).GT.1.E-02)GOTO 15                          000066
      IF(ABS(DP(NS)/DPAV-1.).GT.1.E-03 .AND. ITGL.LT.40)GOTO 15         000066
   14 CONTINUE                                                          000066
      IF(IVIA.EQ.2)GOTO 17                                              000066
      DO 301 NS=1,NSTOT                                                 000066
      IF(M2(NS).LE.0.)GOTO 302                                          000067
  301 CONTINUE                                                          000067
      IVIA=2                                                            000067
   15 CONTINUE                                                          000067
C     ................................................................. 000067
C     END OF LOOP ITGL                                                  000067
```

```
C
  302 CONTINUE
      AIT=ITFREL
      FREL=1.-AIT*0.01
  999 CONTINUE
C     ...............................................................
C     END OF LOOP ITFREL
C
      WRITE(6,16)ITCORR,(DP(NS),NS=1,NSTOT),(MAV(NS),NS=1,NSTOT),(TAV(NS
     *),NS=1,NSTOT)
   16 FORMAT(//  5X,'CHANNEL CALCULATION STOPS IN LOOP ITSL AT ITCORR=',
     *I5/5X,'PRESSURE LOSSES, AVERAGE MASSES, AVERAGE TEMPERATURES:'/
     *(8E15.5))
      RETURN 1
C     ...............................................................
C     CONTRIBUTIONS OF CROSS-FLOW,TURBULENT MIXING AND DENSITY
C     TO THE PRESSURE DROPS OF THE CHANNELS (SIGMA)
C
   17 CONTINUE
      SBMNS=0.
      DO 21 NS=1,NSTOT
      NTYPNS=NTYP(NS)
      RUAS(NS)=MAV(NS)*SQRT(LAM(NS)*0.125)/AZ(NS)*ACH(NTYPNS)
      DPAVF=DPAV-IGRAV*RHOAV(NS)*0.001*H
      BMNS=SQRT(ABS(DPAVF)/(XX*XMEM(NS)))*A(NS)
      SIGMA(NS)=(MAV(NS)-BMNS)/AZ(NS)
      SBMNS=SBMNS+BMNS
   21 CONTINUE
      RETURN
      END
C
C
C
C
      SUBROUTINE CEWA(K,NS,IRH,PROV,PE,RH,AA,DD,GG,AM1,DETOT,H1,ALFA,
     *I,JJJ,H,PR1,PR2,SGDPG,AM1,TT,CCCD,TE,SUR,ITYP,III,HPLUS1,HPLUS2,
     *TIE,SIGMA,PHI,*,D,TWI,TI,C)
C-----------------------------------------------------------------------
C     SUBROUTINE CEWA   EVALUATES FRICTION FACTORS AND APPROXIMATE
C     VALUES OF MASS FLOW RATES AND TEMPERATURE FOR 'CENTRAL-TYPE'  SUB-
C     SUBCHANNELS ( CENTRAL AND WALL CHANNELS ).
C
      REAL LAMI,KI,KAPPA,NUI
      COMMON/GRID2/YY(100,42,3)/HEA5/QQ(42,3)/DAT/PIG/MART/ITCORR
     1       /QPAR1/QDEV/COLAM1/CCLAM3/SUB22/TW(42,3)
     2       /GRAV/IGRAV/GAGR/EPSI
C
      IF(IRH.EQ.1)GOTO 1000
C
C     IN THE CASE OF SMOOTH RODS SINGLE VALUES OF THE SUB-SUBCHANNEL
C     PIN TEMPERATURES ARE NOT COMPUTED
      R1=D*0.5
      RO=0.5*SQRT(D**2+DD*D)
      FACHE=TIS(R1,RO,IRH)
      R1DRO=R1/RO
      YDH=(RO-R1)/RH
C
 1000 CONTINUE
      QROD=QQ(NS,JJJ)*QDEV
      Q=QROD*ALFA/(2.*PIG)*H1
      QA=QROD/SUR
      TI=TIE
C     ...............................................................
C     THE ITERATION PROCEDURE STARTS ASSUMING UNIFORM MASS-FLOW
C     DISTRIBUTION
C
```

```
      DO 10 ITW=1,10                                                    000073
C                                                                       000073
      DO 4 IT=1,50                                                      000074
      DELTAT=(Q+PHI*AA)/(AM1*CP(PB,TI))                                 000074
      TI=TIE+0.5*DELTAT                                                 000074
      IF(ITW.EQ.1 .AND. I.EQ.1) TWI=TI                                  000074
      ETAI=ETA(PB,TI)                                                   000074
      RHOI=RHO(PB,TI)                                                   000074
      REI=AM1*DD/(AA*ETAI)                                              000074
      ETAIW=ETA(PB,TWI)                                                 000074
      RHOIW=RHO(PB,TWI)                                                 000074
      REIW=(ETAI*RHOIW)/(ETAIW*RHOI)*REI                                000074
      IF(IT.EQ.1 .AND. ITW.EQ.1) GOTO 30                                000075
C     ................................................................. 000075
C     AFTER 1.ST ITERATION FRICTION FACTORS ARE EVALUATED FROM THE      000075
C     VALUES OBTAINED IN THE PRECEEDING ITERATION                       000075
C                                                                       000075
      IF(REI.GT.0. .AND. SQ8LI.GT.0.)GOTO 700                           000075
 1001 WRITE(6,699)NS,JJJ,I,REI,SQ8LI                                    000075
  699 FORMAT(//5X,'NS=',I5,5X,'M=',I2,5X,'I=',I3/5X,'RE=',E15.5,5X,'SQRT000075
     *(8/LAM3(A)=',E15.5)                                               000075
      RETURN 1                                                          000075
  700 CONTINUE                                                          000076
      IF(IRH.EQ.2)GOTO 1                                                000076
      SQ8LI=2.5*ALOG(REI/SQ8LI)+5.5-GG                                  000076
      GOTO 3                                                            000076
    1 IF(SQ8LI.LE.0.)GOTO 1001                                          000076
      HPLUSB=RH/DD*REI/SQ8LI                                            000076
      HPLUSW=HPLUSB*REIW/REI                                            000076
      GOTO 31                                                           000076
C     ................................................................. 000076
C     1.ST ITERATION: FRICTION FACTORS ARE EVALUATED BY MEANS OF THE    000076
C     EQUATION (LAMBDAI*RHOI*LI**2/DI) = (LAMBDA*RHO*U**2/D) TOT.       000077
C                                                                       000077
   30 IF(IRH.EQ.2)GOTO 2                                                000077
      SQ8LI=2.5*ALOG(PROV/ETAI*SQRT((DD/DETOT)**3*RHOI))+5.5-GG         000077
      GOTO 3                                                            000077
    2 HPLUSB=RH/DETOT*PROV/ETAI*SQRT(DD/DETOT*RHOI)                     000077
      HPLUSW=RH/DETOT*PROV/ETAIW*SQRT(DD/DETOT*RHOIW)                   000077
C                                                                       000077
   31 CONTINUE                                                          000077
      QPLUS=QA*AA/(AM1*(TE+273.16)*CP(PB,TI))                           000077
      RHPL=RHPLUS(HPLUSB,TWI,TE,QPLUS,HPLUSW,TI,YDH)                    000078
      SQ8LI=2.5*ALOG(DD/RH)+RHPL-GG                                     000078
    3 LAMI=8./SQ8LI**2*CCLAMB                                           000078
      SSS=AA/SQRT(LAMI*H/(2.*RHOI*DD))                                  000078
      SQDPGI=SQRT(ABS(SQDPG**2*DPSI-IGRAV*RHOI*980.665*H))              000078
      AM2=SSS*SQDPGI+SIGMA*AA                                           000078
      IF(IT.EQ.1 .AND. ITW.EQ.1)GOTO 50                                 000078
      IF(ABS(PLAMI/LAMI-1.).LE.1.E-04)GOTO 5                            000078
      PLAMI=PLAMI                                                       000078
      AM3=AM1                                                           000078
   50 PLAMI=LAMI                                                        000079
    4 AM1=AM2                                                           000079
C     ................................................................. 000079
C     END OF LOOP IT                                                    000079
C                                                                       000079
      WRITE(6,5)I,NS,K,ITW,ITCORR,AA,DD,ALFA,LAMI,PLAMI,AM3,AM2,TI,TIE, 000079
     1TWI,PHI,SIGMA                                                     000079
    5 FORMAT(1H1,5X,'CALCULATION STEPS: IT=10 FOR SUBCH.',I3,2X,'(CHANNE000079
     *L NR.',I4,2X,'AXIAL SECTION NR.',I3,')',2X,'ITW=',I2,2X,'ITCORR=',000079
     *I4/5X,'AA=',E15.5/5X,'DD=',E15.5/5X,'ALFA=',E15.5/5X,'LAMI=',E15.5000079
     */5X,'PLAMI=',E15.5/5X,'AM1=',E15.5/5X,'AM2=',E15.5/5X,'TI=',E15.5/000080
     *5X,'TIE=',E15.5/5X,'TWI=',E15.5/5X,'PHI=',E15.5/5X,'SIGMA=',E15.7)000080
      RETURN 1                                                          000080
C                                                                       000080
```

```
    6 IF(QQ(NS,JJJ).LE.1.E-C6)GCTO 12
      IF(IRH.EQ.1)GCTC 13
C     ....................................................................
C     ITERATICN TO FIND ROD TEMPERATURE FOR THE ROUGH PART
C
      KI=KAPPA(PB,TI)
      PRI=ETAI*CP(PB,TI)/KI
      CALL RNU(HPLUSW,TWI,LAMI,REI,PRI,TI,YDH,R1DRO,0.,1.,REIW,YY(K,NS,
     1 JJJ),NUI,GHPL)
      ALFAI=NUI*KI/DC*FACHE
      TIW=TI+QA/ALFAI
      IF(ABS(TIW/TWI-1.).LE.1.E-C4)GCTC12
   10 TWI=TIW
C     ....................................................................
C     END OF LCOP ITW
C
      WRITE(6,11)I,JJJ,NS
   11 FCRMAT(     5X,'CALCULATICN STOPS: ITW=10 FOR SUBCH.',I3,2X, '(M=',
     *I2,2X,'NS=',I5,' )')
      RETURN 1
C
   13 TWI=TW(NS,JJJ)
C
   12 AMT=AMT+AM2
      TT=TT+TI*AM2
      DDDD=DDDD+SSS
      IF(IRH.EQ.1)RETURN
C
      HPLUS1=HPLUS1+HPLUSB*AA
      HPLUS2=HPLUS2+HPLUSW*AA
      RETURN
      END
C
C
C
C
      SUBROUTINE CF1(X1,X2,Y1,Y2,DP1,DP2,ITVIA,XYT,YT)
C---------------------------------------------------------------------
C     CF1 IS USED IN THE CALCULATICN CF THE AVERAGE CROSS-FLOW TEMPERA=
C     TURES AND VELCCITIES
C
      CCMMCN/GAMAR/CXX
      XYT=(X1*Y1+X2*Y2)*CXX+XYT
      YT=(Y1+Y2)*CXX+YT
      RETURN
      END
C
C
C
C
      FUNCTICN CP(P,T)
C---------------------------------------------------------------------
C     FUNCTICN CP EVALUATES THE SPECIFIC HEAT CF THE COOLANT (CAL/G K)
C
      CCMMCN/GASD4/IGAS
      GCTO(10,20,30,40),IGAS
   10 CCNTINUE
C     CASE OF HELIUM CCOLANT
C
      CP=1.242
      RETURN
C
   20 CCNTINUE
C     CASE OF CO2 COOLANT
C
      PP=P
```

```
      TT=T                                                              000086
      P=PP/1.0333                                                       000086
      T=TT+273.16                                                       000086
      TO=273.16                                                         000086
      TF=TO/T                                                           000086
      IF(P-1.) 1,1,2                                                    000086
    1 ECP = P -1.                                                       000086
      GO TO 3                                                           000086
    2 ECP = (P -1.)**1.05                                               000087
    3 CPO=.118+3.51E-4*T-2.34E-7*T*T+6.00E-11*T*T*T                     000087
      CPF = CPO*(1.+1.089E-2*ECP*(TF**3.35))                            000087
      CP=CPF                                                            000087
      T=TT                                                              000087
      P=PP                                                              000087
      RETURN                                                            000087
C                                                                       000087
   30 CONTINUE                                                          000087
      CP=0.                                                             000087
      RETURN                                                            000088
   40 CONTINUE                                                          000088
      CP=0.                                                             000088
      RETURN                                                            000088
      END                                                               000088
C                                                                       000088
C                                                                       000088
C                                                                       000088
C                                                                       000088
      FUNCTION ETA(P,T)                                                 000088
C-----------------------------------------------------------------------000088
C     ETA EVALUATES THE DYNAMIC VISCOSITY OF THE COOLANT (G/CM S)       000088
C                                                                       000088
      COMMON/GASD4/IGAS                                                 000088
      GOTO(10,20,30,40),IGAS                                            000089
   10 CONTINUE                                                          000089
C     CASE OF HELIUM COOLANT                                            000089
C                                                                       000089
      ETA=18.84E-05*((T+273.16)/273.16)**0.66                           000089
      RETURN                                                            000089
C                                                                       000089
   20 CONTINUE                                                          000089
C     CASE OF CO2 COOLANT                                               000089
C                                                                       000089
      PP=P                                                              000090
      TT=T                                                              000090
      P=PP/1.0333                                                       000090
      T=TT+273.16                                                       000090
      TO=273.16                                                         000090
      TF=TO/T                                                           000090
      ETAO=(1.54E-7*SQRT(T))/(1.+(228./T))                              000090
      ETAF=ETAO*(1.+4.78E-3*(P-1.)*(TF**3))                             000090
      ETA=ETAF*98.068                                                   000090
      P=PP                                                              000090
      T=TT                                                              000091
      RETURN                                                            000091
C                                                                       000091
   30 CONTINUE                                                          000091
      ETA=0.                                                            000091
      RETURN                                                            000091
   40 CONTINUE                                                          000091
      ETA=0.                                                            000091
      RETURN                                                            000091
      END                                                               000091
C                                                                       000091
C                                                                       000091
C                                                                       000091
C                                                                       000091
```

```
      REAL FUNCTION KAPPA(P,T)
C-----------------------------------------------------------------------
C     KAPPA EVALUATES THE THERMAL CONDUCTIVITY OF THE COOLANT
C     (CAL/CM S K)
C
      COMMON/GASD4/IGAS
      GOTO(10,20,30,40),IGAS
   10 CONTINUE
C     CASE OF HELIUM COOLANT
C
      KAPPA=35.1E-05*((T+273.16)/273.16)**0.66
      RETURN
C
   20 CONTINUE
C     CASE OF CO2 COOLANT
C
      PP=P
      TT=T
      P=PP/1.0333
      T=TT+273.16
      TO=273.16
      TF=TO/T
      IF(P-1.) 4,4,5
    4 ECL = P-1.
      GO TO 6
    5 ECL = (P -1.)**1.25
    6 IF(T-TO-725.) 1,1,2
    1 CA=3.4943E2
      CB=1.6768E5
      CC=2.7331E7
      GO TO 3
    2 CA=4.0476E2
      CB=1.5904E5
      CC=-1.9206E7
    3 CLAMO=(SQRT(T))/(CA+(CB/T)+(CC/(T*T)))
      CLAMF=CLAMO*(1.+2.14E-3*ECL*(TF**2.36))
      KAPPA=CLAMF/360.
      P=PP
      T=TT
      RETURN
C
   30 CONTINUE
      KAPPA=0.
      RETURN
   40 CONTINUE
      KAPPA=0.
      RETURN
      END
C
C
C
C
      FUNCTION RHO(P,T)
C-----------------------------------------------------------------------
C     RHO EVALUATES THE DENSITY OF THE COOLANT (G/CCM)
C
      COMMON/GASD4/IGAS
      GOTO(10,20,30,40),IGAS
   10 CONTINUE
C     CASE OF HELIUM COOLANT
C
      TODT=273.16/(273.16+T)
      RHO=0.172823E-03*P*TODT-0.904002E-07*P**2*TODT**2.2
      RETURN
C
   20 CONTINUE
```

```
C       CASE OF CO2 COOLANT                                             000098
C                                                                       000098
        PP=P                                                            000098
        TT=T                                                            000098
        P=PP/1.0333                                                     000098
        T=TT+273.16                                                     000098
        T0=273.16                                                       000098
        IF(T-516.) 1, 1, 2                                              000098
      1 CK=.0134                                                        000099
        GO TO 5                                                         000099
      2 IF(T-750.) 3, 4, 4                                              000099
      3 CK=(650.-T)* 1.E-4                                              000099
        GO TO 5                                                         000099
      4 CK=-.01                                                         000099
      5 TF=T0/T                                                         000099
        ROF=1.9635*P*TF*(1.+CK*P*(TF**5))                               000099
        RHO=ROF*0.001                                                   000099
        T=TT                                                            000099
        P=PP                                                            000100
        RETURN                                                          000100
C                                                                       000100
     30 CONTINUE                                                        000100
        RHO=0.                                                          000100
        RETURN                                                          000100
     40 CONTINUE                                                        000100
        RHO=0.                                                          000100
        RETURN                                                          000100
        END                                                             000100
C                                                                       000100
C                                                                       000100
C                                                                       000100
C                                                                       000100
        SUBROUTINE RECANG(I,AI,NS,K,IVIA,IRH,ALFA,AMA1,TI,PB,D,W,RH,DETOT 000101
       *,PROV,DAI,DBI,AAI,ABI,G,SSSA,SSSB, AMTI,NTYP,H1,H,PR1,PR2,SQDPG,JJ000101
       *J,TE,SUR,TW1,AMAI,TAI,AMBI,TBI,III,TIE,TIAV,HPLUSB,HPLUSW,ANGT,EM1000101
       *,XC1,XC2,*,DEPA,CS)                                             000101
C-----------------------------------------------------------------------000101
C       SUBROUTINE RECANG EVALUATES FRICTION FACTORS AND APPROXIMATE MASS 000101
C       FLOW RATES AND TEMPERATURES FOR WALL-TYPE SUB-SUBCHANNELS.      000101
C                                                                       000101
        REAL LAMIA,LAMIB,KI, KAPPA,NUI,NUO                              000101
        COMMON/CORR1/SIGMAI(42,3),PHII(42,3)/COLAM1/COLAMB/COLAM2/COLAMA 000101
      1        /CORR2/CHI(18,2,2),PSI(18,2,2)/GRID2/YY(100,42,3)        000102
      2        /ANG1/RA2(60)/FEA5/QQ(42,3)/DAT/PIG/REC1/PVERT(90),PRAD(90) 000102
      3        /SUB20/PROVI(18,2)/GEN5/DE(42)/SUB22/TW(42,3)/MART/ITCORR 000102
      4        /SUB21/TSCHA(18,2),TSCHB(18,2)/QPAR1/QDEV/QPAR2/QLIM,QLDEV 000102
      5        /WSSCH1/DELTIF(18,2,90),DTIEAV(18,2)/WSSCH2/TIO(18,2,90) 000102
      6        /WSSCH/T1SSC1(18,2),T2SSC1(18,2),T1SSC2(18,2),T2SSC2(18,2) 000102
      7        /WSSCH0/TBSSC1(42,3),TWSSC1(42,3),TBSSC2(+2,3),TWSSC2(42,3) 000102
      8        /GRAV/IGRAV/GAGR/DPSI/GAAG2/FCOPW2(18,2)                 000102
C                                                                       000103
        ICS=1                                                           000103
        IF(I.GT.1)TWI=TW1                                               000103
        IF(ITCORR.EQ.1)PROVI(III,JJJ)=PROV                              000103
        PROVI(III,JJJ)=PROV                                             000103
        DEPA=DETOT                                                      000103
        QROD=QQ(NS,JJJ)*QDEV                                            000103
        Q=QROD*ALFA/(2.*PIG)*H1                                         000103
        QA=QROD/SUR                                                     000103
        QLIN=QLIM*H1*QLDEV                                              000103
        AMABI=AMA1                                                      000103
C       ................................................................000103
C       LOOP ITW1 STARTS (CALCULATION OF THE BULK TEMPERATURES OF THE   000104
C       TWO ZONES DIVIDED BY THE TAU=0 LINE, TAI AND TBI)               000104
C                                                                       000104
        DO 2000 ITW1=1,10                                               000104
```

```
C     ..............................................................000104
C     LOOP ITW STARTS (CALCULATION OF THE PIN TEMPERATURE TWI)         000104
C                                                                      000104
      DO 14 ITW=1,20                                                   000104
C     ..............................................................000104
C     LOOP ITTEMP STARTS (CALCULATION OF THE FRICTION FACTORS AND OF   000104
C     THE MASS FLOW RATES FOR THE TWO ZONES DIVIDED BY THE TAU=0 LINE  000105
C     AND OF THE BULK TEMPERATURE TI FOR THE WHOLE SUB-SUBCHANNEL)     000105
C                                                                      000105
      DO 7 ITTEMP=1,60                                                 000105
      IF(ITW1.GT.1)GOTO 1998                                           000105
      IF(           ITCORR .GT.1 .AND. QQ(NS,JJJ).GT. 1.E-06)GOTO 25000105
      TAI=TI                                                           000105
      TBI=TI                                                           000105
      GOTO 26                                                          000105
   25 CONTINUE                                                         000105
      TAI=TSCHA(III,JJJ)                                               000106
      TBI=TSCHB(III,JJJ)                                               000106
      TI=TIAV                                                          000106
   26 CONTINUE                                                         000106
      IF(ITW.EQ.1 .AND. I.EQ.1)TWI=TBI                                 000106
      IF(ITW.EQ.1)TWO=TWI                                              000106
 1998 CONTINUE                                                         000106
      ETAA=ETA(PB,TAI)                                                 000106
      ETAB=ETA(PB,TBI)                                                 000106
      RHOA=RHO(PB,TAI)                                                 000106
      RHOB=RHO(PB,TBI)                                                 000107
      ETAIW=ETA(PB,TWI)                                                000107
      RHOIW=RHO(PB,TWI)                                                000107
      QPLUS=QA/(AMABI*CP(PB,TBI)*(TE+273.16))                          000107
C                                                                      000107
      IF(IVIA.EQ.2 .OR. ITW1.GT.1)GOTO 1                               000107
C     ..............................................................000107
C     CALCULATION OF THE POSITION OF THE TAU=0 LINE                    000107
C                                                                      000107
      CALL TLINE(I,AI,ITTEMP,NS,K,ALFA,D,W,RH,DEPA  ,PROVI(III,JJJ),IRH,000107
     *DAI,DBI,AAI,ABI,RHPL,G,TWI,TE,QPLUS,ETAA,RHOA,ETAB,RHOB,ETAIW,   000108
     *RHOIW,ANGT,EM1,XC1,XC2,TBI,&8500,CS)                             000108
C                                                                      000108
    1 CONTINUE                                                         000108
      PAI=4.*AAI/DAI                                                   000108
      RO=0.5*SQRT(D**2+C*DBI)                                          000108
      YDH=(RO-0.5*D)/RH                                                000108
      IF(ITTEMP.EQ.1 .AND. ITW.EQ.1 .AND. ITW1.EQ.1)GOTO 30            000108
C     ..............................................................000108
C     AFTER THE FIRST ITERATION THE FRICTION FACTORS ARE EVALUATED     000108
C     BY MEANS OF THE REYNOLDS NUMBERS AND OF THE FRICTION FACTORS     000109
C     COMPUTED AT THE PRECEEDING ITERATION                             000109
C                                                                      000109
      REAI=AMAI*DAI/(AAI*ETAA)                                         000109
      REBI=AMBI*DBI/(ABI*ETAB)                                         000109
      REIW=(ETAB*RHOIW)/(ETAIW*RHOB)*REBI                              000109
      IF(REAI.GT.0. .AND. REBI.GT.0. .AND. SQ8LIA.GT.0. .AND. SQ8LIB.GT.000109
     *0.)GOTO 700                                                      000109
      WRITE(6,699)NS, JJJ,I,REAI,SQ8LIA,REBI,SQ8LIB,ITCORR,ICS         000109
  699 FORMAT(//5X,'NS=',I5,5X,'M=',I2,5X,'I=',I3/5X,'RE A=',E15.5,5X,'SQ000109
     *RT(8/LAMBDA) A=',E15.5/5X,'RE B=',E15.5,5X,'SQRT(8/LAMBDA) B=',E15000110
     *.5/5X,'ITCORR=',I5,5X,'ICS=',I2)                                 000110
 8500 RETURN 1                                                         000110
C                                                                      000110
  700 CONTINUE                                                         000110
      IF(IRH.EQ.2)GOTO 27                                              000110
      SQ8LIB=2.5*ALOG(REBI/SQ8LIB)+5.5-G                               000110
      GA=6.0737                                                        000110
      GOTO 28                                                          000110
   27 HPLUSB=RH/DBI*REBI /SQ8LIB                                       000110
```

```
      HPLUSW=HPLUSB*REIW/REBI
      RHPL=RHPLUS(HPLUSB,TWI,TE,GPLUS,HPLUSW,TBI,YDH)
      SQ8LIB=2.5*ALOG(DBI/RH)+RHPL-G
      GA=5.966
   28 IF(NTYP.EQ.3 .AND. IVIA.EQ.2)GOTO 29
      SQ8LIA=CS*(2.5*ALOG(REAI/SQ8LIA)-GA)+5.5*COLAMA
      GOTO 3
   29 SQ8LIA =SMFUN1(RHOA,ETAA,DETOT,PROV,I,2,REAI,DAI,SQ8LIA,RO,GA,CS)
    3 CS=CSFUN(IRH,REAI,SQ8LIA,SQ8LIB,GA)
      GOTC 6
C     .................................................................
C     FIRST ITERATION : THE FRICTION FACTORS ARE EVALUATED BY MEANS
C     OF THE EQUATION (LAMBDAI*RHOI**2/DI) = (LAMBDA*RHO*U**2/D) TOT.
C
   30 IF(IRH.EQ.2)GOTC 2
      SQ8LIB=2.5*ALOG(PROV/ETAB*SQRT((DBI/DETOT)**3*RHOB))+5.5-G
      GA=6.0737
      GOTC 4
    2 HPLUSB=RH/DETOT*PROV/ETAB*SQRT(DBI/DETOT*RHOB)
      HPLUSW=RH/DETOT*PROV/ETAIW*SQRT(DBI/DETOT*RHOIW)
      RHPL=RHPLUS(HPLUSB,TWI,TE,GPLUS,HPLUSW,TBI,YDH)
      SQ8LIB=2.5*ALOG(DBI/RH)+RHPL-G
      GA=5.966
    4 IF(NTYP.EQ.3 .AND. IVIA.EQ.2)GOTO 5
      SQ8LIA=CS*(2.5*ALOG(PROV/ETAA*SQRT((DAI/DETOT)**3*RHOA))-GA)+5.5
     **COLAMA
      GOTC 6
    5 SQ8LIA =SMFUN1(RHOA,ETAA,DETOT,PROV,I,1,REAI,DAI,SQ8LIA,RO,GA,CS)
C
C
    6 CONTINUE
       LAMIA=8./SQ8LIA**2
       LAMIB=8./SQ8LIB**2
      SSSA=AAI/SQRT(LAMIA*F/(2.*RHOA*DAI))
      SSSB=ABI/SQRT(LAMIB*F/(2.*RHOB*DBI))
      SQDPGB=SQRT(ABS(SQDPG**2*DPSI-IGRAV*RHOB*980.665*H)
     */FCOPW2(III,JJJ))
      SQDPGA=SQRT(ABS(SQDPG**2*DPSI-IGRAV*RHOA*980.665*H)
     */FCOPW2(III,JJJ))
      AMBI=SSSB*SQDPGB+ABI*SIGMAI(NS,JJJ)*CHI(III,JJJ,1)
      AMAI=SSSA*SQDPGA+AAI*SIGMAI(NS,JJJ)*CHI(III,JJJ,1)
      AMTI=AMAI+AMBI
      IF(               ITCORR.GT.1 .AND. QQ(NS,JJJ).GT.1.E-06  .AND.
     *ITW1.EQ.1)GOTO 48
C
      DELTAT=(Q+QLIN*PAI+ PHII(NS,JJJ)*PSI(III,JJJ,1)*(AAI+ABI))/
     *(AMTI*CP(PB,TI))
      TI=TIE+0.5*DELTAT+DELTIE(III,JJJ,I)
      TIO(III,JJJ,I)=TI+0.5*DELTAT
C
   48 CONTINUE
      IF(ITTEMP.EQ.1)GOTO 50
      IF(ABS(AMAI/AMAI1-1.).LE.1.E-03 .AND. ABS(AMBI1/AMBI-1.).LE.1.E-03
     *)GOTO 9
   50 AMAI1=AMAI
      AMBI1=AMBI
      AMABI=AMBI/ABI
    7 CONTINUE
C     .................................................................
C     END OF LOOP ITTEMP: POINT REACHED IN THE CASE OF CONVERGENCE
C     PROBLEMS
C
      WRITE(6,8)I,NS,K,ITW,ITCORR
    8 FORMAT(     5X,'CALCULATION STOPS: ITTEMP=10 FOR SUBCHANNEL',I4,2X,
     *'OF CHANNEL',I4,2X,'(AXIAL SECTION',I4,') ITW=',I2,5X,'ITCORR=',I5
     *)
```

```
      RETURN 1
C     ..................................................................
C     CONVERGENCE  IS REACHED IN THE LOOP ITTEMP
C
    9 CONTINUE
      IF(ITW1.EQ.1)TW1=TWI
      IF(QQ(NS,JJJ).LE.1.E-06)GOTO 2002
      ATI=AAI+ABI
      DEI=ATI/(AAI/DAI+ABI/DBI)
      IF(IRH.EQ.1)GOTO 600
C     ..................................................................
C     CALCULATION OF THE PIN TEMPERATURE ONLY FOR HEATED ROUGHENED
C     SECTIONS
C
      IF(ABS(TWO).LT.3000. .AND. ABS(TWI).LT.3000.)GOTO 2005
      WRITE(6,2004)NS,JJJ,TWO,TWI
 2004 FORMAT(     5X,'STOP IN RECANG: NS=',I5,5X,'JJJ=',I5/5X,'TWO=',E15.
     *5,5X,'TWALL=',E15.5)
      RETURN 1
 2005 CONTINUE
      IF(NTYP.EQ.3 .AND. ITVIA.EQ.2)GOTO 500
      R2=R0+0.25*DAI*XC2
      GOTO 501
  500 R2=RA2(I)
  501 CONTINUE
      R2MROH=(R2-RO)/RH
      R1=D*0.5
      R1DR2=R1/R2
      FACHE=TIS(R1,R2,IRH)
      KI=KAPPA(PB,TI)
      ETAI=ETA(PB,TI)
      RHOI=RHO(PB,TI)
      CPI=CP(PB,TI)
      PRI=ETAI*CPI/KI
      REI=AMTI*DEI/(ETAI*ATI)
      U1DU=AMBI*ATI*RHOI/(AMTI*ABI*RHOB)
      REWO=REIW*ETAIW*RHO(PB,TWO)/(RHOIW*ETA(PB,TWO))
      HPLUSO=HPLUSW*REWO/REIW
      CALL RNU(HPLUSW,TWI,LAMIB,REI,PRI,TI  ,YDH,R1DR2,R2MROH,U1DU,REIW,
     1  YY(K,NS,JJJ),NUI,GHPL)
      CALL RNU(HPLUSO,TWO,LAMIF,REI,PRI,TI  ,YDH,R1DR2,R2MROH,U1DU,REWO,
     |    1.,NUO,GHPL)
      ALFAI=NUI*KI/DEI*FACHE
      TIW=TI+QA/ALFAI
      ALFAO=NUO*KI/DEI
      TWO=TI+QA/ALFAO
      IF(ABS(TWI/TIW-1.).LE.1.E-04)GOTO 16
   14 TWI=TIW
C     ..................................................................
C     END OF LOOP ITW : POINT REACHED IN THE CASE OF CONVERGENCE
C     PROBLEMS
C
      WRITE(6,15)I,JJJ,NS
   15 FORMAT(     5X,'CALCULATION STOPS:ITW =10 FOR SUB-SUBCH.',I3,2X,'(M
     *=',I2,2X,'NS=',I5,')')
      RETURN 1
C     ..................................................................
C     CONVERGENCE  IS REACHED IN THE LOOP ITW
C
   16 CONTINUE
      IF(ITW1.GT.1)GOTO 1999
      TW1=TWI
      IF(ITCORR.EQ.1)RETURN
C     ..................................................................
C     CALCULATION OF THE BULK TEMPERATURES OF THE TWO ZONES DIVIDED BY
C     THE TAU=0 LINE ONLY FOR HEATED ROUGHENED SECTIONS AT ITCORR>1
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C                                                                       000124
 1999 U1STAR=AMBI/(RHOB*ABI)*SQRT(LAMI3*0.125)                          000124
      FF=QA/(RHOI*CPI*U1STAR)                                           000124
      RODR2=RO/R2                                                       000124
      CALL DDCANE(TWO,TI,GHPL,RODR2,R1DR2,YDH,R2MROH,FF,TAI,TIB,TE)     000124
      IF(ABS(TBI/TIB-1.).LE.1.E-04)GOTO 2002                            000124
 2000 TBI=TIB                                                           000124
C     ...................................................................000124
C     END OF LOOP ITW1: POINT REACHED IN THE CASE OF CONVERGENCE        000125
C     PROBLEMS                                                          000125
C                                                                       000125
       WRITE(6,2001)I,NS,JJJ,ITCORR,TBI,TAI,TI,TWI,TWO                  000125
 2001 FORMAT(/5X,'STOP IN RECANG (LOOP ITW1) I=',I3,' NS=',I5,' M=',I2, 000125
     1 ' ITCORR=',I3/5X,'TBI=',E15.5,5X,'TAI=' ,E15.5,5X,'TI=',E15.5,5X,000125
     2 'TWI=',E15.5,5X,'TWO=',E15.5)                                    000125
      RETURN 1                                                          000125
C     ...................................................................000125
C     CONVERGENCE  IS REACHEL IN THE LOOP ITW1                          000125
C                                                                       000126
  600 TWI=TW(NS,JJJ)                                                    000126
C                                                                       000126
 2002 CONTINUE                                                          000126
      TBSSC2(NS ,JJJ)=TI                                                000126
      T1SSC2(III,JJJ)=TBI                                               000126
      T2SSC2(III,JJJ)=TAI                                               000126
      TWSSC2( NS,JJJ)=TWI                                               000126
      IF(I.GT.1)RETURN                                                  000126
C                                                                       000126
      TBSSC1( NS,JJJ)=TI                                                000127
      T1SSC1(III,JJJ)=TBI                                               000127
      T2SSC1(III,JJJ)=TAI                                               000127
      TWSSC1( NS,JJJ)=TWI                                               000127
      RETURN                                                            000127
      END                                                               000127
C                                                                       000127
C                                                                       000127
C                                                                       000127
C                                                                       000127
      SUBROUTINE RECCA1(K,NS,N,NSC45,IRH,PROV,PB,    RH,H1,ALFA,A,DE,MEC,000127
     *AT,DET,ATOT,DETOT,MFLOW,W,D,C, JJJ,NSTR,H,PR1,PR2,SQDPG,TE,SUR,   000127
     *AMT,DDDD,ATSCH,CTU3,EM1,*,ALFACE)                                 000127
C--------------------------------------------------------------------000127
C     SUBROUTINE RECCA1 CALCULATES FRICTION FACTORS  AND APPROXIMATE    000128
C     OUTLET MASS FLOW RATES AND TEMPERATURES FOR WALL CHANNELS AND SUBC000128
C                                                                       000128
      REAL MEC,MFLOW,LAMB,LAMSCH,LAMWC,MSCH1,KAPPA,LAMLAM,MSCH,         000128
     1    MWC1L,MWC2L                                                   000128
      DIMENSION A(45),DE(45),MEC(45)                                    000128
      COMMON/WAC01/XMSCH3(18,2),XMSCHA(18,2)/DAT/PIG/CEN1/G(45)         000128
C         /REC1/        PVERT(90),PRAD(90)/REC2/E(90)/REC3/P( 90)       000128
     1        /SUB1/ASCH(42,3)/SUB2/TSCH(42,3),MSCH(42,3)/SUB3/ADAB(18,2),000129
     2        DETB(18,2)/SUB4/LAMB(18,2)/SUB5/LAMSCH(42,3)              000129
     3        /SUB8/MSCH1(42,3)/SUB23/HPLUSB(42,3),HPLUSW(42,3)         000129
     4        ,CPLUS(42,3),PRB   (42,3),YDDH(42,3)/HEA5/QQ(42,3)/INPAR/IPA 000129
     5        /SUB22/TW(42,3)/WCSE1/DEWC(18,2,2),PHWC(18,2,2)           000129
     6        /LAMIN0/I2TIP(42,3)/LAMIN1/AKAPPA(42) /LAMIN2/FATIP(3),   000129
     7        FDTIP(3)/LAMIN3/F1ATIP(42),F1DTIP(42)/LAMIN4/F2ATIP(42,3), 000129
     8        F2DTIP(42,3)/LAMIN5/RTIP(7)/LAMIN6/ANGLAM/LAMIN7/F1PTIP   000129
     9        /WSSCH1/DELTIF(18,2,90),DTIEAV(18,2)/WSSCH2/TIO(18,2,90)  000129
      COMMON/LAMINK/BKAPPA(7,3)/QPAR1/QDEV/QPAR2/QLINM,QLDEV/HEA10/     000129
     1        QSCH(42,3)/WALLCC/WFCC1(18,2),WFCO(18,2)/WALLKA/AKAWC(2)  000129
     2        /WCSE3/LAMWC(18,2,2)/WCSE4/CTURB2(18,2)/WCSE8/ASCHWC(18,2,2)000129
     3        /WCSE5/TSCWC1(18,2,2)/WCSE9/TAVWC(18,2,2)/GEN2/ACHA(42)   000130
     4        /CORR1/SIGMAI(42,3),PHII(42,3)/CORR2/CHI(18,2,2),PSI(18,2,2)000130
     5        /WSSCH/T1SSC1(18,2),T2SSC1(18,2),T1SSC2(18,2),T2SSC2(18,2) 000130
     6        /WSSCH0/TBSSC1(42,3),TWSSC1(42,3),TBSSC2(42,3),TWSSC2(42,3) 000130
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     7        /LAMIN9/I3TIP(42,3)/SHROUD/TLINER(18,2)/MART/ITCORR
     8        /GRAV/IGRAV/GAGR/CPSI/GAAG1/FCOPW1(3)/GAAG2/FCOPW2(18,2)
      IF(JJJ.GT.1)GOTO 2998
      F1ATIP(NS)=0.
      F1PTIP=0.
 2998 CONTINUE
      III=NS-NSTR
      IF(ITCORR.EQ.1 .AND. K.EQ.1) FCOPW2(III,JJJ)=FCOPW1(2)
      DTIEAV(III,JJJ)=0.
      I2TIP(NS,JJJ)=I3TIP(NS,JJJ)
      IF(                    I2TIP(NS,JJJ).EQ.1)GOTO 2999
C     ...................................................................
C     ...................................................................
C     I3TIP#1: THE TURBULENT CALCULATION MUST BE PERFORMED
C
      TWIAV=0.
      CS=1.
      AMA1=MSCH1(NS,JJJ)/AT
      TETA=ALFA
      ANGT=0.
      AMT=0.
      AMA=0.
      TT=0.
      TTA=0.
      DDDDA=0.
      ATA=0.
      DDDDB=0.
      SRAMIB=0.
      SRAMIA=0.
      HPLUSB(NS,JJJ)=0.
      HPLUSW(NS,JJJ)=0.
      TI=TSCWC1(III,JJJ,1)
      SIGMA2=SIGMAI(NS,JJJ)*CHI(III,JJJ,2)
      PHI2=PHII(NS,JJJ)*PSI(III,JJJ,2)
      ASCHWC(III,JJJ,1)=0.
      IVIA=1
      EMAX=EM1
      XC1=0.
      XC2=1.
      IF(ITCORR.EQ.1)DEWC(III,JJJ,1)=DETOT
C     ...................................................................
C     CALCULATION OF THE "WALL-TYPE SUB-SUBCHANNELS (I= SUB-SUBCHANNEL
C     INDEX)
C
      DO 3 I=1,N
      AI=I
C
    1 CONTINUE
      ANGT=ANGT+TETA
      CALL RECANG(I,AI,NS,K,IVIA,IRH,TETA,AMA1,TI,PB,J,W,RH,DETOT,PROV,
     *DAI,DBI,AAI,ABI,GG,SSSA,SSSB,AMTI,2,.,H,PR1,PR2,SQDPG,JJJ,TE,SUR,
     *TWI,AMAI,TAI,AMBI,TBI,III,TSCWC1(III,JJJ,1),TAVWC(III,JJJ,1),
     *HPLUS1,HPLUS2,ANGT,EM1,XC1,XC2,8777,DEWC(III,JJJ,1),CS)
      IF(E(I).GE.EMAX .AND. IVIA.EQ.1)GOTO 5
C
      TWIAV=TWIAV+TWI*TETA
      AMT=AMT+AMTI
      AMA=AMA+AMAI
      RAMIA=AMTI*AAI/(AAI+ABI)
      RAMIB=AMTI*ABI/(AAI+ABI)
      TT=TT+AMTI*TI
      TTA=TTA+RAMIA*TAI
      SRAMIA=SRAMIA+RAMIA
      SRAMIB=SRAMIB+RAMIB
      DDDDA=DDDDA+SSSA
      DDDDB=DDDDB+SSSB
```

```
      DDDD=DDDDA+DDDDB
      ATA=ATA+AAI
      ASCHWC(III,JJJ,1)=ASCHWC(III,JJJ,1)+AAI+ABI
      DTIEAV(III,JJJ)=DTIEAV(III,JJJ)+AMTI*DELTIE(III,JJJ,I)
      IF(IRH.EQ.1)GOTO 30
      HPLUSB(NS,JJJ)=HPLUSB(NS,JJJ)+HPLUS1*ABI
      HPLUSW(NS,JJJ)=HPLUSW(NS,JJJ)+HPLUS2*ABI
   30 CONTINUE
      IF(IVIA.EQ.1)GOTO 3
      IF(ABS(EMAX*2./C-1.).LE.1.E-05)GOTO 10
C     ..................................................................
C     POINT REACHED BY THE CALCULATION IF THE SHROUD PROFILE HAS
C     BLOCKING TRIANGLES
C
      IVIA=1
      EMAX=C*0.5
      XC1=1./SQRT(3.)
      XC2=2.*XC1
      TETA=ALFA
      E(I)=EM1
      P(I)=PP
    3 CONTINUE
C     ..................................................................
C     I HAS REACHED THE VALUE N, WHICH WOULD MEAN NO "CENTRAL-TYPE"
C     SUB-SUBCHANNELS
C
      WRITE(6,4)NS,JJJ,E(I),ITCORR    ,(I,PVERT(I),PRAD(I),I=1,N)
    4 FORMAT(1H1,5X,'CALCULATION STOPS: NO CENTRAL SUBCHANNELS IN WALL C
     *HANNEL',I4/5X,'M=',I2, 5X,'E(I)=',E15.5,5X, ' ITCORR=',I3
     *           /(5X,'I=',I3,5X,'PVERT=',E15.5,5X,'PRAD=',E15.5))
      RETURN 1
C     ..................................................................
C     RECALCULATION OF THE SUB-SUBCHANNEL FOR WHICH IT WAS E(I)>EMAX,
C     IN ORDER TO FIT EMAX (I.E. E(I)=EMAX)
C
    5 CONTINUE
      IVIA=2
      II=I
      ANGT=ANGT-TETA
      DEE=EMAX-E(I-1)
      PP=P(I-1)-DEE*(P(I-1)-P(I))/(E(I)-E(I-1))
      BETA=ATAN(EMAX*2./(PP*D))
      TETA=BETA-ANGT
      PVERT(I)=PP*D*0.5
      PRAD(I)=PVERT(I)/COS(BETA)
      PAI=DEE*XC2
      WW=W-((EMAX+E(I-1))*0.5-EM1)*XC1
      DAI=4.*(WW-0.5*(D+PVERT(I)+PVERT(I-1)))/XC2
      DBI=2.*(P(I-1)*EMAX-PP*E(I-1))/TETA-D
      PBI=TETA *D*0.5
      AAI=DAI*PAI*0.25
      ABI=DBI*PBI*0.25
      EPS=SQRT(1.+DBI/D)
      GG=GSTAR(EPS)
      GOTO 1
C     ..................................................................
C     ALL THE "WALL-TYPE SUB-SUBCHANNELS HAVE BEEN COMPUTED: CALCULATION
C     OF AVERAGE SUB-SUBCHANNEL VARIABLES FOR THE WALL PORTION
C
   10 CONTINUE
      DTIEAV(III,JJJ)=DTIEAV(III,JJJ)/AMT
      TSCHAB=TT/AMT
      RHOTAB=RHO(PB,TSCHAB)
      PHWC(III,JJJ,1)=BETA*D*0.5
      PSHWC=(EMAX-EM1)*XC2+EM1
      PHWCTL=PHWC(III,JJJ,1)+PSHWC
```

```
      DEWC(III,JJJ,1)=4.*ASCHWC(III,JJJ,1)/PHWCTL
      LAMWC(III,JJJ,1)=((ASCHWC(III,JJJ,1)/DDDD)**2)*2.*DEWC(III,JJJ,1)*
     *     RHOTAB/H
      ATB=ASCHWC(III,JJJ,1)-ATA
      ADAB(III,JJJ)=ASCHWC(III,JJJ,1)/ATB
      DETB(III,JJJ)=4.*ATB/PHWC(III,JJJ,1)
      DDDDB=DDDD-DDDDA
      XMSCHA(III,JJJ)=AMA
      XMSCHB(III,JJJ)=AMT-XMSCHA(III,JJJ)
      TSCHB=(TT-TTA)/SRAMIB
      RHOTB=RHO(PB,TSCHB)
      LAMB(III,JJJ)=((ATB/DDDDB)**2)*2.*DETB(III,JJJ)*RHOTB/H
      AMTAB=AMT
      TTAB=TT
      DDDDAB=DDDD
C     ..................................................................
C     CALCULATION OF THE "CENTRAL-TYPE" SUB-SUBCHANNELS
C
      ALFC=ALFACE
      GAMMA=PIG*0.5-BETA
      AN1=GAMMA/ALFACE
      N1=AN1
      IF(N1.EQ.0)ALFC=GAMMA
      IF(N1.EQ.0)N1=1
      IF(N1.LE.NSC45)GOTO 12
      WRITE(6,11)NS,K,ITCORR
   11 FORMAT(1H1,5X,'N1 GREATER THAN NSC45 FOR CHANNEL',I4,2X,'(AXIAL SE
     *CTION',I3,')'/5X,'ITCORR=',I3)
      RETURN 1
C
   12 CONTINUE
      L=II
      II1=II+1
      DO 1000 I=II1,N
 1000 TIO(III,JJJ,I)=TIO(III,JJJ,L)
      AN1=N1
      BETA1=ALFC*AN1
      IF(ABS(BETA1/GAMMA-1.).LT.1.E-06)GOTO 99
C     ..................................................................
C     CALCULATION OF THE CENTRAL SUB-SUBCHANNEL DEFINED BY AN ANGLE
C     OF THE ROD SECTOR = ALFA1 ( IF ALFA1>0 )
C
      ALFA1=GAMMA-BETA1
      E1=C*0.5*TAN(BETA1)
      DELTAE=PVERT(II)-E1
      AA=C*DELTAE*0.25-ALFA1*D**2*0.125
      DD=8.*AA/(ALFA1*D)
      EPS=SQRT(1.+DD/D)
      GG=GSTAR(EPS)
      AM1=MFLOW*AA/ATOT
      L=II+1
      CALL CEWA(K,NS,IRH,PROV,PE,RH,AA,DD,GG,AM1,DETOT,H1,ALFA1,L,JJJ,H,
     *PR1,PR2,SGDPG,AMT,TT,DDDD,TE,SUR,2,III,HPLUSB(NS,JJJ),HPLUSW(NS,JJ
     *J),TSCWC1(III,JJJ,2),SIGMA2,PHI2,&777,D,TWI,TICEN,C)
      TWIAV=TWIAV+TWI*ALFA1
C     ..................................................................
C     CALCULATION OF THE "CENTRAL-TYPE  SUB-SUBCHANNELS DEFINED BY AN
C     ANGLE OF THE ROD SECTOR = ALFC
C
   99 CONTINUE
      DO 13 J=1,N1
      I=N1-J+1
      IF(N1.EQ.1)GOTO 100
      AA=A(I)
      DD=DE(I)
      GG=G(I)
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      AM1=MEC(I)                                                        000150
      GOTO 101                                                          000150
  100 AA=(C**2*TAN(ALFC)-D**2*ALFC)*0.125                               000150
      DD=8.*AA/(ALFC*D)                                                 000150
      EPSEPS=SQRT(1.+DD/D)                                              000150
      GG=GSTAR(EPSEPS)                                                  000150
      AM1=AA*MEC(1)/A(1)                                                000150
  101 LL=L+J                                                            000150
      CALL CEWA(K,NS,IRH,PRCV,PB,RH,AA,DD,GG,AM1,DETOT,H1,ALFC,LL,JJJ,H,000151
     *PR1,PR2,SQDPG,AMT,TT,DDDD,TE,SUR,2,III,HPLUSB(NS,JJJ),HPLUSW(NS,JJ000151
     *J),TSCWC1(III,JJJ,2),SIGMA2,PHI2,&777,D,TWI,TICEN,C)              000151
      TWIAV=TWIAV+TWI*ALFC                                              000151
   13 CONTINUE                                                          000151
C     ..................................................................000151
C     THE CALCULATION OF THE "CENTRAL-TYPE" SUB-SUBCHANNELS HAS BEEN    000151
C     COMPLETED: CALCULATION OF AVERAGE SUB-SUBCHANNEL VARIABLES FOR THE000151
C     WHOLE CENTRAL PORTION AND FOR THE WHOLE WALL SUBCHANNEL           000151
C                                                                       000151
      TWIAV=TWIAV*2./PIG                                                000152
      PHWC(III,JJJ,2)=GAMMA*D*0.5                                       000152
      ASCHWC(III,JJJ,2)=AT-ASCHWC(III,JJJ,1)                            000152
      DEWC(III,JJJ,2)=4.*ASCHWC(III,JJJ,2)/PHWC(III,JJJ,2)              000152
      TSCHC=(TT-TTAB)/(AMT-AMTAB)                                       000152
      RHOTC=RHO(PB,TSCHC)                                               000152
      DDDDC=DDDD-DDDDAB                                                 000152
      LAMWC(III,JJJ,2)=((ASCHWC(III,JJJ,2)/DDDDC)**2)*2.*DEWC(III,JJJ,2)000152
     *                 *RHOTC/H                                         000152
       ATSCH=TT/AMT                                                     000152
      RHOT=RHO(PB,ATSCH)                                                000153
      DO 14 JWC=1,2                                                     000153
   14 DDDD=DDDD+ASCHWC(III,JJJ,JWC)*SIGMAI(NS,JJJ)*(CHI(III,JJJ,JWC)-1.)000153
     */(SQRT(ABS(SQDPG**2*DPSI-IGRAV*RHOT*980.665*H)))                  000153
      LAMSCH(NS,JJJ)=((AT/DDDD)**2)*2.*DET*RHOT/H                       000153
      CTURB2(III,JJJ)=TURBWC(CTC3,PVERT(II),PRAD(II),D,W,C,GAMMA,ASCHWC 000153
     *(III,JJJ,1),ASCHWC(III,JJJ,2),DEWC(III,JJJ,1),DEWC(III,JJJ,2),EM1)000153
      I2TIP(NS,JJJ)=0                                                   000153
      F2ATIP(NS,JJJ)=1.                                                 000153
      F2DTIP(NS,JJJ)=1.                                                 000153
      IF(I3TIP(NS,JJJ).EQ.2)GOTO 3000                                   000154
      IF(ITCORR.GT.1)GOTO 2999                                          000154
      MSCH(NS,JJJ)=AMT                                                  000154
      TSCH(NS,JJJ)=ATSCH                                                000154
      TW(NS,JJJ)=TWIAV                                                  000154
C     ..................................................................000154
C     ..................................................................000154
C     FOR I3TIP=1 OR I3TIP=3                                            000154
C                                                                       000154
 2999 CONTINUE                                                          000154
      ZWC=(C*0.5-EM1)/SQRT(3.)                                          000155
      PPPP=(W-0.5*D-ZWC)*ANGLAM                                         000155
      OMEGA=ATAN(PPPP*2. /C)                                            000155
      PHWC1L=(PIG*0.5-OMEGA)*RTIP(IPA)                                  000155
      PHWC2L=OMEGA*RTIP(IPA)                                            000155
      AWC2L=              C*0.25*PPPP-RTIP(IPA)**2*0.5*OMEGA            000155
      AWC1L=ASCH(NS,JJJ)*FATIP(2)-AWC2L                                 000155
      PHWCTL=PHWC1L+2.*ZWC+EM1                                          000155
      DEWC1L=4.*AWC1L/PHWCTL                                            000155
      DEWC2L=4.*AWC2L/PHWC2L                                            000155
      MWC1L=MSCH(NS,JJJ)*AWC1L/(ASCH(NS,JJJ)*FATIP(2))                  000156
      MWC2L=MSCH(NS,JJJ)-MWC1L                                          000156
      R1DR2L=1./SQRT(1.+ 2.*AWC1L/(PHWC1L*RTIP(IPA)))                   000156
      R21WA=RTIP(IPA)/R1DR2L                                            000156
      RO2WA=SQRT(RTIP(IPA)**2+2.*RTIP(IPA)*AWC2L/PHWC2L)                000156
      PHWCTE=1.                                                         000156
      PHWC1E=1.                                                         000156
      IF(QQ(NS,JJJ).LE.1.E-06)GOTO 4444                                 000156
```

```
      QROD=QSCH(NS,JJJ)*QDEV
      QLIN=QLINM*QLDEV*C*0.5
      PHWCTE=(QROD+QLIN)*(PHWC1L+PHWC2L)/QROD
      QROD1=QROD*PHWC1L/(PHWC1L+PHWC2L)
      PHWC1E=(QROD1+QLIN)/QROD1*PHWC1L
 4444 FPROV=(DET*FDTIP(2))**2*AT*FATIP(2)/PHWCTE
      WFCO1(III,JJJ)=AKAWC(1)*PHWC1E*FPROV/(AWC1L*DEWC1L**2)
      WFCO(III,JJJ)=(WFCO1(III,JJJ)*PHWC1L+AKAWC(2)*PHWC2L**2*FPROV/
     /(AWC2L*DEWC2L**2))/((PHWC1L+PHWC2L)*BKAPPA(IPA,2))
       WFCO1(III,JJJ)=WFCO1(III,JJJ)/BKAPPA(IPA,2)
      RELA=RELAM(AT*FATIP(2),DET*FDTIP(2),PB,TSCH(NS,JJJ),TW(NS,JJJ),
     *             MSCH(NS,JJJ),TLINER(III,JJJ),2,R1DR2L,PHWCTL/(PHWCTL+
     +PHWC2L))
      LAMLAM=AKAPPA(NS)/RELA
      CALL ENTRFR(K,1,2,RTIP(IPA),RO2WA,R21WA,NS,III,JJJ,DEWC1L,AWC1L,
     *             MWC1L,PB,TSCH(NS,JJJ),LAMLAM)
      CALL ENTRFR(K,2,2,RTIP(IPA),RO2WA,R22WA,NS,III,JJJ,DEWC2L,AWC2L,
     *             MWC2L,PB,TSCH(NS,JJJ),LAMLAM)
      IF(                  I2TIP(NS,JJJ).EQ.1)GOTO 2997
C     ................................................................
C     I3TIP=3: SAGAPO DECIDES WHETHER THE FLOW IS LAMINAR OR TURBULENT
C
      IF(LAMSCH(NS,JJJ).GT.LAMLAM)GOTO 3000
C     ................................................................
C     THE FLOW IS LAMINAR
C
 2997 CONTINUE
      LAMSCH(NS,JJJ)=LAMLAM
      LAMWC(III,JJJ,1)=LAMLAM
      LAMWC(III,JJJ,2)=LAMLAM
      DDDD=AT*FATIP(2)/SQRT(LAMLAM*F/(2.*DET*FDTIP(2)*
     *RHO(PB,TSCH(NS,JJJ))))
      AMT=MSCH(NS,JJJ)
      ATSCH=TSCH(NS,JJJ)
      I2TIP(NS,JJJ)=1
      F2ATIP(NS,JJJ)=FATIP(2)
      F2DTIP(NS,JJJ)=FDTIP(2)
      ASCHWC(III,JJJ,1)=AWC1L
      ASCHWC(III,JJJ,2)=AWC2L
      PHWC(III,JJJ,1)=(PIG*0.5-OMEGA)*D*0.5
      PHWC(III,JJJ,2)=OMEGA*D*0.5
      DEWC(III,JJJ,1)=DEWC1L
      DEWC(III,JJJ,2)=DEWC2L
      HPLUSB(NS,JJJ)=1.
      HPLUSW(NS,JJJ)=1.
      QPLUS(NS,JJJ)=1.
      PRB(NS,JJJ)=1.
      YODH(NS,JJJ)=1.
      TBSSC1( NS,JJJ)=TSCH(NS,JJJ)
      T1SSC1(III,JJJ)=TSCH(NS,JJJ)
      T2SSC1(III,JJJ)=TSCH(NS,JJJ)
      TBSSC2(NS ,JJJ)=TSCH(NS,JJJ)
      T1SSC2(III,JJJ)=TSCH(NS,JJJ)
      T2SSC2(III,JJJ)=TSCH(NS,JJJ)
      TWSSC1( NS,JJJ)=TW(NS,JJJ)
      TWSSC2( NS,JJJ)=TW(NS,JJJ)
      XMSCHA(III,JJJ)=MSCH(NS,JJJ)*ASCHWC(III,JJJ,1)/(ASCH(NS,JJJ)*
     *F2ATIP(NS,JJJ))*0.5
      XMSCHB(III,JJJ)=XMSCHA(III,JJJ)
      ADAB(III,JJJ)=2.
C     FOR LAMINAR AND TURBULENT FLOW
C
 3000 CONTINUE
      FCOPW2(III,JJJ)=FCOPW1(2)+PHWC(III,JJJ,2)/PHWCTL*(FCOPW1(2)-1.)
      F1ATIP(NS)=F1ATIP(NS)+ASCH(NS,JJJ)/ACHA(NS)*F2ATIP(NS,JJJ)
        F1PTIP=F1PTIP+ASCH(NS,JJJ)/ACHA(NS)*F2ATIP(NS,JJJ)/F2DTIP(NS,JJJ)
```

```
      F1DTIP(NS)=F1ATIP(NS)/F1PTIP                                       000163
      IF(IRH.EQ.1 .OR.      I2TIP(NS,JJJ).EQ.1)RETURN                    000163
C     ..................................................................000163
C     ONLY FOR TURBULENT FLOW AND ROUGHENED RODS                         000163
C                                                                        000163
      ATBC=ATB+ASCHWC(III,JJJ,2)                                         000163
      HPLUSB(NS,JJJ)=HPLUSB(NS,JJJ)/ATBC                                 000164
      HPLUSW(NS,JJJ)=HPLUSW(NS,JJJ)/ATBC                                 000164
      AMTBC=AMT-SRAMIA                                                   000164
      TSCHBC=(TT-TTA)/AMTBC                                              000164
      CPTBC=CP(PB,TSCHBC)                                                000164
      QPLUS(NS,JJJ)=QQ(NS,JJJ)*ATBC/(SUR*AMTBC*CPTBC*(TE+273.16))        000164
      PRB(NS,JJJ)=ETA(PB,ATSCH)*CP(PB,ATSCH)/KAPPA(PB,ATSCH)             000164
      YODH(NS,JJJ)=0.5*(SQRT(D**2+16.*ATBC/PIG)-D)/RH                    000164
      RETURN                                                             000164
  777 RETURN 1                                                           000164
      END                                                                000165
C                                                                        000166
C                                                                        000167
C                                                                        000168
C                                                                        000169
C                                                                        000000
C                                                                        000000
C                                                                        000000
C                                                                        000000
      SUBROUTINE RECCA2  (NS,III,NP,INDSP,H,LENGTH,PR1,PR2,PBT,FRELI,FT,000000
     *ITCORR,PIG,D,EPAV,*,WSP,I1SPAC)                                    000000
C-----------------------------------------------------------------------000000
C     SUBROUTINE SUBBAL EVALUATES MASS FLOW RATES AND TEMPERATURES FOR   000000
C     THE TWO PARTS OF WALL SUBCHANNEL                                   000000
C                                                                        000000
      REAL LENGTH,LAMWC,MAWC,M1WC(2),M2WC(2),MSCWC1,MSCH,MSCH1,MAVCF(2),000000
     *      MAV,MAVJT                                                    000000
      DIMENSION WCFUD(2),WCFWC(2),WCF1WC(2),EP1WC(2),QWCL(2),TIWC(2),    000000
     1          TAWC(2),T2WC(2),RHC1(2),RHOAV(2),RUASWC(2),AWC(2),       000001
     2          TMOEX(2),TACF(2),UACF(2),ACF(2),WTWC2(2),WTWC3(2)        000001
     3          ,XMEM(2),DELTAA(2),IPAWC(2),QLINWC(2),THEX(2),DPWC(2),   000001
     4          UWC(2)                                                   000001
      COMMON/CORR1/SIGMAI(42,3),PHII(42,3)/CORR2/CHI(18,2,2),PSI(18,2,2)000001
     1       /GRIDO/CSPAC(42,3,4)/IJ1/NER(42),NIS(42,3)/IND3/NTYP(42)    000001
     2       /GEN2/A(42)/MOB2/UAV(42)/MOB5/TAV(42)/MOB6/MAV(42)          000001
     3       /MOB8/DP(42)/SUBC2/JCHC(3,2)/SUB1/ASCH(42,3)/SUB2/TSCH(42,3)000001
     4       ,MSCH(42,3)/SUB8/MSCH1(42,3)/SUB31/WCFNS(3),DPNS(3),WTNS1(3,000001
     5       3),WTNS2(3,2),UNS(3),RUASNS(3)/HEA10/QSCH(42,3)             000001
     6       /WCSE1/DEWC(18,2,2),PHWC(18,2,2)/WCSE2/MSCWC1(18,2,2)/WCSE5/000002
     7       TSCWC1(18,2,2)/ WCSE3/LAMWC(18,2,2)/WCSE4/CTURB(18,2)       000002
     8       /WCSE6/ASCWC1(18,2,2)/WCSE7/MAWC(18,2,2)                    000002
     9       /WCSE8/ASCHWC(18,2,2)/WCSE9/TAVWC(18,2,2)                   000002
      COMMON /SUBC1/NCHC(3),JSCH(3,3)/GEOO/ACH(3)                        000002
     1       /GRID1/EPS(42,3,5),DISTS(7)/GRID8/PGDP(42,3,4)              000002
     2       /SUB3/ACAB(18,2),DCEB(18,2)/WACO1/XMSCHB(18,2),XMSCHA(18,2) 000002
     3       /QPAR1/QDEV/QPAR2/QLINM,QLDEV/QPAR3/PERL(3)                 000002
     4       /GRIDWC/EPSWC(18,2,2,4),CSPWC(18,2,2,4)/GRAV/IGRAV          000002
     5       /GAAG2/FCOPW2(18,2)                                         000002
     6       /ENEOP/IENE/GRID2/YY(100,42,3)/MIXS2/CY/SECIN/K             000003
      XX=1./980665.                                                      000003
      DO 70 I=1,NP                                                       000003
      FRELWC=FRELI                                                       000003
      NCHCI=NCHC(I)                                                      000003
C                                                                        000003
C     IW IS THE OTHER SUBCHANNEL OF WALL CHANNEL NS; NCHCI IS THE NUMBER000003
C     OF CHANNELS CONNECTED TO SUBCHANNEL I                              000003
C                                                                        000003
      IW=3-I                                                             000003
C                                                                        000004
C     PORTION 1 IS CONNECTED TO AN EXTERNAL CHANNEL; PORTION 2 TO A      000004
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C      CENTRAL CHANNEL ( PORTION INDEX = IPAWC )                          000004
C                                                                         000004
       DO 101 K1=1,NCHCI                                                  000004
       JCHCIK=JCHC(I,K1)                                                  000004
       J=NIS(NS,JCHCIK)                                                   000004
       IPAWC(K1)=3-NTYP(J)+NTYP(J)/3                                      000004
  101  CONTINUE                                                           000004
       DO 3 JWC=1,2                                                       000004
       WCFUD(JWC)=WCFNS(I)*ASCHWC(III,I,JWC)/ASCH(NS,I)                   000005
       MIWC(JWC)=MSCWC1(III,I,JWC)                                        000005
       AWC(JWC)=ASCHWC(III,I,JWC)                                         000005
       DELTAA(JWC)=0.                                                     000005
       QWCL(JWC)=QSCH(NS,I)*PHWC(III,I,JWC)/(LENGTH*0.25*PIG*D)*QDEV      000005
       QLINWC(3-JWC)=QLINM*PEFL(JWC)*0.5*QLDEV/LENGTH                     000005
       TIWC(JWC)=TSCWC1(III,I,JWC)                                        000005
       RHO1(JWC)=RHO(PR1,TSCWC1(III,I,JWC))                               000005
    3  CONTINUE                                                           000005
C      ...............................................................000005
C      ITERATION ON THE RELAXATION FACTOR (LOOP ITFREL)                   000006
C                                                                         000006
       DO 50 ITFREL=1,98                                                  000006
       IVIA=1                                                             000006
C      ...............................................................000006
C      CALCULATION OF THE PRESSURE LOSSES (LOOP ITGL)                     000006
C                                                                         000006
       DO 49 ITGL=1,60                                                    000006
C                                                                         000006
C------EVALUATION OF THE CROSS FLOW SOLUTION                              000006
       CALL CRFL1(ITGL,DPWCAV,FRELWC,ASCH(NS,I),2,AWC,MIWC,DPWC,WCFWC,    000007
     *     WCF1WC,EP1WC)                                                  000007
       DO 5 JWC=1,2                                                       000007
       WCFWC(JWC)=WCFWC(JWC)+WCFUD(JWC)                                   000007
       M2WC(JWC)=MIWC(JWC)-H*WCFWC(JWC)                                   000007
       MAWC(III,I,JWC)=(M2WC(JWC)+MIWC(JWC))*0.5                          000007
       TAWC(JWC)=TSCH(NS,I)                                               000007
       RUASWC(JWC)=MAWC(III,I,JWC)*SQRT(LAMWC(III,I,JWC)*0.125)           000007
    5  CONTINUE                                                           000007
C                                                                         000007
       IF(ITGL.GT.1 .AND. IVIA.EQ.1 )GOTO 30                              000008
C      ...............................................................000008
C      CALCULATION OF THE AVERAGE GAS TEMPERATURES (LOOP ITERM)           000008
C                                                                         000008
       XPREC=1.E-04                                                       000008
       DO 25 ITERM=1,20                                                   000008
C                                                                         000008
C   A) TURBOLENT EXCHANGE BETWEEN THE TWO PARTS OF SUBCHANNEL             000008
C                                                                         000009
       IF(TAWC(1).LE.0. .OR. TAWC(1).GT.3000. .OR. TAWC(2).LE.0. .OR.     000008
     * TAWC(2).GT.3000.)GOTO 99                                           000009
       YYWC=(YY(K,NS,I)-1.)*CY+1.                                         000009
       WTWC1=TME(PBT,MAWC(III,I,1),MAWC(III,I,2),TAWC(1),TAWC(2),LAMWC(II000009
     *I,I,1),LAMWC(III,I,2),AWC(1),AWC(2),CTURB(III,I))*YYWC              000009
       TA12=(MAWC(III,I,1)*TAWC(1)+MAWC(III,I,2)*TAWC(2))/MSCH(NS,I)      000009
       THEX(1)=-(TAWC(1)-TAWC(2))*WTWC1*CP(PBT,TA12)                      000009
       THEX(2)=-THEX(1)                                                   000009
C                                                                         000009
C   B) TURBOLENT EXCHANGE WITH CHANNELS                                   000009
C                                                                         000009
       DO 8 K1=1,NCHCI                                                    000010
       IWC=IPAWC(K1)                                                      000010
       JCHCIK=JCHC(I,K1)                                                  000010
       J=NIS(NS,JCHCIK)                                                   000010
       NTYPJ=NTYP(J)                                                      000010
       MAVJT=MAV(J)*ACH(NTYPJ)/A(J)                                       000010
       WTWC2(IWC)=WTNS2(I,K1)                                             000010
       TAIJ=(TAWC(IWC)*MAWC(III,I,IWC)+TAV(J)*MAVJT )/(MAWC(III,I,IWC)+   000010
```

```
     *      MAVJT )
      THEX(IWC)=THEX(IWC)-(TAWC(IWC)-TAV(J))*WTWC2(IWC)*CP(PBT,TAIJ)
    8 CONTINUE
      IF(NP.EQ.1)GOTO 11
C
C  C) TURBOLENT EXCHANGE WITH THE OTHER SUBCHANNEL
C
      SRUAS=RUASWC(1)+RUASWC(2)+2.*RUASNS(IW)
      DO 10 JWC=1,2
      WTWC3(JWC)=WTNS1(1,2)*(RUASWC(JWC)+RUASNS(IW))/SRUAS
      TAIJ=(TAWC(JWC)*MAWC(III,I,JWC)+TSCH(NS,IW)*MSCH(NS,IW))/
     *    (MAWC(III,I,JWC)+MSCH(NS,IW))
      THEX(JWC)=THEX(JWC)-(TAWC(JWC)-TSCH(NS,IW))*WTWC3(JWC)*CP(PBT,TAIJ
     *)
   10 CONTINUE
   11 CONTINUE
C
C  D) CROSS FLOW EXCHANGE BETWEEN THE TWO PARTS OF SUBCHANNEL
C
      TACF(1)=0.
      MAVCF(1)=0.
      CALL CF1(TAWC(1),TAWC(2),MAWC(III,I,1),MAWC(III,I,2),DPWC(1),
     *DPWC(2),ITGL,TACF(1),MAVCF(1))
      TACF(2)=TACF(1)
      MAVCF(2)=MAVCF(1)
C
C  E) CROSS FLOW EXCHANGE WITH CHANNELS
C
      DO 16 K1=1,NCHCI
      IWC=IPAWC(K1)
      JCHCIK=JCHC(I,K1)
      J=NIS(NS,JCHCIK)
      NTYPJ=NTYP(J)
      MAVJT=MAV(J)*ACH(NTYPJ)/A(J)
      CALL CF1(TAWC(IWC),TAV(J),MAWC(III,I,IWC),MAVJT ,DPWC(IWC),DP(J),
     *ITGL,TACF(IWC),MAVCF(IWC))
   16 CONTINUE
      IF(NP.EQ.1)GOTO 18
C
C  F) CROSS FLOW EXCHANGE WITH THE OTHER SUBCHANNEL
C
      DO 17 JWC=1,2
      CALL CF1(TAWC(JWC),TSCH(NS,IW),MAWC(III,I,JWC),MSCH(NS,IW),
     *DPWC(JWC),DPNS(IW),ITGL,TACF(JWC),MAVCF(JWC))
   17 CONTINUE
   18 CONTINUE
      DO 20 JWC=1,2
      TACF(JWC)=TACF(JWC)/MAVCF(JWC)
      TAICF=( TAWC(JWC)*MAWC(III,I,JWC)+TACF(JWC)*MAVCF(JWC))/(MAWC(III,
     *I,JWC)+MAVCF(JWC))
      CFHEX=WCFWC(JWC)*(TAWC(JWC)-TACF(JWC))*CP(PBT,TAICF)
       XXMAV=MAWC(III,I,JWC)
      XXM2=M2WC(JWC)
      IF(IENE.EQ.2)XXMAV=M1WC(JWC)
      IF(IENE.EQ.2)XXM2=XXMAV
      T2WC(JWC)=TSCWC1(III,I,JWC)+H/(XXMAV*CP(PBT,TAWC(JWC)))*
     *          (QWCL(JWC)+GLINWC(JWC)+THEX(JWC)+CFHEX)
      IF(ABS(PHII(NS,I)).GT.1.E-20)GOTO 200
      PSI(III,I,JWC)=1.
      GOTO 201
  200 CONTINUE
      PSI(III,I,JWC)=(THEX(JWC)+CFHEX)*H/(AWC(JWC)*PHII(NS,I))
  201 CONTINUE
      TAVWC(III,I,JWC)=(XXM2*T2WC(JWC)+M1WC(JWC)*TSCWC1(III,I,JWC))
     *          *0.5  /XXMAV
   20 CONTINUE
```

```
      IF(ITGL.EQ.1)GOTO 30
      IF(ITERM.GT.10)XPREC=1.E-03
      IF(ITERM.GT.15)XPREC=1.E-02
      DO 21 JWC=1,2
      IF(ABS(TAWC(JWC)/TAVWC(III,I,JWC)-1.).GT.XPREC)GOTO 22
   21 CONTINUE
      GOTO 30
   22 CONTINUE
      DO 23 JWC=1,2
   23 TAWC(JWC)=TAVWC(III,I,JWC)
   25 CONTINUE
C     ..................................................................
C     END OF THE LOOP ITERM: POINT REACHED IN THE CASE OF CONVERGENCE
C     PROBLEMS
C
      WRITE(6,26)NS,I,(TAWC(JWC),JWC=1,2),ITCORR
   26 FORMAT(    5X,'STOP IN LOOP ITERM OF SUB. RECCA2. NS=',I5,2X,'I=',
     *I2,5X,'TEMPERATURES='/5X,2E15.7/5X,'ITCORR=',I5)
      RETURN 1
C     ..................................................................
C     CONVERGENCE HAS BEEN REACHED FOR THE ENERGY EQUATIONS; THE CALCU=
C     LATION OF THE PRESSURE DROPS STARTS
C
   30 CONTINUE
      DO 31 JWC=1,2
      RHOAV(JWC)=RHO(PBT,TAVWC(III,I,JWC))
      UWC(JWC)=MAWC(III,I,JWC)/(AWC(JWC)*RHOAV(JWC))
   31 CONTINUE
      DPWCAV=0.
      SMWC1=0.
C
C   A) TURBOLENT EXCHANGE BETWEEN THE TWO PARTS OF SUBCHANNEL
C
      TMOEX(1)=-(UWC(1)-UWC(2))*WTWC1
      TMOEX(2)=-TMOEX(1)
C
C   B) TURBOLENT EXCHANGE WITH CHANNELS
C
      DO 35 K1=1,NCHCI
      JCHCIK=JCHC(I,K1)
      J=NIS(NS,JCHCIK)
      IWC=IPAWC(K1)
      TMOEX(IWC)=TMOEX(IWC)-(UWC(IWC)-UAV(J))*WTWC2(IWC)
   35 CONTINUE
C
C   C) TURBOLENT EXCHANGE WITH THE OTHER SUBCHANNEL
C
      DO 37 JWC=1,2
      IF(NP.NE.1)TMOEX(JWC)=TMOEX(JWC)-(UWC(JWC)-UNS(IN))*WTWC3(JWC)
   37 TMOEX(JWC)=TMOEX(JWC)*FT*H/AWC(JWC)
      UACF(1)=0.
      ACF(1)=0.
C
C   D) CROSS FLOW EXCHANGE BETWEEN THE TWO PARTS OF SUBCHANNEL
C
      CALL CF1(UWC(1),UWC(2),AWC(1),AWC(2),DPWC(1),DPWC(2),    1,JACF(1),
     *         ACF(1))
      UACF(2)=UACF(1)
      ACF(2)=ACF(1)
C
C   E) CROSS FLOW EXCHANGE WITH CHANNELS
C
      DO 40 K1=1,NCHCI
      IWC=IPAWC(K1)
      JCHCIK=JCHC(I,K1)
      J=NIS(NS,JCHCIK)
```

```
      NTYPJ=NTYP(J)
      AJT=ACH(NTYPJ)
      CALL CF1(UWC(IWC),UAV(J),AWC(IWC),AJT ,DPWC(IWC),DP(J),1,
     *         UACF(IWC),ACF(IWC))
   40 CONTINUE
      DO 45 JWC=1,2
C
C  F) CROSS FLOW EXCHANGE WITH THE OTHER SUBCHANNEL
C
      IF(NP.NE.1)       CALL CF1(UWC(JWC),JNS(IW),AWC(JWC),ASCH(NS,IW),
     *      DPWC(JWC),DPNS(IW),1    ,UACF(JWC),ACF(JWC))
C
C
      UACF(JWC)=UACF(JWC)/ACF(JWC)
      CFMOEX=(2.*UWC(JWC)-UACF(JWC))*WCFWC(JWC)*H/AWC(JWC)
      XMEM(JWC)=LAMWC(III,I,JWC)*H/(2.*DEWC(III,I,JWC)*RHOAV(JWC))
      IF(JWC.EQ.1)XMEM(JWC)=XMEM(JWC)*FCDPW2(III,I)
      RE=MAWC(III,I,JWC)*DEWC(III,I,JWC)/(AWC(JWC)*ETA(PBT,TAVWC(III,I,
     1JWC)))
      IF(INDSP.EQ.2)XMEM(JWC)=XMEM(JWC)+(CSPWC(III,I,JWC,I1SPAC)+DSPDPF(
     *EPSWC(III,I,JWC,I1SPAC),DEWC(III,I,JWC),LAMWC(III,I,JWC),WSP,
     *PGDP(NS,I,I1SPAC),RE,2))/RHOAV(JWC)
      DPWC(JWC)=XX*(-(MAWC(III,I,JWC)/AWC(JWC))**2*(XMEM(JWC)-(RHO(PR2,
     *        T2WC(JWC))-RHO1(JWC))/RHOAV(JWC)**2-DELTAA(JWC)/(AWC(JWC)*
     *   RHOAV(JWC)))+TMOEX(JWC)+CFMOEX+IGRAV*980.665*RHOAV(JWC)*H)
      DPWCAV=DPWCAV+DPWC(JWC)*MIWC(JWC)
      SMWC1=SMWC1+MIWC(JWC)
   45 CONTINUE
      DPWCAV=DPWCAV/SMWC1
C     ..................................................................
C     TEST OF CONVERGENCE ON THE PRESSURE DROPS
C
      IF(ITGL.LT.4)GOTO 47
      DO 46 JWC=1,2
      IF(ABS(DPWC(JWC)/DPWCAV-1.).GT.1.E-02)GOTO 47
      IF(ABS(DPWC(JWC)/DPWCAV-1.).GT.1.E-03 .AND. ITGL.LT.40)GOTO 47
   46 CONTINUE
      IF(IVIA.EQ.2)GOTO 55
      IF(M2WC(1).LE.0. .OR. M2WC(2).LE.0.)GOTO 99
      IVIA=2
   47 CONTINUE
      DO 48 JWC=1,2
   48 WCFWC(JWC)=WCFWC(JWC)-WCFUC(JWC)
   49 CONTINUE
C     ..................................................................
C     END OF LOOP ITGL
C
   99 CONTINUE
      AIT=ITFREL
      FRELWC=1.-AIT*0.01
   50 CONTINUE
C     ..................................................................
C     END OF LOOP ITFREL: POINT REACHED IN THE CASE OF CONVERGENCE
C     PROBLEMS
C
      WRITE(6,51)ITCORR,NS,I,(DPWC(JWC),JWC=1,2),(MAWC(III,I,JWC),JWC=1,
     *         2),(TAVWC(III,I,JWC),JWC=1,2),(AWC(JWC),JWC=1,2)
   51 FORMAT(//  5X,'STOP IN LOOP ITGL OF RECCA2: ITCORR=',I5,5X,'NS=',
     1I5,5X,'I=',I2/5X,'PRESSURE LOSSES:',2E15.5/5X,'AVERAGE MASSES:',
     22E15.5/5X,'AVERAGE TEMPERATURES:',2E15.5/5X,'AREAS:',2E15.5)
      RETURN 1
C     ..................................................................
C     THE ENERGY EQUATIONS AND THE AXIAL MOMENTUM EQUATIONS HAVE
C     REACHED CONVERGENCE
C
   55 CONTINUE
```

```
      DO 56 JWC=1,2
      DPAVF=DPAV-IGRAV*RHOAV(JWC)*H*0.001
      BMWC=SQRT(ABS(DPAVF) /(XX*XMEM(JWC)))*AWC(JWC)
      CHI(III,I,JWC)=(MAWC(III,I,JWC)-BMWC)/(AWC(JWC)*SIGMAI(NS,I))
   56 CONTINUE
      EPSM=MAWC(III,I,1)-(XMSCHA(III,I)+XMSCHB(III,I))
      XMSCHA(III,I)=XMSCHA(III,I)+EPSM*(1.-1./ADAB(III,I))
      XMSCHB(III,I)=XMSCHB(III,I)+EPSM/ADAB(III,I)
   70 CONTINUE
      RETURN
      END
      C
      C
      C
      C
      SUBROUTINE RTRI(PBT,TBT,MASSI,DEL,AREAI,ADAB,LAM1,YYI,QA,FACHE,TE,
     * RH,I,II,M,JPIN,TW1,RU1DRU,ITYP,DEI,D,YYDH,*,F2ATIP,F2DTIP)
C-----------------------------------------------------------------------
C     RTRI EVALUATES ROD TEMPERATURES FOR CENTRAL AND CORNER SUBCHANNELS
C     AND FOR THE TWO PARTS OF WALL SUBCHANNELS IN THE ROUGH PORTION.THE
C     BULK TEMPERATURES OF THE TWO REGIONS DEFINED BY THE TAU=0 LINE ARE
C     ALSO COMPUTED.
C
      REAL LAM1,MASSI,KI,KAPPA,NUI,NUC,NUTU
      COMMON/SUB21/TSCHA(18,2),TSCHB(18,2)/SHROUD/TLINER(18,2)
     1         /QSHR/QALIN/TRANS/RHTU,RHSM/LAMINO/I2TIP(42,3)/ISUP/IQLIN
C     ...................................................................
C     TEMLAM IS CALLED IF THE FLOW IS LAMINAR; THE CALCULATION RETURNS
C     THEN AT THE END OF RTRI
C
      IF(I2TIP(I,M).EQ.1)CALL TEMLAM(&2000,PBT,TBT,MASSI,DEI,AREAI,QA,
     &                     QALIN,TE,I,II,M,TW1,ITYP,F2ATIP,F2DTIP,D)
C     *******************************************************************
C     THE FLOW IS TURBULENT: CALCULATION PERFORMED ASSUMING ROUGH FLOW
C     *******************************************************************
C
      R1=D*0.5
      R0=0.5*SQRT(D**2+DEL*D)
      R2=SQRT(D**2+ADAB*DEL*D)*0.5
C     ...................................................................
C     INLET EFFECT ON THE NUSSELT NUMBER OF THE RODS
C
      FACHE=TIS(R1,R2,2)
C
      YDH=(R0-R1)/RH
      R2MR0H=(R2-R0)/RH
      YYDH=YDH+R2MR0H
      R0DR2=R0/R2
      R1DR2=R1/R2
      KI=KAPPA(PBT,TBT)
      ETAI=ETA(PBT,TBT)
      RHOI=RHO(PBT,TBT)
      CPI=CP(PBT,TBT)
      REI=MASSI*DEI/(AREAI*ETAI)
      PRI=ETAI*CPI/KI
      UI=MASSI/(AREAI*RHOI)
      TWALL=TBT
      TW0=TBT
      TB1=TBT
C     ...................................................................
C     CALCULATION OF THE BULK TEMPERATURES OF THE TWO ZONES DIVIDED BY
C     THE TAU=0 LINE ( LOOP ITW )
C
      DO 7 ITW=1,10
      RHO1=RHO(PBT,TB1)
      U1DU=RU1DRU*RHOI/RHO1
```

```
      U1=U1DU*UI                                                        000036
      U1STAR=U1*SQRT(LAM1*0.125)                                        000036
C     ..................................................................000037
C     CALCULATION OF THE SURFACE PIN TEMPERATURE AT INFINITE CONDUCTI=  000037
C     VITY OF THE CANNING METAL AND AT (Q'')SHROUD = 0 ( LOOP ITW1 )    000037
C                                                                       000037
      DO 30 ITW1=1,10                                                   000037
      IF(ABS(TWO).LT.3000..AND. ABS(TWALL).LT.3000.)GOTO 29             000037
      WRITE(6,28)I,JPIN,TWO,TWALL                                       000037
   28 FORMAT(    5X,'STOP IN RTRI: NS=',I5,5X,'PIN=',I5/5X,'TWO=',E15.5,000037
     15X,'TWALL=',E15.5)                                                000037
      RETURN 1                                                          000037
   29 CONTINUE                                                          000038
      ETAW=ETA(PBT,TWALL)                                               000038
      RHOW=RHO(PBT,TWALL)                                               000038
      REW=U1*DE1*RHOW/ETAW                                              000038
      REWO=REW*ETAW*RHO(PBT,TWO)/(RHOW*ETA(PBT,TWO))                    000038
      HPLUSW=RH*REW*SQRT(LAM1*0.125)/DE1                                000038
      HPLUSO=HPLUSW*REWO/REW                                            000038
      CALL RNU(HPLUSW,TWALL,LAM1,REI,PRI,TBT,YDH,R1DR2,R2MROH,U1DU,REW, 000038
     1     YYI,NUI,GHPL)                                                000038
      CALL RNU(HPLUSO,TWO   ,LAM1,REI,PRI,TBT,YDH,R1DR2,R2MROH,U1DU,REWO,000038
     1       1.,NUO,GHPL)                                               000039
      ALFAI=NUI*KI/DEI*FACFE                                            000039
      ALFAO=NUO*KI/DEI                                                  000039
      TW1=TBT+QA/ALFAI                                                  000039
      TWO=TBT+QA/ALFAO                                                  000039
      IF(ABS(TW1/TWALL-1.).LE.1.E-04)GOTO 32                            000039
   30 TWALL=TW1                                                         000039
C     ..................................................................000039
C     END OF LOOP ITW1: POINT REACHED IN THE CASE OF CONVERGENCE        000039
C     PROBLEMS                                                          000039
C                                                                       000040
      WRITE(6,31)I,JPIN,TW1                                             000040
   31 FORMAT(1H1,5X,'STOP IN RTRI (LOOP ITW1) NS=',I5,5X,'PIN=',I5,5X,  000040
     *'TW1=',E15.5)                                                     000040
      RETURN 1                                                          000040
C     ..................................................................000040
C     CONVERGENCE HAS BEEN REACHED FOR THE PIN TEMPERATURE              000040
C                                                                       000040
   32 CONTINUE                                                          000040
      IF(ITYP.EQ.1)GOTO 9                                               000040
C     ..................................................................000041
C     ONLY FOR THE CORNER CHANNELS AND FOR THE WALL PORTION OF THE WALL 000041
C     SUBCHANNELS                                                       000041
C                                                                       000041
      FF=QA/(RHOI*CPI*U1STAR)                                           000041
      CALL DCONNE(TWO,TBT,GHPL,ROOR2,R1DR2,YDH,R2MROH,FF,TSCHA(II,M),   000041
     1   TSCHB(II,M),TE)                                                000041
      IF(ABS(TSCHB(II,M)/TB1-1.).LE.1.E-04)GOTO 9                       000041
      TB1=TSCHB(II,M)                                                   000041
    7 CONTINUE                                                          000041
C     ..................................................................000042
C     END OF LOOP ITW: POINT REACHED IN THE CASE OF CONVERGENCE         000042
C     PROBLEMS                                                          000042
C                                                                       000042
      WRITE(6,8)I,JPIN,TB1                                              000042
    8 FORMAT(1H1,5X,'STOP IN RTRI (LOOP ITW) I=',I5,5X,'PIN=',I5,5X,'TB1000042
     $=',E15.5)                                                         000042
      RETURN 1                                                          000042
C     ..................................................................000042
C     CONVERGENCE HAS BEEN REACHED FOR THE BULK TEMPERATURES OF THE     000042
C     TWO ZONES DIVIDED BY THE TAU=0 LINE; THE ASSUMPTION OF ROUGH FLOW 000043
C     IF TESTED ( THIS POINT IS REACHED ALSO BY THE CALCULATION FOR THE 000043
C     CENTRAL SUBCHANNELS AND THE CENTRAL PORTION OF THE WALL SUBCHANNEL000043
C                                                                       000043
```

```
    9 CONTINUE
      ETA1=ETA(PBT,TB1)
      HPLUSB=HPLUSW*RHO1*ETAW/(ETA1*RHOW)
      RHPL=RHPLUS(HPLUSB,TWALL,TE,XYXYX,HPLUSW,TB1,YDH)
      IF(RHTU.LE.RHSM)GOTO 100
C     ************************************************************
C     THE FLOW IF "HYDRAULICALLY" SMOOTH: THE CALCULATION IS REPEATED IN
C     SUBROUTINE RTSI. THE CALCULATION IS BASED STILL ON THE VOLUMETRIC
C     DIAMETER. THE CALCULATION RETURNS  IMMEDIATELY AFTER COMING BACK
C     FROM RTSI
C     ************************************************************
C
      CALL RTSI(PBT,TBT,MASSI,DEI,AREAI,ADAB,LAM1,YYI,QA,FACHE,TE,RH,I,
     &II,M,JPIN,TW1,RU1DRU,ITYP,DEI,D,YYDH,&8500,F2ATIP,F2DTIP)
      RETURN
C     ************************************************************
C     POINT REACHED IN THE CASE OF ROUGH FLOW
C     ************************************************************
C
  100 IF(ITYP.EQ.1)RETURN
C     ............................................................
C     CALCULATION OF THE SHROUD TEMPERATURE  FOR THE CORNER CHANNELS AND
C     FOR THE WALL PORTION OF THE WALL SUBCHANNELS ( VALUE AT
C     (Q")SHROUD = 0 )
C
      TLINER(II,M)=TWO-FF*(2.5*ALOG((R2-R1)/RH)+GHPL)
      IF(TLINER(II,M).LE.TE)TLINER(II,M)=TE
C     ............................................................
C     CORRECTION OF THE PREVIOUSLY COMPUTED PIN AND SHROUD TEMPERATURES
C     OF THE CORNER CHANNELS AND OF THE WALL PORTION OF THE WALL SUBCHA=
C     NNELS IN THE CASE OF HEATED SHROUD WALLS (SUPERPOSITION PRINCIPLE)
C
      DEIAN=2.*(R2-R1)
      TETA2=0.
      IF(QA.GT.1.E-06)TETA2=(TLINER(II,M)-TBT)*KI/(QA*DEIAN)
      NUI=NUI*DEIAN/DEI
      REI=REI*DEIAN/DEI
      A1=0.45/(2.4+PRI)
      NUTL=TUBENU(REI,PRI)
      PEI=REI*PRI
      FTWA=22.*(0.27*R1DR2**2-1.)/(PEI**0.87*PRI**0.18)*R1DR2
      IF(IQLIN.EQ.1 .AND. ABS(QALIN)
     1.GT.1.E-06)CALL TELIN(TW1,TLINER(II,M),TBT,TE,TETA2,FTWA,
     1 QA,QALIN,NUI,NUTU,A1,KI,R1DR2,DEIAN,I,JPIN,YYI,FACHE)
 2000 RETURN
 8500 RETURN 1
      END
      C
      C
      C
      C
       SUBROUTINE RTSI(PBT,TI,MASSI,DEI,AREAI,ADAB,LAM1,YYI,QA,FACHE,
     * TE,RH,I,II,M,JPIN,TWI,RU1DRU,ITYP,DEIR,D,XXXX,*,F2ATIP,F2DTIP)
C-----------------------------------------------------------------
C     RTSI EVALUATES ROD TEMPERATURES FOR CENTRAL AND CORNER SUBCHANNELS
C     AND FOR THE TWO PARTS OF WALL SUBCHANNELS IN THE SMOOTH PART
C
      REAL NUTU,NUIO,NUI,KI,KAPPA,MASSI,LAM1
      COMMON/SUB21/TSCHA(18,2),TSCHB(18,2)/SHROUD/TLINER(18,2)
     1        /QSHR/QALIN/LAMINO/I2TIP(42,3)/ISUP/IQLIN/ISMO/COTW
     2        /ISMO1/ITECO
C     ............................................................
C     TEMLAM IS CALLED IF THE FLOW IS LAMINAR; THE CALCULATION RETURNS
C     THEN AT THE END OF RTSI
C
      IF(I2TIP(I,M).EQ.1)CALL TEMLAM(&2000,PBT,TI,MASSI,DEIR,AREAI,QA,
```

```
     &                     QALIN,TE,I,II,M,TWI,ITYP,F2ATIP,F2DTIP,D)          000049
C    ******************************************************************000049
C    THE FLOW IS TURBULENT                                              000049
C    ******************************************************************000049
     TG=TE                                                              000050
     IF(ITECC.EQ.2)TG=TI                                                000050
      R1=D*0.5                                                          000050
     R0=0.5*SQRT(D**2+DE1*D)                                            000050
     R2=SQRT(D**2+ADAB*DE1*D)*0.5                                       000050
     DEI=2.*(R2-R1)                                                     000050
     R0DR2=R0/R2                                                        000050
     R1DR2=R1/R2                                                        000050
     R1DR0=R1/R0                                                        000050
C    ..................................................................000050
C    INLET EFFECT ON THE NUSSELT NUMBER OF THE RODS                     000051
C                                                                       000051
     FACHE=TIS(R1,R2,1)                                                 000051
C                                                                       000051
     TWI0=TWI                                                           000051
     KI=KAPPA(PBT,TI)                                                   000051
     ETAI=ETA(PBT,TI)                                                   000051
     RHOI=RHO(PBT,TI)                                                   000051
     CPI=CP(PBT,TI)                                                     000051
     REI=MASSI*DEI/(AREAI*ETAI)                                         000051
     PRI=ETAI*CPI/KI                                                    000052
     A1=0.45/(2.4+PRI)                                                  000052
     A2=0.16*PRI**(-0.15)                                               000052
     A3=1.                                                              000052
     IF(R1DR2.LT.0.2)A3=1.+(7.5*(1./R1DR2-5.)/REI)**0.6                 000052
     NUTU=TUBENU(REI,PRI)                                               000052
     FNU=(1.-A1)/R1DR2**A2  *A3*(TG+273.16)**COTW*NUTU                  000052
C    ..................................................................000052
C    CALCULATION OF THE SURFACE PIN TEMPERATURE AT (Q")SHROUD = 0       000052
C    ( LOOP ITW )                                                       000052
C                                                                       000053
     DO 5 ITW=1,10                                                      000053
     TWALL=TWI                                                          000053
     NUI=FNU/(TWI+273.16)**COTW*YYI*FACHE                               000053
     NUI0=FNU/(TWI0+273.16)**COTW                                       000053
     ALFAI0=NUI0*KI/DEI                                                 000053
     ALFAI=NUI*KI/DEI                                                   000053
     TWI=TI+QA/ALFAI                                                    000053
     TWI0=TI+QA/ALFAI0                                                  000053
     IF(ABS(TWALL/TWI-1.).LE.1.E-04)GOTO 7                              000053
   5 CONTINUE                                                           000054
C    ..................................................................000054
C    END OF LOOP ITW: POINT REACHED IN THE CASE OF CONVERGENCE          000054
C    PROBLEMS                                                           000054
C                                                                       000054
     WRITE(6,6)I,JPIN,TWI,TWALL                                         000054
   6 FORMAT(1H1,5X,'STOP IN RTSI (CHANNEL',I5,' , PIN',I5,') : TW=',    000054
    *E15.7,5X,'TWALL=',E15.7)                                           000054
     RETURN 1                                                           000054
C    ..................................................................000054
C    CONVERGENCE HAS BEEN REACHED FOR THE PIN TEMPERATURE               000055
C                                                                       000055
   7 IF (ITYP.EQ.1)RETURN                                               000055
C    ..................................................................000055
C    CALCULATION OF THE SHROUD TEMPERATURE  FOR THE CORNER CHANNELS AND000055
C    FOR THE WALL PORTION OF THE WALL SUBCHANNELS ( VALUE AT            000055
C    (Q")SHROUD = 0 )                                                   000055
C                                                                       000055
     PEI=REI*PRI                                                        000055
     FTWA=22.*(0.27*R1DR2**2-1.)/(PEI**0.87*PRI**0.18)*R1DR2            000055
     TLINER(II,M)=FTWA*QA*DEI/KI+TI                                     000056
     IF(TLINER(II,M).LE.TE)TLINER(II,M)=TE                              000056
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```
      TETA2=0.
      TSCHA(II,M)=TI
      TSCHB(II,M)=TI
      IF(QA.LE.1.E-06)GOTO 22
      TETA2=(TLINER(II,M)-TI)*KI/(QA*DEI)
      GTI=(1.5*R1DR2+0.5)/(R1DR2+1.)
      GT1=(1.5*R1DRO+0.5)/(R1DRO+1.)
      UI=MASSI/(AREAI*RHOI)
      F1=RO**2-R1**2
      F2=R2**2-RO**2
      FI=F1+F2
      TB1=TI
C     ..............................................................
C     CALCULATION OF THE BULK TEMPERATURES OF THE TWO ZONES DIVIDED BY
C     THE TAU=0 LINE FOR THE CORNER CHANNELS AND FOR THE WALL PORTION OF
C     THE WALL SUBCHANNELS ( LOOP ITW1 )
C
      DO 20 ITW1=1,10
      RHO1=RHO(PBT,TB1)
      ETA1=ETA(PBT,TB1)
      U1DUAS=RU1DRU*RHOI/RHO1*SQRT(LAM1*0.125)
      U1AS=U1DUAS*UI
      FF=RHOI*CPI*U1AS/QA
      DD=ETA1/(RHO1*U1AS)
      AS=-TETA2*PEI*U1DUAS/GTI
      BS=(TWIO-TI)*FF-AS*(ALOG((R2-R1)/DD)-GTI)
      TSCHA(II,M)=FI/F2*TI-F1/F2*(TWIO-(AS*(ALOG((RO-R1)/DD)-GT1)+BS)/
     /FF)
      IF(TSCHA(II,M).LE.TE)TSCHA(II,M)=TE
      TSCHB(II,M)=FI/F1*TI-F2/F1*TSCHA(II,M)
      IF(ABS(TSCHB(II,M)/TB1-1.).LE.1.E-04)GOTO 22
      TB1=TSCHB(II,M)
   20 CONTINUE
C     ..............................................................
C     END OF LOOP ITW1: POINT REACHED IN THE CASE OF CONVERGENCE
C     PROBLEMS
C
      WRITE(6,21)I,JPIN,TB1
   21 FORMAT(1H1,5X,'STOP IN RTSI (LOOP ITW1)I=',I5,5X,'PIN=',I5,'TB1=',
     1E15.5)
      RETURN 1
C     ..............................................................
C     CONVERGENCE HAS BEEN REACHED FOR THE BULK TEMPERATURES OF THE
C     TWO ZONES DIVIDED BY THE TAU=0 LINE
C     CORRECTION OF THE PREVIOUSLY COMPUTED PIN AND SHROUD TEMPERATURES
C     OF THE CORNER CHANNELS AND OF THE WALL PORTION OF THE WALL SUBCHA=
C     NNELS IN THE CASE OF HEATED SHROUD WALLS (SUPERPOSITION PRINCIPLE)
C
   22 IF(IQLIN.EQ.1 .AND. ABS(QALIN)
     0.GT.1.E-06)CALL TELIN(TWI,TLINER(II,M),TI,TE,TETA2,FTWA,QA
     1,QALIN,NUI,NUTU,A1,KI,R1DR2,DEI,I,JPIN,YYI,FACHE)
 2000 RETURN
      END
      C
      C
      C
      C
      SUBROUTINE SUBBAL(NSTOT,NSTR, INDSP,H,LENGTH,D,PIG,PR1,PR2,PBT,FRE
     *L,FT,ITCORR,DPAV,*,WSP,I1SPAC)
C-------------------------------------------------------------------
C     SUBROUTINE SUBBAL EVALUATES THE SUBCHANNEL MASS FLOW RATES AND
C     BULK TEMPERATURES
C
      REAL LAMSCH,MI,MAV,MSCH1,MSCH,MAVCF,LENGTH,M1NS(3),M2NS(3),
     1     MAV1,MAV2 ,MAWC,KAPPA
      DIMENSION RHO1(3),TINS(3),WCFUD(3),WCF1NS(3),EP1NS(3),TANS(3),
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     1          T2NS(3),RHOAV(3),ANS(3),XMEM(3),DE(3) ,A(42)                000062
      COMMON/CORR/SIGMA(42),PHI(42)/CORR1/SIGMAI(42,3),PHII(42,3)           000062
     1       /GRIDO/CSPAC(42,3,4)/IJ1/NER(42),NIS(42,3)/IND3/NTYP(42)       000062
     2       /GEN2/AZ(42)/GEN3/MI(42)/GEN5/DEZ(42)/MOB2/UAV(42)             000062
     3       /MOB4/WCF(42)/MOB5/TAV(42)/MOB6/MAV(42)/MOB8/DP(42)            000062
     4       /SUBC1/NCHC(3),JSCH(3,3)/SUBC2/JCHC(3,2)/SUB1/ASCH(42,3)       000062
     5       /SUB2/TSCH(42,3),MSCH(42,3)/SUB5/LAMSCH(42,3)                  000063
     6       /SUB6/TSCH1(42,3)/SUB8/MSCH1(42,3)/HEA10/QSCH(42,3)            000063
     7       /SUB31/WCFNS(3),DPNS(3),WTNS1(3,3),WTNS2(3,2),UNS(3),RUASNS(000063
     8       3)/MOB24/WT(42,3)/MOB26/RUAS(42)/TUR2/CTURB1(2)                000063
     9       /HEA6/NPIN(42),JPIN(42,3)/GEOD/ACH(3)                          000063
      COMMON/GRID1/EPS(42,3,5),DISTSP(7)/GRID8/PGDP(42,3,4)                 000063
     1       /SUB3/ADAB(18,2),DDTBB(18,2)/WACO1/XMSCHB(18,2),XMSCHA(18,2)000063
     2       /QPAR1/QDEV/QPAR2/CLINM,CLDEV/QPAR3/PERL(3)                    000063
     3       /LAMINO/         I2TIP(42,3) /LAMIN3/F1ATIP(42),F1DTIP(42) 000063
     4       /LAMIN4/F2ATIP(42,3),F2DTIP(42,3)/WCSE7/MAWC (18,2,2)          000063
     5       /WCSE9/TAVWC(18,2,2)/CORR2/CHI(18,2,2),PSI(18,2,2)             000064
     6       /WCSE8/ASCHWC(18,2,2)/COND1/CCOND(42,3)/COND2/CCOND1(2)        000064
     7       /GRAV/IGRAV/SUBDI/IDIV1,IDIV2/GAAG1/FCCPW1(3)                  000064
     8       /ENEOP/IENE/GRID2/YY(100,42,3)/MIXS2/CY/SECIN/K                000064
C                                                                           000064
      XX=1./980665.                                                         000064
C     ..................................................................000064
C     CORRECTION OF THE CHANNEL FLOW AREAS TO TAKE INTO ACCOUNT THAT        000064
C     THE SUBCHANNEL GEOMETRIC PARAMETERS MUST BE BASED ON THE TIP          000064
C     DIAMETER OF THE RODS IN THE CASE OF LAMINAR FLOW                      000064
C                                                                           000065
      DO 1000 NS=1,NSTOT                                                    000065
 1000 A(NS)=AZ(NS)*F1ATIP(NS)                                               000065
C     ..................................................................000065
C     LOOP "NS" STARTS ( NS = CHANNEL INDEX )                               000065
C                                                                           000065
C                                                                           000065
      DO 80 NS=1,NSTOT                                                      000065
      III=NS-NSTR                                                           000065
      FRELI=FREL                                                            000065
      NP=NPIN(NS)                                                           000066
      ITYP=NTYP(NS)                                                         000066
C                                                                           000066
      NI=NER(NS)                                                            000066
      NP1=NP-1                                                              000066
      NSCH=4-ITYP                                                           000066
      SCH=NSCH                                                              000066
      AREASC=ACH(ITYP)/SCH                                                  000066
C     ..................................................................000066
C     CONNECTIONS BETWEEN THE SUBCHANNELS OF CHANNEL "NS" AND THE           000066
C     CHANNELS ADJACENT TO "NS"                                             000067
C                                                                           000067
      CALL SUBCON(NS,NP,NP1,NI)                                             000067
      IF(NPIN(NS).EQ.1)GOTO 65                                              000067
      IF(ITYP.EQ.1 .AND. IDIV1.EQ.IDIV1/2*2)GOTO 65                         000067
      IF(ITYP.EQ.2 .AND. IDIV1.GT.2)GOTO 65                                 000067
C                                                                           000067
      DO 1 I=1,NP                                                           000067
      RHO1(I)=RHO(PR1,TSCH1(NS,I))                                          000067
      MINS(I)=MSCH1(NS,I)                                                   000067
      ANS(I)=ASCH(NS,I)*F2ATIP(NS,I)                                        000068
      DE(I)=DEZ(NS)*F2DTIP(NS,I)                                            000068
      TINS(I)=TSCH1(NS,I)                                                   000068
    1 WCFUD(I)=WCF(NS)*ANS(I)/A(NS)                                         000068
C     ..................................................................000068
C     ITERATION ON THE RELAXATION FACTOR (LOOP ITFREL)                      000068
C                                                                           000068
      DO 48 ITFREL=1,98                                                     000068
      IVIA=1                                                                000068
C     ..................................................................000068
```

```
C     CALCULATION OF THE PRESSURE LOSSES (LOOP ITGL)
C
      DO 47 ITGL=1,60
C
C     EVALUATION OF THE CROSS-FLOW SOLUTIONS
C
      CALL CRFL1(ITGL,DPNSAV,FRELI,A(NS),NP,ANS,MINS,DPNS,WCFNS,WCF1NS,
     *  EP1NS)
      DO 2 I=1,NP
      WCFNS(I)=WCFNS(I)+WCFLD(I)
      M2NS(I)=MINS(I)-H*WCFNS(I)
      MSCH(NS,I)=(M2NS(I)+MINS(I))*0.5
      TANS(I)=TAV(NS)
    2 RUASNS(I)=MSCH(NS,I)*SQRT(LAMSCH(NS,I)*0.125)/ASCH(NS,I)*AREASC
      IF(ITGL.GT.1 .AND. IVIA.EQ.1)GOTO 25
C     ..................................................................
C     CALCULATION OF THE BULK TEMPERATURES ( LOOP ITERM )
C
      XPREC=1.E-04
      DO 20 ITERM=1,20
C
C     A) TURBOLENT EXCHANGE SUBCHANNEL-SUBCHANNEL
C
      DO 4 I=1,NP1
      MAV1=MSCH(NS,I)*AREASC/ASCH(NS,I)
      I1=I+1
      DO 3 II=I1,NP
      MAV2=MSCH(NS,II)*AREASC/ASCH(NS,II)
      IF(TANS(I).LE.0. .OR. TANS(I).GT.3000. .OR. TANS(II).LE.0. .OR.
     *TANS(II).GT.3000.)GOTO 302
       YYIII=((YY(K,NS,I)+YY(K,NS,II))*0.5-1.)*CY+1.
      WTNS1(I,II)=TME(PBT,MAV1,MAV2,TANS(I),TANS(II),LAMSCH(NS,I),
     *LAMSCH(NS,II),AREASC,AREASC,CTURB1(ITYP))*YYIII
      IF(I2TIP(NS,I).EQ.1 .OR. I2TIP(NS,II).EQ.1)WTNS1(I,II)=0.
    3 WTNS1(II,I)=WTNS1(I,II)
    4 CONTINUE
      DO 16 I=1,NP
      THEX=0.
      CONHE=0.
      MAV1=MSCH(NS,I)*AREASC/ASCH(NS,I)
      DO 5 II=1,NP
      IF(I.EQ.II)GOTO 5
      MAV2=MSCH(NS,II)*AREASC/ASCH(NS,II)
      TAIII=(MAV1*TANS(I)+MAV2*TANS(II))/(MAV1+MAV2)
      CONHE=CONHE-(TANS(I)-TANS(II))*CCOND1(ITYP)*(KAPPA(PBT,TANS(I))+
     +KAPPA(PBT,TANS(II)))
      THEX=THEX-(TANS(I)-TANS(II))*WTNS1(I,II)*CP(PBT,TAIII)
    5 CONTINUE
C
C     B) TURBOLENT EXCHANGE SUBCHANNEL-CHANNEL
C
      NCHCI=NCHC(I)
      IF(NCHCI.EQ.0)GOTO 7
      DO 6 K1=1,NCHCI
      M=JCHC(I,K1)
      I1=JSCH(I,M)
      J=NIS(NS,M)
      NTYPJ=NTYP(J)
      MAV2=MAV(J)*ACH( NTYPJ)/AZ(J)
      WTNS2(I,K1)=WT(NS,M)
      IF(I2TIP(NS,I).EQ.1)WTNS2(I,K1)=0.
      IF(I1.NE.0)WTNS2(I,K1)=WTNS2(I,K1)*(RUASNS(I)+RUAS(J))/(RUASNS(I)+
     *              RUASNS(I1)+2.*RUAS(J))
      TAIJ=(TANS(I)*MAV1+TAV(J)*MAV2)/(MAV1+MAV2)
      CONHEP=(TANS(I)-TAV(J))*CCOND(NS,4)*(KAPPA(PBT,TANS(I))+KAPPA(PBT,
     *TAV(J)))
```

```
      IF((ACH(ITYP)/AZ(NS).LE.1.1 .OR. ACH(NTYPJ)/AZ(J).LE.1.1) .AND.     000075
     *(NTYP(NS).EQ.1 .OR. NTYP(J).EQ.1))CONHEP=CONHEP*0.5                 000075
      CONHE=CONHE-CONHEP                                                  000075
    6 THEX=THEX-(TANS(I)-TAV(J))*WTNS2(I,K1)*CP(PBT,TAIJ)                 000075
C                                                                         000076
C     C) CROSS FLOW HEAT EXCHANGE SUBCHANNEL-SUBCHANNEL                   000076
C                                                                         000076
    7 CONTINUE                                                            000076
      TACF=0.                                                             000076
      MAVCF=0.                                                            000076
      DO 8 II=1,NP                                                        000076
      IF(I.EQ.II)GOTO 8                                                   000076
      MAV2=MSCH(NS,II)*AREASC/ASCH(NS,II)                                 000076
      CALL CF1(TANS(I),TANS(II),MAV1,MAV2,DPNS(I),DPNS(II),               000076
     *    ITGL,TACF,MAVCF)                                                000077
C                                                                         000077
C     D) CROSS FLOW HEAT EXCHANGE  SUBCHANNEL-CHANNEL                     000077
C                                                                         000077
    8 CONTINUE                                                            000077
      IF(NCHCI.EQ.0)GOTO 12                                               000077
      DO 11 K1=1,NCHCI                                                    000077
      M=JCHC(I,K1)                                                        000077
      J=NIS(NS,M)                                                         000077
      NTYPJ=NTYP(J)                                                       000077
      MAV2=MAV(J)*ACH(NTYPJ)/AZ(NS)                                       000078
      CALL CF1(TANS(I),TAV(J),MAV1,MAV2,DPNS(I),DP(J),ITGL,TACF,MAVCF)    000078
   11 CONTINUE                                                            000078
   12 CONTINUE                                                            000078
C                                                                         000078
C                                                                         000078
      TACF=TACF/MAVCF                                                     000078
      TAICF=(TANS(I)*MAV1+TACF*MAVCF)/(MAV1+MAVCF)                        000078
      CFHEX=WCFNS(I)*(TANS(I)-TACF)*CP(PBT,TAICF)                         000078
      PHII(NS,I)=(THEX+CFHEX+CONHE)*H/ASCH(NS,I)                          000078
      XXMAV=MSCH(NS,I)                                                    000079
      XXM2=M2NS(I)                                                        000079
      IF(IENE.EQ.2)XXMAV=MINS(I)                                          000079
      IF(IENE.EQ.2)XXM2=XXMAV                                             000079
      T2NS(I)=TSCH1(NS,I)+H/(XXMAV*CP(PBT,TANS(I)))*((QSCH(NS,I)*QD       000079
     +EV+ GLINM*PERL(ITYP)*0.5*GLDEV)/LENGTH+THEX+CFHEX+CONHE)            000079
      TSCH(NS,I)=(XXM2*T2NS(I)+MSCH1(NS,I)*TSCH1(NS,I))*0.5/              000079
     *    XXMAV                                                           000079
   16 CONTINUE                                                            000079
      IF(ITGL.EQ.1)GOTO 25                                                000079
C                                                                         000080
C     TEST OF CONVERGENCE FOR THE GAS TEMPERATURES                        000080
C                                                                         000080
      IF(ITERM.GT.10)XPREC=1.E-03                                         000080
      IF(ITERM.GT.15)XPREC=1.E-02                                         000080
      DO 17 I=1,NP                                                        000080
      IF(ABS(TANS(I)/TSCH(NS,I)-1.).GT.XPREC)GOTO  18                     000080
   17 CONTINUE                                                            000080
      GOTO 25                                                             000080
   18 CONTINUE                                                            000081
      DO 19 I=1,NP                                                        000081
   19 TANS(I)=TSCH(NS,I)                                                  000081
   20 CONTINUE                                                            000081
C     ..................................................................000081
C     END OF LOOP ITERM: POINT REACHED IN THE CASE OF CONVERGENCE         000081
C     PROBLEMS                                                            000081
C                                                                         000081
      WRITE(6,21)NS,(TANS(I),I=1,NP),ITCORR                               000081
   21 FORMAT(    5X,'SUBCHANNEL CALCULATION STOPS IN LOOP ITERM  OF CHAN000081
     *NEL',I6,5X,'TEMPERATURES='/5X,3E15.7/5X,'ITCORR=',I5)               000081
      RETURN 1                                                            000082
C     ..................................................................000082
```

```
C     CONVERGENCE HAS BEEN REACHED FOR THE ENERGY EQUATIONS; THE CALCU=
C     LATION OF THE PRESSURE DROPS STARTS
C
   25 CONTINUE
      DO 26 I=1,NP
      RHOAV(I)=RHO(PBT,TSCH(NS,I))
      UNS(I)=MSCH(NS,I)/(ANS(I)     *RHOAV(I))
   26 CONTINUE
      DPNSAV=0.
      SMSCH1=C.
      DO 40 I=1,NP
      TMOEX=0.
C
C     TURBULENT EXCHANGE SUBCHANNEL-SUBCHANNEL
C
      DO 27 II=1,NP
      IF(I.EQ.II)GOTO 27
      TMOEX=TMOEX-(UNS(I)-UNS(II))*WTNS1(I,II)
   27 CONTINUE
C
C     TURBULENT EXCHANGE SUBCHANNEL-CHANNEL
C
      NCHCI=NCHC(I)
      IF(NCHCI.EQ.0)GOTO 29
      DO 28 K1=1,NCHCI
      M=JCHC(I,K1)
      J=NIS(NS,M)
   28 TMOEX=TMOEX-(UNS(I)-UAV(J))*WTNS2(I,K1)
   29 TMOEX=TMOEX*FT*H/ANS(I)
C
      UACF=0.
      ACF=0.
      AREAI =AREASC*F2ATIP(NS,I)
C
C     CROSS-FLOW EXCHANGE SUBCHANNEL-SUBCHANNEL
C
      DO 30 II=1,NP
      IF(I.EQ.II)GOTO 30
      AREAII=AREASC*F2ATIP(NS,II)
      CALL CF1(UNS(I),UNS(II),AREAI ,AREAII,DPNS(I),DPNS(II),
     *         1,UACF,ACF)
   30 CONTINUE
C
C     CROSS-FLOW EXCHANGE SUBCHANNEL-CHANNEL
C
      IF(NCHCI.EQ.0)GOTO 36
      DO 35 K1=1,NCHCI
      M=JCHC(I,K1)
      J=NIS(NS,M)
      NTYPJ=NTYP(J)
      AREAJ=ACH(NTYPJ)*F1ATIP(J)
      CALL CF1(UNS(I),UAV(J),AREAI ,AREAJ,DPNS(I),DP(J),1,
     *    UACF,ACF)
   35 CONTINUE
C
C
   36 UCF=UACF/ACF
      CFMOEX=(2.*UNS(I)-UCF)*WCFNS(I)/ANS(I)*H
      XMEM(I)=LAMSCH(NS,I)*H/(2.*DE(I) *RHOAV(I))*FCOPW1(ITYP)
      RE=MSCH(NS,I)*DE(I)/(ANS(I)      *ETA(PBT,TSCH(NS,I)))
      IF(INDSP.EQ.2)XMEM(I)=XMEM(I)+(CSPAC(NS,I,I1SPAC)+DSPDPF(EPS(NS,I,
     *I1SPAC),DE(I) ,LAMSCH(NS,I),WSP,PSDP(NS,I,I1SPAC),RE,ITYP))/
     /RHOAV(I)
      DPNS(I)=XX*(-(MSCH(NS,I)/ANS(I)     )**2*(XMEM(I)-(RHO(PR2,T2NS(I))
     *      -RHO1(I))/RHOAV( I)**2)+TMOEX+CFMOEX+IGRAV*RHOAV(I)*980.665*
     *      H)
```

```
      DPNSAV=DPNSAV+DPNS(I)*MSCH1(NS,I)
      SMSCH1=SMSCH1+MSCH1(NS,I)
   40 CONTINUE
      DPNSAV=DPNSAV/SMSCH1
      IF(ITGL.LT.4)GOTO 45
C     ..................................................................
C     TEST FOR THE CONVERGENCE OF THE PRESSURE DROPS
C
      DO 41 I=1,NP
      IF(ABS(DPNS(I)/DPNSAV-1.).GT.1.E-02)GOTO 45
      IF(ABS(DPNS(I)/DPNSAV-1.).GT.1.E-03 .AND. ITGL.LT.40)GOTO 45
   41 CONTINUE
      IF(IVIA.EQ.2)GOTO 50
      DO 301 I=1,NP
      IF(M2NS(I).LE.0.)GOTO 302
  301 CONTINUE
      IVIA=2
   45 CONTINUE
      DO 46 I=1,NP
   46 WCFNS(I)=WCFNS(I)-WCFLD(I)
   47 CONTINUE
C     ..................................................................
C     END OF LOOP ITGL : POINT REACHED IN THE CASE OF CONVERGENCE
C     PROBLEMS
  302 CONTINUE
      AIT=ITFREL
      FRELI=1.-AIT*0.01
   48 CONTINUE
C     ..................................................................
C     END OF LOOP ITFREL: POINT REACHED IN THE CASE OF CONVERGENCE
C     PROBLEMS
C
      WRITE(6,49)ITCORR,NS,(DPNS(I),I=1,NP),(MSCH(NS,I),I=1,NP),
     *     (TSCH(NS,I),I=1,NP)
   49 FORMAT(// 5X,'SUBCHANNEL CALCULATION STOPS  IN LOOP ITGL: ITCORR=
     1',I5,5X,'NS=',I5/5X,'PRESSURE LOSSES + AVERAGE MASSES + AVERAGE TE
     2MPERATURES : '/(8E15.5))
  777 RETURN 1
C     ..................................................................
C     CONVERGENCE HAS BEEN REACHED FOR THE ENERGY EQUATIONS AND FOR THE
C     AXIAL MOMENTUM EQUATIONS
C
   50 CONTINUE
      DO 60 I=1,NP
      DPAVF=DPAV-IGRAV*RHOAV(I)*H*0.001
      BMI=SQRT(ABS(DPAVF) /(XX*XMEM(I)))*ANS(I)
      SIGMAI(NS,I)=(MSCH(NS,I)-BMI)/ASCH(NS,I)
   60 CONTINUE
      GOTO 70
C     ******************************************************************
C     FOR THE CHANNELS WITH ONLY ONE SUBCHANNEL
C
   65 CONTINUE
      DO 66 I=1,NP
      IF(NTYP(NS).NE.2)GOTO 7007
      WCFNS(I)=WCF(NS)
      M1=JCHC(I,1)
      M2=JCHC(I,2)
      WTNS2(I,1)=WT(NS,M1)
      WTNS2(I,2)=WT(NS,M2)
      RUASNS(I)=RUAS(NS)
      UNS(I)=UAV(NS)
 7007 CONTINUE
      MSCH(NS,I)=MAV(NS)*ASCH(NS,I)/AZ(NS)
      TSCH(NS,I)=TAV(NS)
      SIGMAI(NS,I)=SIGMA(NS)
```

```
      PHII(NS,I)=PHI(NS)
      IF(NTYP(NS).NE.3)GOTC 66
      EPSM=MSCH(NS,I)-(XMSCHA(III,I)+XMSCHB(III,I))
      XMSCHA(III,I)=XMSCHA(III,I)+EPSM*(1.-1./ADAB(III,I))
      XMSCHB(III,I)=MSCH(NS,I)-XMSCHA(III,I)
   66 CCNTINUE
C
   70 CONTINUE
      IF(NTYP(NS).NE.2)    GCTC 80
C     *******************************************************************
C     ONLY FOR THE WALL SUBCHANNELS
C
      I2TTIP=0
      DO 4001 I=1,NP
      I2TTIP=I2TTIP+I2TIP(NS,I)
      DO 4000 JWC=1,2
      CHI(III,I,JWC)=1.
      PSI(III,I,JWC)=1.
      TAVWC(III,I,JWC)=TSCH(NS,I)
 4000 MAWC(III,I,JWC)=MSCH(NS,I)*ASCHWC(III,I,JWC)/ANS(I)
      IF(IDIV2.EQ.1)GCTO 4001
      EPSM=MAWC(III,I,1)-(XMSCHA(III,I)+XMSCHB(III,I))
      XMSCHA(III,I)=XMSCHA(III,I)+EPSM*(1.-1./ADAB(III,I))
      XMSCHB(III,I)=MAWC(III,I,1)-XMSCHA(III,I)
 4001 CCNTINUE
C     ...................................................................
C     RECCA2 IS CALLED ONLY IF THE FLOW IS TURBULENT IN THE WHOLE WALL
C     CHANNEL IN CASE OF IDIV2=1
C
      IF(IDIV2.EQ.2 .OR. I2TTIP.NE.0)GOTO 80
      IF(ITYP.EQ.2 .AND. IDIV1.GT.2)GCTO 80
      CALL       RECCA2  (NS,III,NP,INDSP,H,LENGTH,PR1,PR2,PBT,FRELI,FT,
     *ITCORR,PIG,D,DPAV,&777,WSF,I1SPAC)
C
C
   80 CONTINUE
C     ...................................................................
C     END OF LOOP "NS" : THE CALCULATIONS HAVE BEEN PERFORMED FOR ALL
C     SUBCHANNELS OF ALL CHANNELS
C
      RETURN
      END
      C
      C
      C
      C
      SUBROUTINE SUBCCN(NS,NP,NP1,NI)
C-------------------------------------------------------------------------
C     SUBROUTINE SUBCCN EVALUATES THE NUMBER OF CHANNELS CONNECTED TO
C     EACH SUBCHANNEL I OF CHANNEL NS ( NCHC(I) ), IDENTIFIES THESE
C     CHANNELS BY MEANS OF JCHC(I,K), IDENTIFIES WHICH SUBCHANNEL II OF
C     THE SAME CHANNEL NS IS CONNECTED TO THE SAME CHANNEL ( BY MEANS OF
C     JSCH(I,M) ).
C
      COMMON/HEA6/NPIN(42),JPIN(42,3)/IJ1/NER(42),NIS(42,3)
     1        /SUBC1/NCHC(3),JSCH(3,3)/SUBC2/JCHC(3,2)/IND3/NTYP(42)
      DO 4 I=1,NP
      NCHC(I)=0
      DO 3 M=1,NI
      J=NIS(NS,M)
      NPJ=NPIN(J)
      DO 1 IJ=1,NPJ
      IF(JPIN(J,IJ).EQ.JPIN(NS,I))GOTC 2
    1 CCNTINUE
      GOTC 3
    2 NCHC(I)=NCHC(I)+1
```

```
      NCHCI=NCHC(I)                                                     000101
      JCHC(I,NCHCI)=M                                                   000101
      JSCH(I,M)=0                                                       000101
    3 CONTINUE                                                          000101
    4 CONTINUE                                                          000102
      IF(NP .EQ.1)RETURN                                                000102
C                                                                       000102
      DO 9 I=1,NP1                                                      000102
      IF(NCHC(I).EQ.0)GOTO 9                                            000102
      NCHCI=NCHC(I)                                                     000102
      DO 8 K1=1,NCHCI                                                   000102
      I1=I+1                                                            000102
      DO 6 II=I1,NP                                                     000102
      IF(NCHC(II).EQ.0)GOTO 6                                           000102
      NCHCII=NCHC(II)                                                   000103
      DO 5 K2=1,NCHCII                                                  000103
      IF(JCHC(I,K1).EQ.JCHC(II,K2))GOTO 7                               000103
    5 CONTINUE                                                          000103
    6 CONTINUE                                                          000103
      GOTO 8                                                            000103
    7 JCHCIK=JCHC(I,K1)                                                 000103
      JSCH(I,JCHCIK)=II                                                 000103
      JSCH(II,JCHCIK)=I                                                 000103
    8 CONTINUE                                                          000103
    9 CONTINUE                                                          000104
      RETURN                                                            000104
      END                                                               000104
      C                                                                 000104
      C                                                                 000104
      C                                                                 000104
      C                                                                 000104
      SUBROUTINE TELIN(TW1,TLINER,TI,TE,TETA2,FTWA,QA,QALIN,NU1,NUTU,   000104
     1 A1,KI,R1DR2,DEI,I,JPIN,YYI,FACHE)                                000104
C-----------------------------------------------------------------------000104
C     TELIN COMPUTES THE LINER TEMPERATURES AND CORRECTS THE PIN TEMPERA000104
C     OF THE EXTERNAL CHANNELS IN THE CASE OF HEATED LINER (TURB. FLOW) 000104
C                                                                       000104
      COMMON/ISMO/COTW/ISMO1/ITECC                                      000104
      REAL NUTU,NU1,NU2,KI                                              000105
C     ..................................................................000105
C     INLET EFFECT ON THE LINER NUSSELT NUMBER                          000105
C                                                                       000105
      R1=DEI*R1DR2*0.5/(1.-R1DR2)                                       000105
      R2=R1+0.5*DEI                                                     000105
      FACHE=TIS(R1,R2,3)                                                000105
C                                                                       000105
      TG=TE                                                             000105
      IF(ITECC.EQ.2)TG=TI                                               000105
      FNU=(1.-A1*R1DR2**0.6)*NUTU*(TG+273.16)**COTW*YYI*FACHE           000106
C     ..................................................................000106
C     ITERATION FOR THE CALCULATION OF THE LINER TEMPERATURE AT         000106
C     (Q")ROD = 0 ( LOOP ITW1 )                                         000106
C                                                                       000106
      DO 1 ITW=1,10                                                     000106
      TW2=TLINER                                                        000106
      NU2=FNU/(TW2+273.16)**COTW                                        000106
      ALFA2=NU2*KI/DEI                                                  000106
      TLINER=TI+QALIN/ALFA2                                             000106
      IF(ABS(TLINER/TW2-1.).LE.1.E-04)GOTO 5                            000107
    1 CONTINUE                                                          000107
C     ..................................................................000107
C     CONVERGENCE PROBLEMS IN THE LOOP ITW1                             000107
C                                                                       000107
      WRITE(6,2)I,JPIN,TW2                                              000107
    2 FORMAT(1H1,5X,'STOP IN TELIN: I=',I5,5X,'PIN=',I5,5X,'TLINER=',   000107
     1E15.5)                                                            000107
```

```
      STOP                                                              000107
C     ..................................................................000107
C     CONVERGENCE IN LOOP ITW1; CALCULATION OF THE ROD TEMPERATURE AT   000108
C     (Q")ROD = 0                                                       000108
C                                                                       000108
    5 TW1 =FTWA/R1DR2*QALIN*DEI/KI+TI                                   000108
      IF(TW1 .LE.TE)TW1 =TE                                             000108
      TETA1=(TW1 -TI)*KI/(QALIN*DEI)                                    000108
        IF(QA.LE.1.E-06)GOTO 10                                         000108
C     ..................................................................000108
C     REAL ROD TEMPERATURE IN THE CASE OF HEATED ROD AND HEATED SHROUD  000108
C                                                                       000108
      NU1=NU1/(1.+QALIN/QA*TETA1*NU1)                                   000109
      ALFA1=NU1*KI/DEI                                                  000109
      TW1=TI+QA/ALFA1                                                   000109
C     ..................................................................000109
C     REAL SHROUD TEMPERATURE IN THE CASE OF HEATED ROD AND HEATED SHROUD000109
C                                                                       000109
   10 NU2=NU2/(1.+QA/QALIN*TETA2*NU2)                                   000109
      ALFA2=NU2*KI/DEI                                                  000109
      TLINER=TI+QALIN/ALFA2                                             000109
      RETURN                                                            000109
      END                                                               000110
      C                                                                 000110
      C                                                                 000110
      C                                                                 000110
      C                                                                 000110
       SUBROUTINE TEMLAM(*,PBT,TI,MASSI,DEIR,AREAI,QQ,QALIN,TE,I,II,M,  000110
     & TW1,ITYP,F2ATIP,F2DTIP,DVCL)                                     000110
C     ------------------------------------------------------------------000110
C     TEMLAM COMPUTES THE FIN TEMPERATURES AND THE TEMPERATURE  OF THE  000110
C     LINER IN THE SUBCHANNELS WHERE THE FLOW IS LAMINAR ( THE VELOCITY 000110
C     PROFILE IS ASSUMED TO BE ALREADY DEVELOPED AT THE POSITION WHERE T000110
C     HEATING STARTS)                                                   000110
C         ITYP=1 : CENTRAL SUBCHANNELS AND CENTRAL PART OF WALL SUBCHANN000110
C         ITYP=2 : WALL PART OF WALL SUBCHANNELS                        000110
C         ITYP=3 : CORNER CHANNELS                                      000111
C                                                                       000111
      REAL MASSI,KI,KAPPA,NU1,NU1IN,NU2,NU2IN                           000111
      COMMON/INPAR/IPA/LAMIN5/RTIP(7)/QPAR3/PERL(3)/IND3/NTYP(42)       000111
     1       /SUB1/ASCH(42,3)/GECO/ACH(3)/INITL/X/SHROUD/TLINER(18,2)   000111
     2       /SUB21/TSCHA(18,2),TSCHB(18,2)/MART2/NS1,NS2/MART3/TBEQR,  000111
     3       TBEQL/ISUP/IQLIN                                           000111
C                                                                       000111
      QA=QQ*DVCL/RTIP(IPA)*0.5                                          000111
      TSCHA(II,M)=TI                                                    000111
      TSCHB(II,M)=TI                                                    000112
      NTYPI=NTYP(I)                                                     000112
      PW=4.*AREAI*F2ATIP/(DEIR*F2DTIP)                                  000112
      PH=PW-PERL(ITYP)*ASCH(I,M)/ACH(NTYPI)                             000112
      R2=SQRT(RTIP(IPA)**2+2.*RTIP(IPA)*AREAI*F2ATIP/PH)                000112
      DEI=2.*(R2-RTIP(IPA))                                             000112
      RAS=RTIP(IPA)/R2                                                  000112
      KI=KAPPA(PBT,TI)                                                  000112
      ETAI=ETA(PBT,TI)                                                  000112
      RHOI=RHO(PBT,TI)                                                  000112
      CPI=CP(PBT,TI)                                                    000113
      REI=MASSI*DEI/(AREAI*F2ATIP*ETAI)                                 000113
      PRI=ETAI*CPI/KI                                                   000113
      PEI=REI*PRI                                                       000113
      GRI=X/(DEI*PEI)                                                   000113
C                                                                       000113
C-------- (NU 1)INF IF (Q)LIN =0                                        000113
C                                                                       000113
      IF(ITYP.EQ.1)GOTO 1                                               000113
      NU1IN=4.07+1.237/RAS**0.80272                                     000113
```

```
      GOTO 2
    1 NU1IN=RAS/(1.+RAS)*(14.1207+4.1261*ALOG(0.952313/RAS-1.))
    2 CONTINUE
C
C-------- YNU1=(NU 1)/(NU 1)INF IF (Q)LINER =0
C
      IF(GRI.GT. 0.025)GOTO 3
      B=-0.19327+.121747/GRI**0.14828
      GOTO 4
    3 B=-0.0013376+0.0000277181/GRI**1.76255
      IF(B.LT.0.)B=0.
    4 YNU1=(RAS/0.00062)**B
C
      NU1=NU1IN*YNU1
      NU1=NU1*0.967
      ALFA1=NU1*KI/DEI
      TW1=TI+QA/ALFA1
      TL1=0.
      TETA2=0.
      IF(NTYP(I).EQ.2 .AND. ITYP.EQ.1 .AND. I.GE.NS1 .AND. I.LE.NS2)
     *CALL SIMLA2(TI,TW1,TL1,NU1,TETA2,TBEQR,TBEQL)
      IF(ITYP.EQ.1)RETURN 1
C
C---------CALCULATIONS ONLY FOR THE CORNER CHANNELS AND THE WALL PARTS OF
C---------THE WALL SUBCHANNELS (IF  (Q)LINER =0 )
C
C-------- (TETA 2)INF
C
        IF(RAS.GT. 0.1)GOTO 5
      TETA2I=-0.103313*RAS**0.9489
      GOTO 6
    5 TETA2I=0.0142-0.0784857*RAS**0.4828
    6 CONTINUE
C
C-------- YTE2=(TETA 2)/(TETA 2)INF
C
      IF(GRI.GT. 0.01)GOTO 7
      YTE2=31.105*GRI
      GOTO 9
    7 IF(GRI.GE. 0.025)GOTO 8
      YTE2=15.59936*GRI**0.8501383
      GOTO 9
    8 YTE2=1./(0.98293+0.000125822/GRI**2.242421)
      IF(YTE2.GT.1)YTE2=1.
C
    9 TETA2P=TETA2I*YTE2
      TLINER(II,M)=TETA2P*QA*DEI/KI+TI
      TETA2=TETA2P
      IF(I.GE.NS1 .AND. I.LE.NS2)CALL SIMLA1(TE,TI,TW1,TLINER(II,M),NU1,
     *        TETA2,I,M,TBEQR,TBEQL,II)
      IF(TLINER(II,M).LT.TE)TLINER(II,M)=TE
      IF(ABS(QALIN).LE.1.E-06 .OR. IQLIN.EQ.2)RETURN 1
C
C-------- CASE OF HEATED LINER ( FOR CORNER CHANNELS AND WALL PART OF TH
C-------- WALL SUBCHANNELS) : (NU 2) AND (TETA 1) IF (Q)ROD =0
C
      TETA2=0.
      IF(QA.GT.1.E-06)TETA2=(TLINER(II,M)-TI)*KI/(QA*DEI)
C
C-------- (NU 2)INF
C
      NU2IN=4.754*EXP(0.1246*RAS)
C
C-------- YNU2=(NU 2)/(NU 2)INF
C
      IF(GRI.GT. 0.003)GOTO 11
```

```
      YNU2=0.2861/GRI**0.3334                                           000120
      GOTO 12                                                           000120
   11 YNU2=1.+0.060344/GRI**C.506*EXP(-49.*GRI)                        000120
   12 NU2=NU2IN*YNU2                                                    000120
      NU2=NU2*0.967                                                     000121
C                                                                       000121
C-------- (TETA 1)                                                      000121
C                                                                       000121
      TETA1=TETA2P/RAS                                                  000121
      TW1=TETA1*QALIN*DEI/KI+TI                                         000121
      ALFA2=NU2*KI/DEI                                                  000121
      TLINER(II,M)=TI+QALIN/ALFA2                                       000121
      IF(I.GE.NS1 .AND. I.LE.NS2)CALL SIMLA2(TI,TLINER(II,M),TW1,NU2,   000121
     *      TETA1,TBEGL,TBEGR)                                          000121
      IF (TW1.LE.TE)TW1=TE                                              000122
      TETA1=(TW1-TI)*KI/(QALIN*DEI)                                     000122
C                                                                       000122
C--------GENERAL CASE OF HEATED LINER AND ROD (CORNER CHANNELS AND WALL 000122
C--------PART OF THE WALL SUBCHANNELS)                                  000122
C                                                                       000122
      NU2=NU2/(1.+QA/QALIN*TETA2*NU2)                                   000122
      ALFA2=NU2*KI/DEI                                                  000122
      TLINER(II,M)=TI+QALIN/ALFA2                                       000122
      IF(QA.LE.1.E-06)RETURN 1                                          000122
C                                                                       000123
      NU1=NU1/(1.+QALIN/QA*TETA1*NU1)                                   000123
      ALFA1=NU1*KI/DEI                                                  000123
      TW1=TI+QA/ALFA1                                                   000123
      RETURN 1                                                          000123
      END                                                               000123
      C                                                                 000123
      C                                                                 000123
      C                                                                 000123
      C                                                                 000123
      SUBROUTINE TMCF(I,NI,TT,TCTM,MAVI)                                000123
C-----------------------------------------------------------------------000123
C     TMCF EVALUATES THE AVERAGE CROSS-FLOW TEMPERATURES  FOR THE       000123
C     CROSS-FLOW EXCHANGE BETWEEN CHANNELS                              000123
C                                                                       000124
      REAL MAV,MAVI,MAVJ                                                000124
      COMMON/IJ1/NER(42),NIS(42,3)/MOB5/T(42)/MOB8/DP(42)/MOB6/MAV(42)  000124
     1      /GEOD/ACH(3)/IND3/NTYP(42)/GEN2/A(42)                       000124
     2      /HEA6/NPIN(42),JPIN(42,3)/GAMAR/CXX                         000124
      TT=0.                                                             000124
      TCTM=0.                                                           000124
      DO 2 M=1,NI                                                       000124
      J=NIS(I,M)                                                        000124
      NTYPJ=NTYP(J)                                                     000124
      MAVJ=MAV(J)*ACH( NTYPJ)/A(J)                                      000125
      CXX=0.5                                                           000125
      IF((NTYP(I)+NPIN(I).EQ.4) .OR. (NTYP(J)+NPIN(J).EQ.4))CXX=1.      000125
      CALL CF1(T(I),T(J),MAVI,  MAVJ,  DP(I),DP(J),2,TT,TCTM)           000125
    2 CONTINUE                                                          000125
      CXX=1.                                                            000125
      TT =TT/TCTM                                                       000125
      RETURN                                                            000125
      END                                                               000125
      C                                                                 000125
      C                                                                 000125
      C                                                                 000125
      C                                                                 000125
      FUNCTION UA(I,NI,ACHI,IUAV)                                       000125
C-----------------------------------------------------------------------000126
C     UA EVALUATES THE AVERAGE CROSS-FLOW VELOCITIES FOR THE CROSS-FLOW 000126
C     EXCHANGE BETWEEN CHANNELS                                         000126
C                                                                       000126
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      COMMON/IJL/NER(42),NIS(42,3)/MOB8/DP(42)/MO32/U(42)                000126
     1       /GEO0/ACH(3)/IND3/NTYP(42)/LAMIN3/FlATIP(42),FlDTIP(42)      000126
     2       /FEA6/NPIN(42),JPIN(42,3)/GAMAR/CXX                          000126
      UU=0.                                                               000126
      AA=0.                                                               000126
      ACHN=ACHI*FlATIP(I)                                                 000126
      DO 2 M=1,NI                                                         000127
      J=NIS(I,M)                                                          000127
      NTYPJ=NTYP(J)                                                       000127
      ACHJ=ACH(NTYPJ)*FlATIP(J)                                           000127
      CXX=0.5                                                             000127
      IF((NTYP(I)+NPIN(I).EQ.4) .OR. (NTYP(J)+NPIN(J).EQ.4))CXX=1.        000127
      CALL CF1(U(I),U(J),ACHN,ACHJ,DP(I),DP(J),IUAV,UU,AA)                000127
    2 CONTINUE                                                            000127
      CXX=1.                                                              000127
      UA=UU/AA                                                            000127
      RETURN                                                              000128
      END                                                                 000128
      C                                                                   000128
      C                                                                   000128
      C                                                                   000128
      C                                                                   000128
C                                                                         000000
C                                                                         000000
C                                                                         000000
C                                                                         000000
      SUBROUTINE TOTGEO(NSEL,D,C,Z,PIG,NEXCON,NRODS,W,WA,ZA,EM1,PERLT,    000000
     &RTIP)                                                               000000
C-------------------------------------------------------------------------000000
C     TOTGEO CALCULATES FLOW AREAS , EQUIVALENT DIAMETERS AND OTHER       000000
C     GEOMETRIC DATA FOR THE WHOLE BUNDLE FLOW SECTION , FOR THE          000000
C     CHANNELS AND FOR THE SUBCHANNELS                                    000000
C                                                                         000000
C                  VERSION FOR HEXAGONAL BUNDLES                          000000
C     ....................................................................000000
      COMMON/GEO0/ACH(3)/LAMIN2/FATIP(3),FDTIP(3)/QPAR3/PERL(3)           000001
     1       /GEO2/ATOT,DETOT,ASEC/GEO5/ATC,DETC,ATW,DETW,ATA,DETA,AAC,   000001
     2       AAW,AAA/WAKAO/CD,WC,ZD,ZWCD,AWD2,PWWD/GASD3/FSYMM            000001
      SQ3=SQRT(3.)                                                        000001
      W=Z+D*0.5                                                           000001
      WA=W                                                                000001
      ZA=Z                                                                000001
      EXCON=NEXCON                                                        000001
      RODS=NRODS                                                          000001
      EM2=C*0.5-EM1                                                       000001
      ZWC=EM2/SQ3                                                         000002
      DTIP=RTIP*2.                                                        000002
      SIDE=EXCON*C+(2.*W-D)/SQ3                                           000002
      RPER=RODS*PIG*D                                                     000002
      PERLT=6.*SIDE+EXCON*(-12.*EM2+24.*ZWC)                              000002
      ATOT=3.*SQ3/2.*SIDE**2-RPER*D/4.-6.*EM2*ZWC*EXCON                   000002
      DETOT=4.*ATOT/(RPER+PERLT)                                          000002
      GOTO(20,21,22,24),NSEL                                              000002
   20 ASEC=ATOT                                                           000002
      GOTO 23                                                             000002
   21 ASEC=ATOT*0.5                                                       000003
      GOTO 23                                                             000003
   22 ASEC=ATOT/12.                                                       000003
C     EXTENDED AT GA FOR OTHER SYMMETRY SECTIONS (NSEL=4)                 000003
      GOTO 23                                                             000003
   24 ASEC=ATOT/FSYMM                                                     000003
   23 CONTINUE                                                            000003
      ATC=(C**2*SQ3-PIG*D**2/2.)/4.                                       000003
      DETC=4.*ATC/(PIG*D/2.)                                              000003
      ATW=C*(W-D/2.)-D**2*PIG/8.-EM2*ZWC                                  000003
      DETW=4.*ATW/(PIG*D*0.5+2.*EM1+4.*ZWC)                               000004
```

```
      ATA=(W-D/2.)**2/SQ3-D**2*PIG/24.
      DETA=4.*ATA/(D*PIG/6.+(W-D/2)*2./SQ3)
      AAC=ATC/6.
      AAW=ATW*0.5
      AAA=ATA*0.5
      ACH(1)=ATC
      ACH(2)=ATW
      ACH(3)=ATA
      PERL(1)=0.
      PERL(2)=4.*ATW/DETW-C.5*PIG*D
      PERL(3)=4.*ATA/DETA-PIG*D/6.
      FATIP(1)=(C**2*SQ3-PIG*DTIP**2*0.5)*0.25
      FDTIP(1)=4.*FATIP(1)/(PIG*0.5*DTIP)/DETC
      FATIP(1)=FATIP(1)/ATC
      FATIP(2)=C*(W-DTIP*0.5)-DTIP**2*PIG*0.125-EM2*ZWC
      FDTIP(2)=4.*FATIP(2)/(PIG*DTIP*C.5+2.*EM1+4.*ZWC)/DETW
      FATIP(2)=FATIP(2)/ATW
      FATIP(3)=(W-DTIP*0.5)**2/SQ3-DTIP**2*PIG/24.
      FDTIP(3)=4.*FATIP(3)/(DTIP*PIG/6.+(W-DTIP*0.5)*2./SQ3)/DETA
      FATIP(3)=FATIP(3)/ATA
      CD=C/DTIP
      WD=W/DTIP
      ZC=Z/DTIP
      ZWCD=ZWC/DTIP
      AWD2=AAW*FATIP(2)/DTIP**2
      PWWD=4.*AAW*FATIP(2)/(DETW*FDTIP(2)*DTIP)
      WRITE(6,1)ATOT,DETOT,ASEC
      WRITE(6,3)ATC,ATW,ATA,DETC,DETW,DETA
    1 FORMAT(/// 5X,'TOTAL FLOW AREA=',F10.2,1X,'SQCM'/5X,'TOTAL EQUIVAL
     1ENT DIAMETER=',F10.1,1X,'CM'/5X,'FLOW AREA OF SECTION=',F10.2,1X,'
     *SQCM'/)
    3 FORMAT(5X,'FLOW AREAS OF CHANNELS:'/5X,  'CENTRAL=',F10.2/5X,'WALL
     *=',F10.2/5X,'CORNER=',F10.2//5X,'EQUIVALENT DIAMETERS'/5X,'CENTRAL
     *=',F10.1/5X,'WALL=',F10.1/5X,'CORNER=',F10.1////130('*'))
      RETURN
      END
C
C
C
C
      BLOCK DATA
C-----------------------------------------------------------------------
C     BLOCK DATA FOR THE 37-ROD BUNDLE
C
      COMMON/DAT1/A(10)/DAT2/B(10)/DAT4/NDEST,NDEEND/DAT7/CNUSS(2)
     1      /DATKM/D1(7),D2(7)/EXDAT/EX1(7),EX2(7),EX3(7)/EXDAT1/
     2      EX4(7),EX5(7),EX6(7)/BIDAT/BIK(3)/BIDAT1/BIDE(7)/BIDE/IBIDE
     3      /LAMINK/EKAPPA(7,3)/LAMIN9/IBTIP(42,3)/CONDO/FCOND/MART2/
     4      NS1,NS2/WAKA1/IKAPPA/CVREH/ACVS(3),ACVR(3)/LAMIN6/ANGLAM
     5      /GRAV/IGRAV/SIMLAM/ISIMPL/EXAVTW/IEXAV
     6      /SUBDI/IDIV1,IDIV2/IDISPA/IDISP1/IDISP3/IDISP2
     7      /HEA6/NPIN(42),JPIN(42,3)/IND3/NTYP(42)/IJ1/NER(42),
     8      NIS(42,3)/GASD1/NSTCT/GASD2/RAPPAI(42,3)/GASD3/FSYMM
     9      /GASD4/ICAS/MART5/NSTR/ISUP/IQLIN/ISMO/CCTW
      COMMON/GAAG1/FCCPW1(3)/GAAGT/FCCPWT
     1      /ISMO1/ITECO/ENECP/IENE/MIXS1/CY
      DATA A/4.45,0.24,10.3,0.7,0.44,0.36,0.01,0.053,2*0.01/
      DATA B/4.9,7.4,1.1,1.,0.4,0.01,0.,5.0,0.5,2.0/
      DATA NDEST,NDEEND/10,2/
      DATA CNUSS/5.55,3.55/
      DATA D1,D2/7*3.5C2E-02,7*2.95E-05/
      DATA JPIN/1,2*2,3,2*8,2*9,10,2*20,21,22,23,28*0,2,8,3,9,20,9,21,
     1         10,22,0,21,22,23,29*0,3,2*9,10,2*21,2*22,23,33*0/
      DATA NIS/2*3,1,3,6,2,6,4,8,11,5,7,9,13,29*0,6,2,8,11,5,3,7,13,0,
     1         10,11,12,31*0,4,2*0,7,12,9,2*0,12,13,14,29*0/
      DATA NER/1,2,3,2*2,3*3,2,1,3*3,1,28*0/
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```
      DATA NTYP/9*1,3,3*2,3,28*0/
      DATA NPIN/9*3,1,3*2,1,28*0/
      DATA NSTOT,NSTR/14,9/
      DATA IGAS/2/
      DATA FSYMM/6./
      DATA RAPPAI/9*1.,0.5,3*1.,0.5,28*0.,9*1.,0.,3*1.,29*0.,9*1.,33*0./
      DATA EX1,EX2,EX3/7*16.67E-06,7*0.0033E-06,7*0./
      DATA EX4,EX5,EX6/7*16.67E-06,7*0.0033E-06,7*0./
      DATA BIK/1.,-1.2,0./
      DATA BIE/0.,1.,2*0.,1.,-1.2,0./
      DATA IBIDE/1/
      DATA BKAPPA/21*1./
      DATA IBTIP/126*2/
      DATA NS1,NS2/0,0/
      DATA FCOND/1./
      DATA ANGLAM/1./
      DATA ACVS,ACVR/5.14,828.,0.5,8.82,761.,0.5/
      DATA IKAPPA,IGRAV,ISIMPL,IEXAV/1, 0,2*1/
      DATA IDIV1,IDIV2,IDISP1,IDISP2/4*1/
      DATA IQLIN,ITECC,IENE/3*1/
      DATA CCTW/0./
      DATA FCOPW1,FCOPWT/1.,1.028,0.972,1.009/
      DATA CY/1./
      END
C
C
C
C
      FUNCTION DSPDPF(EPS,DE,LAMBDA,WSP,PGDP,RE,ITYP)
C     -----------------------------------------------------------------
C     DSPDPF EVALUATES THE FACTOR TAKING THE LARGER DISTRIBUTED PRESSURE
C     LOSSES IN THE SPACER INTO ACCOUNT
C
C     VERSION FOR THE EXAGONAL BUNDLES
C     .................................................................
      COMMON/IRDSMC/IRH/CVREF/ACVS(3),ACVR(3)
      REAL LAMBDA
      RE=ABS(RE)
      PROV=-GRIFUN(EPS)
      IF(IRH.EQ.1)GOTO 100
C     .................................................................
C     FOR SPACERS IN AXIAL SECTIONS WITH ROUGHENED RODS
C
      CVR=ACVR(1)+ACVR(2)/RE**ACVR(3)
      DSPDPF=PROV+CVR  *0.5*EPS**2
      RETURN
C     .................................................................
C     FOR SPACERS IN AXIAL SECTIONS WITH SMOOTH RODS
C
  100 CONTINUE
      CVS=ACVS(1)+ACVS(2)/RE**ACVS(3)
      DSPDPF=PROV+CVS *0.5*EPS**2
      RETURN
      END
C
C
C
C
      SUBROUTINE HEATI(NSTOT,NSTR,NSEL,NRCMA,IPA)
C-----------------------------------------------------------------------
C     HEATI EVALUATES THE HEAT FLUXES QQ(NS,I) FOR THE RODS ADJACENT TO
C     EACH CHANNEL NS AND THE TOTAL FLUXES QT(NS) ENTERING EACH
C     CHANNEL NS.  HEATI IDENTIFIES ALSO THE CONNECTIONS BETWEEN THE
C     SUBCHANNELS I AND THE ADJACENT RODS BY MEANS OF THE MATRIX JPIN
C     ( NPIN(NS)= NR. OF SUBCH. IN CH. NS = NR. OF PINS ADJ. TO CH. NS)
C
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C              VERSICN FCR HEXAGCNAL BUNDLES
C     ..................................................................
      COMMON/IND1/NROW(42),NUMS(42)/HEA2/Q(3,18),Q0/HEA3/QT(42)
     1      /HEA5/ QQ(42,3)/HEA6/NPIN(42),JPIN(42,3)/HEA7/IDPIN(3,18)
     2      /IND4/NUM3(4),NUM6(4),NUM12(4),NUM18(4),NUM24(4),NUM30(4),
     3      NUM36(4)/HEA10/QSCH(42,3)/HEA1/QQQ(37)/IND3/NTYP(42)
     4      /GASD2/RAPPAI(42,3)
C
      IF(NSEL.EQ.4)GOTO 100
      CALL HEATR(NRCMA)
C
      NAN=1
      NBN=-NRCMA
      NN=1-NRCMA
      DO 15 NS=1,NSTOT
      NUM=NUMS(NS)
      NRC=NROW(NS)
      IF(NS.GT.NSTR)GOTO 12
C
C     CENTRAL CHANNELS AND SUBCHANNELS
      IF(NUM.GT.NUM6(NRO))GOTO 1
      NAM=NUM
      N1=0
      N2=0
      GOTO 6
    1 IF(NUM.GT.NUM12(NRO))GOTO 2
      NAM=NUM-NUM6(NRO)
      N1=NRO
      N2=N1-1
      GOTO 6
    2 IF(NUM.GT.NUM18(NRO))GOTO 3
      NAM=NUM-NUM12(NRO)
      N1=2*NRC
      N2=N1-2
      GOTO 6
    3 IF(NUM.GT.NUM24(NRO))GOTO 4
      NAM=NUM-NUM18(NRO)
      N1=3*NRC
      N2=N1-3
      GOTO 6
    4 IF(NUM.GT.NUM30(NRO))GOTO 5
      NAM=NUM-NUM24(NRC)
      N1=4*NRC
      N2=N1-4
      GOTO 6
    5 NAM=NUM-NUM30(NRO)
      N1=5*NRC
      N2=N1-5
    6 IF(NAM.EQ. NAM/2*2 )GOTO 8
      NUR=(NAM+1)/2+N1
      Q1=Q(NRC,NUR)
      JPIN(NS,1)=IDPIN(NRC,NUR)
      IF(NUR.EQ.6*NRO) NUR=0
      Q2=Q(NRC,NUR+1)
      JPIN(NS,3)=IDPIN(NRC,NUR+1)
      IF(NRO.EQ.1)GOTO 7
      NUR=(NAM+1)/2+N2
      IF(NUR.EQ. 6*NRC-5 ) NUR=1
      Q3=Q(NRO-1,NUR)
      JPIN(NS,2)=IDPIN(NRO-1,NUR)
      GOTO 9
    7 Q3=Q0
      JPIN(NS,2)=1
      GOTO 9
    8 NUR=NAM/2+N2
      Q1=Q(NRC-1,NUR)
```

```
      JPIN(NS,1)=IDPIN(NRO-1,NUR)                                       000022
      IF(NUR.EQ.6*NRO-6) NUR=0                                          000022
      Q2=Q(NRO-1,NUR+1)                                                 000022
      JPIN(NS,3)=IDPIN(NRO-1,NUR+1)                                     000023
      NUR=(NAM+2)/2+N1                                                  000023
      Q3=Q(NRO,NUR)                                                     000023
      JPIN(NS,2)=IDPIN(NRO,NUR)                                         000023
    9 CONTINUE                                                          000023
      QQ(NS,1)=Q1                                                       000023
      QQ(NS,2)=Q3                                                       000023
      QQ(NS,3)=Q2                                                       000023
      IF(NSEL.EQ.3 .AND. NUM.EQ.NRO)GOTO 10                             000023
      NPIN(NS)=3                                                        000023
      GOTO 11                                                           000024
   10 Q2=0.                                                             000024
      Q3=Q3/2.                                                          000024
      NPIN(NS)=2                                                        000024
   11 QT(NS)=(Q1+Q2+Q3)/6.                                              000024
      QSCH(NS,1)=Q1/6.                                                  000024
      QSCH(NS,2)=Q3/6.                                                  000024
      QSCH(NS,3)=Q2/6.                                                  000024
      GOTO 15                                                           000024
C                                                                       000024
C                                                                       000025
   12 IF(NUM.LT.NAN)GOTO 14                                             000025
C                                                                       000025
C     CORNER CHANNELS                                                   000025
      NN=NN+NROMA                                                       000025
      NAN=NAN+NRO                                                       000025
      NBN=NBN+NRO                                                       000025
      NPIN(NS)=1                                                        000025
      QQ(NS,1)=Q(NROMA,NN)                                              000025
      JPIN(NS,1)=IDPIN(NROMA,NN)                                        000025
      IF(NSEL.EQ.3)GOTO 13                                              000026
      IF((NSEL.EQ.2 .AND. NUM.EQ.1).OR.(NSEL.EQ.2 .AND. NUM.EQ.NUM1B(NRO000026
     *)))GOTO 13                                                        000026
      QT(NS)=Q(NROMA,NN)/6.                                             000026
      GOTO 29                                                           000026
   13 QT(NS)=Q(NROMA,NN)/12.                                            000026
   29 QSCH(NS,1)=QT(NS)                                                 000026
      GOTO 15                                                           000026
C                                                                       000026
C     WALL CHANNELS AND SUBCHANNELS                                     000026
   14 NUR=NUM-NBN+NN-1                                                  000027
      Q1=Q(NROMA,NUR)                                                   000027
      JPIN(NS,1)=IDPIN(NROMA,NUR)                                       000027
      IF(NS.EQ.NSTOT .AND. NSEL.EQ.1) NUR=0                             000027
      Q2=Q(NROMA,NUR+1)                                                 000027
      JPIN(NS,2)=IDPIN(NROMA,NUR+1)                                     000027
      QQ(NS,1)=Q1                                                       000027
      QQ(NS,2)=Q2                                                       000027
      IF(NSEL.EQ.3 .AND. NUM.EQ.(NRO/2+1) .AND. NRO.EQ.NRO/2*2)GOTO 30  000027
      NPIN(NS)=2                                                        000027
      GOTO 31                                                           000028
   30 Q2=0.                                                             000028
      NPIN(NS)=1                                                        000028
   31 CONTINUE                                                          000028
      QT(NS)=(Q1+Q2)/4.                                                 000028
      QSCH(NS,1)=Q1*0.25                                                000028
      QSCH(NS,2)=Q2*0.25                                                000028
   15 CONTINUE                                                          000028
C     ADDED AT GA(NSEL=4)                                               000028
      GOTO 104                                                          000028
  100 CONTINUE                                                          000029
      DO 103 NS=1,NSTOT                                                 000029
      NP=NPIN(NS)                                                       000029
```

```
      QT(NS)=0.                                                         000029
      DO 102 M=1,NP                                                     000029
      JPINNM=JPIN(NS,M)                                                 000029
      QQ(NS,M)=QQQ(JPINNM)                                              000029
      IF(NTYP(NS).EQ.2)GOTO 101                                         000029
      QSCH(NS,M)=QQ(NS,M)/6.*RAPPAI(NS,M)                               000029
      GOTO 102                                                          000029
  101 QSCH(NS,M)=QQ(NS,M)*0.25                                          000030
  102 QT(NS)=QT(NS)+QSCH(NS,M)                                          000030
  103 CONTINUE                                                          000030
  104 CONTINUE                                                          000030
      IF(IPA.NE.IPA/2*2)RETURN                                          000030
C                                                                       000030
C                                                                       000030
      WRITE(6,16)                                                       000030
   16 FORMAT(////5X,'RESULTS OF HEATI'////8X,'CHANNEL',3(21X,'ROD',2X)/)000030
      DO 19 NS=1,NSTOT                                                  000030
      NP=NPIN(NS)                                                       000031
      WRITE(6,18)NS,(M,NS,M,JPIN(NS,M),M=1,NP)                          000031
   18 FORMAT(2X,I10,3(3X,I1,') JPIN(',I5,',',I2,')=',I5))               000031
   19 CONTINUE                                                          000031
      RETURN                                                            000031
      END                                                               000031
C                                                                       000031
C                                                                       000031
C                                                                       000031
C                                                                       000031
      SUBROUTINE INDEX(NSEL,NRCMA,NSTR,NSTOT,NRO)                       000031
C-----------------------------------------------------------------------000031
C     INDEX PROVIDES INDICES TO THE CHANNELS                            000031
C                                                                       000031
C                VERSION FOR HEXAGONAL BUNDLES                          000032
C     ..................................................................000032
      COMMON/IND1/NROW(42),NUMS(42)/IND2/NOT(4,30)/IND3/NTYP(42)/IND4/  000032
     1      NUM3(4),NUM6(4),NUM12(4),NUM18(4),NUM24(4),NUM30(4),NUM36(4)000032
      IF(NSEL.EQ.4)GOTO 100                                             000032
      NS=1                                                              000032
      DO  6 NRO=1,NRCMA                                                 000032
      NUM3(NRO)=NRO                                                     000032
      NUM6(NRO)=2*NRO-1                                                 000032
      NUM12(NRO)=2*NUM6(NRO)                                            000032
      NUM18(NRO)=3*NUM6(NRO)                                            000033
      NUM24(NRO)=4*NUM6(NRO)                                            000033
      NUM30(NRO)=5*NUM6(NRO)                                            000033
      NUM36(NRO)=6*NUM6(NRO)                                            000033
      IF(NSEL-2)1,2,3                                                   000033
    1 NUMSP=NUM36(NRO)                                                  000033
      GOTO4                                                             000033
    2 NUMSP=NUM18(NRO)                                                  000033
      GOTO4                                                             000033
    3 NUMSP=NUM3(NRO)                                                   000033
    4 CONTINUE                                                          000034
      DO 5 NUM=1,NUMSP                                                  000034
      NUMS(NS)=NUM                                                      000034
      NROW(NS)=NRO                                                      000034
      NOT(NRO,NUM)=NS                                                   000034
      NTYP(NS)=1                                                        000034
    5 NS=NS+1                                                           000034
    6 CONTINUE                                                          000034
      NSTR=NS-1                                                         000034
      NRO=NRCMA+1                                                       000034
      NUM3(NRO)=NRO/2+1                                                 000035
      NUM6(NRO)=NRO+1                                                   000035
      NUM12(NRO)=NUM6(NRO)+NRO                                          000035
      NUM18(NRO)=NUM12(NRO)+NRO                                         000035
      NUM24(NRO)=NUM18(NRO)+NRO                                         000035
```

```
      NUM30(NRO)=NUM24(NRO)+NRO                                         000035
      NUM36(NRO)=NUM30(NRO)+NROMA                                       000035
      IF(NSEL-2)7,8,9                                                   000035
    7 NUMSP=NUM36(NRO)                                                  000035
      GOTO 10                                                           000035
    8 NUMSP=NUM18(NRO)                                                  000036
      GOTO 10                                                           000036
    9 NUMSP=NUM3(NRO)                                                   000036
   10 NAN=1                                                             000036
      DO 13 NUM=1,NUMSP                                                 000036
      IF(NUM.EQ.NAN)GOTO 11                                             000036
      NTYP(NS)=2                                                        000036
      GOTO 12                                                           000036
   11 NTYP(NS)=3                                                        000036
      NAN=NAN+NRO                                                       000036
   12 NUMS(NS)=NUM                                                      000037
      NROW(NS)=NRO                                                      000037
      NOT(NRO,NUM)=NS                                                   000037
   13 NS=NS+1                                                           000037
      NSTOT=NS-1                                                        000037
C     ADDED AT GA(NSEL=4)                                               000037
  100 IF(NSEL.EQ.4)NRO=NROMA+1                                          000037
      WRITE(6,14)NRO,NSEL,NSTR,NSTOT                                    000037
   14 FORMAT(  //4X,'RESULTS OF INDEX'//5X,'NROWS=',I2,5X,'TYPE OF SECTI000037
     *ON=',I1,5X,'NR. OF CENTRAL CHANNELS=',I4,5X,'TOTAL NUMBER OF CHANN000037
     *ELS=',I4//)                                                       000038
      CALL CONNIJ(NSTR,NSTOT,NROMA,NSEL)                                000038
      RETURN                                                            000038
      END                                                               000038
C                                                                       000038
C                                                                       000038
C                                                                       000038
C                                                                       000038
      SUBROUTINE CONNIJ(NSTR,NSTOT,NROMA,NSEL)                          000038
C-----------------------------------------------------------------------000038
C     CONNIJ EVALUATES FOR EACH CHANNEL I THE NUMBER  NER(I) OF         000038
C     INTERACTIONS WITH OTHER CHANNELS J AND WHICH  CHANNELS INTERACT   000038
C     WITH I.                                                           000038
C                                                                       000038
      COMMON/IND1/NROW(42),NUMS(42)/IND2/NOT(4,30)/IND3/NTYP(42)        000039
     1        /IND4/NUM3(4),NUM6(4),NUM12(4),NUM18(4),NUM24(4),NUM30(4),000039
     2        NUM36(4)/IJ1/NER(42),NIS(42,3)                            000039
      IF(NSEL.EQ.4)GOTO 99                                              000039
      NAN=NROMA+2                                                       000039
      NBN=1                                                             000039
      NCN=-1                                                            000039
      DO 43 NS=1,NSTOT                                                  000039
      NRO=NROW(NS)                                                      000039
      NUM=NUMS(NS)                                                      000039
      NUMA3=NUM3(NRO)                                                   000040
      NUMA6=NUM6(NRO)                                                   000040
      NUMA12=NUM12(NRO)                                                 000040
      NUMA18=NUM18(NRO)                                                 000040
      NUMA24=NUM24(NRO)                                                 000040
      NUMA30=NUM30(NRO)                                                 000040
      NUMA36=NUM36(NRO)                                                 000040
      IF(NS.GT.NSTR)GOTO 29                                             000040
      IF(NUM.GT.1)GOTO 5                                                000040
      IF(NSEL-2)1,2,4                                                   000040
    1 NER(NS)=3                                                         000041
      NIS(NS,3)=NOT(NRO,NUMA36)                                         000041
      GOTO 3                                                            000041
    2 NER(NS)=2                                                         000041
    3 NIS(NS,1)=NS+1                                                    000041
      GOTO 13                                                           000041
    4 IF(NRO.GT.1)GOTO 2                                                000041
```

```
      NER(1)=1                                                          000041
      NIS(1,1)=3                                                        000041
      GOTO 43                                                           000041
    5 IF(NSEL-2)6,7,8                                                   000042
    6 NUMSP=NUMA36                                                      000042
      GOTO 9                                                            000042
    7 NUMSP=NUMA18                                                      000042
      GOTO 9                                                            000042
    8 NUMSP=NUMA3                                                       000042
    9 IF(NUM.EQ.NUMSP)GOTO 10                                           000042
      NER(NS)=3                                                         000042
      NIS(NS,3)=NS+1                                                    000042
      GOTO 12                                                           000042
   10 IF(NSEL.EQ.1)GOTO 11                                              000043
      NER(NS)=2                                                         000043
      GOTO 12                                                           000043
   11 NER(NS)=3                                                         000043
      NIS(NS,3)=NOT(NRO,1)                                              000043
   12 NIS(NS,1)=NS-1                                                    000043
   13 IF(NUM.GT.NUMA6)GOTO 14                                           000043
      NAM=NUM                                                           000043
      GOTO 19                                                           000043
   14 IF(NUM.GT.NUMA12)GOTO 15                                          000043
      NAM=NUM-NUMA6                                                     000044
      GOTO 19                                                           000044
   15 IF(NUM.GT.NUMA18)GOTO 16                                          000044
      NAM=NUM-NUMA12                                                    000044
      GOTO 19                                                           000044
   16 IF(NUM.GT.NUMA24)GOTO 17                                          000044
      NAM=NUM-NUMA18                                                    000044
      GOTO 19                                                           000044
   17 IF(NUM.GT.NUMA30)GOTO 18                                          000044
      NAM=NUM-NUMA24                                                    000044
      GOTO 19                                                           000045
   18 NAM=NUM-NUMA30                                                    000045
   19 IF(NAM.EQ.(NAM/2*2))GOTO 21                                       000045
      I1=1                                                              000045
      IF(NRO.EQ.NROMA)GOTO 20                                           000045
      I2=1                                                              000045
      I3=0                                                              000045
      GOTO 22                                                           000045
   20 I2=2                                                              000045
      I3=1                                                              000045
      GOTO 22                                                           000046
   21 I1=-1                                                             000046
      I2=1                                                              000046
      I3=0                                                              000046
   22 NRO1=NRO+I1                                                       000046
      IF(NUM.GT.NUMA6)GOTO 23                                           000046
      NUMA=(NUM+I1)/I2+I3                                               000046
      GOTO 28                                                           000046
   23 IF(NUM.GT.NUMA12)GOTO 24                                          000046
      NUMA=(NUM+I1-NUMA6)/I2    +NUM6(NRO1)                             000046
      GOTO 28                                                           000047
   24 IF(NUM.GT.NUMA18)GOTO 25                                          000047
      NUMA=(NUM+I1-NUMA12)/I2    +NUM12(NRO1)                           000047
      GOTO 28                                                           000047
   25 IF(NUM.GT.NUMA24)GOTO 26                                          000047
      NUMA=(NUM+I1-NUMA18)/I2    +NUM18(NRO1)                           000047
      GOTO 28                                                           000047
   26 IF(NUM.GT.NUMA30)GOTO 27                                          000047
      NUMA=(NUM+I1-NUMA24)/I2    +NUM24(NRO1)                           000047
      GOTO 28                                                           000047
   27 NUMA=(NUM+I1-NUMA30)/I2    +NUM30(NRO1)                           000048
   28 NIS(NS,2)=NOT(NRO1,NUMA)                                          000048
      GOTO 43                                                           000048
```

```
   29 IF(NUM.GT.1)GOTO 32                                                  000048
      IF(NSEL.EQ.1)GOTO 30                                                 000048
      NER(NS)=1                                                            000048
      GOTO 31                                                              000048
   30 NER(NS)=2                                                            000048
      NIS(NS,2)=NSTOT                                                      000048
   31 NIS(NS,1)=NS+1                                                       000048
      GOTO 43                                                              000049
   32 IF(NSEL-2)33,34,40                                                   000049
   33 NUMSP=NUMA36                                                         000049
      GOTO 35                                                              000049
   34 NUMSP=NUMA18                                                         000049
   35 IF(NUM.EQ.NUMSP)GOTO 37                                              000049
      NIS(NS,1)=NS+1                                                       000049
      NIS(NS,2)=NS-1                                                       000049
      IF(NUM.EQ.NAN)GOTO 36                                                000049
      NER(NS)=3                                                            000049
      NUMA=(NUM-NBN)*2+NCN                                                 000050
      NIS(NS,3)=NOT(NRO-1,NUMA)                                            000050
      GOTO 43                                                              000050
   36 NER(NS)=2                                                            000050
      NAN=NAN+NRO                                                          000050
      NBN=NBN+NRO                                                          000050
      NCN=NCN+2*NROMA-1                                                    000050
      GOTO 43                                                              000050
   37 IF(NSEL.EQ.1)GOTO 38                                                 000050
      NER(NS)=1                                                            000050
      GOTO 39                                                              000051
   38 NER(NS)=2                                                            000051
      NIS(NS,2)=NOT(NRO,1)                                                 000051
   39 NIS(NS,1)=NS-1                                                       000051
      GOTO 43                                                              000051
   40 IF(NUM.EQ.NUMA3)GOTO 41                                              000051
      NER(NS)=3                                                            000051
      NIS(NS,3)=NS+1                                                       000051
      GOTO 42                                                              000051
   41 NER(NS)=2                                                            000051
   42 NIS(NS,1)=NS-1                                                       000052
      NUMA=(NUM-1)*2-1                                                     000052
      NIS(NS,2)=NOT(NRO-1,NUMA)                                            000052
   43 CONTINUE                                                             000052
   99 CONTINUE                                                             000052
      DO 100  NS=1,NSTOT                                                   000052
      NI=NER(NS)                                                           000052
      WRITE(6,200)NS,NTYP(NS),(NIS(NS,M),M=1,NI)                           000052
  200 FORMAT(5X,'NS=',I2,5X,'TYPE=',I1,5X,'CHANNELS CONNECTED:',3I5)       000052
  100 CONTINUE                                                             000052
      RETURN                                                               000053
      END                                                                  000053
C                                                                          000053
C                                                                          000053
C                                                                          000053
C                                                                          000053
      SUBROUTINE HEATR(NROMA)                                              000053
C--------------------------------------------------------------------------000053
C     HEATR PROVIDES INDICES TO THE ROD HEAT FLUXES ( Q(NRO,NUM) ) AND     000053
C     IDENTIFIES THE PINS BY MEANS OF THE MATRIX IDPIN                     000053
C                                                                          000053
C              EXISTS ONLY IN THE VERSION FOR HEXAGONAL BUNDLES            000053
C     .....................................................................000053
      COMMON/HEA1/Q(37)/HEA2/QQ(3,18),QQ0/HEA7/IDPIN(3,18)                 000053
      I=1                                                                  000054
      QQ0=Q(1)                                                             000054
      DO 2 NRO=1,NROMA                                                     000054
      NR36=6*NRO                                                           000054
      DO 1 NUM=1,NR36                                                      000054
```

```
      I=I+1                                                              000054
      IDPIN(NRC,NUM)=I                                                   000054
    1 QQ(NRC,NUM)=Q(I)                                                   000054
    2 CONTINUE                                                           000054
      RETURN                                                             000054
      END                                                                000055
C                                                                        000055
C                                                                        000055
C                                                                        000055
C                                                                        000055
      SUBROUTINE INQUA(NSEL,NSTCT,NRCMA,ATC,ATW,ATA,DETC,DETW,DETA)      000055
C------------------------------------------------------------------------000055
C     INQUA PROVIDES INDICES TO CHANNEL FLOW AREAS AND EQUIVALENT        000055
C     DIAMETERS AND TO SUBCHANNEL  FLOW AREAS                            000055
C                                                                        000055
C                VERSION FOR THE EXAGONAL BUNDLES                        000055
C     ...................................................................000055
      COMMON/IND1/NROW(42),NUMS(42)/IND3/NTYP(42)/SUB1/ASCH(42,3)        000055
     1      /GEN2/A(42)/GEN5/DE(42)                                      000055
     2      /HEA6/NPIN(42),JPIN(42,3)/GASD2/RAPPAI(42,3)                 000056
      II=0                                                               000056
      KK=0                                                               000056
      DO 10 NS=1,NSTCT                                                   000056
      A(NS)=0.                                                           000056
      NP=NPIN(NS)                                                        000056
      IF(NTYP(NS)-2)1,3,6                                                000056
C***** CENTRAL CHANNELS AND SUBCHANNELS*********************************000056
    1 DE(NS)=DETC                                                        000056
      IF(NSEL.EQ.4)GOTO 100                                              000056
      ASCH(NS,1)=ATC/3.                                                  000057
      IF((NSEL.EQ.3).AND.(NROW(NS).EQ.NUMS(NS)))GOTO 2                   000057
      A(NS)=ATC                                                          000057
      ASCH(NS,2)=ASCH(NS,1)                                              000057
      ASCH(NS,3)=ASCH(NS,1)                                              000057
      GOTO 10                                                            000057
    2 CONTINUE                                                           000057
      A(NS)=ATC/2.                                                       000057
      ASCH(NS,2)=ATC/6.                                                  000057
      GOTO 10                                                            000057
C     ADDED AT GA (NSEL=4)                                               000058
  100 CONTINUE                                                           000058
      DO 101 M=1,NP                                                      000058
      ASCH(NS,M)=ATC/3.*RAPPAI(NS,M)                                     000058
  101 A(NS)=A(NS)+ASCH(NS,M)                                             000058
      GOTO 10                                                            000058
C***** WALL    CHANNELS AND SUBCHANNELS*********************************000058
    3 DE(NS)=DETW                                                        000058
C     MODIFIED AT GA                                                     000058
      DO 4 M=1,NP                                                        000058
      ASCH(NS,M)=ATW*0.5                                                 000059
    4 A(NS)=A(NS)+ASCH(NS,M)                                             000059
      GOTO 10                                                            000059
C***** CORNER  CHANNELS AND SUBCHANNELS*********************************000059
    6 DE(NS)=DETA                                                        000059
      IF(NSEL.EQ.4)GOTO 5                                                000059
      IF(NSEL.EQ.1)GOTO 7                                                000059
      IF(NSEL.EQ.3)GOTO 9                                                000059
      IF(II.EQ.0 .OR. KK.EQ.2) GOTO 8                                    000059
      KK=KK+1                                                            000059
    7 CONTINUE                                                           000060
      A(NS)=ATA                                                          000060
      ASCH(NS,1)=A(NS)                                                   000060
      GOTO 10                                                            000060
    8 II=1                                                               000060
    9 CONTINUE                                                           000060
      A(NS)=ATA /2.                                                      000060
```

```
      ASCH(NS,1)=A(NS)                                                  000060
C     ADDED AT GA (NSEL=4)                                              000060
      GOTO 10                                                           000060
    5 ASCH(NS,1)=ATA*RAPPAI(NS,1)                                       000061
      A(NS)=ASCH(NS,1)                                                  000061
   10 CONTINUE                                                          000061
      RETURN                                                            000061
      END                                                               000061
C                                                                       000061
C                                                                       000061
C                                                                       000061
C                                                                       000061
      SUBROUTINE INGE(NROMA,NSEL,NSTR,NSTOT,C,A,D,ATC,ATW,ATA,PIG,PCORR,000061
     *CTU1,CTU2,DETC,DETW,EM1)                                          000061
C-----------------------------------------------------------------------000061
C     INGE EVALUATES THE TURBULENT MIXING CONSTANTS CTURB(I,J) FOR THE  000061
C     THE CHANNEL EXCHANGES AND CTURB1(K) (K=1,2) FOR THE SUBCHANNEL    000061
C     EXCHANGES. FURTHERMORE INGE EVALUATES THE CONSTANTS CCOND(I,J)    000062
C     AND CCOND1(K) FOR THE ENTHALPY EXCHANGE DUE TO CONDUCTION IN GAS  000062
C                                                                       000062
C                VERSION FOR HEXAGONAL BUNDLES                          000062
C     ..................................................................000062
      COMMON/IND1/NROW(42),NUMS(42)/IND3/NTYP(42)/IJ1/NER(42),NIS(42,3) 000062
     1      /TUR1/CTURB(42,3)/GEN5/DE(42)/GEOO/ACH(3)/TUR2/CTURB1(2)    000062
     2      /CCNDO/FCCND/CCND1/CCOND(42,3)/COND2/CCOND1(2)              000062
     3      /GEN2/AREA(42)                                              000062
      REAL NGAPS(42)                                                    000062
      DIMENSION SUM(42)                                                 000063
      WRITE(6,101)                                                      000063
  101 FORMAT(///5X,'MIXING COEFFICIENTS (WITHOUT PCORR CORRECTION:'/)   000063
      SQ3=SQRT(3.)                                                      000063
      R=D*0.5                                                           000063
      A2=A**2                                                           000063
      A3=A*A2                                                           000063
      R2=R**2                                                           000063
      R3=R*R2                                                           000063
      APIN=PIG*R2                                                       000063
      EM2=C*0.5-EM1                                                     000064
      ZWC=EM2/SQ3                                                       000064
      ATW3=EM2*ZWC                                                      000064
      GAP1=C-D                                                          000064
      GAP2=GAP1*0.5                                                     000064
      GAP3=A-R                                                          000064
      YBC=C*0.5/SQ3                                                     000064
      YBW3=A-ZWC/3.                                                     000064
      XBWS3=C*0.5-EM2/3.                                                000064
      YBW=(A**2*C*0.5-2./3.*R3-YBW3*ATW3)/ATW                           000064
      XBWS=2.*(A*C**2*0.125-R3/3.-XBWS3*ATW3*0.5)/ATW                   000065
      XBA=(5./36.*A3-(A/SQ3-R/PIG)*APIN/6.)/(A2/SQ3-APIN/6.)            000065
      YBA=XBA*SQ3                                                       000065
      DELTA1=2.*YBC                                                     000065
      DELTA2=YBC+YBW                                                    000065
      DELTA3=C                                                          000065
      DELTA4=SQRT((A-YBW-YBA)**2+(C*0.5+A/SQ3-XBA)**2)                  000065
      RA1=1.+APIN/(2.*ATC)                                              000065
      RA2=1.+APIN/(ATC+ATW)                                             000065
      RA3=1.+APIN/(2.*ATW)                                              000065
      RA4=1.+APIN*2./(3.*(ATW+ATA))                                     000066
      ALFAW=ATAN(YBW*2./C)                                              000066
      AP1=YBC*C*0.5-APIN/6.                                             000066
      AP2=YBW*C*0.5-ALFAW*R2                                            000066
      AP3=(ATW-AP2)*0.5                                                 000066
      AP4=A2*0.5/SQ3-YBA*XBA*0.5-APIN/12.                               000066
      AS1=GAP1*YBC                                                      000066
      AS2=GAP1*YBW                                                      000066
      AS3=C*0.5*GAP3                                                    000066
```

```
      AS4=(A/SQ3-XBA)*GAP3
      R1A1=AS1/AP1
      R1A2=AS2/AP2
      R1A3=AS3/AP3
      R1A4=AS4/AP4
      DO 10 I=1,NSTOT
      ITYP=NTYP(I)
      GOTO (1,2,4),ITYP
    1 SUM(I)=3.*R1A1
      GOTO 3
    2 SUM(I)=R1A2+2.*R1A3
    3 NGAPS(I)=3.
      GOTO 10
    4 SUM(I)=2.*R1A4
      NGAPS(I)=2.
   10 CONTINUE
      DO 24 I=1,NSTOT
      NTYPI=NTYP(I)
      AREAI=ACH(NTYPI)
      RAPPI=AREA(I)/AREAI
      NI=NER(I)
      DO 23 M=1,NI
      J=NIS(I,M)
      NTYPJ=NTYP(J)
      AREAJ=ACH(NTYPJ)
      RAPPJ=AREA(J)/AREAJ
      RAPGAP=1.
      IF(ABS(RAPPI-1.).GT.0.1 .AND. ABS(RAPPJ-1.).GT.0.1)RAPGAP=0.5
      IF(I.GT.NSTR)GOTO 16
      IF(NTYP(J).EQ.2)GOTO 15
      DELTA     =DELTA1
      RAPPA=RA1
      GOTO 17
   15 DELTA     =DELTA2
      RAPPA=RA2
   17 GAP=GAP1*RAPGAP
      GOTO 22
   16 IF(NTYP(I).EQ.3)GOTO 20
      IF(NTYP(J)-2)15,19,20
   19 DELTA     =DELTA3
      RAPPA=RA3
      GOTO 21
   20 DELTA     =DELTA4
      RAPPA=RA4
   21 GAP     =GAP3
   22 CONTINUE
      DEIJ=(AREAI+AREAJ)/(AREAI/DE(I)+AREAJ/DE(J))
      YH  =   1.14*SQRT((NGAPS(I)+NGAPS(J))/(SUM(I)+SUM(J)))*RAPPA**2
      WRITE(6,100)M,I,J,YH
  100 FORMAT(3(5X,I5,') YH(',I3,',',I2,')=',E15.7))
      CTURB( I,M)=YH*GAP/DELTA*DEIJ*0.05*PCORR
      CCOND(I,M)=GAP/DELTA*FCOND*0.5
   23 CONTINUE
   24 CONTINUE
      WRITE(6,102)
  102 FORMAT(///)
      DELSC1=C-(7.*C**3/48.-R3)/(0.25*C**2-PIG*R2*SQ3/6.)
      DELSC2=C-2.*XBWS
      CTURB1(1)=CTU1*C.05*DETC*YBC/DELSC1
      CTURB1(2)=CTU2*C.05*DETW*(A-ZWC)/DELSC2
      CCOND1(1)=YBC/DELSC1*FCOND*C.5
      CCOND1(2)=(A-ZWC)/DELSC2*FCOND*C.5
      RETURN
      END
C
C
```

```
C
C
      FUNCTION DSPDPF(EPS,DE,LAMBDA,WSP,PCOP,RE,ITYP)
C     ------------------------------------------------------------------
C     DSPDPF EVALUATES THE FACTOR TAKING THE LARGER DISTRIBUTED PRESSURE
C     LOSSES IN THE SPACER INTO ACCOUNT
C
C     VERSION FOR THE 12-ROD BUNDLES
C
      COMMON/IROSMO/IRH/CVREF/ACVS(3),ACVR(3)
      REAL LAMBDA
      RE=ABS(RE)
      PROV=-GRIFUN(EPS)
      IF(IRH.EQ.2)GOTO 5
C     ..................................................................
C     COEFFICICIENT AA FOR SMOOTH SECTIONS
C
      AA=1.
      GOTO 200
C     ..................................................................
C     COEFFICICIENT AA ROUGHENED SECTIONS
C
    5 GOTO(10,20,30,40),ITYP
C
C     ITYP=1: CENTRAL CHANNELS
C     ITYP=2: WALL CHANNELS
C     ITYP=3: CORNER CHANNELS
C     ITYP=4: WHOLE BUNDLE FLOW SECTION
C
   10 AA=0.
      GO TO 200
   20 AA=0.366
      GOTO 200
   30 AA=0.575
      GOTO 200
   40 AA=0.247
C
C
  200 CV=6.82*AA*(1.+891.*RE**(-0.8135))+10.7*(1.-AA)*(1.+6026.*RE**
     *(-1.104))
      DSPDPF=PROV+CV   *0.5*EPS**2
      RETURN
      END
C
C
C
C
      SUBROUTINE INDEX(NSEL,NROMA,NSTR,NSTOT,NRO)
C-----------------------------------------------------------------------
C     INDEX PROVIDES INDICES TO THE CHANNELS
C
C                VERSION FOR THE 12-ROD BUNDLES
C     ..................................................................
      COMMON/IND3/NTYP(42)/IJ1/NEP(42),NIS(42,3)
      IF(NSEL.EQ.3)GOTO 1
      NSTOT=28
      NSTR=13
      GOTO 2
    1 NSTOT=11
      NSTR=6
    2 CONTINUE
      NRO=NROMA
      WRITE(6,14)NRO,NSEL,NSTR,NSTOT
   14 FORMAT(  //4X,'RESULTS OF INDEX'//5X,'NROWS=',I2,5X,'TYPE OF SECTI
     *ON=',I1,5X,'NR. OF CENTRAL CHANNELS=',I4,5X,'TOTAL NUMBER OF CHANN
     *ELS=',I4//)
```

```
      DO 100 NS=1,NSTCT                                                 000006
      NI=NER(NS)                                                        000006
      WRITE(6,200)NS,NTYP(NS),(NIS(NS,M),M=1,NI)                        000006
  200 FORMAT(5X,'NS=',I2,5X,'TYPE=',I1,5X,'CHANNELS CONNECTED:',3I5)    000006
  100 CONTINUE                                                          000006
      RETURN                                                            000006
      END                                                               000006
C                                                                       000006
C                                                                       000006
C                                                                       000006
C                                                                       000006
      SUBROUTINE TOTGEO(NSEL,D,C,Z,PIG,NEXCON,NRODS,WW,WA,ZA,EM1,PERLT, 000006
     &RTIP)                                                             000006
C-----------------------------------------------------------------------000007
C     TOTGEO CALCULATES FLOW AREAS , EQUIVALENT DIAMETERS AND OTHER     000007
C     GEOMETRIC DATA FOR THE WHOLE BUNDLE FLOW SECTION , FOR THE        000007
C     CHANNELS AND FOR THE SUBCHANNELS                                  000007
C                                                                       000007
C                  VERSION FOR THE 12-ROD BUNDLES                       000007
C     ..................................................................000007
      COMMON/GEO0/ACH(3)/LAMIN2/FATIP(3),FDTIP(3)/QPAR3/PERL(3)         000007
     1       /GEO2/ATCT,DETCT,ASEC/GEO5/ATC,DETC,ATW,DETW,ATA,DETA,AAC, 000007
     2       AAW,AAA/WAKAO/CD,WD,ZD,ZWCD,AWD2,PWWD                      000007
      SQ3=SQRT(3.)                                                      000008
      D2=D**2                                                           000008
      EM2=C*0.5-EM1                                                     000008
      ZWC=EM2/SQ3                                                       000008
      DTIP=RTIP*2.                                                      000008
      ATC=(C**2*SQ3-PIG*D2*0.5)*0.25                                    000008
      DETC=8.*ATC/(PIG*D)                                               000008
      ATW=C*Z-0.125*PIG*D2-EM2*ZWC                                      000008
      DETW=4.*ATW/(2.*EM1+4.*ZWC+PIG*D*0.5)                             000008
      ATA=Z**2/SQ3      -PIG*D2/24.                                     000008
      DETA=4.*ATA/(   PIG*D/6.+2.*Z/SQ3)                                000009
      AAC=ATC/6.                                                        000009
      AAW=ATW*0.5                                                       000009
      AAA=ATA*0.5                                                       000009
      ATOT=13.*ATC+9.*ATW+6.*ATA                                        000009
      DETOT=ATCT/(13.*ATC/DETC+9.*ATW/DETW+6.*ATA/DETA)                 000009
      IF(NSEL.EQ.3)GOTO 1                                               000009
      ASEC=ATCT                                                         000009
      GOTO 2                                                            000009
    1 ASEC=ATCT/3.                                                      000009
    2 CONTINUE                                                          000010
      ACH(1)=ATC                                                        000010
      ACH(2)=ATW                                                        000010
      ACH(3)=ATA                                                        000010
      PERLT=4.*ATOT/DETOT-12.*PIG*D                                     000010
      PERL(1)=0.                                                        000010
      PERL(2)=4.*ATW/DETW-0.5*PIG*D                                     000010
      PERL(3)=4.*ATA/DETA-PIG*D/6.                                      000010
      WW=Z+0.5*D                                                        000010
      ZA=Z                                                              000010
      WA=WW                                                             000011
      FATIP(1)=(C**2*SQ3-PIG*DTIP**2*0.5)*0.25                          000011
      FDTIP(1)=4.*FATIP(1)/(PIG*0.5*DTIP)/DETC                          000011
      FATIP(1)=FATIP(1)/ATC                                             000011
      FATIP(2)=C*(WW-DTIP*0.5)-DTIP**2*PIG*0.125-EM2*ZWC                000011
      FDTIP(2)=4.*FATIP(2)/(PIG*DTIP*0.5+2.*EM1+4.*ZWC)/DETW            000011
      FATIP(2)=FATIP(2)/ATW                                             000011
      FATIP(3)=(WA-DTIP*0.5)**2/SQ3-DTIP**2*PIG/24.                     000011
      FDTIP(3)=4.*FATIP(3)/(DTIP*PIG/6.+(WA-DTIP*0.5)*2./SQ3)/DETA      000011
      FATIP(3)=FATIP(3)/ATA                                             000011
      CD=C/DTIP                                                         000012
      WD=WW/DTIP                                                        000012
      ZD=Z/DTIP                                                         000012
```

```
      ZWCD=ZWC/DTIP
      AWD2=AAW*FATIP(2)/DTIP**2
      PWWD=4.*AAW*FATIP(2)/(DETW*FDTIP(2)*DTIP)
      WRITE(6,3)ATOT,DETOT,ASEC
      WRITE(6,4)ATC,ATW,ATA,DETC,DETW,DETA
    3 FORMAT(///5X,'TOTAL FLOW AREA=',F10.3,' SQCM'/5X,'TOTAL EQUIVALENT
     1 DIAMETER=',F10.2,' CM'/5X,'FLOW AREA OF SECTION=',F10.3,' SQCM'/)
    4 FORMAT(5X,'FLOW AREAS OF CHANNELS:'/5X,'CENTRAL=',F10.3/3X,'WALL='
     1,F10.3/6X,'CORNER=',F10.3//5X,'EQUIVALENT DIAMETERS:'/5X,'CENTRAL=
     2',F10.2/8X,'WALL=',F10.2/6X,'CORNER=',F10.2///130('*'))
      RETURN
      END
C
C
C
C
      SUBROUTINE INGE(NROMA,NSEL,NSTR,NSTOT,C,A,D,ATC,ATW,ATA,PIG,PCORR,
     *CTU1,CTU2,DETC,DETW,EM1)
C-----------------------------------------------------------------------
C     INGE EVALUATES THE TURBULENT MIXING CONSTANTS CTURB(I,J) FOR THE
C     THE CHANNEL EXCHANGES AND CTURB1(K) (K=1,2) FOR THE SUBCHANNEL
C     EXCHANGES. FURTHERMORE INGE EVALUATES THE CONSTANTS CCOND(I,J)
C     AND CCOND1(K) FOR THE ENTHALPY EXCHANGE DUE TO CONDUCTION IN GAS
C
C                   VERSION FOR THE 12-ROD BUNDLES
C     ...................................................................
      COMMON/IND3/NTYP(42)/IJ1/NER(42),NIS(42,3)/GE00/ACH(3)
     1        /GEN5/DE(42)/TUR1/CTURB(42,3)/TUR2/CTURB1(2)
     2        /CONDO/FCOND/COND1/CCOND(42,3)/COND2/CCOND1(2)
      DIMENSION SUM(42)
      REAL NGAPS(42)
      SQ3=SQRT(3.)
      R=D*0.5
      R2=R**2
      R3=R2*R
      A2=A**2
      A3=A2*A
      APIN=PIG*R2
      EM2=C*0.5-EM1
      ZWC=EM2/SQ3
      ATW3=EM2*ZWC
      GAP1=C-D
      GAP3=A-R
      YBC=C*0.5/SQ3
      YBW3=A-ZWC/3.
      XBWS3=C*0.5-EM2/3.
      YBW=(A**2*C*0.5-2./3.*R3-YBW3*ATW3)/ATW
      XBWS=2.*(A*C**2*0.125-R3/3.-XBWS3*ATW3*0.5)/ATW
      XBA=(5./36.*A3-(A/SQ3-R/PIG)*APIN/6.)/(A2/SQ3-APIN/6.)
      YBA=XBA*SQ3
      DELTA1=2.*YBC
      DELTA2=YBC+YBW
      DELTA3=C
      DELTA4=SQRT((A-YBW-YBA)**2+(C*0.5+A/SQ3-XBA)**2)
      RA1=1.+APIN/(2.*ATC)
      RA2=1.+APIN/(ATC+ATW)
      RA3=1.+APIN/(2.*ATW)
      RA4=1.+APIN*2./(3.*(ATW+ATA))
      ALFAW=ATAN(YBW*2./C)
      AP1=YBC*C*0.5-APIN/6.
      AP2=YBW*C*0.5-ALFAW*R2
      AP3=(ATW-AP2)*0.5
      AP4=A2*0.5/SQ3-YBA*XBA*0.5-APIN/12.
      AS1=GAP1*YBC
      AS2=GAP1*YBW
      AS3=C*0.5*GAP3
```

```
      AS4=(A/SQ3-XBA)*GAP3                                           000018
      R1A1=AS1/AP1                                                   000018
      R1A2=AS2/AP2                                                   000018
      R1A3=AS3/AP3                                                   000018
      R1A4=AS4/AP4                                                   000018
C EACH CENTRAL CHANNEL HAS 3 GAPS. IT IS CONNECTED TO 3 CENTRAL CHANNELS000019
C OR TO 2 CENTRAL CHANNELS AND TO 1 WALL CHANNEL                     000019
      DO 7 I=1,NSTOT                                                 000019
      ITYP=NTYP(I)                                                   000019
      GOTO (1,2,4),ITYP                                              000019
    1 SUM(I)=3.*R1A1                                                 000019
      GOTO 3                                                         000019
    2 SUM(I)=R1A2+2.*R1A3                                            000019
    3 NGAPS(I)=3.                                                    000019
      GOTO 7                                                         000019
    4 SUM(I)=2.*R1A4                                                 000020
      NGAPS(I)=2.                                                    000020
    7 CONTINUE                                                       000020
      DO 15 I=1,NSTOT                                                000020
      NI=NER(I)                                                      000020
      DO 15 M=1,NI                                                   000020
      J=NIS(I,M)                                                     000020
      IF(I.GT.NSTR)GOTO 10                                           000020
      IF(NTYP(J).EQ.2)GOTO 8                                         000020
C  I=CENTRAL CHANNEL, J=CENTRAL CHANNEL                              000020
      DELTA=DELTA1                                                   000021
      RAPPA=RA1                                                      000021
      GOTO 9                                                         000021
C  I=CENTRAL CHANNEL, J=WALL CHANNEL (OR VICE VERSA)                 000021
    8 DELTA=DELTA2                                                   000021
      RAPPA=RA2                                                      000021
    9 GAP=GAP1                                                       000021
      GOTO 14                                                        000021
   10 IF(NTYP(I).EQ.3)GOTO 12                                        000021
      IF(NTYP(J)-2)8,11,12                                           000021
C  I=WALL CHANNEL , J=WALL CHANNEL                                   000022
   11 DELTA=DELTA3                                                   000022
      RAPPA=RA3                                                      000022
      GOTO 13                                                        000022
C  I=CORNER CHANNEL, J=WALL CHANNEL (OR VICE VERSA)                  000022
   12 DELTA=DELTA4                                                   000022
      RAPPA=RA4                                                      000022
   13 GAP=GAP3                                                       000022
   14 YH=1.14*SQRT((NGAPS(I)+NGAPS(J))/(SUM(I)+SUM(J)))*RAPPA**2     000022
      NTYPI=NTYP(I)                                                  000022
      NTYPJ=NTYP(J)                                                  000023
      AREAI= ACH(NTYPI)                                              000023
      AREAJ= ACH(NTYPJ)                                              000023
      DEIJ=(AREAI+AREAJ)/(AREAI/DE(I)+AREAJ/DE(J))                   000023
      CTURB(I,M)=YH*GAP/DELTA*DEIJ*0.05*PCORR                        000023
      CCOND(I,M)=GAP/DELTA*FCOND*0.5                                 000023
   15 CONTINUE                                                       000023
      DELSC1=C-(7.*C**3/48.-R3)/(C.25*C**2-PIG*R2*SQ3/6.)            000023
      DELSC2=C-2.*XBWS                                               000023
      CTURB1(1)=CTU1*C.C5*DETC*YBC/DELSC1                            000023
      CTURB1(2)=CTU2*C.05*DETW*(A-ZWC)/DELSC2                        000024
      CCOND1(1)=YBC/DELSC1*FCOND*C.5                                 000024
      CCOND1(2)=(A-ZWC)/DELSC2*FCOND*C.5                             000024
      IF(NSEL.EQ.1)RETURN                                            000024
      CTURB(1,1)=CTURB(1,1)*C.5                                      000024
      CTURB(1,2)=CTURB(1,2)*C.5                                      000024
      CTURB(2,1)=CTURB(2,1)*C.5                                      000024
      CTURB(6,2)=CTURB(6,2)*C.5                                      000024
      CCOND(1,1)=CCOND(1,1)*C.5                                      000024
      CCOND(1,2)=CCOND(1,2)*C.5                                      000024
      CCOND(2,1)=CCOND(2,1)*C.5                                      000025
```

```
      CCOND(6,2)=CCOND(6,2)*0.5                                         000025
      RETURN                                                            000025
      END                                                               000025
C                                                                       000025
C                                                                       000025
C                                                                       000025
C                                                                       000025
      SUBROUTINE INQUA(NSEL,NSTOT,NRCMA,ATC,ATW,ATA,DETC,DETW,DETA)     000025
C-----------------------------------------------------------------------000025
C     INQUA PROVIDES INDICES TO CHANNEL FLOW AREAS AND EQUIVALENT       000025
C     DIAMETERS AND TO SUBCHANNEL  FLOW AREAS                           000025
C                                                                       000025
C                VERSION FOR THE THE 12-ROD BUNDLES                     000025
C     ..................................................................000026
      DIMENSION ACH(3),D(3)                                             000026
      COMMON/GEN2/A(42)       /IND3/NTYP(42)/SUB1/ASCH(42,3)/GEN5/DE(42)000026
     1       /HEA6/NPIN(42),JPIN(42,3)                                  000026
      ACH(1)=ATC                                                        000026
      ACH(2)=ATW                                                        000026
      ACH(3)=ATA                                                        000026
      D(1)=DETC                                                         000026
      D(2)=DETW                                                         000026
      D(3)=DETA                                                         000026
      DO 1 NS=1,NSTOT                                                   000027
      NP=NPIN(NS)                                                       000027
      NSCH=4-NTYP(NS)                                                   000027
      SCH=NSCH                                                          000027
      NTYPNS=NTYP(NS)                                                   000027
      DE(NS)=D(NTYPNS)                                                  000027
      DO 1 M=1,NP                                                       000027
    1 ASCH(NS,M)=ACH(NTYPNS)/SCH                                        000027
      IF(NSEL.EQ.1)GOTO 3                                               000027
      ASCH(2,2)=ASCH(2,2)*0.5                                           000027
      ASCH(6,1)=ASCH(6,1)*0.5                                           000028
    3 CONTINUE                                                          000028
      DO 4 NS=1,NSTOT                                                   000028
      NP=NPIN(NS)                                                       000028
      A(NS)=0.                                                          000028
      DO 4 M=1,NP                                                       000028
    4 A(NS)=A(NS)+ASCH(NS,M)                                            000028
      RETURN                                                            000028
      END                                                               000028
C                                                                       000028
C                                                                       000028
C                                                                       000028
C                                                                       000028
      SUBROUTINE HEATI(NSTOT,NSTR,NSEL,NRCMA,IPA)                       000028
C-----------------------------------------------------------------------000029
C     HEATI EVALUATES THE HEAT FLUXES QQ(NS,I) FOR THE RODS ADJACENT TO 000029
C     EACH CHANNEL NS AND THE TOTAL FLUXES QT(NS) ENTERING EACH         000029
C     CHANNEL NS.  HEATI IDENTIFIES ALSO THE CONNECTIONS BETWEEN THE    000029
C     SUBCHANNELS I AND THE ADJACENT RODS BY MEANS OF THE MATRIX JPIN   000029
C     ( NPIN(NS)= NR. OF SUBCH. IN CH. NS = NR. OF PINS ADJ. TO CH. NS) 000029
C                                                                       000029
C                VERSION FOR THE 12-ROD BUNDLES                         000029
C     ..................................................................000029
      COMMON/HEA1/Q(37)/HEA3/QT(42)/IND3/NTYP(42)                       000029
     1       /HEA5/QQ(42,3)/HEA6/NPIN(42),JPIN(42,3)/HEA10/QSCH(42,3)   000030
      DO 3 NS=1,NSTOT                                                   000030
      NP=NPIN(NS)                                                       000030
      DO 2 M=1,NP                                                       000030
      JPINNM=JPIN(NS,M)                                                 000030
      QQ(NS,M)=Q(JPINNM)                                                000030
      IF(NTYP(NS).EQ.2)GOTO 1                                           000030
      QSCH(NS,M)=QQ(NS,M)/6.                                            000030
      GOTO 2                                                            000030
```

```
    1 QSCH(NS,M)=QQ(NS,M)*0.25                                          000030
    2 CONTINUE                                                          000031
    3 CONTINUE                                                          000031
      IF(NSEL.EQ.1)GOTO 4                                               000031
      QSCH(2,2)=QSCH(2,2)*0.5                                           000031
      QSCH(6,1)=QSCH(6,1)*0.5                                           000031
    4 CONTINUE                                                          000031
      DO 5 NS=1,NSTOT                                                   000031
      NP=NPIN(NS)                                                       000031
      QT(NS)=0.                                                         000031
      DO 5 M=1,NP                                                       000031
    5 QT(NS)=QT(NS)+QSCH(NS,M)                                          000032
      IF(IPA.NE.IPA/2*2)RETURN                                          000032
C                                                                       000032
      WRITE(6,6)                                                        000032
    6 FORMAT(////5X,'RESULTS OF HEATI'////8X,'CHANNEL',3(21X,'ROD',2X)/)000032
      DO 8 NS=1,NSTOT                                                   000032
      NP=NPIN(NS)                                                       000032
      WRITE(6,7) NS,(M,NS,M,  JPIN(NS,M),M=1,NP)                        000032
    7 FORMAT(2X,I10,3(3X,I1,') JPIN(',I5,',',I2,')=',I5))               000032
    8 CONTINUE                                                          000032
      RETURN                                                            000033
      END                                                               000033
C                                                                       000033
C                                                                       000033
C                                                                       000033
C                                                                       000033
      BLOCK DATA                                                        000033
C---------------------------------------------------------------------- 000033
C     BLOCK DATA FOR THE 12-ROD BUNDLES ( 1/3.RD OF THE WHOLE BUNDLE    000033
C     FLOW SECTION )                                                    000033
C                                                                       000033
      COMMON/DAT1/A(10)/DAT2/B(10)/DAT4/NDEST,NDEEND/DAT7/CNUSS(2)      000033
     1      /DATKM/D1(7),D2(7)/EXDAT/EX1(7),EX2(7),EX3(7)/EXDAT1/       000033
     2      EX4(7),EX5(7),EX6(7)/BIDAT/BIK(3)/BIDAT1/BIE(7)/BIDE/IBIDE  000033
     3      /LAMINK/BKAPPA(7,3)/LAMIN5/I3TIP(42,3)/CONDO/FCOND/MART2/   000034
     4      NS1,NS2/WAKA1/IKAPPA/CVREH/ACVS(3),ACVR(3)/LAMIN6/ANGLAM    000034
     5      /GRAV/IGRAV/HEA6/ NPIN(42),JPIN(42,3)/IND3/NTYP(42)/IJ1/    000034
     6      NER(42),NIS(42,3)/SIMLAM/ISIMPL/EXAVTW/IEXAV/ISUP/IQLIN     000034
     7      /SUBCI/IDIV1,IDIV2/IDISPA/IDISP1/IDISPB/IDISP2              000034
     8      /ISMO/COTW/GASD1/NSTOT/GASD2/RAPPAI(42,3)/GASD3/FSYMM       000034
     9      /GASD4/IGAS/MART5/NSTR/GAAG1/FCOPW1(3)/GAAGT/FCOPWT         000034
      COMMON/ISMO1/ITECO/ENECP/IENE/MIXS1/CY                            000034
      DATA A/4.4,0.24,0.,1.,0.44,0.5,0.01,0.053,10.,10./                000034
      DATA B/4.7,359.,2.,1.,0.4,0.01,0.,5.0,0.5,2.0/                    000034
      DATA NDEST,NDEEND/10,2/                                           000035
      DATA CNUSS/5.55,3.55/                                             000035
      DATA D1,D2/7*2.897E-02,7*3.87E-05/                                000035
      DATA JPIN/2*3,4,5,6,7,4,2*5,2*6,32*0,4,5,6,7,3,5,0,6,0,7,33*0,3*3,000035
     $      37*0/                                                       000035
      DATA NIS/2,1,2,3,4,5,3,7,8,9,10,31*0,6,3,4,5,6,1,8,9,10,11,5,33*0,000035
     $      7,9,11,3*0,4,33*0/                                          000035
      DATA NER/2*2,3*3,3*2,3,2*2,31*0/                                  000035
      DATA NTYP/6*1,2,3,2,3,2,31*0/                                     000035
      DATA NPIN/1,2,3*3,2*2,1,2,1,2,31*0/                               000035
      DATA EX1,EX2,EX3/0.1665E-04, 5*0.1524E-04,0.1665E-04, 0.667E-08,  000036
     *      5*0.726E-08,0.667E-08,0.,5*-0.488E-11,0./                   000036
      DATA EX4,EX5,EX6/7*0.1524E-04,7*0.726E-08,7*-0.488E-11/           000036
      DATA BIK/1.,-1.2,0./                                              000036
      DATA BIE/0.01,1.,-3.35,0.,0.995,-2.83,0./                         000036
      DATA IBIDE/1/                                                     000036
      DATA BKAPPA/21*1./                                                000036
C     ..................................................................000036
C     TURBULENT CALCULATION IS IMPOSED FOR ALL SUBCHANNELS              000036
C                                                                       000036
      DATA I3TIP/126*2/                                                 000037
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      DATA NS1,NS2/0,0/                                               000037
C                                                                     000037
      DATA FCCND/1./                                                  000037
      DATA ANCLAM/1./                                                 000037
      DATA ACVS,ACVR/4.75,643.,0.527,8.,3500.,0.8/                    000037
C     ...............................................................000037
C     IF THE DIRECTION OF THE FLOW IS COINCIDENT TO THAT OF THE       000037
C     GRAVITATIONAL FORCE IGRAV=1; IF IT IS OPPOSITE IGRAV=-1         000037
C     IF THE GRAVITATIONAL FORCE IS NOT TAKEN INTO ACCOUNT IGRAV=0    000037
C     ISIMPL=2 IN THE CASE OF LAMINAR FLOW, IF THE NUSSELT NUMBERS    000038
C     OF THE EXTERNAL CHANNELS "NS" ( NS1-1<NS<NS2+1 ), I.E. IF IT MUST 000038
C     BE  CO1,CO2#1 IN SIMLA1. IN THE OTHER CASES ISIMPL=1            000038
C     IEXAV=2 IF AN AVERAGE VALUE OF THE PIN TEMPERATURES AND AN AVERAGE000038
C     VALUE OF THE SHROUD TEMPERATURES MUST BE COMPUTED IN WALLTE FOR  000038
C     THE EXTERNAL CHANNELS INSTEAD OF THE REAL VALUES. OTHERWISE     000038
C     IEXAV=1                                                         000038
C                                                                     000038
      DATA IKAPPA,IGRAV,ISIMPL,IEXAV/1,0,2*1/                         000038
C     ...............................................................000038
C     ADDED AT GA. IDIV1=1: NORMAL SUBDIVISION INTO SUBCHANNELS;      000039
C                  IDIV1=2: NO SUBDIVISION FOR CENTRAL CHANNELS;      000039
C                  IDIV1=3: NO SUBDIVISION FOR WALL CHANNELS;         000039
C                  IDIV1=4: NO SUBDIVISION FOR CENTRAL AND WALL CHANNELS000039
C                  IDIV2=1: NORMAL SUBDIVISION INTO PORTIONS OF WALL  000039
C                           SUBCHANNELS                               000039
C                  IDIV2=2: NO SUBVISION FOR WALL SUBCHANNELS         000039
C                  IDISP1=1 IF THE SPACER EFFECT ON NU IS CONSIDERED  000039
C                  IDISP1=2 IF THE SPACER EFFECT ON NU IS NOT CONSIDERED000039
C              IDISP2=1 THE EFFECT OF THE LAST SPACER OF EACH AXIAL   000039
C                       PORTION ON NU IN THE SUCCEEDING PORTION IS TAKEN 000040
C                       INTO ACCOUNT                                  000040
C              IDISP2=2 THE EFFECT OF THE LAST SPACER OF EACH AXIAL   000040
C                       PORTION ON NU IN THE SUCCEEDING PORTION IS NOT 000040
C                       TAKEN INTO ACCOUNT                            000040
C                                                                     000040
      DATA IDIV1,IDIV2,IDISP1,IDISP2/1,1,1,1/                         000040
      DATA IQLIN,ITECC,IENE/3*1/                                      000040
      DATA FCOPW1,FCOPWT/4*1./                                        000040
      DATA CY/1./                                                     000040
      DATA IGAS/1/                                                    000041
      DATA NSTOT,NSTR/2*0/                                            000041
      DATA FSYMM/1./                                                  000041
      DATA RAPPAI/126*1./                                             000041
      DATA CCTW/0.2/                                                  000041
      END                                                             000041
```