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Institut für Neutronenphysik und Reaktortechnik
Projekt Schneller Brüter

SAGAPØ
A Computer Code for the Thermo-fluiddynamic Analysis of Gas Cooled Fuel Element Bundles

A. Martelli

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A computer code for the thermo-fluiddynamic analysis of gas cooled fuel element bundles

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Summary

This paper is a guide for the users of the Fortran computer code SAGAPØ, which has been developed by the author for the thermo-fluiddynamic analysis of gas cooled fuel element bundles.

The physical models and the mathematical procedures used in SAGAPØ have been already described by the author of this work in a previous paper. Thus this work contains only a description of the structure of the code, together with the other informations necessary to the users.

A listing of SAGAPØ is included in Appendix, together with an example of input preparation and parts of printed results.

SAGAPØ, ein Rechenprogramm zur thermo- und fluiddynamischen Analyse von gasgekühlten Brennelementbündeln

Zusammenfassung

Diese Arbeit ist ein Handbuch für die Benutzer des vom Autor zur thermo- und fluiddynamischen Analyse von gasgekühlten Brennelementbündeln entwickelten Fortran-Rechenprogramms SAGAPØ.

Die in SAGAPØ angewendeten physikalischen Modelle und mathematischen Methoden wurden vom Autor dieser Arbeit schon in einem früheren Bericht beschrieben. Deshalb enthält diese Arbeit nur die Beschreibung der Struktür des Codes, zusammen mit den anderen Informationen, die für die Benutzer notwendig sind.

Eine Liste des ausführenden Programms von SAGAPØ, ein Beispiel von Eingabedaten und Teile einer Ergebnisliste sind im Appendix beigefügt.

CONTENTS

1. INTRODUCTION

SAGAPØ is a computer code for the analysis of the steady state pressure drop and pin and shroud surface temperatures for gas cooled bundles of partly smooth and partly roughened rods, i.e. for bundles as those used in the Gas Cooled Fast Reactors with fuel element rods.

The SAGAPØ code was initially developed for the analysis in turbulent flow conditions /1,2,3/. Later the possibility of performing calculations in the case of laminar flows was also introduced in the code, to allow the prediction of the thermo-fluiddynamic behaviour of the Gas Cooled Fast Reactor also in the case of low Reynolds number /4,5/.

With SAGAPØ thermo-fluiddynamic calculations for bundles with a hexagonal shroud profile can be performed. A modification of the code is also available for the calculations of the Calibration Elements, which have been tested in the Institute of Neutron Physics and Reactor Engineering of the Karlsruhe Nuclear Center in order to allow the thermo-fluiddynamic design of the 12-rod bundle fuel element to be irradiated in the Mol Reactor BR2 /1,2,3/. In this version of the code only a few subroutines of the original version have been replaced or eliminated: these modifications concern only geometry and indexing computations.

The physical models and the mathematical procedures used in SAGAPØ were accurately described by the author of this work in a previous paper /5/. Thus only the structure of the code will be presented here, together with the informations necessary to the users. Frequent references to equations presented in /5/ will be made in this work, to better explain which calculations are performed in the single subprograms and to describe the meaning of some parameters. For this aim, some references will be made also to equations presented in /1,2/.

Zum Druck eingereicht am: 15. August 1977

2. GENERAL INFORMATIONS

2.1 Geometries

2.1.1 Flow section geometry

Fig.1 shows the geometry of a 19-rod bundle with a hexagonal shroud profile, whereas Fig.2 refers to the 12-rod bundles. Both figures show the usual division of the flow section into central, wall and corner channels. The only possible shape of the corner channels in the present version of SAGAPØ is the angular one, as shown by the figures. Blocking triangles with base angles of 30° (as those used in the 12-rod bundles) can be considered in the wall channels. As described in /5/, a very fine subdivision of the flow section is performed by SAGAPØ: the central and the wall channels are subdivided into subchannels, each wall subchannel into a central and a wall portion (see Fig.3a)and finally each corner channel, each central subchannel and both portions of the wall subchannels into sub-subchannels (see Fig.3b).

The calculations can be performed in the whole flow section, in a half of it or in 1/12 th of it, in the version concerning hexagonal bundles; they can be performed in the whole flow section or in 1/3 rd of it, in the version concerning the 12-rod bundles (1/3 rd of the total flow area is the minimum section which could be considered for the 12-rod bundles, due to the spacer profile,see /5/).

SAGAPØ -in its present version- will handle problems up to 42 flow channels and 19 rods. These maximum values for the number of the channels and of the rods was selected for practical reasons, because up to now calculations have been performed only for 19- and 12-rod bundles (for a 19-rod bundles the total number of channels is 42) and because with higher values of these parameters a storage requirement larger than 480 K would have been necessary for SAGAPØ on the computer IBM 370-168 of the Karlsruhe Nuclear Center: this would have meant a very low priority and thus a very long time before getting outputs, at the time of the calculations for the 19- and the 12-rod bundles. To be able to calculate bundles with a larger amount of rods and of channels, the dimensions of the various tensors have to be increased.

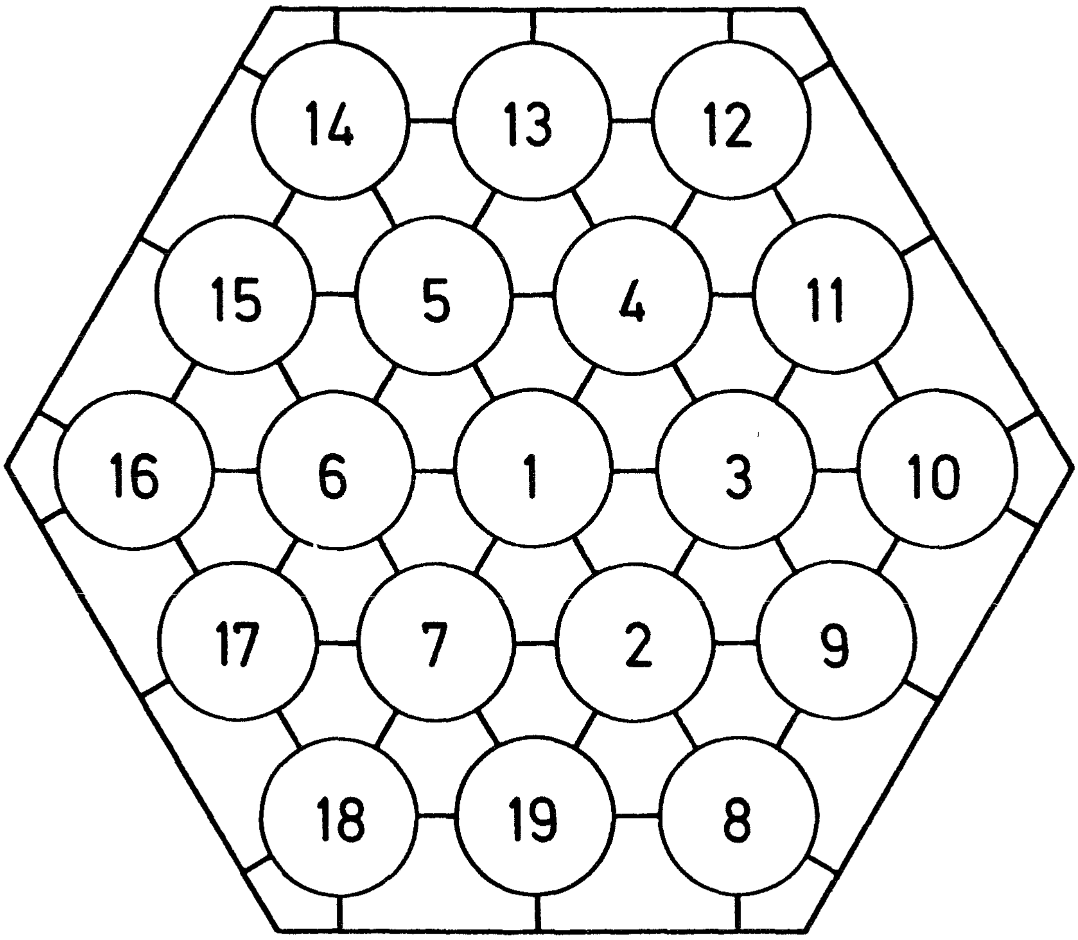


Fig.1 Geometry of the flow section for a 19-rod bundle. Subdivision into channels. Indexing of the rods.

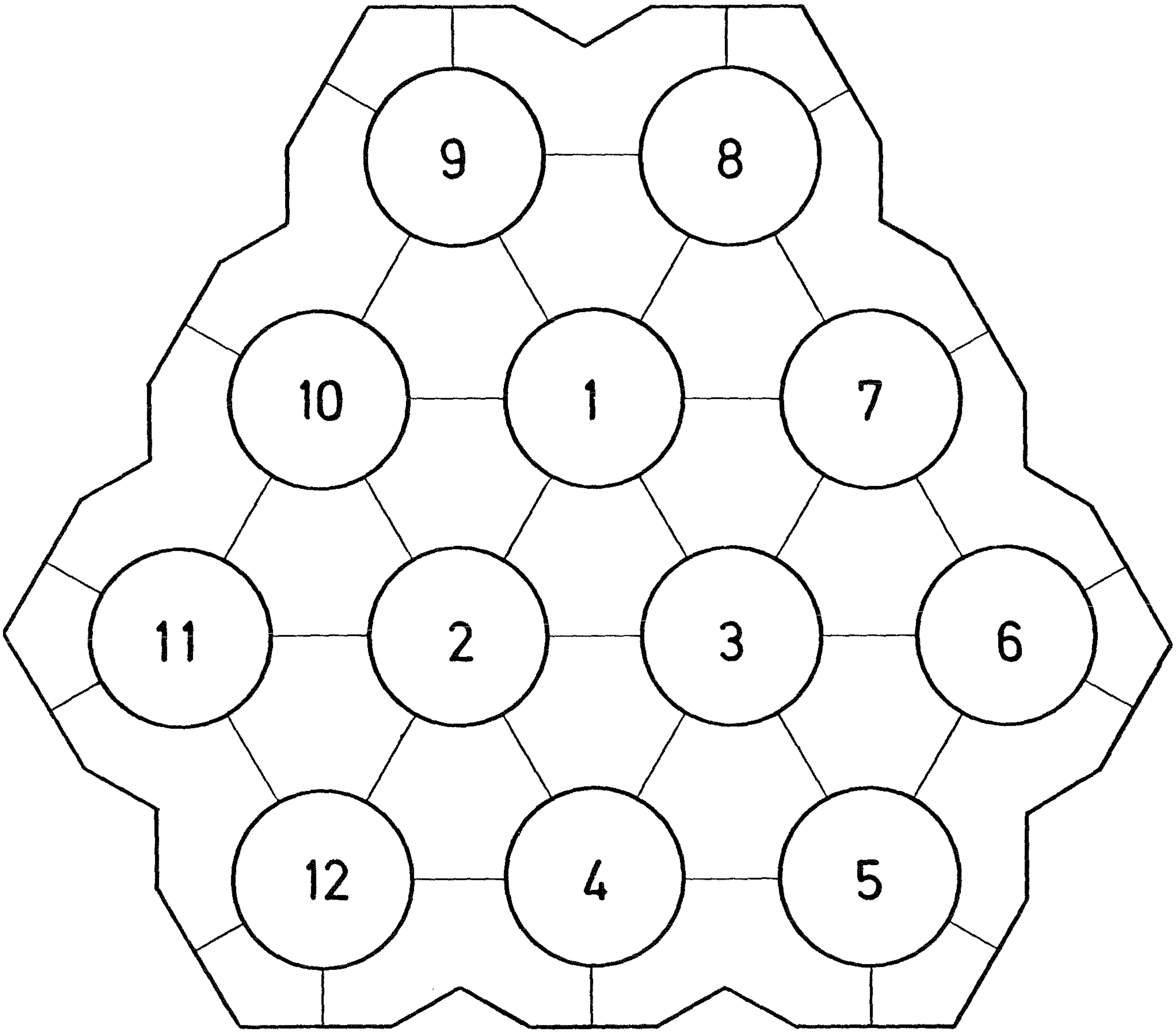
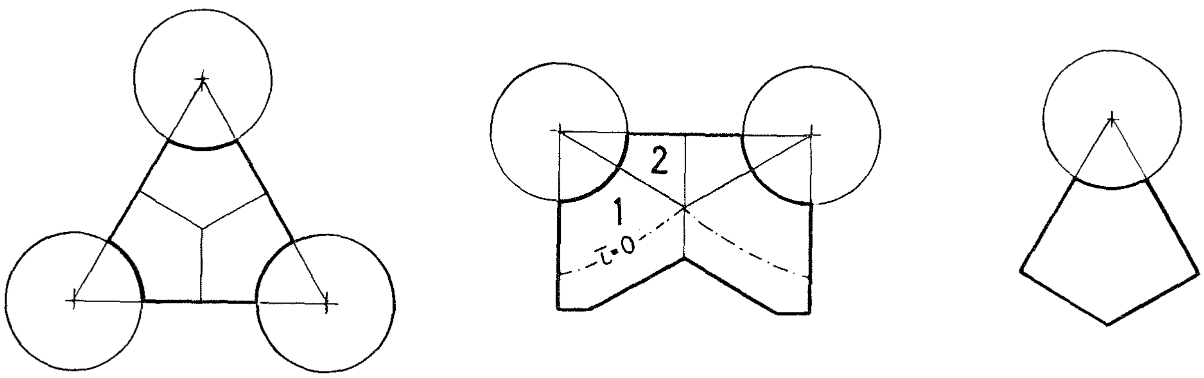


Fig.2 Geometry of the flow section for the 12-rod bundles. Subdivision into channels. Indexing of the rods.

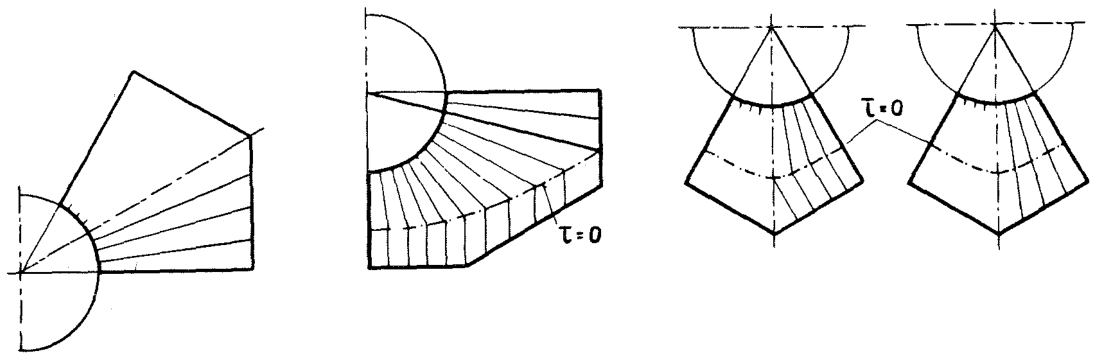


central channels and subchannels

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

corner channels (no subdivision into subchannels)

Fig.3a 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.3b Subdivision into sub-subchannels

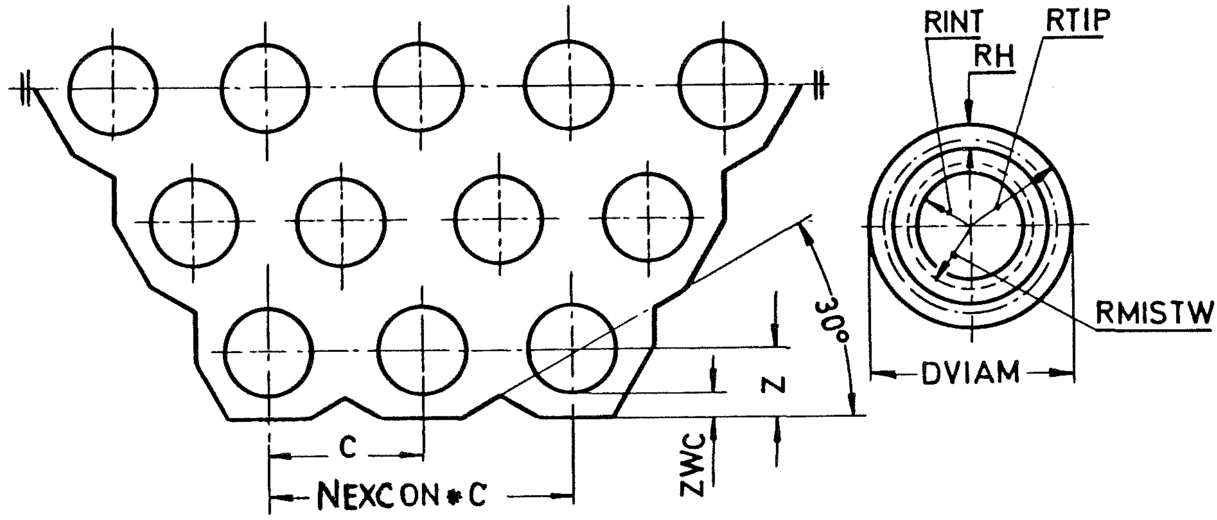


Fig. 4 Geometric parameters needed by SAGAPØ as input information for the definition of the flow section geometry (for the symbology see also 3.1).

The geometrical parameters (as flow areas, equivalent diameters, etc.) of the channels, of the subchannels, of the two portions of the wall subchannels and of the sub-subchannels needed for the calculations are all computed authomatically by SAGAPØ: a very small amount of geometrical parameters is needed by SAGAPØ as input information (see 3.1, Cards 1, 3-8 and Fig.4).

2.1.2. Axial geometry

By means of SAGAPØ it is possible to calculate bundles with partly smooth and partly roughened rod surfaces, with or without unheated ends. In the present version of the code all the rods must have an equal geometry. In the case of roughened rods, the calculations are based on the volumetric diameter, which is the diameter of the smooth rod having the same volume as the roughened rod. The volumetric diameters must be provided as input data, for each of the axial portions into which the rods can be divided.*)

It is possible to bundle up to 5 axial portions of the rods, choosing between the two following possibilities:

*) see below

A-1) unheated smooth portion - 2) heated smooth portion - 3) heated or unheated rough portion - 4) heated smooth portion - 5) unheated smooth portion.

B-1) unheated smooth portion - 2) unheated rough portion - 3) heated or unheated rough portion - 4) unheated rough portion - 5) unheated smooth portion.

The first possibility refers to the 19-rod bundle and the second one to the 12-rod bundles. Each of the mentioned axial portions is identified in SAGAPØ by means of a different value of the index IPA (see flow-chart for the main program, Fig.11). More precisely (see Fig.5):

IPA = 1 for the first unheated smooth portion
IPA = 2 for the first heated smooth portion
IPA = 3 for the first unheated rough portion
IPA = 4 for the central heated or unheated rough portion
IPA = 5 for the last unheated rough portion
IPA = 6 for the last heated smooth portion
IPA = 7 for the last unheated smooth portion

Either the lengths of the axial portions corresponding to IPA=3 and to IPA=5 or the lengths of the axial portions corresponding to IPA=2 and to IPA=6 must be set equal to 0 in input (the first case refers to the 19-rod bundle (A), the second case to the 12-rod bundles (B)). In both cases, if some of the remaining five portions do not exist, it is sufficient to set their lengths equal to zero.

In this way isothermal calculations are also possible. It is important to point out that, if a roughened axial portion exists in the rods, portion 3 must have a length different from 0 (and this both for case A and for case B). This means also that in the case of isothermal calculations of bundles with partly roughened rods, the lengths of portions 2 and 4 and the powers of all pins and of the shroud have to be set equal to zero (both in the case A and in the case B).

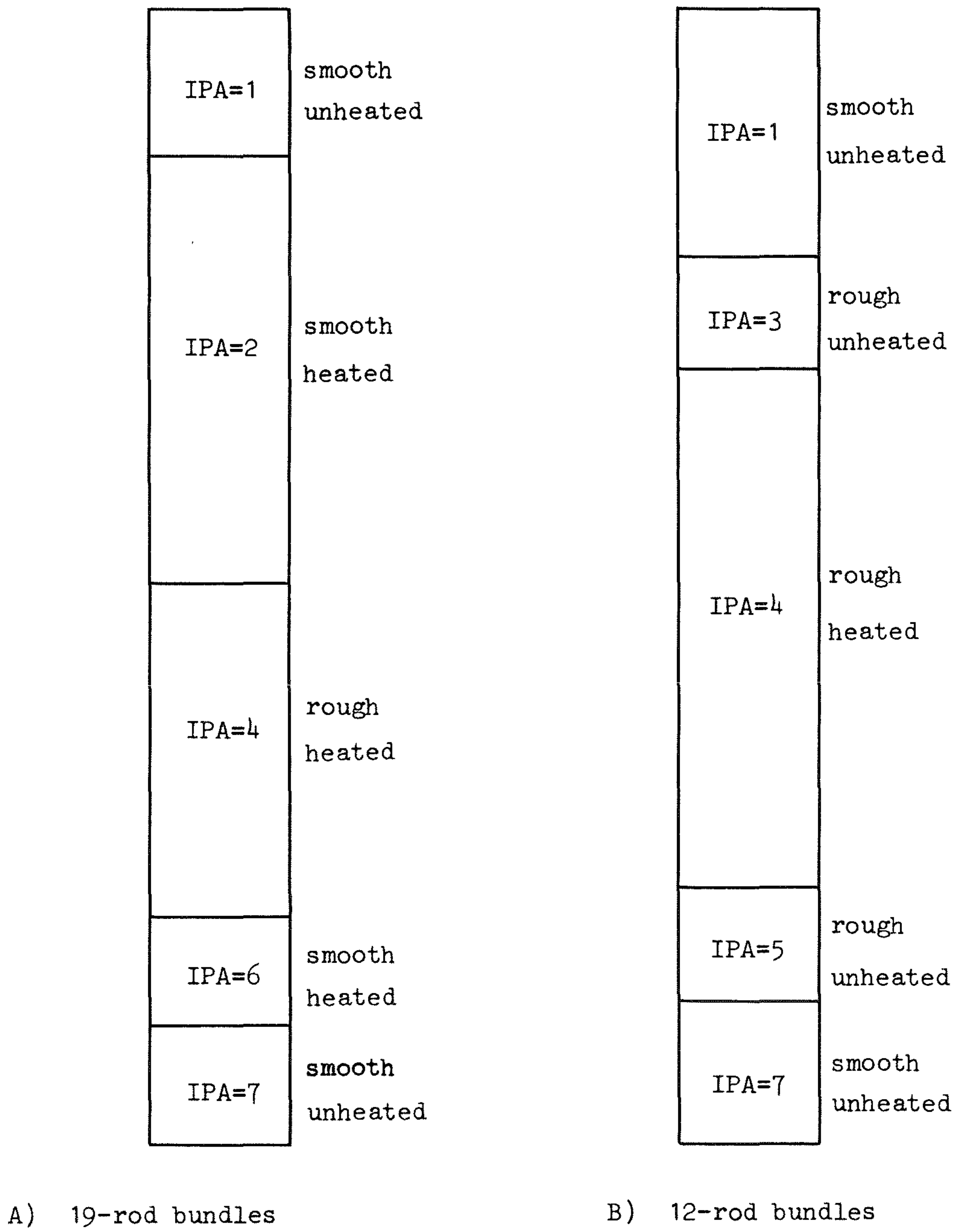


Fig.5 Axial geometry

Each of the mentioned five axial portions is divided into axial sections, up to a maximum number of 100 section per portion. The lengths of these sections are defined as a factor X_D times the equivalent diameter of the central channels, as described in paragraph 1.1 of /5/. As input are required only the approximate values of the X_D factors in the regions where the spacer grids dont have any effect on the pin temperatures and those in the regions where the spacer grids have an effect on the pin temperatures (see also chapter 2 in /5/, and 3.1, Cards 19, 20, in this work)

2.1.3 Spacer geometry

Only spacers of grid-type can be considered in the present version of SAGAPØ. Up to 7 grids are at the moment allowed. The axial positions of the grid middle sections, the axial width of the grids (assumed equal for all spacers), the blockage factors for each subchannel and portion of wall subchannel, together with the corresponding values of the ratios of the wetted perimeters inside and outside the spacers are required as input data for SAGAPØ (see 3.1, Cards 37-(38 + 4 * NSPACT)).

2.2 Inlet conditions

The calculation can be started at the bundle inlet or at any point after the bundle inlet; it can be stopped at the end of any of the five axial portions described in 2.1 (see 3.1, Card 13, 14). The possibility of starting at a point after the bundle inlet allows dividing long computations into some steps.

With SAGAPØ it is possible to consider uniform mass-flow-rate and gas-temperature distributions at the starting point of the calculation or to impose any other starting distribution for these variables.

In the first case the inlet mass flow rates and the gas temperatures of the channels, of the subchannels and of both portions of the wall subchannels are authomatically established by SAGAPØ, in the second case these values are read as input data (see SUBRØUTINE INLCØN).

The assumption of uniform mass-flow-rate and gas-temperature distributions is normally made when the calculation is started at the bundle inlet, due to a lack of information on the real distributions at this point (see calculations for the 19- and the 12-rod bundles in /5/). Anyway non-uniform distributions can be assumed by SAGAPØ also in this case.

If a calculation is performed in more than one step, at each new step the outlet mass-flow-rate and gas-temperature distributions of the preceeding step can be read as inlet distributions (see 3.1, Card 13). At the end of each step the outlet mass-flow-rates and gas-temperature distributions can be punched, so that the preparation of the input cards for the next step is simplified (see 3.1 , Card (40 + 4 * NSPACT)).

If a calculation is started after the bundle inlet, the inlet pressure drop is authomatically set equal to 0 by SAGAPØ (see flow chart for the main program, Fig. 11).

2.3 Heating of the rods and of the shroud

With SAGAPØ the rods can be assumed to be equally or unequally heated. The shroud walls can be heated or unheated. A constant or not constant axial power profile for the rods and the shroud can be assumed.

In the present version of SAGAPØ the maximum powers per unit length must be provided in input for each rod and for the shroud (see 3.1, Cards 30, 31). The axial power profiles (local power/maximum power) are defined in SAGAPØ by means of polynomial equations (both for the rods and for the shroud), whose coefficients must be provided in input (see 3.1, Cards 35 and 36). The rod power profiles are assumed to be all equal to each other in the present version of SAGAPØ. Several axial power profiles can be assumed for the rods and the shroud in each heated axial portion, up to a maximum number of 7 for the whole bundle length (see 3.1, Cards 32).

The end points of each of these profiles are provided in input (see 3.1, Cards 33): they are end points for the rod profiles and for the shroud profiles, at the same time. For each heated axial portion the zero of the abscissa for the contained axial power profiles is at the inlet section of the axial portion (see 3.1, Card 34) *). Thus for each heated axial portion there is at least one power profile.

The walls of each rod and of the shroud are considered to be uniformly heated in their peripheral direction, in the present version of SAGAPØ.

It is finally assumed that the total powers from the rods and from the shroud are the powers which correspond to nominal dimensions of the rods and of the shroud (i.e. not affected by the correction due to the thermal expansion of the structure; see subroutine MØDFQD and function FQDEV in paragraph 5)

2.4 Comparison between computed and experimental results

If it is required by the user (see 3.1, Card (40 + 4 * NSPACT)), the pressure losses and the subchannel pin and shroud temperatures are punched on cards, which can be used as input data for plotting programs, thus allowing the comparison between computed and experimental results.

A direct comparison between calculated and measured pressure drops can be be authomatically performed by SAGAPØ (up to 10 pressure taps can be considered; see 3.1, Card 16): the code prints the computed and the measured pressures and pressure drops at the desired positions, together with the error of the calculations with reference to the experimental data (see paragraph 4.4).

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*) This has been made to avoid complications in the procedure for the correction of the geometric parameters of each axial portion, due to the assumed different thermal expansion of the structure in each axial portion.

The printing of the computed pin temperatures at up to a maximum number of 10 desired axial position is also possible with SAGAPØ (see 3.1, Card 17).

2.5 Differences between the two versions of the SAGAPØ code

In the original version of the code, which refers to hexagonal rod assemblies, the indexing of the channels, of the subchannels, of their geometrical parameters and of the rods, the connection of the channels, of the subchannels and of the portions of wall subchannels with each other and the identification of the rods adjacent to each channel, to each subchannel or portion of wall subchannel are authomatically established by the code, by means of general procedures which are valid for hexagonal bundles with any number of rows of rods.

The indexing, connection and identification procedures are enclosed in the subroutines INDEX, INQUA, INGE, HEATR, HEATI, and CØNNIJ.

To perform the calculations for the 12-rod bundles indices, connections and identification parameters are given in input (in BLØCK DATA), because there is no need to established general procedures for bundles of such a form. Thus, in this second version, the subroutines HEATR and CONNIJ are eliminated and the subprograms INDEX, INQUA, INGE, HEATI, TØTGEØ and DSPDPF of the original version are replaced with others with the same name. Furthermore, as mentioned before, BLØCK DATA contains more input data as in the case of hexagonal bundles (see 3.4).

All the other subprograms are common to both versions of the code. Modifications were performed on some of them to allow their use also for the 12-rod bundles, in order to reduce the number of the subprograms to be replaced. These modifications refer mainly to the possibility of considering blocking triangles in wall channels.

Figs. 6,7,8 show the indexing of the channels and of the rods in the case of a 19-rod bundle (for the whole flow section, for a half of it and for 1/12 th, respectively). Figs. 9 and 10 show the indexing in the case of the 12-rod bundles (for the whole flow section and for 1/3 rd of it, respectively).

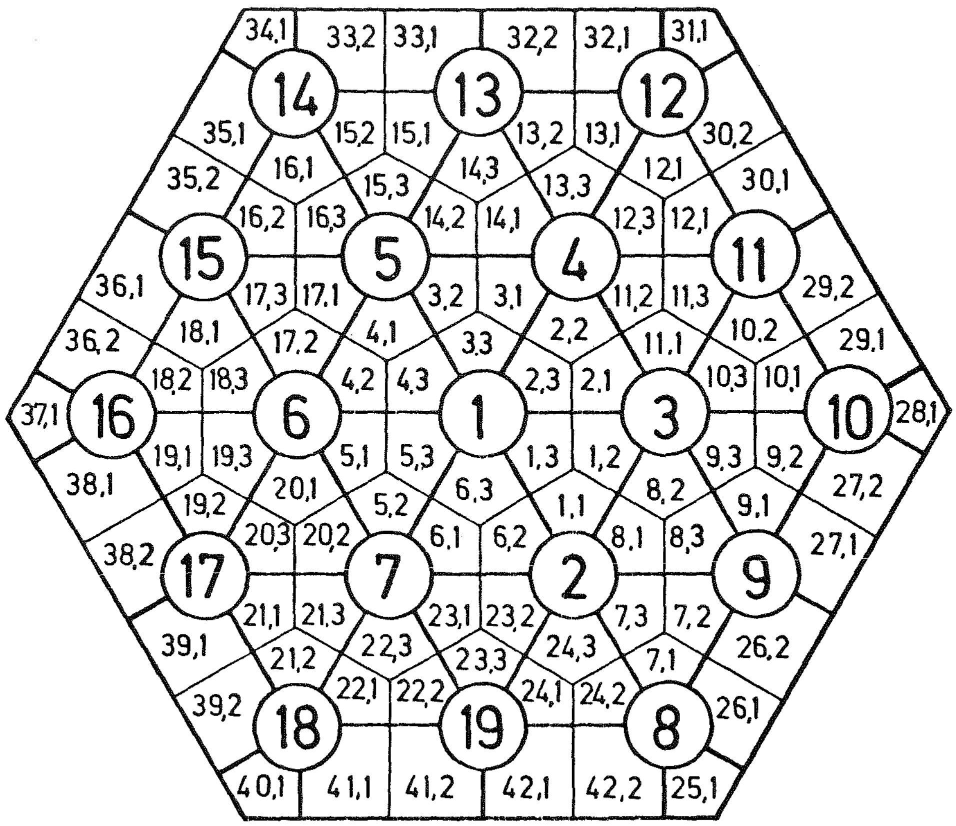

Fig.6 Indexing of the channels and of the subchannels for the whole flow section of a 19-rod bundle

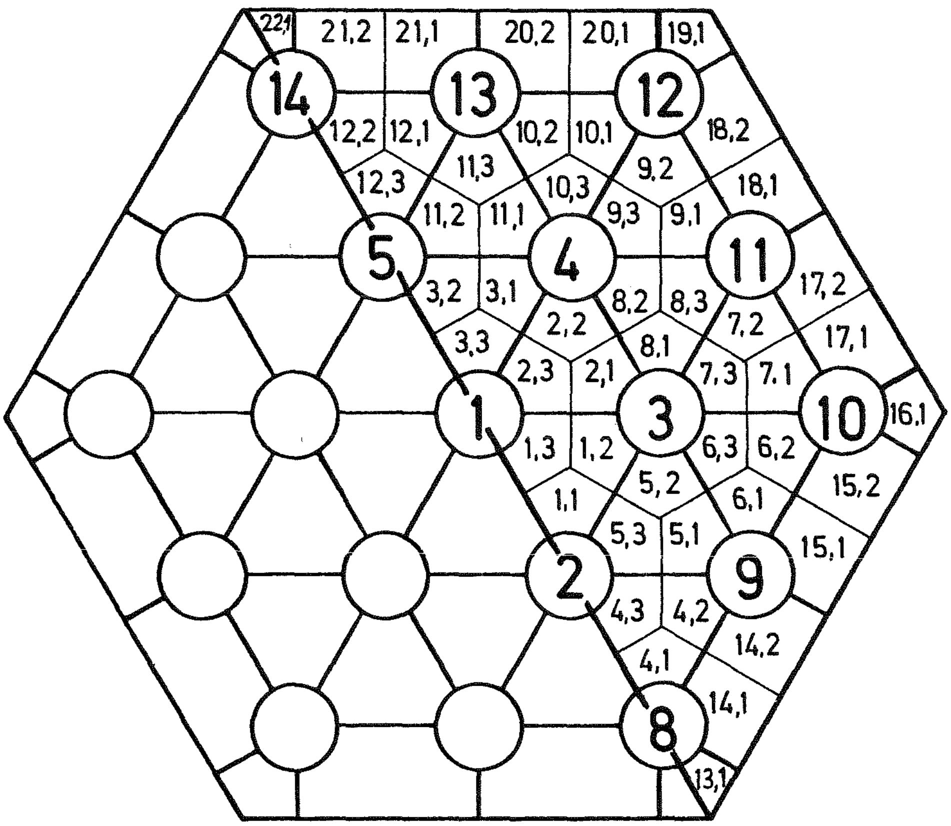

Fig.7 Indexing of the channels and of the subchannels for a half of the whole flow section of a 19-rod bundle.

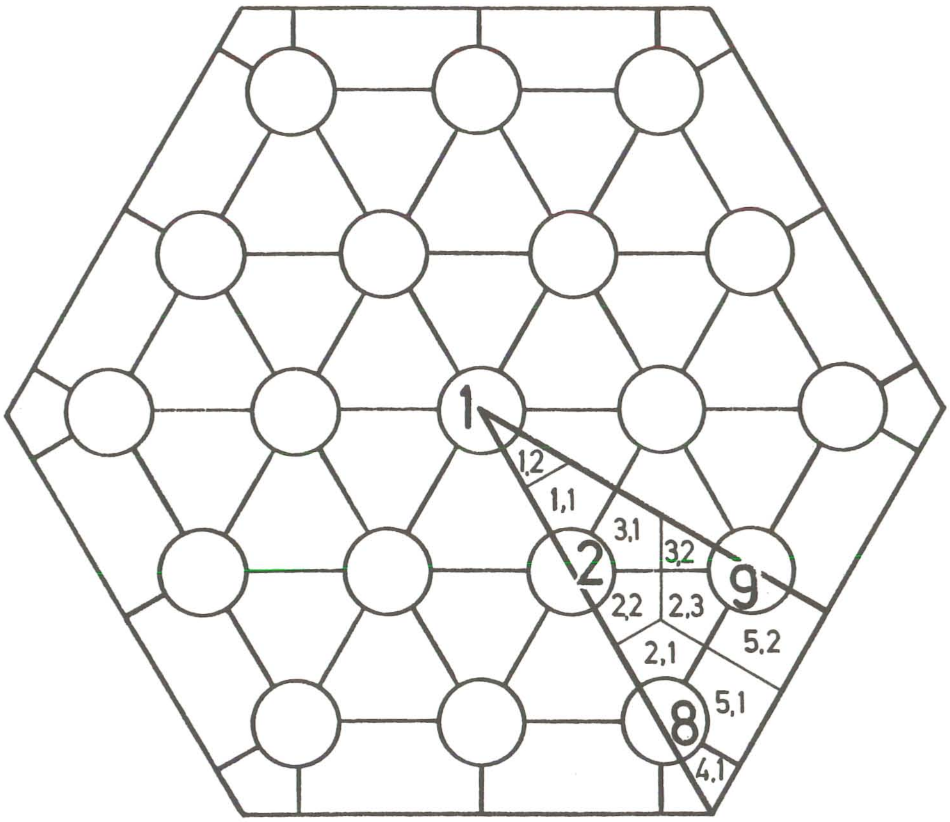

Fig.8 Indexing of the channels and of the subchannels for 1/12th of the whole flow section of a 19-rod bundle.

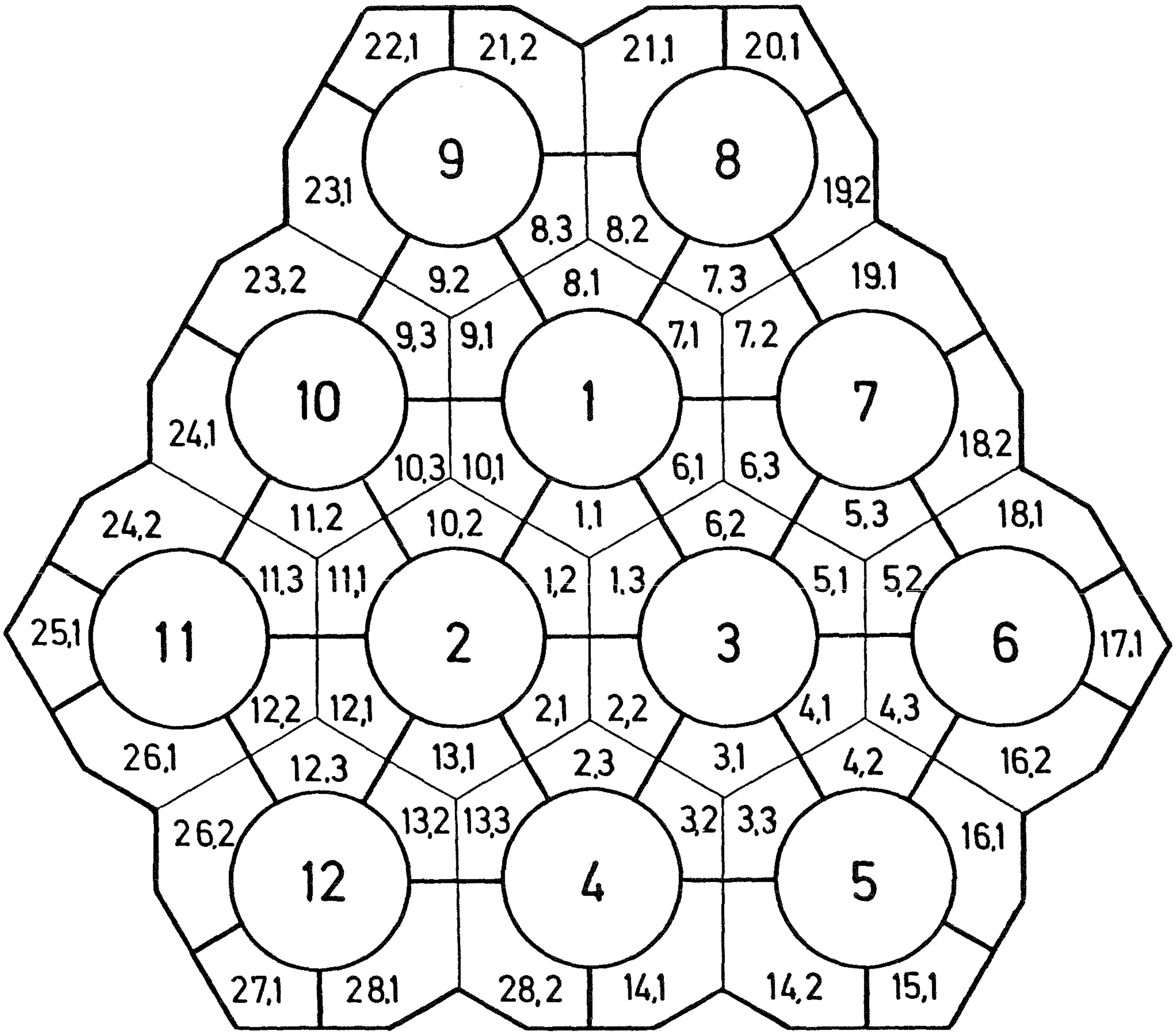

Fig.9 Indexing of the channels and of the subchannels for the whole flow section of the 12-rod bundles.

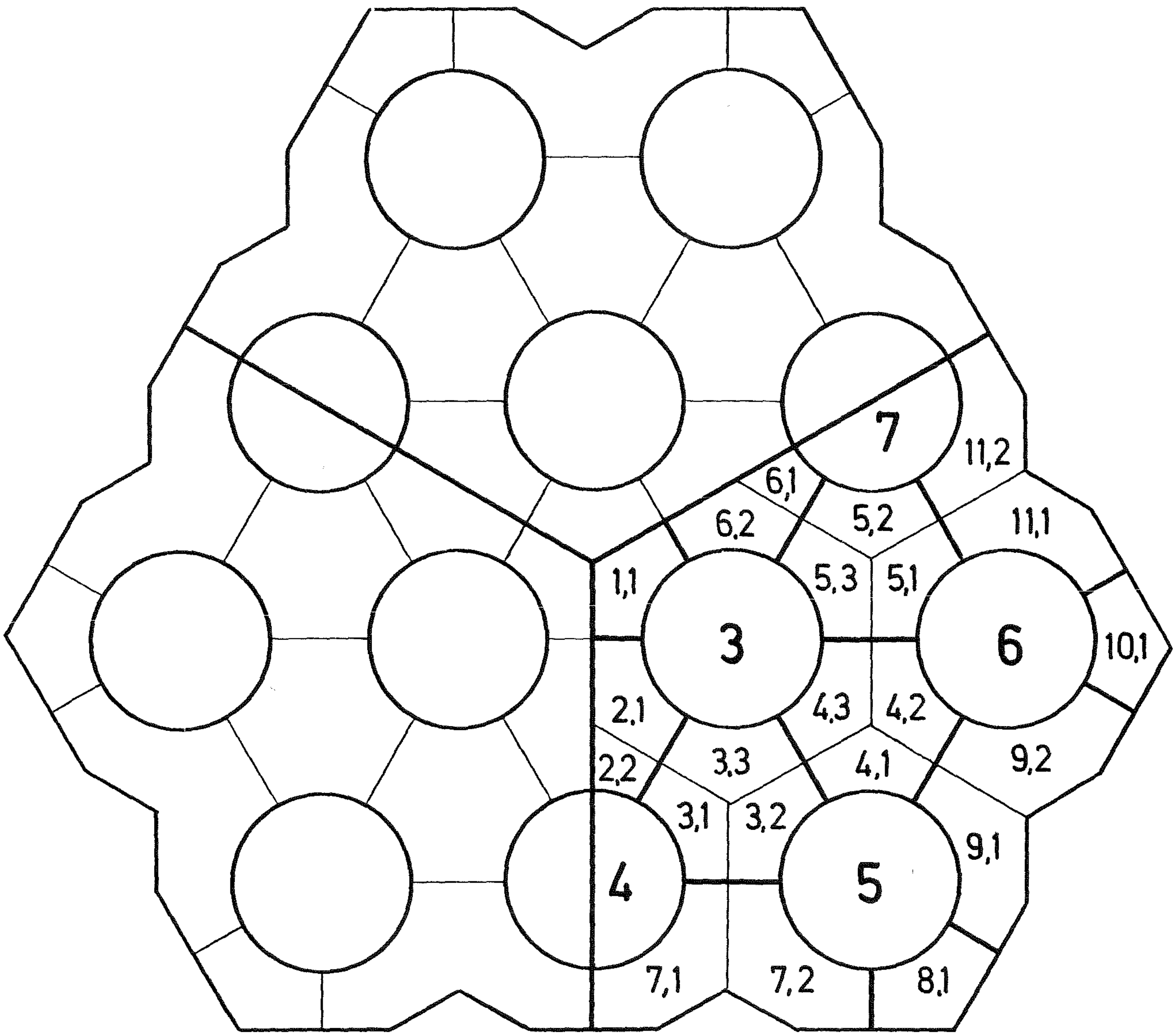

Fig. 10 Indexing of the channels and of the subchannels for 1/3rd of the whole flow section of the 12-rod bundles.

3. INPUT PREPARATION FOR THE SAGAPØ CODE

In the present version of the SAGAPØ code the input data must be partly punched on cards (most of which are read in the main program and only a few in the subroutine INLCØN) and partly provided in DATA blocks, which are all contained in the BLØCK DATA. Furthermore, the equations for the calculation of the physical properties of the gas coolant must be provided in separate FUNCTIØNS.

In the following paragraphs the input preparation is accurately described. The dimensions are provided (for the dimensional variables). The input geometric parameters correspond to the nominal geometry (i.e. not thermally expanded). An example of input for the 19-rod bundle is also contained in Appendix 2.

3.1 Cards read in the main programm

1st Card

NEXCØN NRØDS NSPACT NSPAC(1) NSPAC(2) NSPAC(3) NSPAC(4) NSPAC(5)
(Format (8I10))

NEXCØN = number of the rows of rods (excluded the central rod, in the case of hexagonal bundles)
NRØDS = total number of rods
NSPACT = total number of spacer grids
NSPAC(1) = number of spacer grids in the 1st axial portion
NSPAC(2) = " " " " " " 2nd " "
NSPAC(3) = " " " " " " 3rd " "
NSPAC(4) = " " " " " " 4th " "
NSPAC(5) = " " " " " " 5th " "

2nd Card

NSPAC(6) NSPAC(7)
(Format (8I10))
NSPAC(6) = number of spacer grids in the 6th axial portion
NSPAC(7) = " " " " " " 7th " "

3rd Card

C Z ZWC RH PLEN(1) PLEN(2) PLEN(3) PLEN(4)
(Format(8F10.5))

C	=	pitch of the rods (cm)
Z	=	distance between the center of the external rods and the shroud walls (cm)
ZWC	=	height of the blocking triangles in the wall channels (cm)
RH	=	height of the roughness ribs (cm)
PLEN(1)	=	length of the 1st axial portion (cm)
PLEN(2)	=	" " " 2nd " " "
PLEN(3)	=	" " " 3rd " " "
PLEN(4)	=	" " " 4th " " "

4th Card *)

PLEN(5) PLEN(6) PLEN(7) VDIAM(1) VDIAM(2) VDIAM(3) VDIAM(4) VDIAM(5)
(Format (8F10.5))

PLEN(5)	=	length of the 5th axial portion (cm)
PLEN(6)	=	" " " 6th " " "
PLEN(7)	=	" " " 7th " " "
VDIAM(1)	=	volumetric diameter of the rods of the 1st axial portion (cm)
VDIAM(2)	=	" " " " " " " 2nd " " "
VDIAM(3)	=	" " " " " " " 3rd " " "
VDIAM(4)	=	" " " " " " " 4th " " "
VDIAM(5)	=	" " " " " " " 5th " " "

5th Card *)

VDIAM(6) VDIAM(7)
(Format (8F10.5))

VDIAM(6)	=	volumetric diameter of the 6th axial portion (cm)
VDIAM(7)	=	" " " " 7th " " "

---

*) Note that VDIAM(I) can be set equal to zero if PLEN(I) = 0 . Note also that in the case of smooth rods the volumetric diameter is equal to the outer diameter.

6th Card

AREFB RMISTW(1) RMISTW(2) RMISTW(3) RMISTW(4) RMISTW(5) RMISTW(6) RMISTW(7) (Format(8F10.5))

AREFB = total area of the reference surface of the 3rd axial portion of each rod for the definition of the Biot number (cm^2). It corresponds to the area of the root surface or of the surface including the rib faces, i.e. to the summation of the areas A_r or A_t (respectively) defined in (III.26) and (III.15) of /5/. Note that AREFB must be equal for all rods in the present version of SAGAPØ. Note also that AREFB must be different from zero also in the case of isothermal calculations.

RMISTW(1) = radius at which the pin temperatures are measured in the 1st axial portion (cm)

RMISTW(2) = radius at which the pin temperatures are measured in the 2nd axial portion (cm)

RMISTW(3) = radius at which the pin temperatures are measured in the 3rd axial portion (cm)

RMISTW(4) = radius at which the pin temperatures are measured in the 4th axial portion (cm)

RMISTW(5) = radius at which the pin temperatures are measured in the 5th axial portion (cm)

RMISTW(6) = radius at which the pin temperatures are measured in the 6th axial portion (cm)

RMISTW(7) = radius at which the pin temperatures are measured in the 7th axial portion (cm)

In each axial portion I RMISTW(I) must be equal for all rods. Therefore, for different position of the thermocouples, an average position must be assumed. If no thermocouples are set in the rods or if the thermocouples measure the surface temperatures, RMISTW(I) must be set equal to the volumetric radius.

7th Card *)

RINT(1) RINT(2) RINT(3) RINT(4) RINT(5) RINT(6) RINT(7) RTIP(1)
(Format (8F10.5))

RINT(1)	=	inner radius of the canning in the 1st axial portion (cm)
RINT(2)	=	" " " " " " " 2nd " " "
RINT(3)	=	" " " " " " " 3rd " " "
RINT(4)	=	" " " " " " " 4th " " "
RINT(5)	=	" " " " " " " 5th " " "
RINT(6)	=	" " " " " " " 6th " " "
RINT(7)	=	" " " " " " " 7th " " "
RTIP(1)	=	tip radius of the roughness ribs in the 1st axial portion (cm)

8th Card *)

RTIP(2) RTIP(3) RTIP(4) RTIP(5) RTIP(6) RTIP(7)
(Format(8F10.5))

RTIP(2)	=	tip radius of the roughness ribs in the 2nd axial portion (cm)
RTIP(3)	=	" " " " " " " " 3rd " " "
RTIP(4)	=	" " " " " " " " 4th " " "
RTIP(5)	=	" " " " " " " " 5th " " "
RTIP(6)	=	" " " " " " " " 6th " " "
RTIP(7)	=	" " " " " " " " 7th " " "

9th Card

NDVQ NSEL NSC30C NSC30W NSC30A
(Format (8I10))

NDVQ = number of the different values of the rod powers
If the rods are all equally heated NDVQ = 1, otherwise NDVQ must be set equal to NRØDS (see 1st card)

*) As for RMISTW(I) also RINT(I) and RTIP(I) must be equal for each rod in portion I. If portion I is smooth RTIP(I) is set equal to the outer radius of the rods.

NSEL = index to establish the portion of the whole bundle flow section which must be considered.

For the hexagonal bundles:

NSEL = 1: whole bundle flow section

NSEL = 2: half of the bundle flow section

NSEL = 3: 1/12 th of the bundle flow section

For the 12-rod bundles:

NSEL = 1: whole bundle flow section

NSEL = 3: 1/3 rod of the bundle flow section

NSC30C = number of sub-subchannels in 30° for the central subchannels and for the central portions of the wall subchannels

NSC30W = number of sub-subchannels in 30° for the wall portion of the wall subchannels

NSC30A = number of sub-subchannels in 30° for the corner channels.

<u>1oth Card *)</u>

PE PE1 TE TE1 MFLØW XLAM1(1) XLAM1(2) XLAM1(3)
(Format (8F10.5))

PE = pressure at the point where the calculation is started (dimensions in Kg/cm^2 or in bar, depending on the value of INDPR, see 15th Card)

PE1 = pressure at the bundle inlet (same dimensions as PE)

TE = bulk temperature for the whole bundle flow section at the point where the calculation is started (°C)

TE1 = bulk temperature for the whole bundle flow section at the bundle inlet (°C)

MFLØW = mass flow rate through the whole bundle flow section (g/s)

XLAM1(1) = approximate value of the whole bundle friction factor $\lambda = 4f$ for the 1st axial portion

XLAM1(2) = approximate value of the whole bundle friction factor $\lambda = 4f$ for the 2nd axial portion

XLAM1(3) = approximate value of the whole bundle friction factor $\lambda = 4f$ for the 3rd axial portion

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*) Note that the first iteration values XLAM1(I) dont need to be very precise. Also with initial values which are very far from the real λ values, convergence was normally always reached.
If PLEN(I) = 0 XLAM1(I) can be set equal to 0.

11th Card *)

XLAM1(4) XLAM1(5) XLAM1(6) XLAM1(7)
(Format(8F10.5))

XLAM1(4) = approximate value of the whole bundle friction factor $\lambda = 4f$ for the 4th axial portion

XLAM1(5) = approximate value of the whole bundle friction factor $\lambda = 4f$ for the 5th axial portion

XLAM1(6) = approximate value of the whole bundle friction factor $\lambda = 4f$ for the 6th axial portion

XLAM1(7) = approximate value of the whole bundle friction factor $\lambda = 4f$ for the 7th axial portion

12th Card

CØLAMA
(Format(8F10.5))

CØLAMA = factor $R_s = b_s/5.5$ which takes into account the effect of the roughness of the shroud walls on the friction factors of the wall and corner channels (see (I.88),(I.91) and (III.18) in /5/).

13th Card

IPAST IPAEND IREAD1
(Format(8I10))

IPAST = index of the axial portion at which it is desired to start the calculation (not necessarely from its beginning)

IPAEND = index of the axial portion at the end of which it is desired to end the calculation

IREAD1 = index which establishes whether the mass-flow-rate and temperature distributions must be considered uniform or non-uniform at the point where the calculation is started.

IREAD1 = 1: uniform distributions (evaluated in the subroutine INLCØN)

IREAD1 = 2: other distributions (to be read in the subroutine INLCØN)

*) Note that the first iteration values XLAM1(I) dont need to be very precise. Also with initial values which are very far from the real λ values, convergence was normally always reached. If PLEN(I) = 0 XLAM1(I) can be set equal to 0.

14th Card

STLEN
(Format (8F10.5))

STLEN = distance from the bundle inlet to the point at which the calculation is started (cm)

15th Card

INDPR INDQ
(Format (8I10))

INDPR = index which establishes the dimensions of the read pressure values (see Cards 1o and 28/a, b,...)
INDPR = 1: dimensions in Kg/cm^2
INDPR = 2: dimensions in bar

INDQ = index which establishes the dimensions of the maximum powers per unit length (see Cards 30/a,b,... and 31)
INDQ = 1: dimensions in cal/s cm
INDQ = 2: dimensions in W/cm

16th Card

NEXPRT NEXPR(1) NEXPR(2) NEXPR(3) NEXPR(4) NEXPR(5) NEXPR(6) NEXPR(7)
(Format (8I10))

NEXPRT = total number of the experimental pressure values to be read (see Cards 28/a,b,...)

NEXPR(1)	=	number	of	the	experimental	pressure	values	in	the	1st	axial	portion
NEXPR(2)	=	"	"	"	"	"	"	"	"	2nd	"	"
NEXPR(3)	=	"	"	"	"	"	"	"	"	3rd	"	"
NEXPR(4)	=	"	"	"	"	"	"	"	"	4th	"	"
NEXPR(5)	=	"	"	"	"	"	"	"	"	5th	"	"
NEXPR(6)	=	"	"	"	"	"	"	"	"	6th	"	"
NEXPR(7)	=	"	"	"	"	"	"	"	"	7th	"	"

Obviously it must be $\sum_{I=1}^{7}$ NEXPR(I) = NEXPRT. Some or all NEXPR(I) can be equal to zero. For each axial portion I,NEXPR(I) comparisons between computed and experimental pressure drops will be made authomatically by SAGAPO.

17th Card

NEXTWT NEXTW(1) NEXTW(2) NEXTW(3) NEXTW(4) NEXTW(5) NEXTW(6) NEXTW(7)
(Format (8I10))

NEXTWT = total number of axial positions where a print of the pin temperatures is required

NEXTW(1) = number of axial positions in the 1st axial portion where a print of the pin temperatures is required

NEXTW(2) = number of axial positions in the 2nd axial portion where a print of the pin temperatures is required

NEXTW(3) = number of axial positions in the 3rd axial portion where a print of the pin temperatures is required

NEXTW(4) = number of axial positions in the 4th axial portion where a print of the pin temperatures is required

NEXTW(5) = number of axial positions in the 5th axial portion where a print of the pin temperatures is required

NEXTW(6) = number of axial positions in the 6th axial portion where a print of the pin temperatures is required

NEXTW(7) = number of axial positions in the 7th axial portion where a print of the pin temperatures is required

It must be pointed out that average pin temperatures are computed and printed for each axial section. The NEXTW(I) prints refer to special axial positions specified in input (see Cards 29/a,b,...). Obviously it must be $\sum_{I=1}^{7}$ NEXTW(I) = NEXTWT. Furthermore some or all NEXTW(I) can be equal to zero.

18th Card

ITCM ITC1 ITC2 MSUBDH
(Format (8I10))

ITCM = maximum number of iterations allowed for the loop ITCØRR (see Fig.11))

ITC1 = number of iteration after which a precision of 10^{-3} instead of 10^{-4} is required on the whole bundle friction factor λ_T for the convergence in the iteration loop ITCØRR. This option was introduced to overcome critical points in some calculations, where a precision of 10^{-4} could not be achieved on λ.

ITC2 = number of iterations by which the calculation must be repeated in the loop ITCØRR, without testing the convergence. A minimum value of 3 for ITC2 is advised, to be sure that the convergence of λ_T means also convergence of the other variables involved in the iteration loop ITCØRR (see also paragraph 5.2 in this work).

MSUBDH = maximum allowed number of successive halvings of the length of an axial section in the case of convergence problems in the subroutines TRICA1, RECCA1, ANGCA1, BALA, SUBBAL and in the subroutines connected to them (see subroutine SUBDH).

19th Card

XDE1(1) XDE1(2) XDE1(3) XDE1(4) XDE1(5) XDE1(6) XDE1(7) XDE2(1)
(Format (8F10.5))

XDE1(1) = approximate desired value of the X_D factor for the definition of the length of the axial sections in the regions outside the influence of the spacers (length of the section = X_D·equivalent diameter of the central channels, see 1.1 in /5/), for the 1st axial portion

XDE1(2) = as above for the 2nd axial portion

XDE1(3) = as above for the 3rd axial portion

XDE1(4) = as above for the 4th axial portion

XDE1(5) = as above for the 5th axial portion

XDE1(6) = as above for the 6th axial portion

XDE1(7) = as above for the 7th axial portion

XDE2(1) = approximate desired value of the X_D factor for the part of the regions where the pin temperatures are influenced by the spacers, which begins 3 central equivalent diameters after the inlet section of a spacer and ends 11 central equivalent diameters after this inlet section (see 1.1 and (III.11), (III.12), (III.40) and (III.41) in /5/), for the 1st axial portion *)

---

*) In the other part of these regions (see (III.10) and (III.39) of /5/) a subdivision into 4 axial sections is made authomatically by SAGAPØ (see also the flow-chart for the subroutine AXSEC, Fig.13).

20th Card

XDE2(2) XDE2(3) XDE2(4) XDE2(5) XDE2(6) XDE2(7)
(Format (8F10.5))

XDE2(2) = approximate desired value of the X_D factor for the part of the regions where the pin temperatures are influenced by the spacers, which begins 3 central equivalent diameters after the inlet section of a spacer and ends 11 central equivalent diameters after this inlet section (see 1.1 and (III.11), (III.12), (III.40) and (III.41) in /5/), for the 2nd axial portion *)

XDE2(3) = as above for the 3rd axial portion

XDE2(4) = as above for the 4th axial portion

XDE2(5) = as above for the 5th axial portion

XDE2(6) = as above for the 6th axial portion

XDE2(7) = as above for the 7th axial portion

21st Card

FT PCØRR CTU1 CTU2 CTU3
(Format (8F10.5))

FT = factor f_T which takes into account the imperfect analogy between eddy diffusivity of heat and momentum (see (I.38) in /5/)

PCØRR = correction factor for the Ingesson mixing factors (see (I.11) in /5/; PCØRR = K_{CORR} in /5/)

CTU1 = mixing factors for the turbulent exchange between central subchannels of the same central channel (see (I.44) in /5/; CTU1 = I in /5/)

CTU2 = mixing factor for the turbulent exchange between wall subchannels of the same wall channel (see (I.44) in /5/; CTU2 = I in /5/)

CTU3 = mixing factor for the turbulent exchange between the two portions of each wall subchannel (see paragraph 1.6 in /5/)

---

*) In the other part of these regions (see (III.10) and (III.39) of /5/) a subdivision into 4 axial sections is made authomatically by SAGAPØ (see also the flow-chart for the subroutine AXSEC, Fig.13).

22nd Card

TWPRCF TCPRCF
(Format (8F10.5))

TWPRCF = β_W correction factors for the inlet gas temperatures of the wall sub-subchannels (definition see (42) in /1/)

TCPRCF = β_C correction factors for the inlet gas temperatures of the corner sub-subchannels (definition see (42) in /1/)

The β_W and β_C coefficients were used in the first calculations performed for the first 12-rod bundle (KE 1) /1,2/, where it seemed to be necessary to evaluate the local pin temperatures exactly at the positions of the thermocouples. These local temperatures were thought to be appreciably different from the average subchannel values,due to the too small distance Z between the external rods and the shroud. In the calculations performed later for the KE III and the 19-rod bundle /3,4,5/ both β values were assumed equal to 0, because the values of Z are there sufficiently large, so that considerable peripheral variations of the pin temperatures inside each external subchannel are avoided for these bundles (see chapter 3 in /5/).

23rd Card

CINL CØUT
(Format (8F10.5))

CINL = coefficient for the pressure loss at the bundle inlet (see (III.10) and (III.20) in /5/; CINL = K_E in /5/)

CØUT = coefficient for the pressure recovery at the bundle outlet (see paragraph 8 in /1/; CØUT = K_O in /1/; CØUT was set equal to zero for the calculations performed for the 19 rod bundle /5,6/ and for the KE III /3,5/)

24th Card

FAREL(1) FAREL(2) FAREL(3) FAREL(4) FAREL(5) FAREL(6) FAREL(7)
(Format (8F10.5))

FAREL(1) = initial value for the relaxation factor F_{Rel} in the convergence procedure for the solution of the system of the axial momentum equations in the 1st axial portion (see (I.50) in /5/)
FAREL(2) = as above for the 2nd axial portion
FAREL(3) = as above for the 3rd axial portion
FAREL(4) = as above for the 4th axial portion
FAREL(5) = as above for the 5th axial portion
FAREL(6) = as above for the 6th axial portion
FAREL(7) = as above for the 7th axial portion

As pointed out in paragraph 1.7 of /5/ the input relaxation factor is authomatically corrected by SAGAPØ in the case of convergence problems in the solution procedure (see subroutines BALA, SUBBAL, RECCA2)

25th Card *)

TWTIPA(1) TWTIPA(2) TWTIPA(3) TWTIPA(4) TWTIPA(5) TWTIPA(6) TWTIPA(7) TBTIPA(1)
(Format (8F10.5))

TWTIPA(1) = average value of the pin temperatures in the 1st axial portion (°C)
TWTIPA(2) = " " " " " " " " 2nd " " "
TWTIPA(3) = " " " " " " " " 3rd " " "
TWTIPA(4) = " " " " " " " " 4th " " "
TWTIPA(5) = " " " " " " " " 5th " " "
TWTIPA(6) = " " " " " " " " 6th " " "
TWTIPA(7) = " " " " " " " " 7th " " "
TBTIPA(1) = average value of the bulk temperature for the whole bundle flow section in the 1st axial portion (°C)

---

*) The temperatures TWTIPA, TBTIPA and TBPIPA are used to correct the nominal geometric parameters in order to take into account the thermal expansion of the structure (see 3.1.3 in /5/ and functions TBFUN and TWFUN in paragraph 5 of this work)

26th Card *)

TBTIPA(2) TBTIPA(3) TBTIPA(4) TBTIPA(5) TBTIPA(6) TBTIPA(7) TBPIPA(1) TBPIPA(2)
(Format (8F10.5))

TBTIPA(2) = average value of the bulk temperature for the whole bundle flow section in the 2nd axial portion (°C)

TBTIPA(3) = average value of the bulk temperature for the whole bundle flow section in the 3rd axial portion (°C)

TBTIPA(4) = average value of the bulk temperature for the whole bundle flow section in the 4th axial portion (°C)

TBTIPA(5) = average value of the bulk temperature for the whole bundle flow section in the 5th axial portion (°C)

TBTIPA(6) = average value of the bulk temperature for the whole bundle flow section in the 6th axial portion (°C)

TBTIPA(7) = average value of the bulk temperature for the whole bundle flow section in the 7th axial portion (°C)

TBPIPA(1) = average value of the shroud temperature in the 1st axial portion (°C)

TBPIPA(2) = " " " " " " " " 2nd " " "

27th Card *)

TBPIPA(3) TBPIPA(4) TBPIPA(5) TBPIPA(6) TBPIPA(7)
(Format (8F10.5))

TBPIPA(3) = average value of the shroud temperature in the 3rd axial portion (°C)

TBPIPA(4) = " " " " " " " " 4th " " "

TBPIPA(5) = " " " " " " " " 5th " " "

TBPIPA(6) = " " " " " " " " 6th " " "

TBPIPA(7) = " " " " " " " " 7th " " "

---

*) The temperatures TWTIPA, TBTIPA and TBPIPA are used to correct the nominal geometric parameters in order to take into account the thermal expansion of the structure (see 3.1.3 in /5/ and functions TBFUN and TWFUN in paragraph 5 of this work).

Cards 28/a,b,...

(fail if NEXPRT = o, i.e. no comparison between computed and measured pressures is required)

XEXPR(1) PEX(1) XEXPR(2) PEX(2) ... XEXPR(NEXPRT) PEX(NEXPRT) PEXØUT
(8 data per card with the Format (8F10.5))

⋮
XEXPR(I) = distance from the bundle inlet to the Ith pressure tap (cm)
PEX(I) = experimental pressure at the position XEXPR(I) (dimensions depending on the value of INDPR, see 15th Card)
⋮
PEXØUT = experimental pressure at the bundle outlet (dimensions depending on the value of INDPR, see 15th Card) (=0 if not measured)

Cards 29/a,b,...

(fail if NEXTWT = o, i.e. no print of the pin temperatures at special axial positions is required)

XEXTW(1) XEXTW(2) ... XEXTW(NEXTWT)

(8 data per card with the Format (8F10.5))

⋮
XEXTW(I) = distance from the bundle inlet to the Ith position at which a print of the pin temperatures is required (cm)
⋮

Cards 30/a,b,...

QPIN(1) QPIN(2) ... QPIN(NRØDS)
(8 data per card with the Format (8F10.5))

⋮
QPIN(I) = maximum power per cm in the Ith rod (dimensions of the power depending on the value of INDQ, see 15th Card)
⋮

It is important to point out that if NDVQ = 1 (i.e. all the rods are equally heated) only QPIN(1) must be punched (if NDVQ ≠ 1 all the QPIN values must be provided). In the case of isothermal calculations it is obviously QPIN(1) = 0 and NDVQ=1 (see also 9th Card).

Card 31

QLINMT
(Format (8F10.5))

QLINMT = maximum power per cm in the shroud (dimensions of the power depending on the value of INDQ, see 15th Card)

Card 32

NDPRQT NDPRQ(1) NDPRQ(2) NDPRQ(3) NDPRQ(4) NDPRQ(5) NDPRQ(6) NDPRQ(7)
(Format (8F10.5))

NDPRQT = total number of the different profiles of power in the rods and in the shroud
NDPRQ(1) = number of the different profiles of power in the rods and in the shroud in the 1st axial portion
NDPRQ(2) = as above for the 2nd axial portion
NDPRQ(3) = as above for the 3rd axial portion
NDPRQ(4) = as above for the 4th axial portion
NDPRQ(5) = as above for the 5th axial portion
NDPRQ(6) = as above for the 6th axial portion
NDPRQ(7) = as above for the 7th axial portion

Obviously it must be $\sum_{I=1}^{7}$ NDPRQ(I) = NDPRQT. Furthermore NDPRQ(I) must be equal to zero if the Ith portion is unheated or does not exist. NDPRQ(I) is always >0 (at least equal to 1) for each heated existing axial portion (see 2.3 in this work). In the case of isothermal computations it is NDPRQT = NDPRQT(I) = 0.

Cards 33/a,b,...

(fail if NDPRQT = 0, i.e. isothermal calculation)

X2DPRQ(1) X2DPRQ(2) ... X2DPRQ(NDPRQT)

(8 data per card with the Format (8F10.5))

⋮

X2DPRQ(I) = distance from the bundle inlet to the end point of the Ith power profile (cm)

⋮

For each heated existing axial portion there must be at least one index I at which X2DPRQ(I) is equal to the distance of the end point of the axial portion from the bundle inlet. The distances X2DPRQ(I) are common to the power profiles of the rods and of the shroud, so that at the positions where the power profile changes for the rods, a new power profile must be considered also for the shroud, and vice versa (see also 2.3 in this work).

Card 34

(fails if NDPRQT = 0, i.e. isothermal calculation)

NQDCØ

(Format (8I10))

NQDCØ = maximum necessary number of the coefficients a_{ji} of the polynomial equations defining the power profiles j, i.e. of the equations:

$$\dot{Q}'_j(x)/\dot{Q}'_{Max} = \sum_{i=1}^{NQDCØ} a_{ji} \quad (X - X_{0\,IPA})^{i-1}$$

$\dot{Q}'_j(x)$ is the power per cm in a rod or in the shroud at the axial position X, $\dot{Q}'_{Max}$ the maximum power per cm and $X_{0\,IPA}$ the axial distance from the bundle inlet at which the axial portion IPA begins (X and $X_{0\,IPA}$ in cm)

The value of NQDCØ must be set equal to the maximum value necessary for the profiles of the rods and of the shroud (i.e. an equal number of coefficients a_{ji} must be considered for the rods and for the shroud and for all power profiles). NQDCØ = 7 is the maximum number of coefficients which can be considered in the present version of SAGAPØ. Obviously some of the coefficients a_{ji} can be set equal to zero, for each profile (see Cards 35 and 36).

Cards 35/a,b,...

(fail if NDPRQT = 0, i.e. isothermal calculation)

QDCØ(1,1) QDCØ(1,2) ... QDCØ(1, NQDCØ) QDCØ(2,1) QDCØ(2,2) ... QDCØ(2, NQDCØ) ... QDCØ(NDPRQT, 1) QDCØ(NDPRQT, 2) ... QDCØ(NDPRQT, NQDCØ)

(6 data per card with the Format (6E12.5))

⋮

QDCØ(J,I) = Jth coefficient of the Ith profile in the rods (see a_{ji}, description of Card 34).

⋮

Cards 36/a,b,...

(fail if NDPRQT = 0, i.e. isothermal calculation)

QLDCØ(1,1) QLDCØ(1,2) ... QLDCØ(1, NQDCØ) QLDCØ(2,1) QLDCØ(2,2) ...
QLDCØ(2, NQDCØ) ... QLDCØ(NDPRQT, 1) QLDCØ(NDPRQT, 2) ... QLDCØ(NDPRQT, NQDCØ)

(6 data per card with the Format (6E12.5))

⋮

QLDCØ(J,I) = Ith coefficient of the Ith power profile in the shroud (see a_{ji}, description of the 34th Card).

⋮

Cards 37/a,b,...

(fail if NSPACT = 0, i.e. no spacers)

WSPO DIST(1) DIST(2) ... DIST(NSPACT)

(8 data per card with the Format (8F10.5))

WSPO = axial width of the spacer grids (cm)

⋮

DIST(I) = distance from the bundle inlet to the middle section of the Ith spacer (cm)

⋮

Cards 38/a,b,...

(fail if NSPACT = 0, i.e. no spacers)

GRI(1,1,1) GRI(1,2,1) GRI(1,3,1) GRI(2,1,1) GRI(2,2,1) GRI(2,3,1) ...
GRI(NSTØT, 1,1) GRI(NSTØT, 2,1) GRI(NSTØT, 3,1)

(6 data per card with the Format (6F10.5))

⋮

GRI(NS,J,1) = blockage factor of the subchannel J of channel NS, for the 1st spacer

⋮

This reading procedure of the blockage factors needs the knowledge of the channel disposition (NSTØT is the total number of channels, in the considered symmetry section, which does not need to be read because it is established in the subroutine INDEX). Furthermore, it is also necessary to know which rods are adjacent to each channel, to be able to establish different values of the blockage factors for each subchannel J of each channel NS: as each subchannel J is adjacent to only one rod, it is sufficient to read the index IRGRI(NS,J) of the rod adjacent to it (see Cards(38+4*NSPACT/)/a,b...) to identify the subchannel to which the read value of the blockage factor refers. In this way it is not necessary to know also which subchannel disposition inside each channel is fixed by SAGAPØ for the calculations: the indices J for the reading of the subchannel blockage factors can be fixed by the user, provided that the right values of IRGRI(NS,J) are established at the same time in Cards (38+4*NSPACT). Furthermore, it must be pointed out that for a channel with a number J_{max} of subchannels less than 3 (as always for the corner and the wall channels and also for some central channels in the case of symmetry sections), the values of the blockage factors for the existing J_{max} subchannels must be punched in the first J_{max} fields reserved to the channel. The fields corresponding to $J > J_{max}$ can be left blank.

This rather complicated reading procedure was necessary especially for the calculation for the 12 rod bundles, which had a very complicated grid profile (see Fig.40 in /5/). A simpler procedure can be easily introduced in SAGAPØ.

Cards 39/a,b,...

(fail if NSPACT = 0, i.e. no spacers)

GRIP(1,1,1) GRIP(1,2,1) GRIP(1,3,1) GRIP(2,1,1) GRIP(2,2,1) GRIP(2,3,1) ...
GRIP(NSTØT,1,1) GRIP(NSTØT,2,1) GRIP(NSTØT,3,1)

(6 data per card with the Format (6F10.5))

⋮

GRIP(NS,J,1) = wetted perimeter inside the spacer/ wetted perimeter outside the spacer, for subchannel J of channel NS, for the 1st spacer

⋮

The same remarks made for the blockage factors are valid also for the GRIP values. It must be only added that the GRIP parameters are necessary if a sophisticated model for the calculation of the pressure drops due to the spacer grids is used (see /1/, /2/). For the actual model used for their calculation in SAGAPØ (see (I.9) in /5/) the GRIP parameters are of no use. Therefore they were all set equal to 1 for the calculations performed for the 19-rod bundle and the KE III /3, 4,5/.

Cards 40/a,b,...

(fail if NSPACT = 0, i.e. no spacers)

GRI1(1,1,1) GRI1(1,2,1) GRI1(2,1,1) GRI1(2,2,1) ... GRI1(NSPER,1,1) GRI1(NSPER,2,1)

(6 data per card with the Format (6F10.5))

⋮

GRI1(K,J,1) = ratio between the blockage factor of the wall portion of the Jth subchannel of the Kth external channel and the blockage factor of the whole Jth external subchannel

⋮

NSPER is the number of external channels, which does not need to be read because it is established in the main program.
About the index J the same remarks made for the description of cards 39 and 40 are valid also here. There is only to notice that the maximum value of J is here 2 because the maximum number of subchannels in a wall channel is 2. GRI1 values are read also for the corner channels, although they have a meaning only for the wall subchannels (which are divided into a wall and central portion): thus the fields for the GRI1 values referring to corner channels can be left blank.
It must be pointed out that the division of the wall subchannels into two portions is performed authomatically by SAGAPØ: the GRI1 values for the wall subchannels are not known a priori, therefore a first calculation with all GRI1 = 1 must be always performed. Then, if it is desired to see the effects of the different values of the blockage factors on the mass-flow and temperature distributions inside the wall subchannels, GRI1 values can be evaluated from the results of this first calculation and used as input data for a new calculation.

Cards 41/a,b,...

(fail if NSPACT = 0, i.e. no spacers)

GRI2(1,1,1) GRI2(1,2,1) GRI2(2,1,1) GRI2(2,2,1) ... GRI2(NSPER,1,1) GRI2(NSPER,2,1)

(6 data per card with the Format (6F10.5))

:

GRI2(K,J,1) = ratio between the blockage factor of the central portion of the Jth subchannel of the Kth external channel and the blockage factor of the whole Jth external channel.

:

The same remarks made in the description of Cards 41 are valid also here.

Cards for the 2nd spacer

(fail if NSPACT < 2)

Cards 42/a,b,...: similar to cards 38/a,b,...

Cards 43/a,b,...: similar to cards 39/a,b,...

Cards 44/a,b,...: similar to cards 40/a,b,...

Cards 45/a,b,...: similar to cards 41/a,b,...

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.
.
.

Cards for the NSPACT th spacer

(fail if NSPACT = 0)

Cards (38+(NSPACT-1)*4)/a,b,...: similar to cards 38/a,b,...

Cards (39+(NSPACT-1)*4)/a,b,...: similar to cards 39/a,b,...

Cards (40+(NSPACT-1)*4)/a,b,...: similar to cards 40/a,b,...

Cards (41+(NSPACT-1)*4)/a,b,...: similar to cards 41/a,b,...

Cards(38+4*NSPACT)/ a,b,...

IRGRI(1,1) IRGRI(1,2) IRGRI(1,3) IRGRI(2,1) IRGRI(2,2) IRGRI(2,3) ... IRGRI(NSTØT,1) IRGRI(NSTØT,2) IRGRI(NSTØT,3)

(6 data per card with the Format (6I10))

:

IRGRI(NS,J) = index of the rod adjacent to the J^{th} subchannel of channel NS

:

(see description for cards 38/a,b,...). As for the previously described grid parameters, if a channel contains a number J_{max} of subchannels less than 3, the IRGRI values for the existing subchannels must be punched in the first J_{max} fields reserved to the channel and the fields corresponding to $J>J_{max}$ will be left blank.

Card (39+4*NSPACT)

TIMEPU

(Format (F10.5))

TIMEPU = computation time (in seconds) after which the punching of the mass-flow rates and of the gas temperatures of the channels, of the subchannels and of the two portions of the wall subchannels is required. After this punching the computation will be stopped (see subroutine TMPUN)

Card (40+4*NSPACT)

IPUNCH

(Format (8I10))

IPUNCH = option for punching the computed pin and shroud temperatures and the pressure drops

IPUNCH=1: punching

IPUNCH=2: not punching

3.2 Cards read in the subroutine INLCØN

The subroutine INLCØN contains the READ statements for the inlet mass-flow rates and for the inlet gas temperatures of the channels, of the subchannels and of the two portions of the wall subchannels. These cards fail if IREAD1=1, i.e. if uniform distributions for the inlet mass-flow rates and for the inlet gas temperatures are assumed.

To read these cards it is not only necessary to know the channel disposition, but also the disposition of the subchannels inside each channel which is established by SAGAPØ. Normally this is no problem, because non-uniform distributions for the inlet mass-flow rates and for the inlet gas temperatures are normally assumed only to go on with a new step for a calculation which has previously stopped because the allowed computing time TIMEPU has been elapsed **). In this case the necessary cards are all provided directly as output of the preceeding calculation step (they are punched by means of punching statements contained in the subroutine TMPUN). Furthermore the outlet mass flow rates and gas temperatures of the channels, of the subchannels and of the two portions of the wall subchannels are printed for all axial sections.

Cards (40+4*NSPACT)a,b,...*)

MI(1) TEMP(1) MI(2) TEMP(2) ... MI(NSTØT) TEMP(NSTØT)
(8 data per card with a format(8F10.5))

⋮

MI(NS) = mass flow rate of channel NS at the point where the calculation is started (g/s)

TEMP(NS)= gas temperature of channel NS at the point where the calculation is started (°C)

⋮

---

*) As usual NSTØT is the total number of channels for the considered symmetry section, evaluated as the subroutine INDEX.

**) or because the end of the axial section IPAEND has been reached.

Card (41+4*NSPACT)/a *)

MSCH1(1,1) TSCH1(1,1) ... MSCH1(1,NPIN(1)) TSCH1(1,NPIN(1))
(Format (8F10.5))

⋮

MSCH1(1,M) = mass flow rate of subchannels M of channel 1 at the point where the calculation is started (g/s)

TSCH1(1,M) = gas temperature of subchannel M of channel 1 at the point where the calculation is started (°C)

⋮

⋮

Card (40+4*NSPACT+NS)/a *)

(Format (8F10.5))

⋮

MSCH1(NS,M) = mass flow rate subchannel M channel NS at the point where the calculation is started (g/s)

TSCH1(NS,M) = gas temperature of subchannel M of channel NS at the point where the calculation is started (°C)

⋮

Card (40+4*NSPACT+NS)/b

(fails if NTYP(NS)≠2, i.e. if channel NS is not a wall channel; obviously channel 1 can be never a wall channel, thus Card (41+4*NSPACT)/b does never exist).

MSCWC1(NSW,1,1) TSCW1(NSW,1,1) MSCWC1(NSW,1,2) TSCWC1(NSW,1,2) MSCWC1(NSW,2,1) TSCWC1(NSW,2,1) MSCWC1(NSW,2,2) TSCWC1(NSW,2,2) **)
(Format (8F10.5))

MSCWC1(NSW,1,1) = mass flow rate of the wall portion of subchannel 1 of channel NS at the point where the calculation is started (g/s)

---

*) NPIN(NS) is the number of the pins adjacent to channel NS (the parameters NPIN(NS) are evaluated in the subroutine HEATI). Note that NPIN(NS) is always ≤3; thus 1 card is always sufficient foe each channel NS.

**) NSW = NS-NSTR, where NSTR is the number of central channels for the considered symmetry section (evaluated in the subroutine INDEX).

TSCWC1(NSW,1,1) = gas temperature of the wall portion of subchannel 1 of channel NS at the point where the calculation is started (°C)

MSCW1(NSW,1,2) = mass flow rate of the central portion of subchannel 1 of channel NS at the point where the calculation is started (g/s)

TSCWC1(NSW,1,2) = gas temperature of the central portion of subchannel 1 of channel NS at the point where the calculation is started (°C)

MSCWC1(NSW,2,1) = mass flow rate of the wall portion of subchannel 2 of channel NS at the point where the calculation is started (g/s)

TSCWC1(NSW,2,1) = gas temperature of the wall portion of subchannel 2 of channel NS at the point where the calculation is started (°C)

MSCWC1(NSW,2,2) = mass flow rate of the central portion of subchannel 2 of channel NS at the point where the calculation is started (g/s)

TSCWC1(NSW,2,2) = gas temperature of the central portion of subchannel 2 of channel NS at the point where the calculation is started (°C)

Note that these data are exactly 8 for each wall channel and thus they are all punched in one card.

⋮

Cards (40+4*NSPACT+NSTOT)/a,b

They refer to channel NSTØT, i.e. to the last channel which must be considered. They are similar to cards (40+4*NSPACT+NS)/a,b.

3.3 BLØCK DATA for hexagonal bundles

In this paragraph the input data which must be provided in BLØCK DATA by means of DATA statements are described for the original version of the SAGAPØ Code (i.e. for hexagonal bundles). In the next paragraph the additional data which were provided in BLØCK DATA for the calculations of the 12-rod bundles are also described.

1) CØMMØN BLØCK /DAT1/

A(1), A(2),...,A(10)
A(J), J=1, 10: parameters for the $G(h^+)$ function (see function GHPLUS).

2) CØMMØN BLØCK /DAT2/

B(1), B(2),...,B(10)
B(J), J=1, 10: parameters for the $R(h^+)$ function (see function RHPLUS).

3) CØMMØN BLØCK /DAT4/

NDEST, NDEEND

NDEST = number of equivalent diameters after the beginning of an axial portion of the bundle or after a spacer, defining the beginning of a region where the flow is supposed to be indisturbed. In the performed calculations NDEST=10 was assumed.

NDEEND= number of equivalent diameters before the end of an axial portion of the bundle or before a spacer, defining the end of a region where the flow is supposed to be indisturbed. In the performed calculations NDEEND=2 was assumed.

In the regions defined by NDEST and NDEEND average values of some important variables will be evaluated and printed by SAGAPØ (see 4.4 in this work).

4) CØMMØN BLØCK /DAT7/

CNUSS(1), CNUSS(2)

CNUSS(1) = parameter defining the maxima of the correction profiles for the Nusselt numbers due to the influence of spacers ($Y_{sp} = Nu_B/Nu_{B\infty}$) for heated axial sections with smooth rods.

CNUSS(2) = parameter defining the maxima of the correction profiles for the Nusselt numbers due to the influence of spacers ($Y_{sp} = Nu_B/Nu_{B\infty}$) for heated axial sections with roughened rods.

For smooth and roughened axial sections $Y_{sp_{max}}$ is defined as:

$$Y_{sp_{max}} = 1 + CNUSS * \varepsilon^2$$

where the ε's are the blockage factors (see (II·10) - (II·12) and (II·39) - (II·41) in /5/). For the performed calculations the following CNUSS values where used /5/:

CNUSS(1) = 5.55
CNUSS(2) = 3.55

5) CØMMØN BLØCK /DATKM/

D1(1), D1(2),...,D1(7), D2(1), D2(2),...,D2(7)

⋮ ⋮

D1(I), D2(I) = coefficients for the equation defining the thermal conductivity of the canning metal for the Ith axial portion of the bundle as a function of the canning temperature (see function KMET).

⋮ ⋮

6) CØMMØN BLØCK /EXDAT/

EX1(1), EX1(2),...,EX1(7), EX2(1), EX2(2),...,EX2(7), EX3(1), EX3(2),...,EX3(7)

⋮ ⋮ ⋮

EX1(I), EX2(I), EX3(I) = coefficients for the equation defining the thermal expansion of the canning of the Ith axial portion as a function of the canning temperature (see function EXPCØ)

⋮ ⋮ ⋮

7) CØMMØN BLØCK /EXDAT1/

EX4(1), EX4(2),..., EX4(7), EX5(1), EX5(2),...,EX5(7), EX6(1), EX6(2),...,EX6(7)

⋮ ⋮ ⋮

EX4(I), EX5(I), EX6(I) = coefficients for the equation defining the thermal expansion of the shroud metal as a functions of the shroud temperature (see function EXPCL)

⋮ ⋮ ⋮

8) CØMMØN BLØCK /BIDAT/

BIK(1), BIK(2), BIK(3)

BIK(1), BIK(2), BIK(3) = coefficients for the equations defining the fin efficiency K_∞ as a function of the Biot number (see function KINF in this work and (II•20) in /5/)

9) CØMMØN BLØCK /BIDAT1/

BIE(1), BIE(2), BIE(3), BIE(4), BIE(5), BIE(6), BIE(7)

BIE(1), BIE(2),...,BIE(7) = coefficients and parameters for the equations defining the fin efficiency E_∞ as a function of the Biot number (see function EINF in this work and (II•19) in /5/).

10) CØMMØN BLØCK /BIDE/

IBIDE

IBIDE = option for the definition of the Biot number (see subroutine CØRRTE)

IBIDE=1 : $Bi = \alpha (T_{WR_{av}}) h_R / k_c (T_{WR_{av}})$

IBIDE=2 : $Bi = \alpha (T^{\infty}_{WR}) h_R / k_c (T^{\infty}_{WR})$

This option was necessary because of the different definitions for the Biot number available in the literature /7,8,9/. IBIDE=1 for the 12-rod bundles (see (III•14) in /5/) and IBIDE=2 for the 19-rod bundle (see (III•26) in /5/).

11) CØMMØN BLØCK /LAMINK/

BKAPPA(1,1), BKAPPA(2,1),..., BKAPPA(7,1), BKAPPA(1,2), BKAPPA(2,2),..., BKAPPA(7,2), BKAPPA(1,3), BKAPPA(2,3),..., BKAPPA(7,3)

:

BKAPPA(I,1) = K=λRe value for the central channels in the Ith axial portion of the bundle in the case of laminar flow (see(IV.3)in/5/).

BKAPPA(I,2) = K=λRe value for the wall channels in the Ith axial portion of the bundle in the case of laminar flow (see (IV.3)in /5/).

BKAPPA(I,3) = K=λRe value for the corner channels in the Ith axial portion of the bundle in the case of laminar flow (see (IV.3) in /5/).

K values for the three types of channels and also for both portions of the wall subchannels can be also computed authomatically by SAGAPØ as a function of the geometric parameters with equation which are well applicable at the normal values of the geometric parameters (see option IKAPPA, CØMMØN BLØCK/WAKA1/). If it is desired to compute the K values authomatically, the input BKAPPA values are not used by SAGAPØ.

12) CØMMØN BLØCK/MART2/

NS1, NS2

NS1 = index of the external channel at which the simplified procedure described in paragraph 4.6 of /5/ starts to be applied

NS2 = index of the external channel at which the simplified procedure described in paragraph 4.6 of /5/ ends to be applied.

Note that NS1 and NS2 must correspond to external channels or must be both equal to zero, otherwise the calculation stops in subroutine KAPCØR. If NS1=NS2=0 the simplified procedure is not applied. It must be reminded that this simplified procedure had to be introduced to allow calculations for laminar flows in the 19 rod bundle which otherwise could not be performed because of convergence problems. The convergence problems were mainly caused by the fact that conduction in the rods in the circumpherential direction cannot be taken into account in the present version of SAGAPØ.

The simplified procedure will be eliminated in the future, as soon as the possibility of taking into account the conduction effects will be introduced. Due to the provisory nature of the mentioned procedure and because only 1/12th of the 19-rod bundle was computed (i.e. a section which contains only one wall channel and only one corner channel), the possibility of considering only one big external channel (corner + wall channels) was introduced. The values NS1=4 und NS2=5 were used for the laminar calculations performed for the 19-rod bundle.

13) CØMMØN BLØCK /LAMIN9/

I3TIP(1,1), I3TIP(2,1), ..., I3TIP(42.1), I3TIP(1,2), I3TIP(2,2),..., I3TIP(42,2), I3TIP(1,3), I3TIP(2,3), ..., I3TIP(42,3)

:

I3TIP(NS,J)= option for subchannel J of channel NS, defining which flow conditions have to be considered in the subchannel.

:

I3TIP=1 : laminar conditions are imposed by the user

I3TIP=2 : turbulent conditions are imposed by the user

I3TIP=3 : the decision whether the flow conditions have to be considered as laminar or as turbulent is left to SAGAPØ

As pointed out in paragraph 4.7 of /5/, convergence difficulties occured with I3TIP=3. It must be pointed out that, if it is desired to impose different I3TIP(NS,J) values to the different subchannels, the channel and subchannel dispositions fixed by SAGAPØ must be known to the user.

14) CØMMØN BLØCK/WAKA1/

IKAPPA

IKAPPA = option for the laminar calculations

IKAPPA=1 : the K=λRe values are computed by means of equations (IV·4)-(IV·13) of /5/.

IKAPPA=2 : the K=λRe values are set equal to the BKAPPA values (see CØMMØN BLØCK/LAMINK/); furthermore the K values of both portions of the wall subchannels are assumed to be equal to the K values of the whole wall subchannels.

15) CØMMØN BLØCK/CONDO/

FCØND

FCØND = geometric factor K_G for the enthalpy exchange due to thermal conduction within the gas (see (I•18) in /5/).

No correlations are known to the author for the calculation of these factors. Therefore they are assumed to be equal to 1 in the present version of SAGAPØ.

16) CØMMØN BLØCK/CVREH/

ACVS(1), ACVS(2), ACVS(3), ACVR(1), ACVR(2), ACVR(3)

ACVS(1), ACVS(2), ACVS(3): coefficients for the equation defining the C_v values as a function of the Reynolds number, for spacer grids set in smooth axial sections (see function DSPDPF in this work and (I·9) in /5/).

ACVR(1), ACVR(2), ACVR(3)= coefficients for the equation defining the C_v values as a function of the Reynolds number, for spacer grids set in the roughened axial sections (see function DSPDPF in this work and (I·9) in /5/).

17) CØMMØN BLØCK /LAMIN6

ANGLAM

ANGLAM = input value for the parameter β, which defines the position of the line dividing the two portions of the wall subchannels in the case of laminar flow (see 4.2.3 in /5/).

IF IKAPPA=1 the β value is computed in the subroutine SELAWA by means of the function BETAF and therefore the input value is not used.

Recently three new options have been introduced in SAGAPØ, whose values must be provided in BLØCK DATA: <u>ISIMPL</u> (CØMMØN BLØCK /SIMLAM/, see subroutine SIMLA1), <u>IEXAV</u> (CØMMØN BLØCK /EXAVTW/, see subroutine WALLTE) and <u>IGRAV</u> (CØMMØN BLØCK /GRAV/: IGRAV=1 to take into account the gravitational force if the direction of the flow is coincident to that of the gravitational force, IGRAV=-1 if it is opposite, IGRAV=0 if the gravitational force is not taken into account).

3.4 BLØCK DATA for the 12-rod bundles

To perform calculations for the 12-rod bundles the following data (which concern the indexing of the channels, of the subchannels and of the rods and the identification of the connections between them) must be provided in BLØCK DATA, besides the previously described data:

18) CØMMØN BLØCK /HEA6/*)

NPIN(1), NPIN(2),..., NPIN(42)

⋮

NPIN(NS) = number of the pins adjacent to channel NS

⋮

JPIN(1,1), JPIN(2,1),..., JPIN(42,1), JPIN(1,2), JPIN(2,2),..., JPIN(42,2), JPIN(1,3), JPIN(2,3),..., JPIN(42,3)

⋮

JPIN(NS,J)= index of the Jth pin adjacent to channel NS

⋮

If NPIN(NS) is less than 3, the indices JPIN(NS,J) for the existing adjacent pins (i.e. for J ≤ NPIN(NS)) must be provided at first. The values of JPIN(NS,J) at J > NPIN(NS) will be then set equal to zero. The vector NPIN and the matrix JPIN are computed in the subroutine HEATI in the version of SAGAPØ referring to hexagonal bundles.

19) CØMMØN BLØCK /IND3/ *)

NTYP(1), NTYP(2),..., NTYP(42)

⋮

NTYP(NS) = type of channel NS

⋮
NTYP(NS) = 1 : central channel
NTYP(NS) = 2 : wall channel
NTYP(NS) = 3 : corner channel

---

*) Note that all the variables are dimensioned for a bundle with 42 channels in the present version of SAGAPØ. If the considered symmetry section contains a smaller number of channels the variables relating to the existing NSTØT channels must be provided at first in the DATA statements, whereas the further 42-NSTØT variables can be set equal to zero.

20) CØMMØN BLØCK /IJ1/*)

NER(1), NER(2),..., NER(42)

⋮

NER(NS) = number of the channels which are adjacent to channel NS

⋮

NIS(1,1), NIS(2,1),..., NIS(42,1), NIS(1,2), NIS(2,2),...,
NIS(42,2), NIS(1,3), NIS(2,3),..., NIS(42,3)

⋮

NIS(NS,J) = index of the Jth channel adjacent to channel NS

⋮

If NER(NS) is less than 3, the indices NIS(NS,J) for the existing adjacent channels (i.e. for J ≤ NER(NS)) are provided at first. The values of NIS(NS,J) at J > NER(NS) will be then set equal to zero.

Examples of BLØCK DATA for the KEIII, both for calculations to be performed in the whole bundle flow section and for calculations in 1/3rd of it are enclosed in Appendix 4. Figs. 9,10 will also help to understand this part of the input preparation.

---

*) Note that all the variables are dimensioned for a bundle with 42 channels in the present version of SAGAPØ. If the considered symmetry section contains a small number of channels, the variables relating to the existing NSTØT channels must be provided at first in the DATA statements, whereas the further 42-NSTØT variables can be set equal to zero.

3.5 FUNCTIØNS defining the physical properties of the gas coolant

The physical properties of the gas coolant are computed as functions of the pressure P (dimensioned in Kg/cm^2) and of the temperature T (dimensioned in ^{o}C) by means of the following functions.

1) FUNCTIØN CP(P,T), for the specific heat at constant pressure c_p (dimensions in cal/g ^{o}C)
2) FUNCTIØN ETA(P,T), for the dynamic viscosity η (dimensions in g/cm s)
3) REAL FUNCTIØN KAPPA(P,T), for the thermal conductivity k (dimensions in cal/cm s ^{o}C).
4) FUNCTIØN RHØ(P,T), for the density ρ (dimensions in g/cm^3)

The equations used for the calculations performed in the case of helium coolant are presented in the listing enclosed in this paper (see also (III·1)-(III·4) in /5/).
In the case of other coolants it is sufficient to provide the equations to be used in the mentioned FUNCTIØNS.

4. OUTPUT OF THE SAGAPØ CODE

The most important computed variables are printed by SAGAPØ (the prints include also most of the input data). The computed pressure losses and the pin and shroud temperatures can be punched (if IPUNCH=1, see 3.1, Card (40+4*NSPACT)), in order to provide input data for a plotting code. The outlet mass flow rates and the outlet gas temperatures of the channels, of the subchannels and of the portions of the wall subchannels will be punched if the calculation has been stopped before the desired point (i.e. if the time necessary for the calculation has elapsed the value TIMEPU *), or if the end of the axial portion IPAEND has been reached**).

In this paragraph the output information provided by SAGAPØ will be shortly described: a long description is not necessary because explanations of the output results are frequently printed by SAGAPØ. Most of the WRITE statements are contained in the main program: in the case of results printed in subroutines, the name of the subroutine will be cited.

4.1. First set of printed data

1) total number of rods

2) Conditions at the inlet of the bundle

- pressure (Kg/cm^2 and bar)
- gas temperature for the whole bundle flow section (^{o}C)

3) mass flow rate for the bundle flow section (g/s)

4) nominal geometry

- pitch of the rods (cm)
- distance between the center of the external rods and the shroud (cm)

---

*) See 3.1, Card (39+4*NSPACT)

**) See 3.1, Card 13

- height ZWC of the blocking triangles (cm)
- total length of the bundle (cm)
- total length of the heated part (cm)
- lengths and volumetric diameters for the existing axial portions (cm)
- height of the rougheness ribs, RH (if a portion of the rods is roughened) (cm)

5) $R(h^+)$ and $G(h^+)$ functions used in the calculations

G(H+) = $G(h^+)$
HW+ = value of h^+ computed at the pin temperature TW
PR = Prandtl number
RO = radius of the τ=0 line for the equivalent annulus
R1 = volumetric radius of the rods
R2 = inner radius of the outer wall for the equivalent annulus
R(H+) = $R(h^+)$ parameter
RH = height of the rougheness ribs
TB = bulk temperature in the whole bundle flow section of the equivalent annulus
TB1 = bulk temperature in the zone inside the τ=0 line of the equivalent annulus
TW = surface pin temperature at infinite conductivity of the canning

6) Powers in the rods and in the shroud

- maximum power in the shroud (cal/s cm)
- maximum powers for each rod (cal/s cm)
- end points for the power profiles and coefficients a_{j1}, a_{j2}, ... for each profile j (see 3.1, Card 35 /a,b,... and Cards 36 /a,b,...)

7) Disposition of the channels (print in subroutine INDEX)

- number NRØWS of the rows of channels
- type of section (=NSEL, see 3.1, 9th Card)
- number of central channels
- total number of channels
- type of eaxh channel NS and indices of the channels adjacent to it (TYPE=1 for central channels, TYPE=2 for wall channels, TYPE=3 for corner channels)

8) Nominal axial geometry of the spacers

- axial width of the spacers
- distances between the middle sections of each spacer and the bundle inlet(cm)

4.2 Data and results for the whole axial portions, printed for each axial portion

1) title for the identification of the axial portion

2) geometric parameters corrected for the thermal expansion

- pitch C of the rods (cm)
- distance Z between the centers of the external rods and the shroud (cm)
- height ZWC of the blocking triangles (cm)
- volumetric diameter of the rods (cm)
- length of the axial portion (cm)

3) number of the spacer grids in the axial portion

4) conditions at the inlet of the axial portion

- bulk temperature for the whole bundle flow section (^{o}C)
- pressure (Kg/cm^2 and bar)

5) height of the roughness (in the case of a roughened portion, i.e. if $3 \leq IPA \leq 5$)

6) rods adjacent to each channel (print in the subroutine HEATI, made in the case of heated portions)

JPIN(NS,J) : index of the Jth rod adjacent to channel NS (see also 3.4)

7) flow areas and equivalent diameters (print in the subroutine TØTGEØ)

- flow area and equivalent diameter of the total bundle flow section (cm^2 and cm, respectively)
- flow area for the considered symmetry section (cm^2)
- flow areas and equivalent diameters for the three types of channels (cm^2 and cm, respectively). Note that these flow areas refer to the entire channels

8) values of the blockage factors EPSILØN of the whole bundle flow section, of the channels and of the subchannels, for all spacers present in the bundle axial portion (if there are some)

9) geometry of the sub-subchannels contained in the central channels

- flow area and equivalent diameter of 1/6th of an entire central channel (cm^2 and cm, respectively)
- indices of the sub-subchannel and corresponding flow areas and equivalent diameters, for all sub-subchannels contained in 1/6 th of the entire channel

10) geometry of the sub-subchannels contained in the corner channels

- flow area and equivalent diameter of a half of the entire channel (cm^2 and cm, respectively)
- indices of the sub-subchannels and corresponding flow areas and equivalent diamters, for all sub-subchannels contained in a half of the entire channel

11) inlet pressure loss (Kg/cm^2 and bar) and assumed CINL coefficient (see 3.1, 23rd Card)

12) subdivision into axial sections

- length of the axial portion (cm)
- number of the axial sections into which the axial portion has been divided in the subroutine AXSEC
- input relaxation factor FREL (see FAREL, 3.1., 24th card).

4.3 Results for each axial section of each axial portion, printed for each axial section

1) identification of the axial section

- index, length and position of the middle point (HEIGHT) of the axial section
- spacer index in the case of presence of a spacer

2) results for the whole bundle flow section

- outlet bulk temperature T 2 (^{o}C)
- outlet pressure P 2 (Kg/cm^2)
- average pressure P AV(Kg/cm^2)
- pressure loss DELTAP (Kg/cm^2)
- friction factor LAMBDA ($=\lambda_T=4f$)

3) information about the convergence procedures

- number ITCØRR of the iterations which were necessary for the convergence in the loop ITCØRR (see main program, Fig. 11)
- number ITGL of the iterations which were necessary for the convergence of the axial momentum equations, for the channels at the last iteration **ITCØRR (see sobroutine BALA, Fig.14)**
- total number ITGL1 of the iterations which were necessary for the convergence of the axial momentum equations for the channels

$$\left(ITGL1 = \sum_{I=1}^{ITCØRR} ITGL \right)$$

- number ITERM of iterations which were necessary for the convergence of the energy equations at the last iterations ITCØRR and ITGL (see subroutine BALA, Fig.14)
- relaxation factor at which the convergence of the axial momentum equations of the channels was reached (see subroutine BALA, Fig.14)

4) Results of the channel calculations (for each channel)

- index of the channel
- outlet mass flow rate (g/s)
- average mass flow rate (g/s)
- outlet bulk temperature (°C)
- average bulk temperature (°C)
- pressure loss (Kg/cm^2)
- average velocity UAV (cm/s)
- net cross-flow rate per unit length WCF (g/s cm)
- summation MO of the outlet mass flow rates of all sub-subchannels of the channel (g/s) *) **)
- friction factor LAM **)
- turbulent rates per unit length WT(NS,K) exchanged between the channel NS and the adjacent channels K (g/s cm)

5) Average rod temperatures (for each channel)

- channel index
- for each rod
  - . rod index
  - . rod temperature at the radial position of the thermocouples (average for the subchannel adjacent to the rod) (°C)
  - . total power provided from the rod in the axial section (cal/s)

---

*) This print is made to allow controlling if the convergence of λ_T in the loop ITCØRR means really convergence of the other variables.

**) This print is made only in the axial sections without spacer grids: in the axial sections which contain a spacer these variables are not computed.

6) Results of the calculations in the subchannels for each subchannel of each channel *)

- channel index [A]
- subchannel index, index of the corresponding rod [A]
- outlet mass flow rate ØUT. MASS (g/s) [A]
- outlet bulk temperature ØUT. TEMP (°C) [A]
- friction factor LAMBDA [A]
- Reynolds number REB (gas properties computed at the bulk temperature) [A]
- Reynolds number REW (gas properties computed at the surface pin temperature) [A]
- Power Q LINER provided by the shroud to the subchannel in the axial section [A] **)
- Biot number BIØT [R-H]
- Surface pin temperature at infinite conductivity of the canning TW INF. (average for the subchannel) (°C) [A]
- shroud temperature T AT LINER (average for the subchannel)(°C) [WC-H]
- values of h_B^+ (the gas properties computed at the subchannel bulk temperature) HB+ [R]
- value of h_w^+ (the gas properties computed at the subchannel pin temperature) HW+ [R]
- parameter R(H+) [R]
- parameter G(HW+) [R-H]
- Nusselt number NU [H]
- Pin to bulk temperature ratio TW/TB (both temperatures are °K) [R-H]
- ratio TW/TE between the pin temperature TW and the gas temperature at

---

*) Prints for all subchannels → [A]
Prints only for wall subchannels → [W]
Prints only for wall or corner channels → [WC]
Prints only for roughened sections → [R]
Prints only for heated sections → [H]
Prints only for sections without spacers → [NS]

**) Obviously Q LINER=0 for the central subchannels the bundle inlet TE (both temperatures are in ^{o}K) [R-H]

- ratio Y/RH between $Y = r_2 - r_1$ (r_2 and r_1 are the inner radius of the outer wall and the outer radius of the inner wall for the equivalent annulus, respectively) and the height RH of the rougheness ribs [R-H]
- parameter $G(h^+)$ reduced to TW/TB=1, Y/RH=100, Prandtl number PR=1 [R-H]
- bulk temperature TBSSCH(1) for the whole sub-subchannel "1" of the subchannel [H-NS] *)
- rod temperature TWSSCH(1) at the radial position of the thermocouples for the sub subchannel "1" of the subchannel (^{o}C) [H-NS] *)
- bulk temperature TBSSCH(N) for the whole sub-subchannel "N" of the subchannel (^{o}C) [H-NS] *)
- rod temperature TWSSCH(N) at the radial position of the thermocouples for the sub-subchannel "N" of the subchannel (^{o}C) [H-NS] *)
- average bulk temperature TA of the outer zone (i.e. outside the τ=0 line) for the whole subchannel (^{o}C) [WC-H-NS]

---

*) In the case of central subchannels and corner channels both sub-subchannels which are placed each at one of the two gaps between the containing central subchannel or corner channel and one of the two adjacent channels are indicated with the index "1": the pin and gas temperatures for these two sub-subchannels are assumed to be equal in the present version of SAGAPØ (as no conduction in the pins in the azimuthal direction is taken into account). In the case of the wall subchannels, index "1" refers to the sub-subchannel set at the gap between the containing wall portion of wall subchannel and the adjacent external channel.
With index "N" are indicated - in the case of central subchannels and outer channels - the two sub-subchannel (adjacent to each other) which are placed in the center of the central subchannel or of the corner channel (also for them the temperatures are assumed to be equal). In the case of wall subchannels, "N" indicates the sub-subchannel of the wall portion which is adjacent to the central portion.
Finally, it must be pointed out that in the axial sections with smooth rods the values of the pin and gas temperatures for the single wall and corner sub-subchannels are not computed in the present version of SAGAPØ: these temperatures are all set equal to the corresponding values of the containing wall portion of wall subchannel or corner channel (see 1.9.3. in /5/).

- average bulk temperature TB of the inner zone (i.e. inside the τ=0 line) of the whole corner channel or of the whole wall portion of wall subchannel (^{o}C) [WC-H-NS]
- average bulk temperature TBC of the inner zone (i.e. inside the τ=0 line) of the whole corner channel or of the whole wall subchannel (^{o}C) [WC-H-NS] *)
- rod temperature TW(1) at the radial position of the thermocouples for the wall portion (portion 1) of the wall subchannels (^{o}C) [W-H-NS]
- rod temperature TW(2) at the radial position of the thermocouples for the central portion (portion 2) of the wall subchannels (^{o}C) [W-H-NS]
- bulk temperature T1SSCH(1) for the inner zone (i.e. inside the τ=0 line) of the sub-subchannel "1" of an external subchannel (^{o}C) [WC-H-NS] **)
- bulk temperature T2SSCH(1) for the outer zone (i.e. outside the τ=0 line, of sub-subchannel "1" of an external subchannel (^{o}C) [WC-H-NS] **)
- bulk temperature T1SSCH(N) for the inner portion (i.e. inside the τ=0 line) of the sub-subchannel "N" of an external subchannel (^{o}C) [WC-H-NS] **)
- bulk temperature T2SSCH(N) for the outer portion (i.e. outside the T=0 line) of the sub-subchannel "N" of an external subchannel (^{o}C) [WC-H-NS] **)
- outlet mass flow rate MØUT(1) for the wall portions of the wall subchannels (g/s) [W]
- outlet bulk temperature TØUT(1) for the wall portions of the wall subchannels (^{o}C) [W]
- flow area AREA(1) for the wall portions of the wall subchannels (cm^2) [W]

*) For the corner channels it is obviously TB=TBC, whereas for the wall subchannels TBC is obtained averaging TB and the bulk temperature of the central portion.

**) see note pag.59

- friction factor LAMBDA(1) for the wall portions of the wall subchannels [W]
- outlet mass flow rate MØUT(2) for the central portions of the wall subchannels (g/s) [W]
- outlet bulk temperature TØUT(2) for the central portions of the wall subchannels (^oC) [W]
- flow area AREA(2) for the central portions of the wall subchannels (cm^2) [W]
- friction factor LAMBDA(2) for the central portions of the wall subchannels [W].

4.4 Recapitulatory prints for each axial portion of the bundle

1) Inlet values for each of the axial sections of the bundle portion

- index of the axial section
- distance between the inlet of the axial section and the point where the calculation has been started (cm)
- bulk temperature for the whole bundle flow section (^oC)
- inlet pressure (kg/cm^2 and bar)

2) Average values for each of the axial sections of the bundle portion (values for the whole bundle flow section)

- index of the axial portion
- coolant density (g/cm^3)
- coolant viscosity (g/cm s)
- coolant velocity (m/s)
- Reynolds number
- friction factor

3) Total pressure drop for the whole computed axial portion of the bundle (kg/cm^2)

4) Mean values obtained averaging the variables in the regions where indisturbed flow is supposed

(see 3.3 CØMMØN BLØCK/DAT4/). The variables refer to the whole bundle flow section.

- bulk temperature (^oC)
- pressure (kg/cm^2 and bar)
- coolant density (g/cm^2)
- coolant viscosity (g/cm s)
- coolant velocity (m/s)
- Reynolds number
- friction factor

5) Mean values (for roughened axial portions) obtained averaging the variables in the regions where indisturbed flow is supposed (see 3.3 , CØMMØN BLØCK/DAT4/)
The variables refer to each subchannel of each channel

- channel index
- subchannel index, index of the rod adjacent to the subchannel
- h_B^+ (HB+) *)
- h_W^+ (HW+) *)
- $R(h^+)$ (R(H+)) *)
- $G(h^+)$(G(HW+)) *)
- $Q^+ = \frac{\dot{Q}''A}{\dot{m}C_pT_E}$

  ($\dot{Q}''$=power per unit surface, A=flow area, $\dot{m}$=mass flow rate, c_p=specific heat at constant pressure, T_E= gas temperature at the bundle inlet in ^oK)
- T_W/T_B (TW/TB) *)
- T_W/T_E (TW/TE) *)
- $(r_2-r_1)/h_R$ (Y/RH) *)
- $G(h^+)$ parameter reduced to T_W/T_B=1, Pr=1, Y/RH=100 *)

---

*) See paragraph 4.3 in this work for the meaning of these variables.

6) Temperatures for the correction of the geometric parameters due to the thermal expansion of the structure *)

- input and computed average pin temperature TWTIPA (^{o}C)
- input and computed average bulk temperature TBTIPA (^{o}C)
- input and computed average shroud temperature TBPIPA (^{o}C)

7) Comparison between experimental and computed pressure drops, for all pressure taps in the axial portion **)

- dimensions ("kg/cm^2" or "bar")
- index of the pressure tap
- distance HEIGHT from the point where the calculation has been started (cm)
- experimental pressure P EX
- experimental pressure drop (DP EX.= P EX. -PE1) from the bundle inlet ***)
- theoretical pressure P TH.
- theoretical pressure drop (DP TH. = P TH. - PE1) from the bundle inlet ***)
- difference between the computed and the measured pressure (P TH. - P EX.)
- percentage error on the computed pressure drop ((DP TH. - DP EX.)/ DP EX. * 100)

8) Print of the pin temperature at special axial positions, for all the positions contained in the axial portion ****)

- index of the axial position
- distance HEIGHT from the point where the calculation has been started (cm)

---

*) Average values for each axial portion of the bundle (see also 3.1, Cards 23, 24 and 25)

**) This print is performed if NEXPR>0 for the axial portion of the bundle (see 3.1, 16th Card)

***) See 3.1, 10th Card, about PE1

****) This print is performed if NEXTW>0 for the axial portion (see 3 .1, 17th Card).

- for each subchannel of each channel
  - . subchannel index M
  - . channel index NS
  - . index JPIN of the rod adjacent to subchannel M
  - . pin temperature TW TH.(NS,JPIN) (^{o}C)

4. 5 Final Prints

- pressure recovery at the bundle outlet (kg/cm^2)
- pressure at the bundle outlet (kg/cm^2 and bar)
- used coefficient CØUT for the pressure recovery (see 3.1, 23rd Card)
- experimental pressure at the bundle outlet *)
- total theoretical pressure drop, from the bundle inlet to the bundle outlet (DP TH. = P TH. - PE1) *)
- total experimental pressure drop, from the bundle inlet to the bundle outlet (DP EX. = P EX. - PE1) *)
- precentage error on the total computed pressure drop ((DP TH. - DP EX.)/DP EX. * 100) *)

4.6 Punched Cards

As already mentioned, in the case of IPUNCH=1 (see 3.1 , Card (40+4*NSPACT)) the computed pressure drops and the computed pin and shroud temperatures (together with the necessary information about the spacers positions) are punched by SAGAPØ on cards. This punching is made for each of the computed $\bar{N}$ axial sections**). The WRITE statements for this punching are all contained in the main program (see Fig. 11 and Cards 1-(9+(NTØT-1)*4), in this

---

*) These prints are made only if the input value of PEXØUT is greater than zero, i.e. if the comparison between the computed and the measured total pressure drop is required (see 3.1, Cards 28/a,b,...)

**) N=1 for the axial section which begins at the point where the calculation is started, $N=N_{TOT}$ for the last axial section of the bundle. If the calculation stops before the bundle outlet, only the punching for a certain number $\bar{N}$ of axial section ($\bar{N} \leq N_{TOT}$) will be obviously made.

paragraph). A second set of cards is punched (by means of WRITE statements contained in the subroutine TMPUN) to provide the necessary set of new input cards for a new step of calculation, if the computation has been stopped before the bundle outlet, because the allowed calculation time TIMEPU has been elapsed or if the calculation has reached portion IPAEND (see 3.1, 13th Card) and IPAEND<7.

4.6.1 Cards punched in the case of IPUNCH=1

Card 1 *)

NSPACT
(Format (8I10))
NSPACT = total number of spacers (see 3 .1, 1st Card)

Card 2 *)

(fail if NSPACT=0, i.e., in the case of no spacers)
DIST(1) DIST(2)...DIST(NSPACT)
(3 data per card with the Format 3E15.5)

:

DIST(I) = distance of the Ith spacer from the bundle inlet (cm)
(see 3.1, Cards 37/a,b,...)

:

The lengths DIST(I) are already corrected to take into account the thermal expansion.

Card 3 *)

IPA
(Format (8I10))
IPA = index of the first existing axial portion in the bundle

*) These cards are punched only if the calculation is started from the bundle inlet, i.e. only if STLEN=0 (see 3.1, 14th card)

Card 4 *)

XLTØT DPBAR(1)

(Format 3E15.5)

XLTØT = 0 (a zero is punched, because XLTØT corresponds here to a point immediately after the bundle inlet: the inlet pressure drop DPBAR(1) is assumed to be localized at the bundle inlet)

DPBAR(1) = absolute value of the inlet pressure drop (bar)

Card 5

(for the 1st computed axial section)

IPA

(Format (8I10))

IPA = index of the axial portion containg the 1st computed axial section

Card 6

(for the 1st computed axial section)

XLTØT DPBAR(2)

(Format (3E15.5))

XLTØT = distance from the bundle inlet to the end point of the 1st computed of axial section (cm)

DPBAR(2) = absolute value of the pressure drop from the bundle inlet to the position XLTØT (bar)

---

*) These cards are punched only if the calculation is started from the bundle inlet, i.e. only if STLEN=0 (see 3.1, 14th card)

Card 7 *)

(for the 1st computed axial section)
XM
(Format (3E15.5))
XM = distance from the bundle inlet to the central plane of the 1st computed axial section (cm)

Card 8/1 *)

(for the 1st computed axial section)
TW(1,1) ... TW(1, NPIN(1))
(Format (3E15.5))
⋮
TW(1, M) = pin temperature at the radial position of the thermocouples for subchannel M of channel 1 at the axial position XM (°C)
⋮

⋮

Card 8/NSa *)

(for the 1st computed axial section)
TW(NS,1) ... TW(NS, NPIN(NS))
(Format (3E15.5))
⋮
TW(NS, M) = pin temperature at the radial position of the thermocouples for subchannel M of channel NS at the axial position XM (°C)
⋮

---

*) These cards are punched only in the case of heated axial sections. NPIN(NS) is the number of pins adjacent to channel NS (the NPIN parameters are established in the subroutine HEATI; see also 3.2, Cards (41+4*NSPACT)) One card is sufficient for the punching of the TW values for all subchannels M of a channel NS, because NPIN(NS) $\leq$3.
Note finally that the subchannel indexing is that which is fixed by SAGAPØ in the subroutine INDEX (see prints for the subchannels to get to know the indexing procedure).

Card 8/NSb*)

(for the first computed axial section, only in the case of external channels, i.e. for NS >NSTR**))

TLINER (NS-NSTR,1) TLINER(NS-NSTR, NPIN(NS))* **)

(Format (3E15.5))

TLINER(NS-NSTR,1) = shroud temperature for subchannel 1 of channel NS at the axial position XM (^{o}C)

TLINER(NS-NSTR,2) = shroud temperature for subchannel 2 of channel NS at the axial position XM (^{o}C)***)

⋮

Card 8/NSTØTa*)

(for the 1st computed axial section)
Similar to card 8/NSa, for channel NSTØT (last channel).

Card 8/NSTØTb*)

(for the 1st computed axial section)
Similar to card 8/NSb, for channel NSTØT (last channel).

Cards for the 2nd computed axial section (N=2)

Card 9 : similar to card 5
Card 10: similar to card 6
Card 11: similar to card 7
Card 12/1,..., 12/NSa, 12/NSb,..., 12/NSTØTa, 12/NSTØTb: similar to cards 8/1,... 8/NSa, 8/NSb,..., 8/NSTØTa, 8/NSTØTb

⋮

---

*) see note pag. 67

**) Card 8/1b does not exist, because channel 1 is never an external channel.

***) Obviously, if channel NS is a corner channel or a wall channel with only one subchannel (i.e. NPIN (NS)=1) only TLINER(NS-NSTR,1) will be punched.

Cards for the $\bar{N}$th computed axial section

Card (5 + ($\bar{N}$-1) *4) : similar to card 5
Card (6 + ($\bar{N}$-1) *4) : similar to card 6
Card (7 + ($\bar{N}$-1) *4) : similar to card 7
Cards (8 + ($\bar{N}$-1)*4)/1, ..., (8 + ($\bar{N}$-1)*4/NSa, (8 + ($\bar{N}$-1)*4)/NSb, ..., , (8 + ($\bar{N}$-1)*4)/NSTØTa, (8 + ($\bar{N}$-1)*4)/NSTØTb: similar to cards 8/1, ..., 8/NSa, 8/NSb, ..., 8/NSTØTa, 8/NSTØTb

Card (9 + (N_{TOT} -1) *4)

(fail if the calculation has been not be carried out up to the bundle outlet; in this case it is $\bar{N}<N_{TOT}$)

DPØBAR
(Format (3E15.5))
DPØBAR = total pressure drop, from the bundle inlet to the bundle outlet, included the pressure recovery at the bundle outlet (bar)

4.6.2 Cards punched if the computation time TIMEPU has been elapsed

Card (9 + ($\bar{N}$-1) * 4)

PE PE1 TE TE1 MFLØW XLAM1(1) XLAM1(2) XLAM1(3)
(Format (8F10.5))

PE = outlet pressure for the axial section at which the calculation has been stopped = inlet pressure for the next calculation step (dimensions in kg/cm^2 or in bar, depending on the value of INDPR, see 3.1, 15th card)

PE1 = pressure before the bundle inlet (same dimensions as PE)

TE = outlet bulk temperature for the whole bundle flow section, for the axial section at which the calculation has been stopped = inlet bulk temperature for the next calculation step (^oC)

TE1 = bulk temperature for the whole bundle flow section at the bundle inlet (^{o}C)

MFLØW = mass flow rate through the whole bundle flow section (g/s)

XLAM1(1) = approximate value of the whole bundle friction factor $\lambda_T = 4f_T$ for the 1st axial portion

XLAM1(2) = approximate value of the whole bundle friction factor $\lambda_T = 4f_T$ for the 2nd axial portion

XLAM1(3) = approximate value of the whole bundle friction factor $\lambda_T = 4f_T$ for the 3rd axial portion

This card must replace the 10th input card (see 3.1) in order to start a new calculation step.

Card (10+ ($\bar{N}$-1) * 4)

IPAST IPAEND IREAD1

(Format (3I10))

IPAST = index of the axial portion in which the calculation will be stopped = index of the axial portion in which the next calculation step must start

IPAEND = index of the axial portion at the end of which it is desired to end the calculation (it is the input value IPAEND for the present calculation step) (see 3.1, 13th Card) *)

IREAD1 = 2 (this option is set authomatically equal to 2, in order to allow the reading of non-uniform mass-flow-rate and gas-temperature inlet disturbutions in the next calculation step; see 3.1, 13th Card)

This card must replace the 13th input card (see 3.1) in order to start a new calculation step.

Card (11 + ($\bar{N}$-1) * 4)

STLEN

(Format (8F10.5)

STLEN = distance from the bundle inlet to the end point of the axial section at which the calculation has been stopped = distance from the bundle inlet to the point at which the calculation will start

*) The punched IPAEND value must be replaced to start a new calculation step if the present step is stopping because portion IPAEND(<7)has been reached.

in the next step (cm)

This card must replace the 14th input card (see 3.1) in order to start a new calculation step.

Cards (12 - ($\bar{N}$-1) * 4)/a, b, ... - (12 - ($\bar{N}$-1) * 4)/ a,b

In this last block of cards the outlet mass flow rates and gas temperatures of the channel, of the subchannels and of the two portions of the wall subchannels (inlet values for a new calculation step) are punched with the Formats described in 3.2. Cards (11 + ($\bar{N}$-1) * 4)/a,b,...- (11 + ($\bar{N}$-1) *4 + NSTØT)/a,b will be used as input Cards (40+4*NSPACT)/a,b,... -(40+4*NSPACT + NSTØT)/a,b in the next calculation step (see 3 .2).

5. STRUCTURE OF SAGAPØ

5.1. Introductory remarks

In the next paragraphs the main program and all subprograms, of which SAGAPØ consists, will be shortly described. For each subprogram, the used equations will be cited, referring mainly to /5/ (sometimes also to /1/ or to /2/). Furthermore the meaning of the subprogram arguments *) will be explained. For most of the subprograms **) the name of the calling subprogram will be cited. For the main program and for some important subroutines, simplified flow-charts are also included in this work (see Figs. 11-23).

5.2 Main program

The main program reads most of the input data, performs some simple calculations, organizes the calculations performed mostly in subprograms and prints and punchs most of the output data. The input and the output steps have been accurately described in paragraphs 3 and 4. In Fig.11 a simplified flow-chart of the main program is presented.

5.3 FUNCTIØN AKA

AKA computes the parameter $k_A=k_A(r_1/r_2, \Phi_A)$ (AKA) which takes into account the inlet effect on the pressure drop in the case of laminar flow (see (IV.19)-(IV.28) in /5/). AKA is called by the subroutine ENTRFR.

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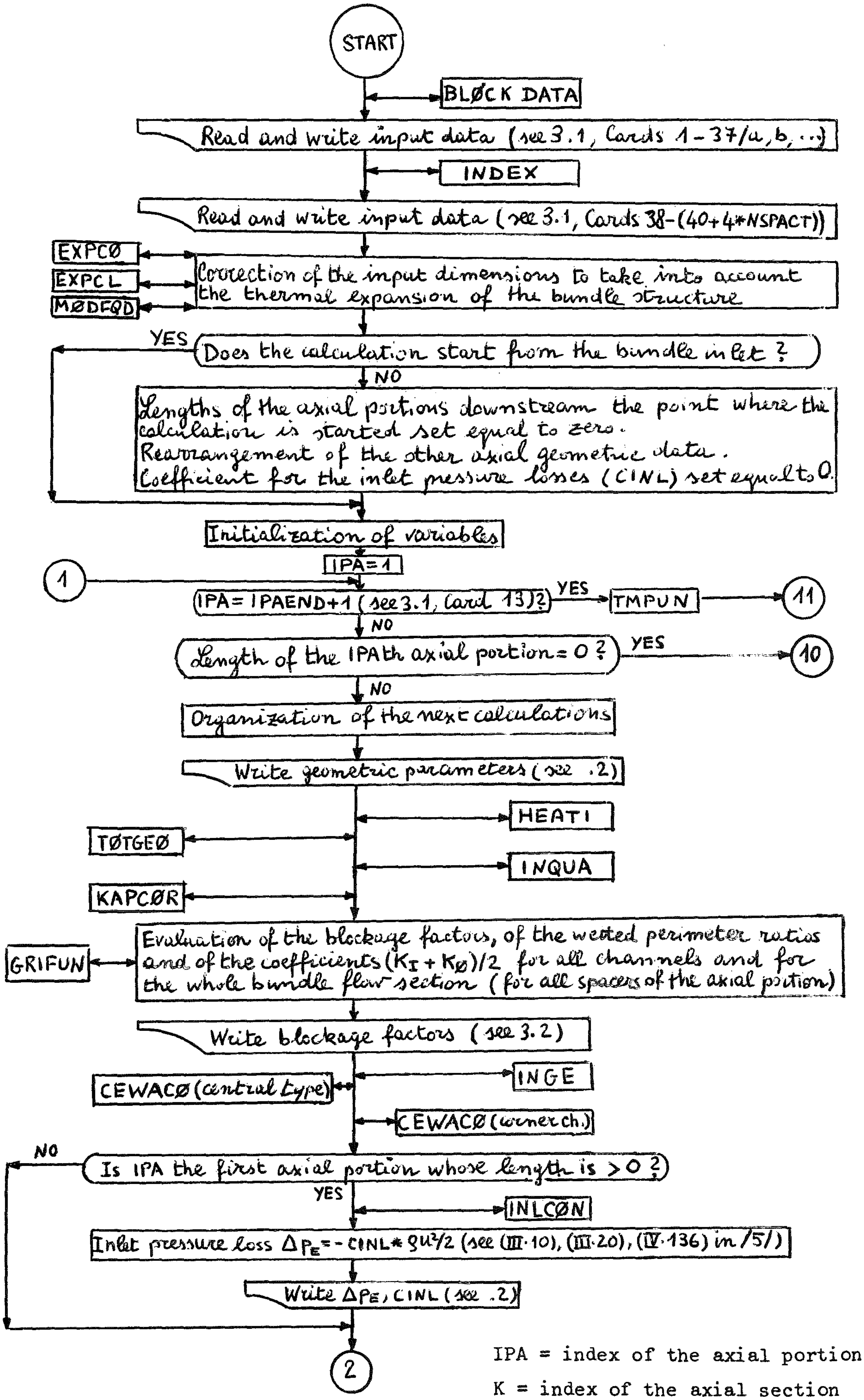
*) It must be pointed out that the geometric parameter are all based on the volumetric diameter (and not on the tip diameter), in the case of roughened rods, if it is not differently specified.

**) Except for some subprograms which are called by a large number of other subprograms.



IPA = index of the axial portion

K = index of the axial section

ITCØRR = iteration index for the convergence of λ_{TOT}

Fig.11 Simplified flow chart for the main program

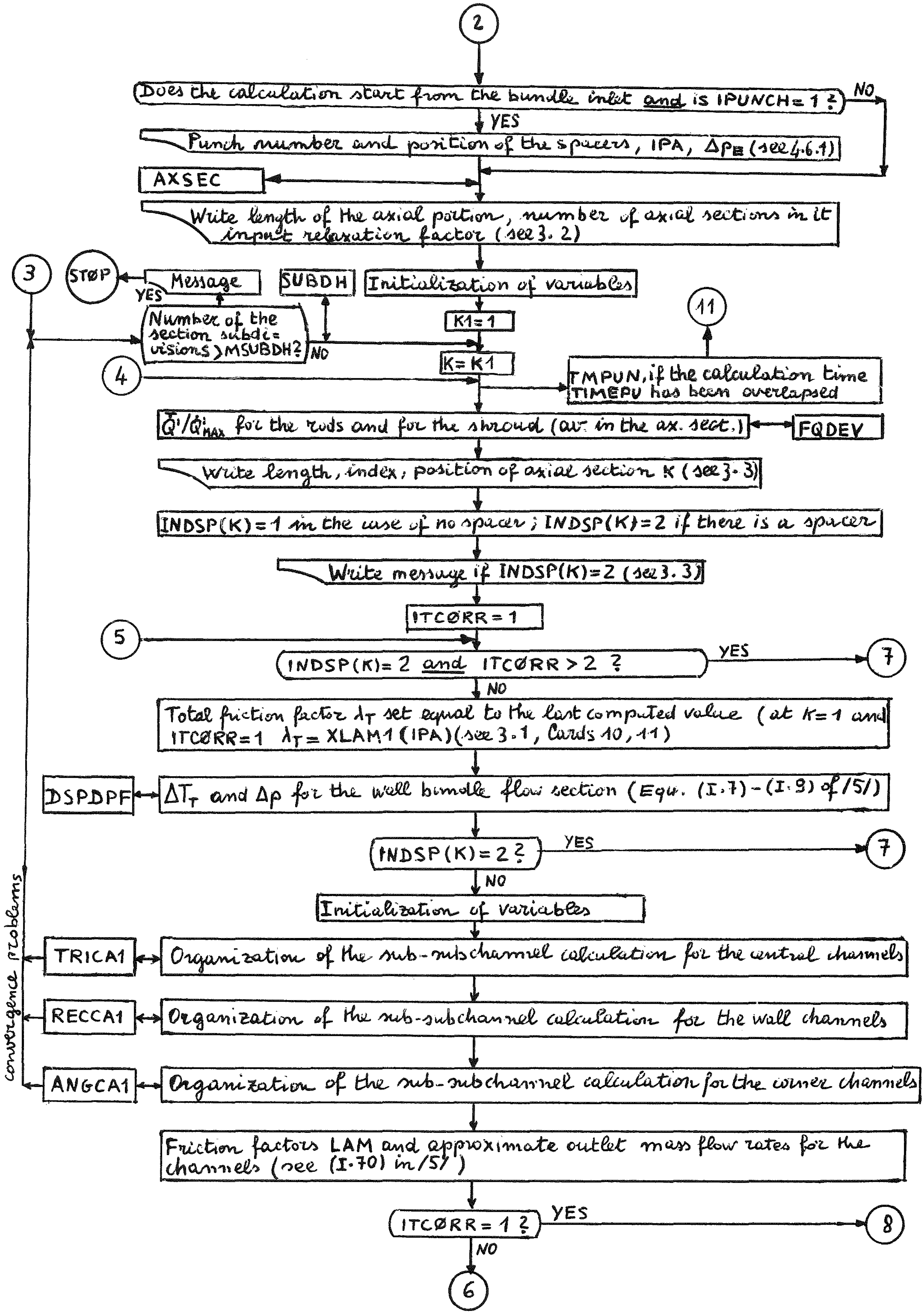


Fig.11 (continuation)

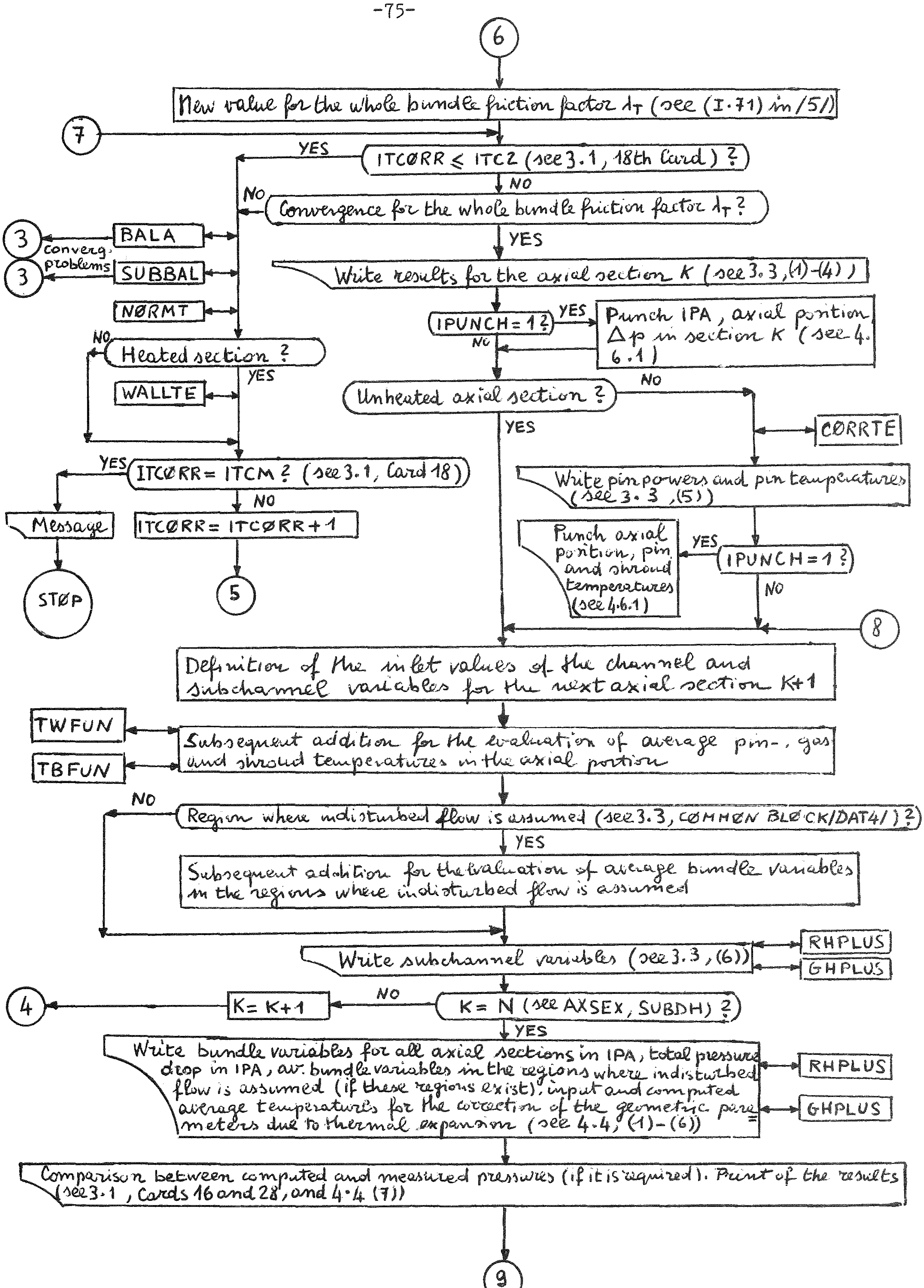


Fig. 11 (continuation)

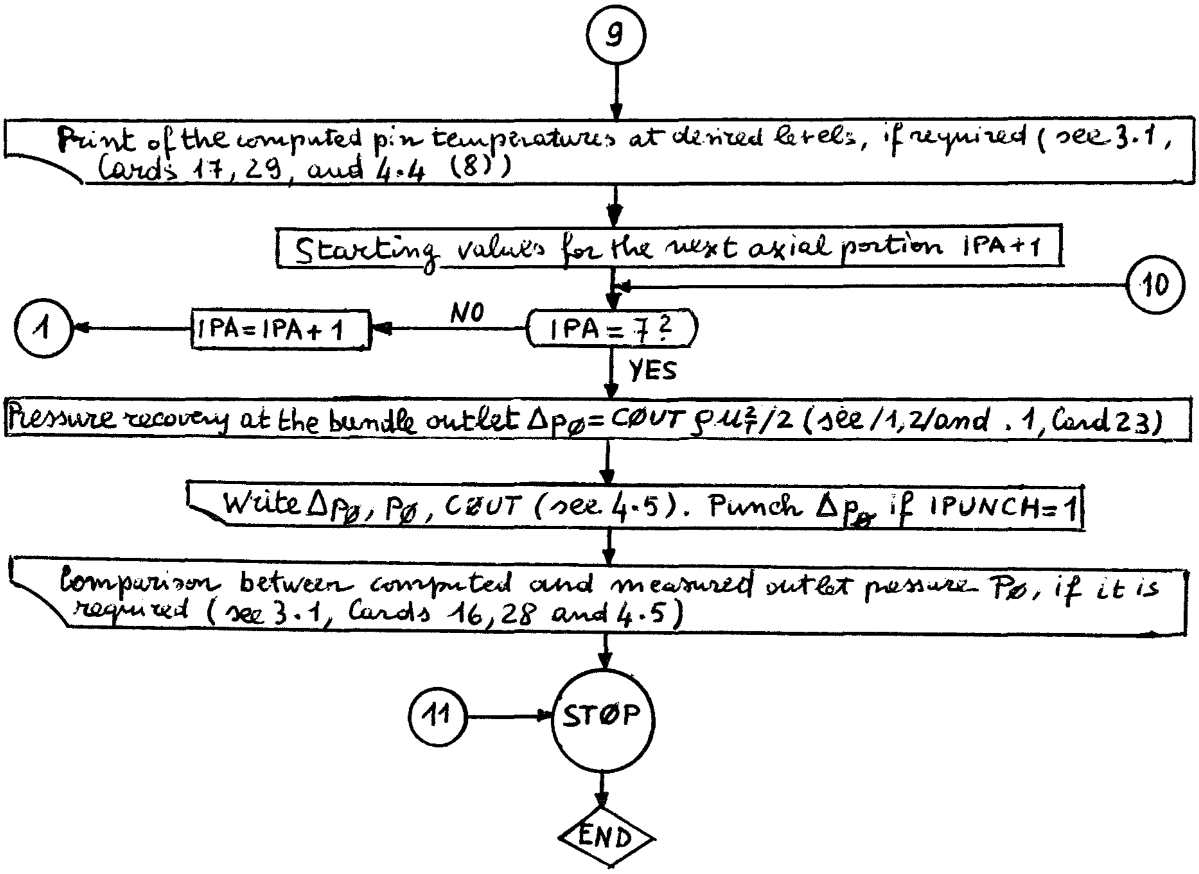


Fig. 11 (continuation)

Arguments:

R1DR2 = r_1/r_2
PHI = Φ_A

5.4 SUBRØUTINE ANGCA1

ANGCA1 organizes the sub-subchannel calculation for the corner channels. Furthermore it computes the friction factors LAMSCH for the whole corner channels, both in the case of turbulent flow (see (I.66) in /5/) and in the case of laminar flow (see (IV.3), (IV.7), (IV.32) in /5/). In the case of turbulent flow ANGCA1 evaluates also the friction factors LAMB and the equivalent diameters DETB of the inner zones of the corner channels, the ratios ADAB between the flow area of the inner zone and the flow area of the whole corner channels. Finnaly it computes average values of some sub-subchannel variables (see flow chart, Fig.12). ANGCA1 is called by the main program.

Arguments:

K = index of the axial section
NS = channel index
N = number of sub-subchannels in a half of the entire corner channel (i.e. for a rod sector of an angle $\pi/6$)
IRH = index for the type of the rod surface (IRH=1 for smooth rods, IRH=2 for roughened rods)
PRØV = P_T (see (I.111) in /5/)
PB = average pressure for the axial section (kg/cm^2)
RH = height of the roughness ribs (cm)
H1 = (length of the axial section)/(length of the containing axial portion)

ALFA	$= \frac{\pi/6}{N}$ = angle of the rod sector for each sub-subchannel of the corner channel
A(1)...A(N)	= flow areas of the sub-subchannels (cm^2)
AT	= flow area for a half of the entire corner channel (cm^2)
DET	= equivalent diameter for the corner channel (cm)
DETØT	= equivalent diameter for the whole bundle flow section (cm)
D	= volumetric diameter of the rods (cm)
W	= distance Z (between the centers of the external rods and the shroud) + D/2 (cm)
NSTR	= number of the central channels in the bundle
H	= length of the axial section K (cm)
PR1	= inlet pressure for the axial section (kg/cm^2)
PR2	= outlet pressure for the axial section (kg/cm^2)
SQDPG	$= \sqrt{\lvert \Delta p_T \rvert g_c}$
TE	= gas temperature at the bundle inlet, average for the whole bundle flow section (^oC)
SUR	= volumetric surface of a rod for the whole axial portion (cm^2)
AMT	= summation of the computed average mass flow rates of the sub-subchannels contained in the half of the entire corner channel (g/s)
DDDD	= summation of the computed terms $\frac{Ai}{\sqrt{\frac{\lambda_i \Delta x}{2D_i \rho_i}}}$ (see (I·66) in /5/)
*	= for RETURN1, in the case of convergence problems in the subroutine RECANG (the axial section will be halved)
AMA	= summation of the computed average mass flow rates of the outer zones (i.e. outside the τ=0 line) of the sub-sub-channels contained in the half of the entire corner channel (g/s)
AMB	= summation of the computed average mass flow rates of the inner zones (i.e. inside the τ=0) of the sub-subchannels contained in the half of the entire corner channel (g/s)

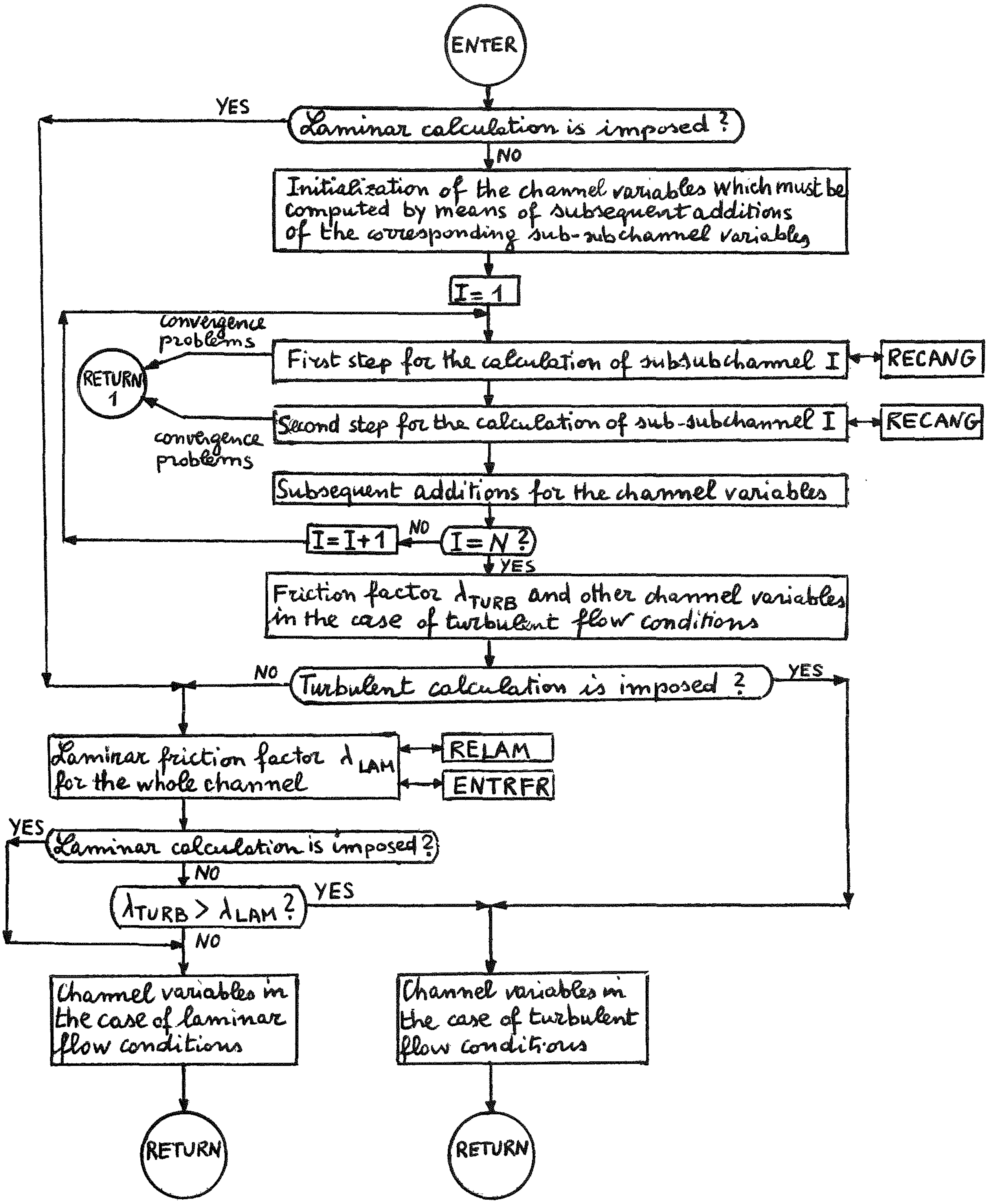


Fig. 12 Simplified flow-chart for the subroutine ANGCA1

I=sub-subchannels index

5.5 SUBRØUTINE AXSEC

AXSEC establishes the number of axial sections into which each axial portion of the bundle has to be divided, the lengths of these axial sections (fixing the positions X(K) and X(K+1) of the inlet and outlet planes of each axial section K with the procedure described in 1.1 of /5/) and the correction factors YY(=Y_{sp} in /5/) for the Nusselt numbers of the subchannels, which take into account the spacer effects on the heat transfer coefficients (see) (II.10) - (II.12) and (II.39) - (II.41) in /5/); see also flow chart Fig.13). AXSEC is called by the main program.

Arguments:

NDE1	= input value XDE1 for the axial portion (see 3.1, 19th Card)
NDE2	= input value XDE2 for the axial portion (see 3.1, Cards 19 and 20)
DETC	= equivalent diameter of the central channels (cm)
WSP	= axial width of the spacer grids (cm)
CØNST	= CNUSS value for the axial portion (see 3.3 , CØMMØN BLØCK/DAT7/)
DDD	= distance from the point where the calculation has been started to the end of the axial portion (cm)
II	= index of the first spacer whose position has been not yet reached by the calculation (if the last spacer present in the bundle has been already overtaken, II is the index of this last spacer)
HH	= distance from the point where the calculation has been started to the beginning of the axial portion (cm)
MSPAC	= number of spacers in the axial portion
LENGTH	= length of the axial portion (cm)
N	= number of axial sections in the axial portion, computed in AXSEC
IPA	= index of the axial portion
QTØT	= 0 for unheated axial portions; $(\sum_{I=1}^{NRØDS} QPIN(I))$*LENGTH for heated ax.port. (see 3.1, Cards 1,30)
NSTØT	= total number of channels
XMAXNU	= parameter for the correction profiles for the Nusselt numbers, which fixes the number of equivalent diameters from the inlet section of a spacer to the point at which the profiles have a maximum. In the present version of SAGAPØ XMAXNU = 1.6 is assumed for the smooth axial portions and XMAXNU = 1 is assumed for the roughened axial portions (see main program and mentioned equations in /5/).

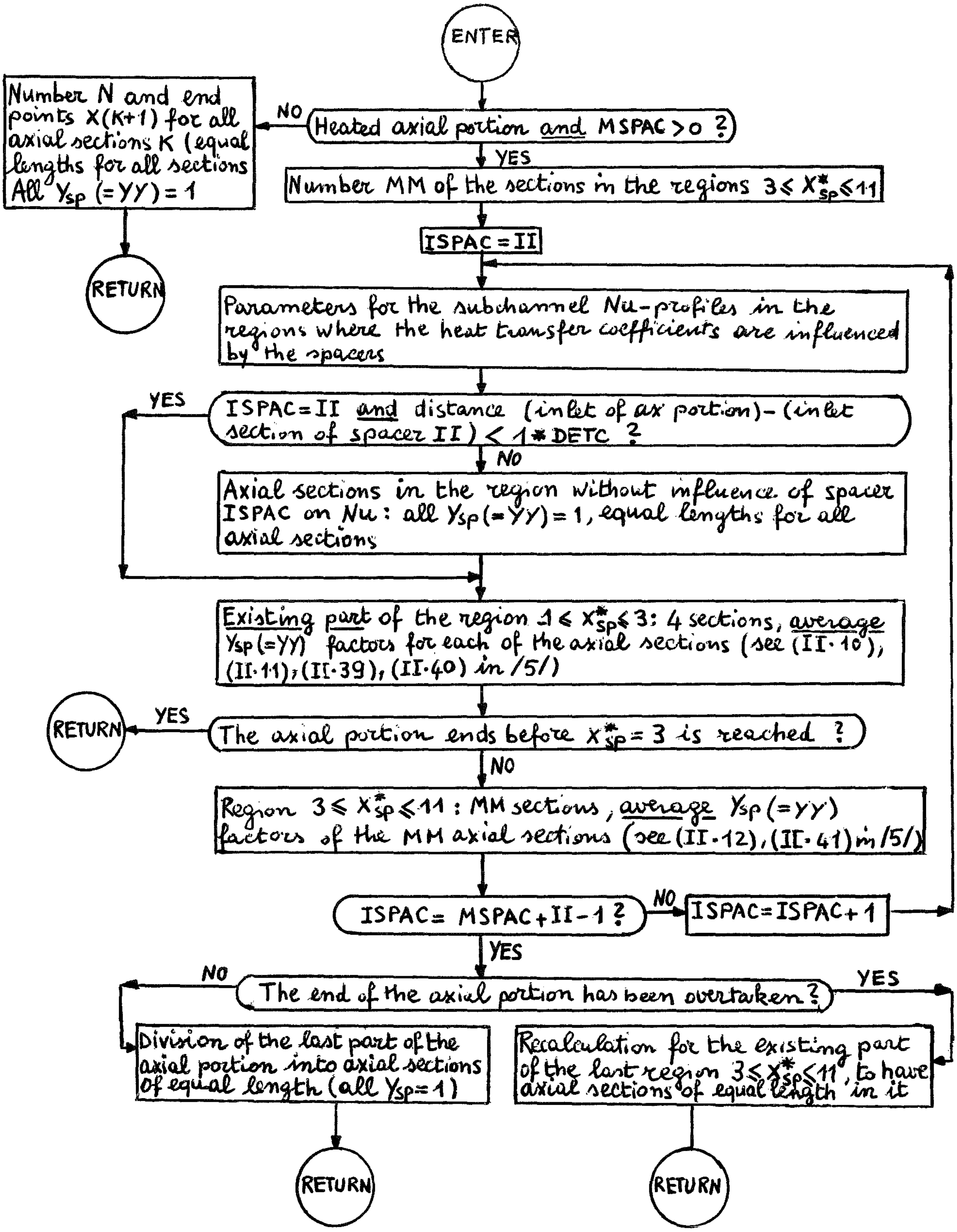


Fig. 13 Simplified flow chart for the subroutine AXSEC

ISPAC = spacer index

CHSLNU = parameter for the correction profiles for the Nusselt numbers, which fixes the value of the correction factors γ_{sp} at three equivalent diameters after the inlet section of the spacers

$Y_{sp}(X^*_{sp} = 3) = 1 + CNUSS * \varepsilon^2 *CHSLNU$ (ε=blockage factor)

In the present version of SAGAPØ CHSLNU = 2/3 is assumed for the smooth axial portions and CHSLNU=0.5 is assumed for the roughened axial portions (see main program and mentioned equations in /5/).

5.6 SUBRØUTINE BALA

BALA computes the average and the outlet mass-flow rates MAV and M2, the turbulent rates WT, the cross-flow rates WCF, the average velocities UAV, the pressure losses DP, the inlet and the average gas temperatures TAV and TEMP2 and some other channel variables (see flow chart, Fig.14) for all channels, at each axial section K, using the equations described in 1.5 of /5/. BALA is called by the main program.

Arguments:

K = index of the axial section

NSTØT = total number of the channels

INDSP = index for the presence of a spacer in the axial section
INDSP=1 : no spacers
INDSP=2 : there is a spacer

ASEC = area of the considered symmetry section of the bundle (cm^2)

H = length of the axial section (cm)

LENGTH = length of the axial portion containing the axial section (cm)

PR1 = inlet pressure for the axial section (kg/cm^2)

PR2 = outlet pressure for the axial section (kg/cm^2)

PBT = average pressure for the axial section (kg/cm^2)

FREL = relaxation factor (FREL=input value (see 3.1, 24th Card) the first time that BALA is used for calculation of each axial portion, then FREL=value previously computed in BALA itself)

FT = input factor f_T (see 3.1, 21st Card)

ITCØRR = actual value of the iteration index in the loop for the convergence of the whole bundle friction factor (see main program, Fig.11)

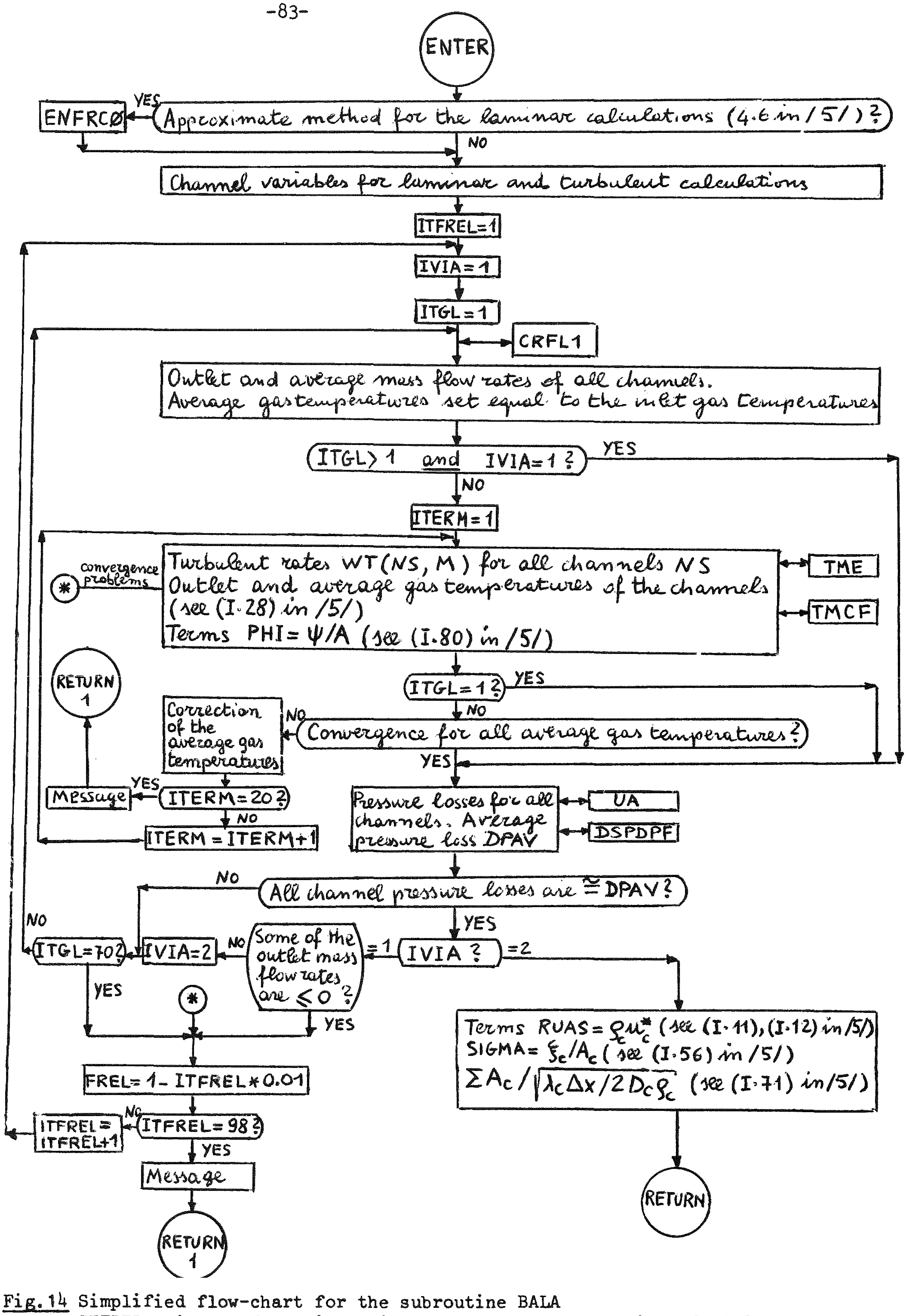


Fig. 14 Simplified flow-chart for the subroutine BALA

ITFREL = index of the iteration loop for the correction of FREL

ITGL = index of the iteration loop for the convergence of the axial momentum equations

ITERM = index of the iteration loop for the convergence of the energy equations

ITCM = maximum number of iterations for the loop ITCØRR (see 3.1, 18th Card)

DPAV = average pressure loss for the channels, computed in BALA (see (I·51) in /5/) (kg/cm^2)

ITERM = number of iterations necessary for the convergence of the energy equations in BALA

ITGL = number of iterations necessary for the convergence of the axial momentum equations in BALA

* = for RETURN1, in the case of convergence problems (the axial section will be halved)

WSP = axial width of the spacers (cm)

I1SPAC = index of the first spacer which has been not yet overtaken by the calculation in the preceeding axial section.*)

5.7 FUNCTIØN BETAF

BETAF evaluates the parameter β(BETAF) for determination of the separation line for the two portions of the wall subchannels in the case of laminar calculations (see (IV·18) in /5/). BETAF is called by the subroutine SELAWA.

Arguments:

P = (pitch of the rods)/(tip diameter of the rods)

W = (distance between the center of the external rods and the shroud + tip radius of the rods)/(tip diameter of the rods)

ZWC = (height of the blocking triangles)/(tip diameter of the rods)

5.8 SUBRØUTINE CEWA

CEWA performs the calculations for the "central-type" sub-subchannels, i.e. for the sub-subchannels contained in a central subchannel or in the central portion of a wall subchannel. It is used only for turbulent calculations. The equations described in 1.9.1 and in chapter 2 of /5/ are applied in CEWA. CEWA is called by the subroutines TRICA1 and RECCA1. About CEWA see flow-chart in Fig.15.

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*) I1SPAC=1 for the first spacer contained in the axial portion

Arguments:

K	= index of the axial section
NS	= index of the containing channel
IRH	= index for the type of the rod surface (IRH=1 for smooth rods, IRH=2 for roughened rods)
PRØV	= P_T (see (I·111) in /5/)
PB	= average pressure for the axial section (kg/cm^2)
RH	= height of the roughness ribs (cm)
AA	= flow area of the sub-subchannel (cm^2)
DD	= equivalent diameter of the sub-subchannel (cm)
GG	= terms G_{iS} and G_{iR} (see (I·73), (I·76) in /5/)
AM1	= first iteration value for the mass-flow rate of the sub-subchannel (it corresponds to an uniform mass distribution) (g/s)
DETØT	= equivalent diameter for the whole bundle flow section (cm)
H1	= (length of the axial section)/(length of the containing axial portion)
ALFA	= $\frac{\pi/6}{\text{nr. of sub-subchannels in } \pi/6}$
I	= index of the sub-subchannel
JJJ	= index of the containing subchannel
H	= length of the axial section (cm)
PR1	= inlet pressure for the axial section (kg/cm^2)
PR2	= outlet pressure for the axial section (kg/cm^2)
SQDPG	= $\sqrt{\lvert\Delta p\rvert g_c}$
AMT	= summation of the mass flow rates $\dot{m}_i$ for the already computed sub-subchannels of the subchannel JJJ (g/s)
TT	= summation of the terms $\dot{m}_i T_i$ for the subchannel JJJ (g $^\circ$C/s)
DDDD	= summation of the terms $\frac{A_i}{\sqrt{\frac{\lambda_i \Delta x}{2D_i \rho_i}}}$ (see (I·66) in /5/) for the already computed sub-subchannels of subchannel JJJ
TE	= gas temperature at the bundle inlet ($^\circ$C)
SUR	= volumetric surface of a rod for the whole axial portion (cm^2)
ITYP	= type of the containing subchannel (ITYP=1: central subchannels; ITYP=2: wall subchannels)

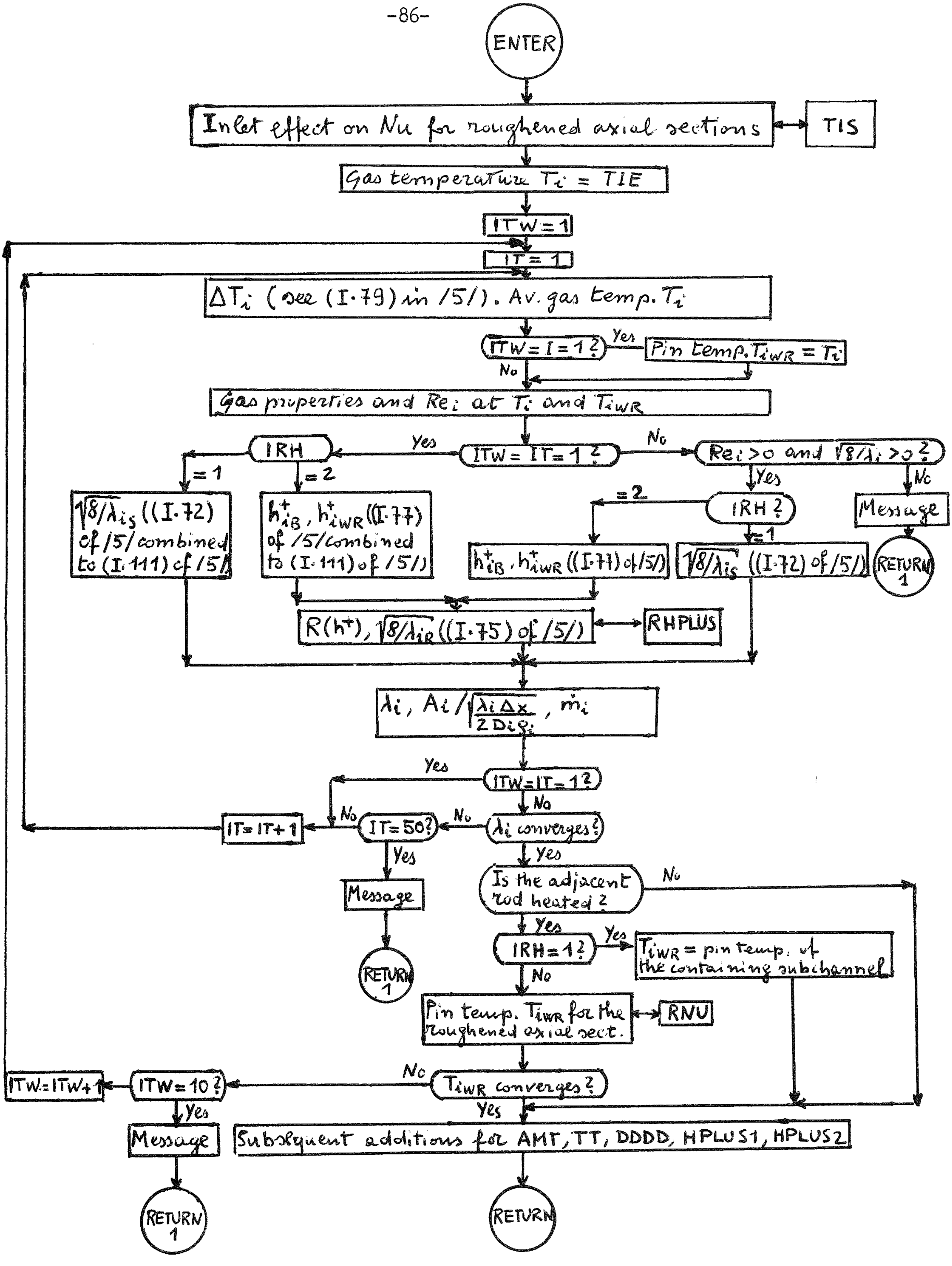

Fig. 15 Simplified flow chart for the subroutine CEWA

ITW = iteration index for the convergence of the pin temperature T_{iWR}

IT = iteration index for the convergence of the friction factor λ_i

III	=	NS-NSTR (NSTR = number of the central channels)
HPLUS1	=	summation of the terms $h^+_{Bi}.A_i$ for the already computed sub-subchannels of the subchannel JJJ (cm^2)
HPLUS2	=	summation of the terms $h^+_{Wi}.A_i$ for the already computed sub-subchnannels of the subchannel JJJ (cm^2)
TIE	=	inlet temperature for the sub-subchannel (= inlet temperature of the containing central subchannel or central portion of wall subchannel in the present version of SAGAPØ) (^{o}C)
SIGMA	=	parameter ξ/A for containing central subchannel or central portion of wall subchannel (see 1.8 in /5/)
PHI	=	parameter ψ/A for the containing central subchannel or central portion of wall subchannel (see (I·80) in /5/)
*	=	for RETURN 1 in the case of convergence problems
D	=	volumetric diameter of the rods (cm)
TWI	=	surface pin temperature at infinite conductivity of the canning for the last computed sub-subchannel (if I=1 TWI is set equal to the bulk temperature TI at the first iteration) (^{o}C)
TI	=	average gas temperature of the sub-subchannel (^{o}C)
C	=	pitch of the rods (cm)

5.9 SUBRØUTINE CEWACØ

CEWACØ evaluates the total flow areas AREA(I), the total equivalent diameters DE(I) and the total mass-flow rates ME(I) (corresponding to an uniform mass flow distribution) for the "central-type" sub-subchannels (i.e. for the sub-subchannels contained in central subchannels or in central portions of wall subchannels) and for the sub-sunchannels defined in the second calculation step of the corner channels. Furthermore it computes the coefficients G(I) (=G_i, defined by (I·73) or (I·76) in /5/) for the central sub-subchannels and evaluates the following geometric parameters for the corner sub-subchannels:

PER(I)	=	wetted perimeter of the shroud for sub-subchannel I(cm)
RR2(I)	=	inner radius of the outer wall for the annulus equivalent to the whole sub-subchannel I (cm)
ALFA12(I)	=	(inner radius)/(outer radius) for the annulus equivalent to the whole sub-subchannel I

Arguments:

N = number of sub-subchannels contained in a half of the entire central subchannels or in a half of the entire corner channels (i.e. in $\pi/6$)

NN = N for the corner sub-subchannels

= 3/2*N for the central sub-subchannels (the central portions of the wall subchannel could be **larger than the central** subchannels)

NTYP = type of the sub-subchannels (NTYP=12 for the central sub-subchannels, NTYP=3 for the corner sub-subchannels)

ALFA = $\frac{\pi/6}{N}$ = angle of the rod sector for each sub-subchnanel

D = volumetric diameter of the rods (cm)

X = 0.5*(pitch of the rods) for the central sub-subchannels (cm)

= distance between the external rods and the shroud for the corner sub-subchannels (cm)

AT = flow area of a half of an entire central subchannel or corner channel (cm^2)

DET = equivalent diameter of the central subchannels or of the corner channels (cm)

ATØT = flow area for the whole bundle (cm^2)

AREA(1)... AREA(NN)

= flow areas of the central or of the corner sub-subchannels, computed in CEWACØ (cm^2)

DE(1)...DE(NN)

= equivalent diameters of the central or of the corner sub-subchannels, computed in CEWACØ (cm)

ME(1)...ME(NN)

= mass flow rates in the case of uniform distribution, for the central or for the corner sub-subchannels, computed in CEWACØ (g/s)

5.10 SUBRØUTINE CF1

CF1 is used for the evaluation of the cross-flow variables $\sum(\bar{T}\ \dot{\bar{m}})^{CF}$ and $\sum(\bar{u}\ A)^{CF}$*) in the calculations for the channels, the subchannels and the two portions of the wall subchannels (see subroutines BALA, SUBBAL, TMCF UA, RECCA2). In the procedure used in the present version of SAGAPØ the cross-flow temperature $\bar{T}_1^{CF}$ is assumed to be equal to the average of the temperatures (let say T_1 and T_2) of the two entire connected channels, subchannels or portion of wall subchannels, weighted with the mass flow rates (see (I.24)in /5/ for the channel calculation); $\dot{m}^{CF}$ is the therefore equal to the summation of the mass-flow rates (let say $\dot{m}_1$ and $\dot{m}_2$) of the two entire connected channels, subchannels or portions of wall subchannels. Similarly the cross-flow velocity $\bar{u}^{CF}$ is assumed to be equal to the average of the velocities (let say $\bar{u}_1$ and $\bar{u}_2$) of the two entire connected channels, subchannels or portions of wall subchannels, weighted with the flow areas (see (I.32) in /5/); A^{CF} is therefore equal to the summation of the flow areas (let say A_1 and A_2) of the two entire connected channels, subchannels or portions of wall subchannels. With these definitions of $\bar{T}^{CF}$ and $\bar{u}^{CF}$ the identification of the "donors" is not needed (see 1.5.2, 1.5.3 in /5/), therefore CF1 is now very simple and most of its input arguments (which were used in the previous version of the code /1/) are now not needed. CF1 is called by the subroutines UA, TMCF, SUBBAL and RECCA2.

Arguments

X1	= $\bar{T}_1$ (°C)	or $\bar{u}_1$ (cm/s)
X2	= $\bar{T}_2$ (°C)	or $\bar{u}_2$ (cm/s)
Y1	= $\bar{\dot{m}}_1$ (g/s)	or A_1 (cm^2)
Y2	= $\bar{\dot{m}}_2$ (g/s)	or A_2 (cm^2)
DP1	= Δp_1 (pressure loss) (kg/cm^2)**)	
DP2	= Δp_2 (pressure loss) (kg/cm^2)**)	

*) Each time that CF1 is used, the terms referring to the considered exchange are added to the input values of $\sum(\bar{T}\ \dot{m})^{CF}$ and of $\sum(\bar{u}\ A)^{CF}$, as also to $\sum \dot{m}^{CF}$ and to $\sum A^{CF}$.

**) not used in the present version of SAGAPØ

ITVIA = option (not used in the present version of SAGAPØ) for the procedure required for the evaluation of $\bar{T}^{CF}$ and $\bar{u}^{CF}$ (see /1/)

ITVIA = 1 : as in /5/

ITVIA > 1 : $\bar{T}^{CF}$, $\bar{u}^{CF}$ = bulk temperature and mean velocity of the donor.

XYT = $\sum(\bar{T}\ \dot{\bar{m}})^{CF}$ (g °C/s) or $\sum(\bar{u}\ A)^{CF}$ (cm^3/s)

YT = $\sum \dot{m}^{CF}$ (g/s) or $\sum A^{CF}$ (cm^2)

5.11 SUBRØUTINE CØNNIJ

CØNNIJ is used only in the version of SAGAPØ concerning hexagonal bundles, to evaluate the number NER(NS) of the adjacent channels for each channel NS and to identify these channels by means of the matrix NIS(NS,M) (NIS(NS,1) = index of the first channel adjacent to channel NS, ..., NIS(NS, NER(NS)) = index of the last channel adjacent to channel NS). CØNNIJ is called by INDEX, which prepares also some input parameters for the procedure of CØNNIJ. The procedures used in CØNNIJ are partly derived by the HERA-1A code of Nijsing and Eifler /10/.

Arguments:

NSTR = number of the central channels

NSTØT = total number of channels

NRØMA = number of the rows of rods (excluded the central rod)

NSEL = index to establish the portion of the whole bundle flow section which must be considered (see 3.1, 9th Card)

5.12 SUBRØUTINE CØRRTE

CØRRTE is used in the case of roughened rods and turbulent flow to correct the surface pin temperatures (computed integrating the logarithmic temperature profiles, i.e. corresponding to the case of infinite conductivity of the canning metal) to take into account the Biot effect (see 2.1.6 in /5/).

The Biot number (BIØT) is computed by means of(III.14) or (III.25) of /5/ depending on the value of the index IBIDE (see 3.3 , CØMMØN BLØCK/BIDE/). If there are no thermocouples or if the thermocouples are set at the outer surfaces of the pins, equation (III.19) of /5/ is used for the correction; if the thermocouples are set below the outer surfaces, (III.20) of /5/ is used (see RMISTW, 3.1, 3rd Card).

Furthermore the correction due to the temperature difference between tip and root of the ribs, in the case of roughened rods and laminar flow, is also made in CØRRTE (see 4.1 in /5/).

Finally CØRRTE organizes also the correction of the surface pin temperatures (for smooth and roughened rods, turbulent and laminar flow) to take into account the position of the thermocouples inside the canning. This correction is performed by means of the function TWCTEP.
CØRRTE is called by the main program.

Arguments:

TW	= pin temperature (input: not corrected value; output: corrected value) (^{o}C)
TB	= gas temperature (^{o}C)
PB	= average pressure for the axial section (kg/cm^2)
NS	= channel index
M	= subchannel index
I	= 0 for the subchannels
	= 1 for the wall portions of the wall subchannels and for sub-subchannel "1" of each subchannel (see note pag. 59)
	= 2 for the central portions of the wall subchannels and for sub-subchannel "N" of each subchannel (see note pag.59)
BIØT	= Biot number computed in CØRRTE
TWINF	= not corrected pin temperatures (=input TW value) (^{o}C)

5.13 FUNCTIØN CP

CP evaluates the coolant specific heat at constant pressure c_p (CP) as a function of the pressure and of the temperature ($[c_p]$ = cal/g °C; about CP see also 3.5)

Arguments:

P = pressure (kg/cm²)
T = temperature (°C)

5.14 SUBRØUTINE CRFL1

CRFL1 evaluates the cross-flow rates W^{CF} at each iteration of the loop ITGL, for the calculation of the channels, of the subchannels and of the two portions of the wall subchannels (it is called by the subroutines BALA, SUBBAL and RECCA2). In CRFL1 the equations described in 1.7 of /5/ are applied.

Arguments:

ITGL = actual value of the iteration index in the convergence loop for the solution of the axial momentum equations ($^{(i)}$ in 1.7 of /5/)

DPJAV = average pressure loss at the preceeding iteration ($\Delta p_{av}^{(i-1)}$ in 1.7 of /5/) (kg/cm²)

FREL = actual value of the relaxation factor

AJT = area of the computed portion of the whole bundle flow section, for the channel calculation (cm²)
= flow area of containing channel, for the subchannel calculation (cm²)
= flow area of the containing wall subchannel,for the calculation in the two portions of the wall subchannels (cm²)

JMAX = total number of channels, for the channel calculation
= number of subchannels in the containing channel, for the subchannel calculation
= 2, for the calculation in the two portions of the wall subchannels

AJ(1)...AJ((JMAX)
= flow areas of the channels or of the subchannels, or of the two portions of a wall subchannel (cm^2)

MJ(1)...MJ(JMAX)
= mass flow rates at the inlet of the axial section, for the channels, or for the subchannels,or for the two portions of a wall subchannel (g/s)

DPJ(1)...DPJ(JMAX)
= pressure drops computed at the preceeding iteration ($\Delta p^{(i-1)}$in 1.7 of /5/), for the channels, or for the subchannels, or for the two portions of a wall subchannel (kg/cm^2)

WCFJ(1)...WCFJ(JMAX)
= cross-flow rates at the preceeding iteration, for the channels ($=W_c^{CF(i-1)}$,in 1.7 of /5/); modified cross-flow rates $\gamma^{CF(i-1)}$ for the subchannels or the two portions of the wall subchannels (see (I.53), (I.54) in /5/) (g/s cm)

WCFJ1(1)...WCFJ1(JMAX)
= cross-flow rates at two iterations before, for the channels ($=W_c^{CF(i-2)}$ in 1.7 of /5/); modified cross-flow rates $\gamma^{CF(i-2)}$, for the subchannels or the two portions of the wall subchannels (see (I.53), I.54) in /5/) (g/s cm)

EP1J(1)...EP1J(JMAX)
= difference ($\Delta p^{(i-2)} - \Delta p_{av}^{(i-2)}$) for the channels, or for the subchannels, or for the two portions of the wall subchannels (kg/cm^2)

5 .15 FUNCTIØN CSFUN

CSFUN computes the parameters c_s for the velocity profiles in the zones outside the $\tau = 0$ line (see (I.88)-(I.90) and (I.102) in /5/). c_s=CSFUN=1 in case of smooth rods /5/. For roughened rods the calculation is performed combining equations (55) and (56) of /11/ to (I.88) of /5/ (in the case of wall sub-subchannels and in the first calculation step for the corner sub-subchannels) or to (I.91) of /5/ (in the second calculation step for the corner sub-subchannels). CSFUN is called by the subroutine RECANG.

Arguments:

IRH	= index for the type of the rod surface (IRH=1 for smooth rods, IRH=2 for roughened rods)
REAI	= Reynolds number for the outer zone (i.e. outside the τ=0 line) of the sub-subchannel
SQ8LIA	= $\sqrt{8/\lambda_{ia}}$ (see 1.9.2 of /5/); the input value of this argument is corrected in CSFUN)
SQ8LIB	= $\sqrt{8/\lambda_{ib}}$ (see 1.9.2 of /5/)
GA	= 6.037 or=5.966 for the wall sub-subchannels and for the first calculation step of the corner sub-subchannels, in the case of smooth or roughened rods, respectively (see (I.88) in /5/)
	= G_{ai} for the second calculation step of the corner sub-subchannels (see (I.92) of /5/)

5 .16 SUBRØUTINE DDØNNE

DDØNNE is used in the case of axial sections where the rods are roughened and the flow is turbulent, to compute the gas temperatures of the two zones of the corner channels, of the wall portions of the wall subchannels and of the "wall-type" sub-subchannels, which are divided by the τ=0 line. It makes use of equations (II.16)-(II.18) of /5/. It is called by the subroutines RTRI and RECANG.

Arguments:

TWO	= $T^{\infty}_{WR\infty}$, surface pin temperature at infinite conductivity of the canning metal (^{o}C)
TBT	= bulk temperature for the whole corner channel, or for the whole wall portion of wall subchannel, or for the whole sub-subchannel (^{o}C)
GHPL	= $G(h^{+})$ parameter
RODR2	= r_o/r_2 *)
R1DR2	= r_1/r_2 *)
YDH	= $(r_o-r_1)/h_R$ *)
R2MROH	= $(r_2-r_o)/h_R$ *)
FF	= $\dot{Q}''_R/(\rho_B c_{P_B} u_b \sqrt{\frac{\lambda_b}{8}})$ *)
T2	= T_a, bulk temperature for the zone outside the τ=0 line (^{o}C)
T1	= T_b, bulk temperature for the zone inside the τ=0 line (^{o}C)
TE	= gas temperature at the bundle inlet (^{o}C)

5.17 FUNCTIØN DSPDPF

DSPDPF was introduced in SAGAPØ to evaluate the coefficients $K_D/2$ (for the whole bundle flow section, for the channels, for the subchannels and for the portions of wall subchannels), which take into account the pressure loss due to friction inside the spacers (see /1,2/). As the method proposed in /1,2/ for the evaluation of the K_D's has been later demonstrated to be not good enough (see 1.4 in /5/), in the present version of the SAGAPØ code the global coefficients K_{sp} are computed by means of (I.9) of /5/; **) thus the K_D's are obtained subtracting from the K_{sp}'s the terms referring to the local pressure losses at the inlet and at the outlet of the spacer (see function GRIFUN). This procedure is used to easily allow the reintroduction in DSPDPF of a better method for the calculation of the coefficients K_D. Obviously most of the arguments of DSPDPF are not used in the

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*) For the symbology see chapter 2 in /5/

**) $K_{sp} = C_v(Re)\varepsilon^2$, where ε is the blockage factor, Re the Reynolds number outside the spacer and $C_v(Re)$ is computed as:

C_v = ACVS1 + ACVS2/Re^{ACVS3} in the case of smooth axial sections

C_v = ACVR1 + ACVR2/Re^{ACVR3} in the case of roughened axial sections

(see 3.3, CØMMØN BLØCK/CVREH/), for the hexagonal bundles. For the 12-rod bundles the method proposed in /12/ is used.

present version of DSPDPF, because they are useful only for the method described in /1,2/.
DSPDPF is called by the main program and by the subroutines BALA, SUBBAL and RECCA2.

Arguments:

EPS	= ε, blockage factor
DE	= equivalent diameter outside the spacer (cm)
LAMBDA	= friction factor outside the spacer
WSP	= axial width of the spacers (cm)
PGDP	= ratio between the wetted perimeter inside the spacer and the wetted perimeter outside the spacer
RE	= Reynolds number outside the spacer.
ITYP	= type of the flow section (=1 for the central channels, =2 for the wall channels, = 3 for the corner channels, =4 for the whole bundle flow section)

5.18 FUNCTIØN EINF

EINF evaluates the fin efficiency E_∞ (=EINF; for the definition see (II.19) in /5/) as a function of the Biot number (see (III.14) and (III.25) in /5/). To allow an easy approximation of the available curves $E_\infty = E_\infty$ (Bi) for the 12-rod bundles (see 3.3 in /5/), E_∞ is computed as follows:

E_∞ = BI5 + BI6 * Bi + BI7 * Bi^2, if Bi $\leq$ BI4
E_∞ = BI8 + BI9 * Bi + BI10 * Bi^2, if Bi > BI4

The coefficients BI5,...,BI10 must be provided in BLØCK DATA (see 3.3, CØMMØN BLØCK/BIDAT1/). EINF is called by the subroutine CØRRTE.

Argument :

BIØT = Biot number (Bi)

5.19 SUBRØUTINE ENFRCØ

ENFRCØ is used for the laminar calculations if the simplified procedure described in 4.6 of /5/ is applied. In this case ENFRCØ evaluates the average γ_{EX} coefficient defined by (I.88) of /5/. Furthermore it corrects the previously computed friction factors $\lambda(\lambda=K\gamma/Re)$ of the corner and wall channels, of the wall subchannels and of both portions of the wall subchannels, to take into account that γ_{EX} has to be used instead of the real γ coefficients defined by the equations (IV.32) and (IV.36) of /5/. ENFRCØ is called by the subroutine BALA. All variables are provided to ENFRCØ in CØMMØN (no arguments).

5.20 SUBRØUTINE ENTRFR

ENTRFR is used in the case of laminar calculations to evaluate the coefficients γ which take into account the inlet effect on the friction factors. The γ-coefficients are computed at each axial section for all subchannnels and for the two portions of all wall subchannels with the equations described in 4.2.4-4.2.7 of /5/.
Furthermore ENTRFR corrects the fully-developed-flow friction factors of all subchannels and of the two portions of all wall subchannels (previously computed in the subroutines TRICA1, RECCA1 and ANGCA1) multiplying them by the corresponding γ-coefficients.
ENTRFR is called by the subroutines ANGCA1, RECCA1 and TRICA1.

Arguments:

K	= index of the axial section
I	= 1 for the corner channels, for the central channels and for the wall portions of the wall subchannels
	= 2 for the central portions of the wall subchannels
ITYP	= index for the identification of the type of channel (ITYP=1 for the central channels, ITYP=2 for the wall channels, ITYP=3 for the corner channels)

R1	= tip radius of the rods (cm)
RO	= radius of the maximum velocity line (cm)
R2	= inner radius of the outer wall for the annulus whose inner zone is equivalent to the inner zone of the subchannel or of the portion of wall subchannel (cm)
NS	= channel index
III	= NS-NSTR (NSTR= number of the central channels)
JJJ	= subchannel index
DE	= equivalent diameter (based on the volumetric diameter of the rods) (cm)
A	= flow area (based on the volumetric diameter of the rods) (cm)
M	= mass-flow rate (g/s)
P	= average pressure for the axial section (kg/cm^2)
TB	= bulk temperature (^oC)
LAMLAM	= laminar friction factor (in input it is the value corresponding to fully developed flow conditions, $\lambda = K/Re$; in output it is the corrected value, $\lambda = K\gamma/Re$)

5.21 FUNCTIØN ETA

ETA evaluates the dynamic viscosity η (ETA) of the coolant as a function of the pressure and of the temperature ($[\eta]$ = g/cm s; about ETA see also 3 .5)

Arguments:

P	= pressure (kg/cm^2)
T	= temperature (^oC)

5.22 FUNCTIØN EXPCL

EXPCL evaluates the expansion coefficient β_s (EXPCL) of the shroud metal for the correction of geometric parameters of the shroud (see (III.5) of /5/), as a function of the average shroud temperature T_s in each axial portion IPA (=TBPIPA(IPA), see 3.1, Cards 26 and 27). β_s is computed as:

$$\beta_s = EX4(IPA) + EX5(IPA) * T_s + EX6(IPA) * T_s^2$$

where IPA is the index of the axial portion and the coefficients EX4, EX5 and EX6 must be provided in BLØCK DATA (see 3.3, CØMMØN BLØCK/EXDAT1/). EXPCL is called by the main program.

Argument:

T = T_s = TBPIPA(IPA), input value for the average shroud temperature in the IPAth axial portion (^{o}C)

5.23 FUNCTIØN EXPCØ

EXPCØ evaluates the expansion coefficient of the steel β_m (EXPCØ) for the correction of the geometric parameters of the rods and of the spacers (see (III.5) of /5/), as a function of the average rod temperature TWTIPA(IPA), or as a function of the average gas temperature TBTIPA(IPA), in each axial portion IPA (see 3.1, Cards 25 and 26, see also 3.1.3 in /5/). β_m is computed as:

$$\beta_m = EX1(IPA) + EX2(IPA) * T + EX3(IPA) * T^2$$

where IPA is the index of the axial portion, T=TWTIPA or = TBTIPA and the coefficients EX1, EX2 and EX3 must be provided in BLØCK DATA (see 3.3, CØMMØN BLØCK/EXDAT/). EXPCØ is called by the main program.

Argument:

T = TWTIPA(IPA) (average pin temperature in the IPAth axial portion) or = TBTIPA(IPA) (average gas temperature in the IPAth axial portion) (^{o}C)

5.24 FUNCTIØN FKAPPA

FKAPPA evaluates the K=λRe values (FKAPPA) for the calculation of the friction factors of the corner channels and of the wall portions of the wall subchannels, in the case of fully developed laminar flow conditions. Equations (IV.7) and (VI.8) of /5/ are used in FKAPPA. FKAPPA is called by the subroutine SELAWA.

Argument:

R = r^*, defined by (IV.9) of /5/ in the case of corner channels and by (IV.10) of /5/ in the case of wall portions of wall subchannels.

5.25 FUNCTIØN FQDEV

FQDEV integrates the power profiles (for the rods and for the shroud) in each axial section. If the power profiles do not change in the axial section, FQDEV is called (by the main program) once for the rod profile and once for the shroud profile and the integration is carried out from the inlet of the axial section (x_1) to its outlet (x_2). If the profiles change in the axial section, FQDEV is called four times (the first two times the integrations are carried out from the inlet of the axial section (x_1) to the point where the profiles change (x_2), the second two times from the point where the profiles change (x_1) to the outlet of the axial section (x_2)).

FQDEV is computed as follows:

$$\text{FQDEV} = \int_{x_1}^{x_2} \left[\dot{Q}'_j(x)/\dot{Q}'_{Max}\right] dx = \int_{x_1}^{x_2} \left[\sum_{i=1}^{NQDC\emptyset} a_{ji} \, (x-x_{OIPA})^{i-1}\right] dx =$$

$$= \sum_{i=1}^{NQDC\emptyset} \frac{a_{ji}}{i} \left[(x_2-x_{OIPA})^i - (x_1-x_{OIPA})^i\right] =$$

$$= \sum_{i=1}^{NQDC\emptyset} \left(\frac{a_{ji}}{i\ \beta^i_{IPA}}\right) \left[(x^*_2 - x^*_{OIPA})^i - (x^*_1 - x^*_{OIPA})^i \right] \quad ^{*)}$$

where the β_{IPA}'s are the expansion coefficients (see functions EXPCØ and EXPCL), the lengths $(x-x_{OIPA})$ are the nominal distances from the inlet of the axial portion IPA, the lengths $(x^*-x^*_{OIPA})$ are the distances corrected to take into account the thermal expansion (see also 3.1, Card 34, and subroutine MØDFQD).

Arguments:

A(1)...A(N) = coefficients $\left(\frac{a_{ji}}{i\ \beta^i_{IPA}}\right)$ for the j th power profile of the rods or of the shroud (computed in the subroutine MØDFQD)

N = input value NQDCØ (see 3.1, Card 34)

X1 = $x^*_1-x^*_{OIPA}$ = distance from the inlet of the axial portion IPA to the point where the integration is started (i.e. to the inlet of the axial section, or to the point where the power profiles change; see above)

X2 = $x^*_2-x^*_{OIPA}$ = distance from the inlet of the axial portion IPA to the point where the integration is ended (i.e. to the outlet of the axial section or to the point where the power profiles change; see above)

---

*) This equation implies that the nominal total power is removed by the coolant in each axial portion (see 2.3)

5.26 FUNCTIØN GHPLUS

GHPLUS evaluates the parameter $G(h^+)$ (GHPLUS) with the method suggested by Dalle Donne /11/ (see also (III.9), (III.22), (III.23) in /5/). The $G(h^+)$ function is computed as: *)

$$G(h^+) = GHPL \cdot Pr^{A5} \cdot \left(\frac{T_{WR}^{\infty}}{T_B}\right)^{A6} \cdot \left(\frac{h_R}{A7 \cdot (r_2 - r_1)}\right)^{A8}$$

$$GHPL = \begin{cases} g_1 = A1 \cdot (h_{WR}^+)^{A2} + \dfrac{A3}{(h_{WR}^+)^{A4}} & , \text{ if } g_1 > A10 \\ A10 & , \text{ if } g_1 \leq A10 \end{cases}$$

The parameters A1,..., A10 must be provided in BLØCK DATA (see 3 .3, CØMMØN BLØCK/DAT1/). In the present version of the method of Dalle Donne /11/ it is A3 = 0 and A4 = 1.

Arguments:

HPLUSW	=	h_{WR}^+
TW	=	T_{WR}^{∞} - 273.16, surface pin temperature at infinite conductivity of the canning metal (°C)
TBT	=	T_B-273.16, bulk temperature (°C)
PR	=	Prandtl number
YDH	=	$(r_o-r_1)/h_R$
REW	=	Reynolds number (gas properties evaluated at the pin surface temperature)
R2MROH	=	$(r_2-r_o)/h_R$ (=0 for the central subchannels and for the central portion of the wall subchannels)

*) for the symbology see also chapter 3 of /5/

5 .27 FUNCTIØN GKAPPA

GKAPPA evaluates the $K = \lambda Re$ values (GKAPPA) for the calculation of the friction factors of the central subchannels and of the central portions of the wall subchannels, in the case of fully developed laminar flow conditions. Equations (IV.4) and(IV.5) of /5/ are used in GKAPPA. GKAPPA is called by the subroutine SELAWA.

Argument:

X = $\bar{X}$, defined by (IV.5) of /5/ in the case of the central subchannels and by (IV.11) of /5/ in the case of the central portions of wall subchannels.

5 . 28 FUNCTIØN GRIFUN

GRIFUN evaluates the coefficient $(K_I+K_O)/2$ (GRIFUN) for the local pressure losses at the inlet (K_I) and at the outlet (K_O) of the spacers (for the whole bundle flow section, for the channels, for the subchannels and for the two portions of the wall subchannels). The method which is used in the present version of SAGAPØ for the evaluation of K_I and K_O is described in /1,2/. GRIFUN is called by the main program.

Argument:

EPS = blockage factor.

5 . 29 FUNCTIØN GSTAR

GSTAR evaluates the parameters G_{iS}, G_{iR}, G_{biS}, G_{biR} (defined by the equations (I.73), (I.76), I.83), (I.85) of /5/) used in the sub-sub-channel calculations. GSTAR is called by the subroutines CEWACØ , TLINE, RECCA1.

Argument:

EPS = r_{oi}/r_1 (radius of the τ=0 line for the equivalent annulus/ volumetric radius of the rods)

5.30 SUBRØUTINE HEATI

Two different versions of HEATI are available: one is used for the calculation of hexagonal bundles and the other one for the calculation of the 12-rod bundles.
In the version concerning the hexagonal bundles HEATI evaluates, for each axial portion, the number of pins NPIN(NS) which are adjacent to each channel NS, the indices JPIN(NS,M) of the pins adjacent to each subchannel M of channel NS, the powers QSCH(NS,M) (QSCH(NS,M) = [maximum power per unit axial length removed from rod JPIN(NS,M) by the coolant flowing in subchannel M of channel NS] *[length of the axial portion]), the powers QQ(NS,M) (QQ(NS,M)=[total maximum power per unit axial length removed from rod JPIN(NS,M)] *[length of the axial portion]) and the powers QT(NS) (QT(NS) = [total maximum power per unit axial length removed by the coolant flowing in channel NS] *[length of the axial portion]). For all powers the dimensions are cal/s. The procedures used in this version of HEATI are partly derived from the HERA-1A code of Nijsing and Eifler /10/.

In the version of the SAGAPØ code which concerns the 12-rod bundles the vector NPIN and the matrix JPIN are provided in BLØCK DATA (see 3.4, CØMMØN BLØCK/HEA6/). Thus the structure of HEATI is here very simple: HEATI evaluates only the powers QSCH(NS,M), QQ(NS,M) and QT(NS). The subroutine HEATI is called by the main program.

Arguments:

NSTØT = total number of channels
NSTR = number of the central channels
NSEL = index to establish which portion of the whole bundle flow section must be considered (see 3.1, 9th Card)
NRØMA = number of the rows of rods (excluded the central rod, in the case of hexagonal bundles)
IPA = index of the axial portion

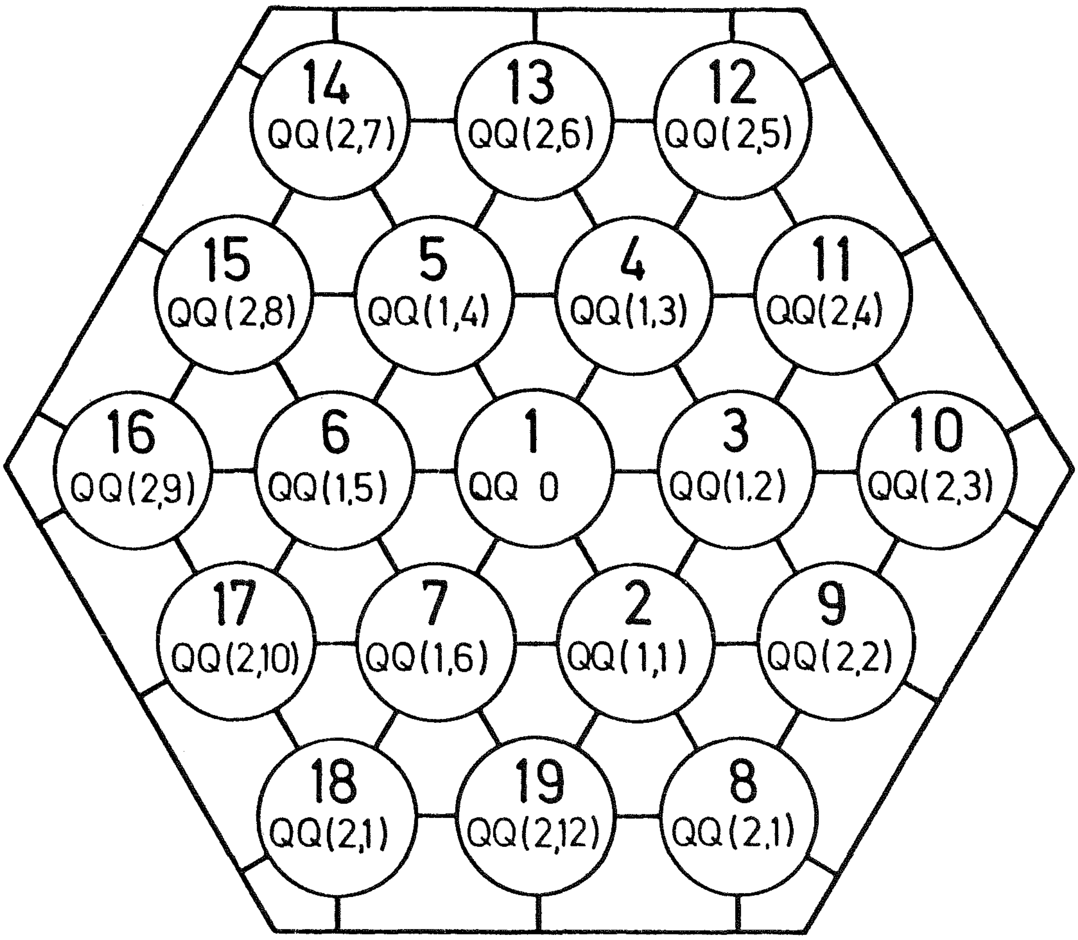

Fig. 16 Indexing of the rods in the subroutine HEATR

5.31 SUBRØUTINE HEATR

HEATR is used only in the version of the SAGAPØ-code concerning the calculation of hexagonal bundles. It is called by the subroutine HEATI. It provides indices to the rods and to the corresponding powers in a form which is useful for the indexing procedures used in HEATI (and derived from/10/) for the hexagonal bundles. The input indices I of each rod are each set equal to an element IDPIN(NRØ, NUM) of the matrix IDPIN (NRØ = index of the row of rods, which increases starting from the bundle center, being NRØ=0 for the central rod; NUM=index for the identification of each rod in the containing row NRØ). Similarly a matrix QQ is defined in HEATR, whose elements QQ(NRØ, NUM) are set equal to the input powers Q(I)= Q(IDPIN (NRØ, NUM)) at I > 1 (i.e. excluded the central rod). For the central rod the power QQO = Q(1) is defined in HEATR.

Note that Q(I) = [maximum power per unit axial length removed from rod I] *[length of the axial portion] (cal/s).

Fig. 16 will help to understand the identification procedure used in HEATR.

Argument:

NRØMA = number of the rows of rods (excluded the central rod).

5.32 SUBRØUTINE INDEX

Two different versions of INDEX are available: one is used for the calculation of hexagonal bundles and the other one for the calculation of the 12-rod bundles.

In the version concerning the hexagonal bundles INDEX defines the channel disposition(as shown by Fig. 1), defines the vectors NUMS and NRØW (NUMS(NS)= index which establishes the position of channel NS in the containing row of channels; NRØW(NS) = index of the row of channels containing channel NS), defines the matrix NØT (NØT (NRØ, NUM) = index NS of the channel contained in the row NRØ = NRØW(NS) at the position NUM = NUMS(NS)) and some other vectors useful for the calculations which must be performed in the subroutines CØNNIJ, HEATI, INQUA and INGE (see listing). Furthermore INDEX computes the total number of channels NSTØT, the number of central channels NSTR and the number of the rows of channels NRØ. Finally INDEX evaluates the type NTYP(NS) of each channel NS contained in the considered portion of the bundle flow section (NTYP(NS) is set equal to 1 for central channels, to 2 for wall channels and to 3 for corner channels). This version of INDEX is partly derived from /10/.

In the version concerning the 12-rod bundles INDEX is very simple because the vector NTYP is provided as input in BLØCK DATA (see 3 .4, CØMMØN BLØCK/IND3/) and because the definitions of NUMS, NRØW, NØT, etc. is not needed.*) In this version INDEX fixes only the values of NSTØT, NSTR and NRØ.

Arguments:

NSEL	= index to establish which portion of the whole bundle flow section must be considered (see 3 .1, 9th Card)
NRØMA	= number of the rows of rods (excluded the central rod, in the case of hexagonal bundles).
NSTR	= number of the central channels, computed in INDEX
NSTØT	= total number of channels, computed in INDEX
NRØ	= number of the rows of rods, computed in INDEX.

*) This is due to the modification of the subroutines INQUA, HEATI and INGE and due to the fact that the subroutine CØNNIJ is not used in the version of SAGAPØ concerning the 12-rod bundles (the vector NER and the matrix NIS are provided as input in BLØCK DATA; see 3.4, CØMMØN BLØCK /IJ1/).

5.33 SUBRØUTINE INGE

INGE evaluates the following geometric factors:

$$CTURB(I,M) = K_{CORR}\ G_{IK_M}\ I_{IK_M}\ D_{\overline{IK}_M} / 20\ \delta_{IK_M}$$

for the turbulent exchange between each channel I and each of the connected channels K_M (see (I.11) in /5/);

$$CC\O ND(I,M) = K_G\ G_{IK_M}\ /\ 2\ \delta_{IK_M}$$

for the enthalpy exchange due to the conduction in the gas between each channel I and each of the connected channels K_M (see (I.18) in /5/);

$$CTURB1(1) = I_{central} \left[G_{sc_1\ sc_2}\ D_{central}\ /\ 20\ \delta_{sc_1\ sc_2} \right]_{central}$$

for the turbulent exchange between the subchannels sc_1 and sc_2 of a central channel (see (I.44) in /5/) ;

$$CTURB1(2) = I_{wall} \left[G_{sc_1\ sc_2}\ D_{wall}\ /20\ \delta_{sc_1\ sc_2} \right]_{wall}$$

for the turbulent exchange between the subchannels sc_1 and sc_2 of a wall channel (see (I.44) in /5/) ;

$$CC\O ND1(1) = K_G \left[G_{sc_1\ sc_2}\ /\ 2\ \delta_{sc_1\ sc_2} \right]_{central}$$

for the enthalpy exchange due to conduction in the gas between the subchannels sc_1 and sc_2 of a central channel (see (I.18) in /5/);

$$CC\emptyset ND1(2) = K_G \left[G_{sc_1\ sc_2} / 2\ \delta_{sc_1\ sc_2} \right]_{wall}$$

for the enthalpy exchange due to conduction in the gas between the subchannels sc_1 and sc_2 of a wall channel (see (I.18) in /5/).

Two versions exist for the subroutine INGE: one is used for the calculation of the hexagonal bundles and the other one for the calculation of the 12-rod bundles. INGE is called by the main program.

Arguments:

NRØMA	= number of the rows of rods (excluded the central rod in the case of hexagonal bundles)
NSEL	= index which establishes which portion of the whole bundle flow section must be considered (see 3.1, 9th Card)
NSTR	= number of the central channels
NSTØT	= total number of the channels
C	= pitch of the rods (cm)
A	= distance between the centers of the external rods and the shroud (cm)
D	= volumetric diameter of the rods (cm)
ATC	= flow area of the <u>entire</u> central channels (cm^2)
ATW	= flow area of the <u>entire</u> wall channels (cm^2)
ATA	= flow area of the <u>entire</u> corner channels (cm^2)
PIG	= π = 3.141593
PCØRR	= input factor K_{CORR} (see (I.11) in /5/ and 3.1, 21st Card, in this work)
CTU1	= input factor I for the central subchannels (see (I.44) in /5/ and 3.1, 21st Card, in this work)
CTU2	= input factor I for the wall subchannels (see (I.44) in /5/ and 3.1, 21st Card, in this work)
DETC	= equivalent diameter of the central channels (cm)
DETW	= equivalent diameter of the wall channels (cm)
EM1	= (C-base of the blocking triangles)/2 (cm)

5 .34 SUBRØUTINE INLCØN

INLCØN establishes the mass-flow rates and the gas temperatures of the channels (MI, TEMP), of the subchannels (MSCH1, TSCH1) and of the two portions of the wall subchannels (MSCWC1, TSCWC1) *) at the point where the calculation is started. If the input value of IREAD1 (see 3.1, Card 13) is equal to 1, **uniform** mass-flow and gas-temperature distributions are assumed; if IREAD1 is equal to 2 the mass flow rates and the gas temperatures are read in INLCØN (see 3.2).

INLCØN initializes also the average mass flow rates (MSCH) and the average gas and pin temperatures (TSCH and TW) of the subchannels. INLCØN is called by the main program.

Arguments:

NSTØT	= total number of the channels
MFLØW	= mass-flow rate through the whole bundle flow section (g/s)
ATØT	= flow area of the whole bundle flow section (cm^2)
TE	= bulk temperature for the whole bundle flow section at the point where the calculation is started (^oC)
IREAD1	= index which establishes whether the mass-flow-rate and the gas-temperature distributions must be considered uniform or non-uniform at the point where the calculation is started (see 3.1, 13rd Card)
NSTR	= number of the central channels

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*) If uniform distributions are assumed, the mass-flow rates of the two portions of the wall subchannels are computed in the main program, after evaluating in RECCA1 the position of the line which divides the two portions.

5.35 SUBRØUTINE INQUA

INQUA computes the flow areas A(NS) of all channels NS into which the considered bundle symmetry section is subdivided and the flow areas ASCH(NS,M) of all subchannels M contained in each channel. Furthermore INQUA defines the vectór DE, whose elements DE(NS) are the equivalent diameters of the NSth channel. All geometric parameters computed in INQUA are based on the volumetric diameter of the rods.
Two versions of INQUA exist, one for the hexagonal bundles and one for the 12-rod bundles. INQUA is called by the main program.

Arguments:

NSEL	= index which establishes which portion of the whole bundle flow section must be considered (see 3.1, 9th Card)
NSTØT	= total number of the channels
NRØMA	= number of the rows of rods (excluded the central rod in the case of hexagonal bundles)
ATC	= flow area of the entire central channels (cm^2)
ATW	= flow area of the entire wall channels (cm^2)
ATA	= flow area of the entire corner channels (cm^2)
DETC	= equivalent diameter of the central channels (cm)
DETW	= equivalent diameter of the wall channels (cm)
DETA	= equivalent diameter of the corner channels (cm)

5.36 SUBRØUTINE KAPCØR

KAPCØR organizes the calculation of the laminar K = λRe-values for the channels in the case of IKAPPA = 1 (computation in subroutine SELAWA; see 3.3, CØMMØN BLØCK /WAKA1/). If IKAPPA = 2, KAPCØR saves the input K-values provided in BLØCK DATA. Furthermore KAPCØR corrects the K-values computed in SELAWA by means of equations (IV.85) - (IV.87) of /5/, if the simplified procedure described in 4.6 of /5/ has to be applied. KAPCØR is called by the main program.

NSTØT	= total number of the channels
NSTR	= number of the central channels

5.37 REAL FUNCTIØN KAPPA

KAPPA evaluates the coolant thermal conductivity k (KAPPA) as a function of the temperature ($[k]$ = cal/cm s^{o}C; about KAPPA see also 3.5).

Arguments:

P = pressure (kg/cm^2)

T = temperature (^{o}C)

5.38 REAL FUNCTIØN KINF

KINF evaluates the fin efficiency K_∞ (=KINF; for the definition see (II.20) in /5/) as a function of the Biot number (Bi).K_∞ is computed as follows:

$$K_\infty = BI1 + BI2 * Bi + BI3 * Bi^2$$

The coefficients BI1, BI2, BI3 must be provided in BLØCK DATA (see 3.3, CØMMØN BLØCK/BIDAT/). KINF is called by the subroutine CØRRTE.

Argument:

BIØT = Biot number

5.39 REAL FUNCTIØN KMET

KMET evaluates the thermal conductivity of the canning metal k_c (KMET) as a function of the canning temperature T_{WR} (^{o}C)($[k_c]$=cal/cm s ^{o}C, $[T_{WR}]$ =^{o}C). k_c is computed as follows:

k_c = D1(IPA) + D2(IPA) * T_{WR}

where IPA is the index of the axial portion and the coefficients D1, D2 must be provided for all axial portions in BLØCK DATA (see 3.3, CØMMØN BLØCK/DATKM/). KMET is called by the subroutine CØRRTE.

Argument:

TW = T_{WR}, canning temperature (^{o}C)

5.40 SUBRØUTINE MØDFQD

MØDFQD computes the coefficients A(I,J) = $a_{ij}/j\ \beta^{j}_{IPA}$ for a power profile "i" of the rods or of the shroud, each time that it is called by the main program (see also function FQDEV).

Arguments:

I = index of the power profile

NI = total number of the different power profiles (=NDPRQT in 3.1, Card 32)

NJ = number of the coefficients (=NQDCØ in 3.1, Card 34)

A(I,1)...A(I,NJ)
= coefficients $a_{i1}...a_{i\ NQDCØ}$ in input; coefficients $(a_{ij}/\beta_{IPA})...(a_{i\ NQDCØ}/NQDCØ * \beta^{NQDCØ}_{IPA})$ in output

EXF = β_{IPA}, average expansion coefficient for the axial portion IPA computed at the pin temperature TWTIPA(IPA) (see 3.1, 25th Card)

5.41 SUBRØUTINE NEWTØN

NEWTØN is used in the calculations of the laminar friction factors of the central subchannels and of the central portions of the wall subchannels to evaluate the outer radius r_{2A} of the annulus whose inner zone (i.e. inside the τ=0 line) is equivalent to the central subchannel or to the central portion of the wall subchannel. In NEWTØN equation (IV.37) of /5/ is solved iteratively, using the Newton method. NEWTØN is called by subroutine ENTRFR.

Arguments:

R0	= r_{OA}, radius of the τ=0 line (cm)
R1	= r_1, outer radius of the rods (tip radius in the case of roughened rods) (cm)
R2	= r_{2A} (see above) (cm)

5.42 SUBRØUTINE NØRMT

NØRMT normalizes the average gas temperatures TAV(NS) of the channels NS at each axial section, making use of (I.30) of /5/. With similar equations NØRMT normalizes also the average gas temperatures of the subchannels M of each channel NS (TSCH(NS,M)) and the average gas temperatures of both portions 1 and 2 of each wall subchannel M of each channel NS (TAVWC(NS-NSTR, M, 1), TAVWC(NS-NSTR, M, 2)) so that the average enthalpy in each channel is always equal to the summation of the average enthalpies in the contained subchannels and that the average enthalpy in each wall subchannel is always equal to the summation of the average enthalpies in its two portions. NØRMT is called by the main program.

Arguments:

NSTØT	= total number of the channels
NSTR	= number of the central channels
TBT	= average gas temperaturefor the whole bundle flow section, in the axial section (^{o}C)

ATØT = flow area of the whole bundle flow section (cm^2)

ASEC1 = flow area of the considered symmetry section of the whole bundle (cm^2)

MFLØW = mass-flow rate through the whole bundle (g/s)

5.43 SUBRØUTINE RECANG

RECANG performs the turbulent calculations for each "wall-type" sub-subchannel (i.e. for each of the sub-subchannels contained in the corner channels and in the wall portions of the wall subchannels). The equations described in 1.9.2. and in chapter 2 of /5/ are applied in RECANG (see flow chart, Fig. 17). RECANG is called by the subroutines RECCA1 and ANGCA1.

Arguments:

I = sub-subchannel index (integer form)

AI = sub-subchannel index (real form)

NS = channel index

K = index of the axial section

IVIA = index which establishes if the position of the τ=0 line must be computed (IVIA=1) or not (IVIA=2). IVIA=1 for most*) of the sub-subchannels contained in the wall portions of the wall subchannels and in the first step for the calculation of the corner sub-subchannels
IVIA=2 in the second step for the calculation of the corner sub-subchannels

IRH = index for the type of the rod surface (IRH=1 for smooth rods, IRH=2 for roughened rods)

ALFA = angle of the rod sector for sub-subchannel I

AMA1 = (inlet mass flow rate)/ (flow area) for the containing wall subchannel or for the containing corner channel (g/s cm^2)

TI = T_i; in input : assumed equal to the bulk temperature of sub-subchannel I-1 (if I=1 TI is the inlet average temperature - in the axial section of the containing wall portion of wall subchannel or of the containing corner channel); in output: bulk temperature T_i of sub-subchannel I (^oC)

*) see flow chart Fig. 17.

PB = average pressure for the Kth axial section (kg/cm^2)

D = volumetric diameter of the rods (cm)

W = distance between the centers of the external rods and the shroud + D/2 (cm)

RH = height of the roughness ribs (cm)

DETØT = equivalent diameter for the whole bundle flow section (cm)

PRØV = P_T (see (I.111) in /5/)

DAI = equivalent diameter of the outer zone of the sub-subchannel (i.e. outside the τ=0 line) (cm)

DBI = equivalent diameter of the inner zone of the sub-subchannel (i.e. inside the τ=0 line) (cm)

AAI = flow area of the outer zone of the sub-subchannel (cm^2)

ABI = flow area of the inner zone of the sub-subchannel (cm^2)

G = factors G_{biS} of G_{biR} defined by (I.83) or (I.85) of /5/.

SSSA = $A_{ai} \Big/ \sqrt{\dfrac{\lambda_{ai}\ \Delta x}{2D_{ai}\ \rho_{ai}}}$, computed in RECANG (see (I.66) and (I.94) of /5/)

SSSB = $A_{bi} \Big/ \sqrt{\dfrac{\lambda_{bi}\ \Delta x}{2D_{bi}\ \rho_{bi}}}$, computed in RECANG (see (I.66) and (I.95) of /5/)

AMTI = $\bar{\bar{m}}_{ti}$, total mass-flow rate in sub-subchannel I computed in RECANG (g/s)

NTYP = type of the containing channel (NTYP=2 for wall channels, NTYP = 3 for corner channels)

H1 = (length of the axial section)/(length of the containing axial portion)

H = length of the axial section (cm)

PR1 = inlet pressure for the axial section (kg/cm^2)

PR2 = outlet pressure for the axial section (kg/cm^2)

SQDPG = $\sqrt{|\Delta p|\, g_c}$

JJJ = index of the containing subchannel of channel NS

TE = gas temperature at the bundle inlet (^oC)

SUR = volumetric surface of a rod, for the whole axial portion (cm^2)

TW1 = in input: surface pin temperature for sub-subchannel I-1 at ITW1 = 1 (if I=1 TW1 is not defined in input); in output: surface pin temperature for sub-subchannel I at ITW1=1 (see also flow chart, Fig. 17)

AMAI	= $\bar{\dot{m}}_{ai}$ mass flow rate in the outer zone of the sub-subchannel, computed in RECANG (g/s)
TAI	= $\bar{T}_{ai}$, bulk temperature in the outer zone of the sub-subchannel, computed in RECANG (^{o}C)
AMBI	= $\bar{\dot{m}}_{bi}$, mass flow rate in the inner zone of the sub-subchannel, computed in RECANG (g/s)
TBI	= $\bar{T}_{bi}$, bulk temperature in the inner zone of the sub-sub-channel, computed in RECANG (^{o}C)
III	= NS-NSTR (NSTR = number of the central channels)
TIE	= inlet temperature (in the axial section) of the containing wall portion of wall subchannel or of the containing corner channel (^{o}C)
TIAV	= average temperature (in the axial section) of the containing wall portion of wall subchannel or of the containing corner channel (^{o}C)
HPLUSB	= h^{+}_{Bi} for the sub-subchannel
HPLUSW	= h^{+}_{iWR} for the sub-subchannel (see (I.86) in /5/)
ANGT	= $\sum_{L=1}^{I} ALFA_L$
EM1	= (pitch of the rods - base of the blocking triangle)/2 for sub-subchannels contained in wall subchannels (cm)
	= 0 for corner sub-subchannels
XC1	= 0 for the sub-subchannels contained in corner channels and in the zone of the wall portions of the wall subchannels where the sub-subchannels are defined by lines normal to the shroud walls (see Fig. 3b)
	= $1/\sqrt{3}$ for the sub-subchannels contained in the wall portions of the wall subchannels and defined by lines which are not normal to the shroud walls
XC2	= 1 if XC1 = 0
	= 2 * XC1 if XC1 = $1/\sqrt{3}$
*	= for RETURN 1, in the case of convergence problems
DEPA	= DETØT in the present version of SAGAPØ (it was the equivalent diameter of the containing corner channel or of the containing wall portion of wall subchannel in /1,2/; see 1.9.3 in /5/) (cm)

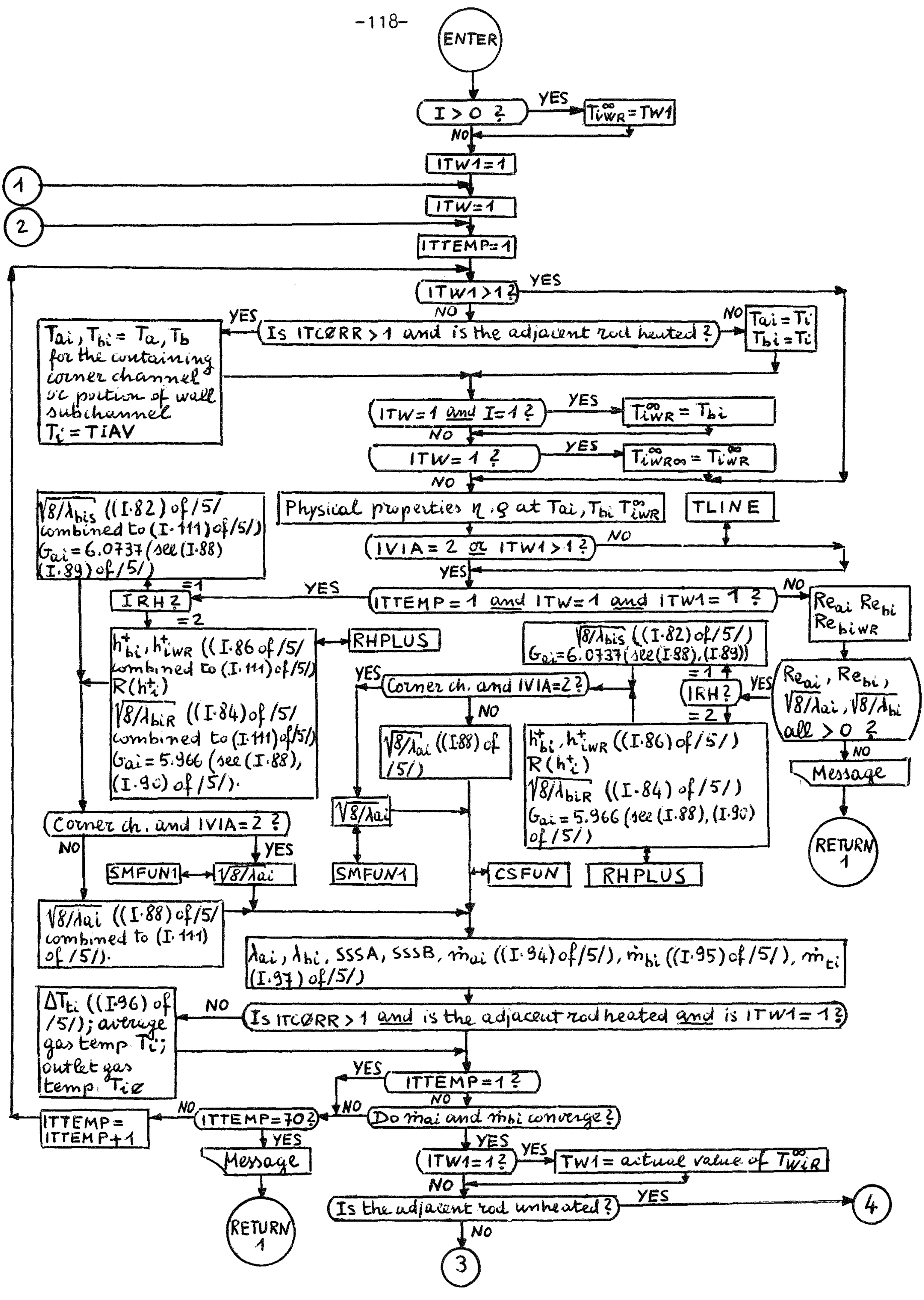

Fig. 17 Simplified flow chart for the subroutine RECANG. ITW1=iteration index for the convergence of the bulk temperature T_b of the inner zone
ITW=iteration index for the convergence of the surface pin temperature T^{∞}_{iWR}
ITTEMP=iteration index for the convergence of the mass-flow rates $\dot{m}_{ai}$ and $\dot{m}_{bi}$ of the tub zones divided by the τ=0 line

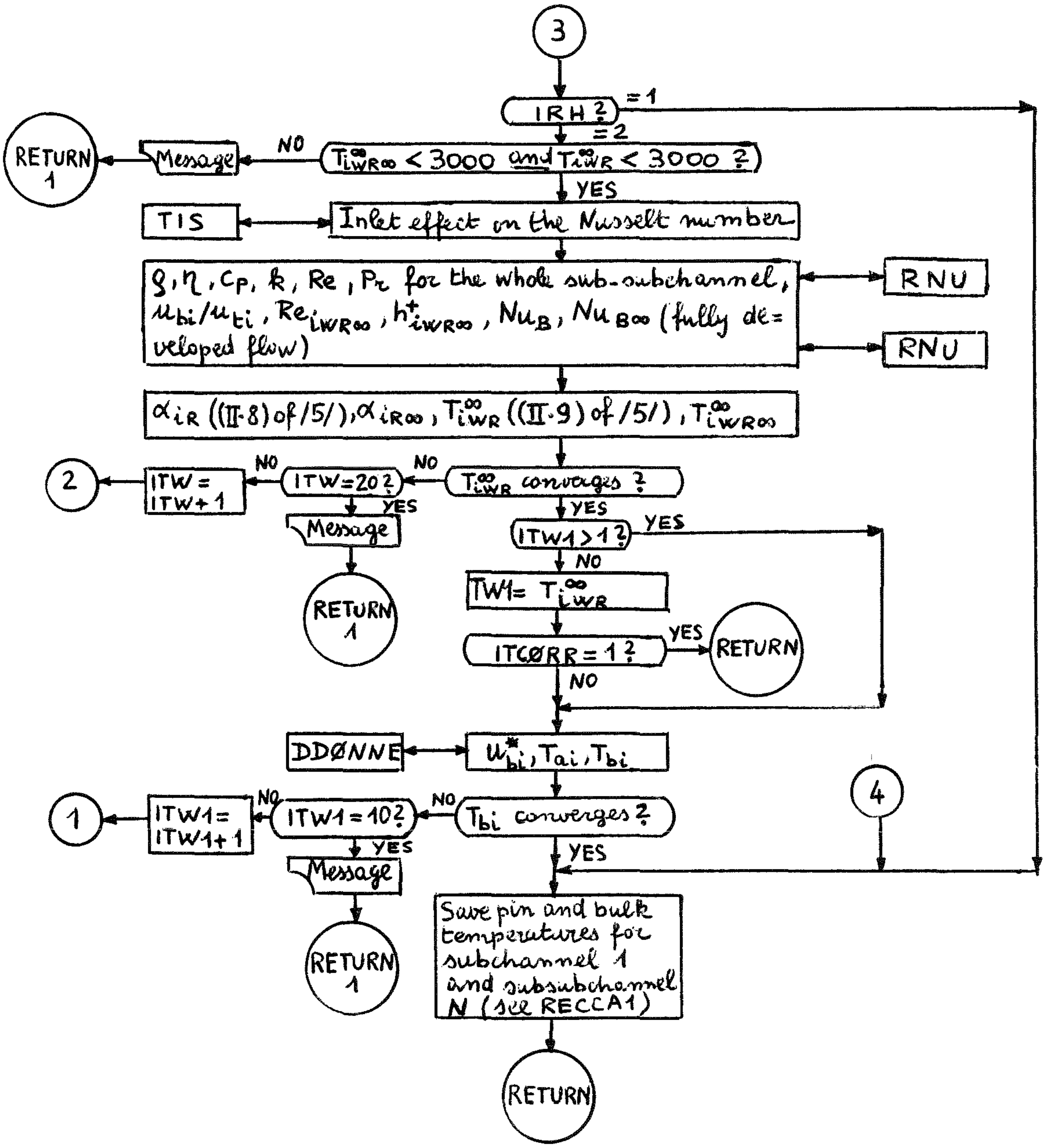

Fig.17 (continuation)

CS = in input: c_s value for sub-subchannel I-1 (if I=1 c_s=1);
in output: c_s value for sub-subchannel I (see (I.89),(I.90) in /5/ and function CSFUN is this work)

5.44 SUBRØUTINE RECCA1

RECCA1 organizes the sub-subchannel calculation for the wall subchannels (which is performed in the subroutine RECANG for the "wall-type" sub-subchannels and in the subroutine CEWA for the "central-type" sub-sub-channels). Furthermore it computes the friction factors LAMSCH for the whole wall subchannels, the friction factors LAMWC, the flow areas ASCHWC the equivalent diameters DEWC and the rod heated perimeters PHWC for both wall (1) and central (2) portions of the wall subchannels. These computations are performed both in the case of turbulent flow (see /5/,(I.66), (I.69) for the friction factors) as in the case of laminar flow (see /5/, (IV.3), (IV.4), (IV.7), (IV.10) - (IV.13), (IV.18) for the friction factors)*). In the case of turbulent flow RECCA1 evaluates also the friction factor LAMB and the equivalent diameter DETB for the inner zone of the wall portions, the mass-flow rates XMSCHA and XMSCHB for the outer and the inner zones of the wall portions, the ratios ADAB between the flow area of the whole wall portions and the flow area of the inner zone of the wall portions. Some average values of sub-sub-channel variables are finally computed in RECCA1 (see flow chart, Fig.18). RECCA1 is called by the main program.

Arguments:

K = index of the axial section

NS = channel index

N = number of the "wall-type" sub-subchannels in a rod sector of an angle of $\pi/2$

NSC45 = number of the "central-type" sub-subchannels in a rod sector of an angle of $\pi/4$ (Obviously the angles of the rod sectors for the central portions cannot be larger than $\pi/4$)

*) In the case of laminar calculations the friction factors of the two portions are set equal to the subchannel friction factor (see also SUBBAL and RECCA2)

IRH	= index for the type of the rod surface (IRH=1 for smooth rods, IRH=2 for roughened rods)
PRØV	= P_T (see (I.111) of /5/)
PB	= average pressure for the axial section (kg/cm^2)
RH	= height of the rougheness ribs (cm)
H1	= (length of the axial section) /(length of the containing axial portion)
ALFA	= $\frac{\pi/2}{N}$ = angle of the rod sector for each "wall-type" sub-subchannel of the wall subchannel
A(1)...A(NSC45)	= flow areas of the "central-type" sub-subchannels (cm^2)
DE(1)...DE(NSC45)	= equivalent diameters of the "central-type" sub-subchannels (cm)
MEC(1)... MEC(NSC45)	= mass-flow rates of the "central-type" sub-subchannels corresponding to an uniform mass distribution (g/s)
AT	= flow area of the wall subchannels (cm^2)
DET	= equivalent diameter of the wall subchannels (cm)
ATØT	= flow area for the whole bundle flow section (cm^2)
DETØT	= equivalent diameter for the whole bundle flow section (cm)
MFLØW	= mass-flow rate through the whole bundle flow section (g/s)
W	= distance between the centers of the external rods + volumetric radius of the rods (cm)
D	= volumetric diameter of the rods (cm)
C	= pitch of the rods (cm)
JJJ	= subchannel index
NSTR	= number of the central channels
H	= length of the axial section K (cm)
PR1	= inlet pressure for the axial section (kg/cm^2)
PR2	= outlet pressure for the axial section (kg/cm^2)
SQDPG	= $\sqrt{\lvert\Delta p\rvert g_c}$
TE	= gas temperature at the bundle inlet, average for the whole bundle flow section (^oC)
SUR	= volumetric surface of a rod, for the whole axial portion (cm^2)
AMT	= summation of the computed average mass flow rates of the sub-subchannels contained in the whole wall subchannel (g/s)
DDDD	= summation of the computed terms $\frac{A_{ti}}{\sqrt{\frac{\lambda_{ti}\ \Delta x}{2\ D_{ti}\ \rho_{ti}}}}$ (see (I.66) in /5/)

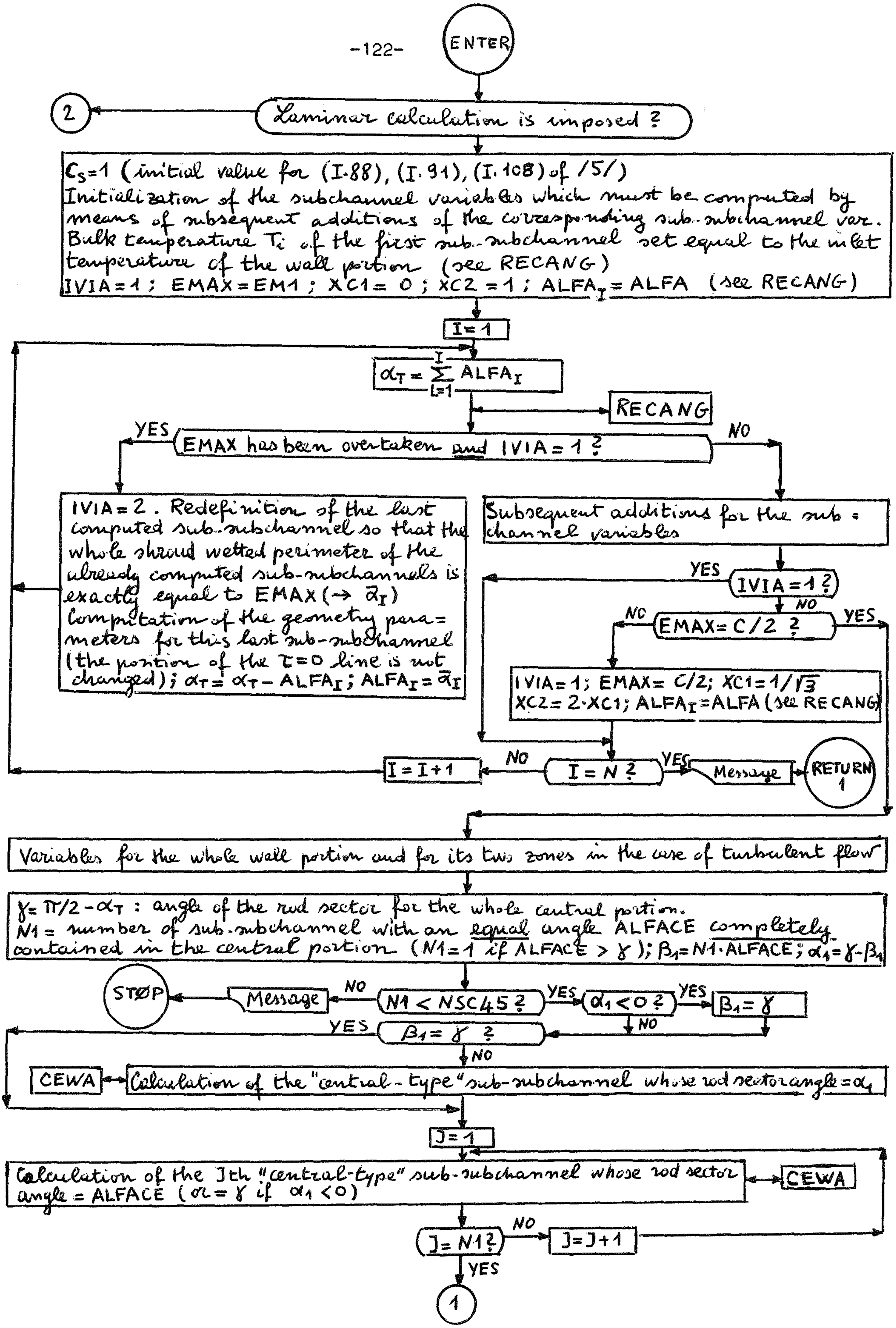

Fig. 18 Simplified flow-chart for subroutine RECCA1
I = index of the "wall-type" sub-subchannels
J = index of the "central-type" sub-subchannels

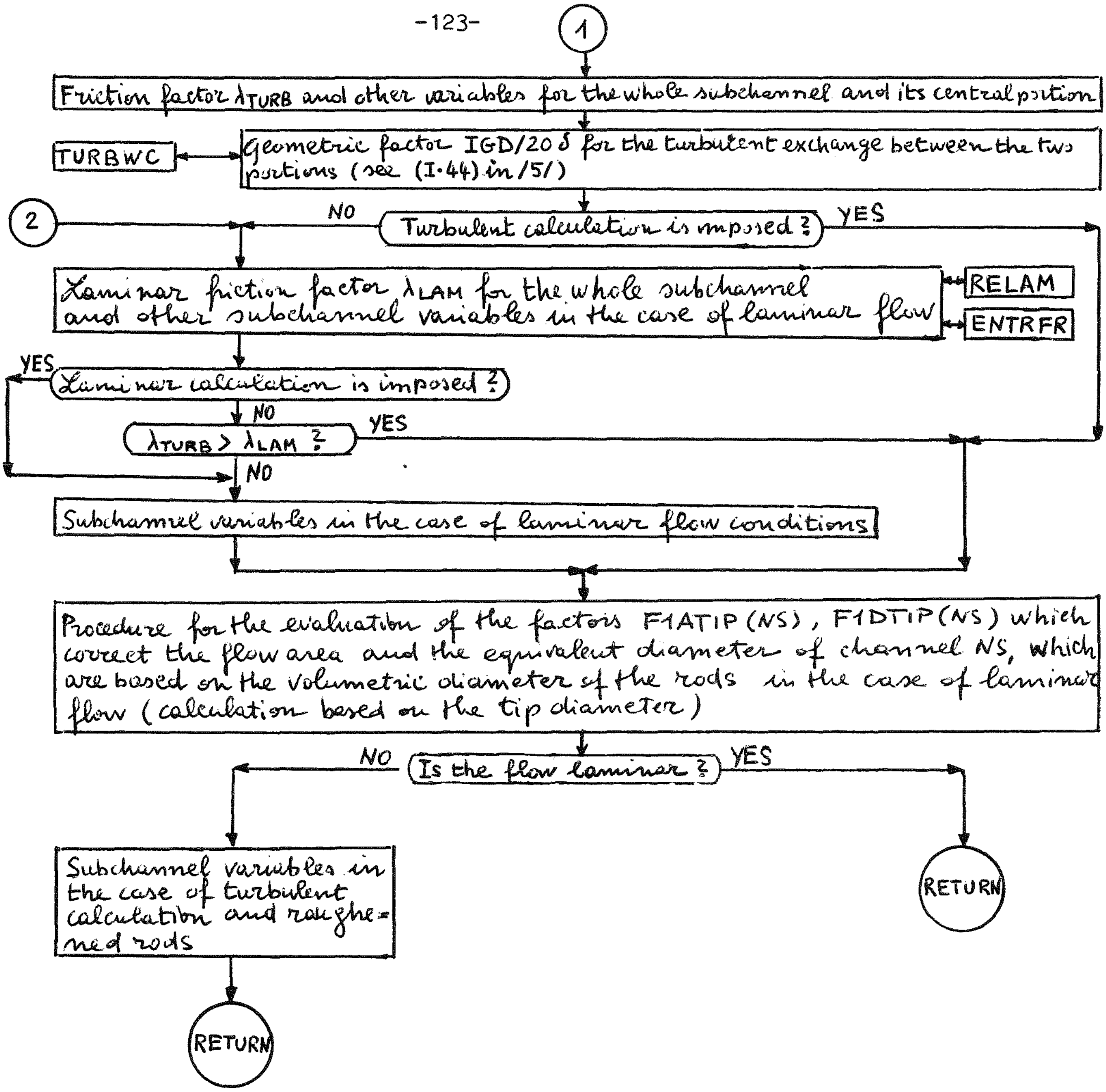

Fig. 18 (continuation)

ATSCH = bulk temperature of subchannel JJJ computed averaging the sub-subchannel bulk temperatures (^{o}C)

CTU3 = mixing factor for the turbulent exchange between the two portions of each wall subchannel (see 3.1, Card 21)

EM1 = (pitch of the rods-base of the blocking triangle)/2 (cm)

* = for RETURN1, in the case of convergence problems in the subroutine RECANG or in the subroutine CEWA (the axial section will be halved)

ALFACE = $\frac{\pi/4}{NSC45}$ = angle of the rod sector for each "central type" sub-subchannel

5.45 SUBRØUTINE RECCA2

RECCA2 computes the average mass flow rates MAWC and the average gas temperatures TAVWC and some other variables for both portions of each wall subchannel, at each axial section, in the case of turbulent flow in the wall subchannel (see 1.6 of /5/)
RECCA2 is called by the subroutine SUBBAL. *)

Arguments:

NS = channel index

III = NS-NSTR (NSTR=number of the central channels)

NP = number of the pins adjacent to the wall channel NS=number of the subchannels contained in the wall channel NS

INDSP = index for the presence of a spacer in the axial section (INDSP=1 : no spacers; INDSP=2 : there is a spacer)

H = length of the axial section (cm)

LENGTH = length of the axial portion containing the axial section (cm)

PR1 = inlet pressure for the axial section (kg/cm^2)

PR2 = outlet pressure for the axial section (kg/cm^2)

PBT = average pressure for the axial section (kg/cm^2)

FRELI = value of the relaxation factor at which convergence was

---

*) As the structure of RECCA2 is very similar to that of BALA, no flow chart is presented here for RECCA2.

reached in the previously performed calculation step of the wall subchannels of channel NS

FT = input factor f_T (see 3.1, 21st Card)

ITCØRR = actual value of the iteration index in the loop for the convergence of the whole bundle friction factor (see main program Fig.11)

PIG = π=3.141593

D = volumetric diameter of the rods (cm)

DPAV = average pressure loss for the channels (see subroutine BALA) (kg/cm^2)

* = for RETURN1, in the case of convergence problems

WSP = axial width of the spacers (cm)

I1SPAC = index of the first spacer which has been not yet overtaken by the calculation in the preceeding axial sections. *)

5.46 FUNCTIØN RELAM

RELAM computes the Reynolds numbers Re_x (=RELAM) to be used for the calculation of the subchannel friction factors in the case of laminar flow ($\lambda_{lam}=K/Re_x$, see (IV.3) in /5/; see also note pag.120 in this work). The temperature T_x (at which the gas properties are defined for the evaluation of Re_x) is set equal to the bulk temperature in the case of unheated sections and at ITCØRR=1 also in the case of heated sections. For heated sections at ITCØRR>1,T_x is set equal to the surface pin temperature in the case of central subchannels and it is computed by means of the function TNU in the case of corner channels and wall subchannels. RELAM is called by the subroutines TRICA1, RECCA1 and ANGCA1.

Arguments:

A = flow area of a half of the entire central channel or of a half of the entire corner channel or of a wall subchannel (area based on the tip diameter in the case of roughened rods) (cm^2)

---

*) I1SPAC=1 for the first spacer contained in the axial portion

D = equivalent diameter of the subchannel, based on the tip diameter in the case of roughened rods (cm)

TB = subchannel bulk temperature (^{o}C)

TW = subchannel pin temperature (^{o}C)

M = subchannel mass-flow rate (g/s)

TLINER = subchannel shroud temperature, in the case of corner and wall subchannels (^{o}C)
= 0, in the case of central subchannels

ITYP = index for the type of the subchannel (ITYP=1:central; ITYP=2 : wall; ITYP=3 : corner)

RIDR2L = (tip radius of the rods)/(inner radius of the outer wall of the annulus which is equivalent to the whole channel), for the corner channels
= (tip radius of the rods)/(inner radius of the outer wall of the annulus which is equivalent to the whole wall portion), for the wall subchannels
= 0 for the central subchannels.

PH1DPH = 1 for the central subchannels and for the corner channels
= (total wetted perimeter for the wall portion)/(total wetted perimeter for the whole subchannel), for the wall subchannels (the wetted perimeters are based on the tip diameter, in the case of roughened rod)

5.47 FUNCTIØN RHØ

RHØ evaluates the coolant density ρ(RHØ) as a function of the pressure and of the temperature ($[\rho] = g/cm^3$; about RHØ see also 3.5)

Arguments:

P = pressure (kg/cm^2)

T = temperature (^{o}C)

5.48 FUNCTIØN RHPLUS

RHPLUS evaluates the parameter $R(h^+)$ (RHPLUS) with the method suggested by Dalle Donne /11/ (see (III.8), (III.19) of /5/ and also 1.10 in /5/). The $R(h^+)$ function is evaluated as follows *):

$$R(h^+) = r = \left[B1 + \frac{B2}{(h^+)^{B3}}\right]^{B4} + B5 \cdot \ln\left(\frac{h_R}{B6(r_o - r_1)}\right) + \frac{B8}{(h^+)^{B9}} \cdot \left(\frac{T^{\infty}_{WR}}{T_b} - 1\right)^{B10}$$

(where $h^+ = h^+_{WR}$ in the case of heated roughened rods (IRHPL=1), $h^+ = h^+_b$ in the case of unheated roughened rods (IRHPL=2) **) <u>if</u>:

$$r \leq 5.5 + 2.5 \ln h^+_B$$

(see (I.115) in /5/). If this condition is not satisfied $R(h^+)$ is computed as:

$$R(h^+) = 5.5 + 2.5 \ln (h^+_B)$$

The parameters B1,..., B10 must be provided in BLØCK DATA (see 3.3, CØMMØN BLØCK/DAT2/). In the present version of the method of Dalle Donne / 11/ B4=1.

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*) For the symbology see also paragraph 1.10 and chapter 3, both in /5/.

**) The value of IRHPL is established in the main program. There IRHPL is set equal to 2 only at IPA=5 (at IPA=1,2,3,4,6,7 IRHPL=1); at IPA=3 this is not necessary because the pin temperatures are all set equal to the bulk temperatures of the adjacent subchannels.

Arguments:

HPLUSB = $h_b^+ = h^+$ value defined with the gas properties evaluated at the bulk temperature T_b of the subchannel zone which is inside the τ=0 line.

TW = T_{WR}^{∞} - 273.16, surface pin temperature at infinite conductivity of the canning metal (°C)

TE = bulk temperature for the whole bundle flow section at the bundle inlet (°C) *)

QPLUS = $\dot{Q}''A/(\dot{m}c_pT_E)$ (symbology see 4.4 in this work) *)

HPLUSW = $h_{WR}^+ = h^+$ value defined with the gas properties evaluated at the surface pin temperature corresponding to an infinite conductivity of the canning metal

TB1 = T_b - 273.16, bulk temperature of the subchannel inner zone (°C)

YDH = $(r_o - r_1)/h_R$

5.49 SUBRØUTINE RNU

RNU evaluates the turbulent Nusselt numbers for the sub-subchannels, for the corner channels, for the central subchannels and for both portions of the wall subchannels in the case of axial sections with roughened rods (Nu for unheated shroud walls). RNU makes use of equations (II.4) - (II.7) of /5/. RNU is called by the subroutines CEWA, RECANG and RTRI. **)

Arguments:

HPLUSW = $h_{WR}^+ = h^+$ value defined with the gas properties evaluated at the surface pin temperature T_{WR}^{∞} (or $T_{WR\infty}^{\infty}$)

TWI = surface pin temperature T_{WR}^{∞} (or $T_{WR\infty}^{\infty}$) at infinite conductivity of the canning metal (°C)

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*) These parameters are not used any more in the present version of the Dalle Donne method / 11/.

**) For the symbology see chapter 2 of /5/.

LAMIB = friction factor λ_b for the zone inside the τ=0 line

REI = Reynold number Re_B

PRI = Prandtl number Pr_B

TBT = bulk temperature T_B (^oC)

YDH = $(r_o-r_1)/h_R$

R1DR2 = r_1/r_2 in the case of "wall-type" sub-subchannels, or of corner channels, or of wall portions of wall subchannels
= r_1/r_o in the case of "central-type" sub-subchannels, or of central subchannels, or of central portions of wall subchannels

R2MRO = $(r_2-r_o)/h_R$ in the cases where R1DR2=r_1/r_2
= 0 in the cases where R1DR2=r_1/r_o

U1DU = u_b/u_B in the cases where R1DR2 = r_1/r_2
= 1 in the cases where R1DR2 = r_1/r_o

REW = Reynolds number defined with the gas properties evaluated at the surface pin temperature T_{WR}^{∞} (or $T_{WR\infty}^{\infty}$)

YYI = $Nu_B/Nu_{B\infty}$, factor which takes into account the effect of the spacers on the surface pin temperture (YYI=1 if the calculation of the surface pin temperatures corresponding to industurbed flow conditions is required) *)

NUI = Nusselt number Nu_B (or $Nu_{B\infty}$, if YYI=1), computed in RNU

GHPL = $G(h^+)$ factor, computed in RNU by means of function GHPLUS.

5.50 SUBRØUTINE RTRI

RTRI is called by the subroutine WALLTE, in the case of axial sections with roughened rods, for the calculation of the surface pin temperature TW1 (corresponding to an infinite conductivity of the canning metal) of a central subchannel, or of a corner channel, or of one of the two portions of a wall subchannel. If the flow in subchannel M of channel I must be considered as laminar at iteration ITCØRR (i.e. if I2TIP(I,M)=1,

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*) In this case TWI = $T_{WR\infty}^{\infty}$, otherwise TWI=T_{WR}^{∞}

see ANGCA1, RECCA1 and TRICA1), the subroutine TEMLAM is immediatly called by RTRI. *) Otherwise, the pin temperature TW1 is computed iteratively with the equations described in 2.1.2 - 2.1.5 of /5/,making use of the subroutine RNU. Together with the pin temperatures, in the case of a corner channel or of the wall portion of a wall subchannel, also the bulk temperatures TSCHA and TSCHB of the outer and of the inner zone are computed (making use of the subroutine DDØNNE) and the shroud temperature TLINER is evaluated. These temperatures TSCHA, TSCHB and TLINER(as the previously computed value of TW1) correspond to the real average bulk temperature and to zero heat flux from the shroud (see 2.1 in /5/). Then, if the h^+ value is such that the flow has to be considered as "hydraulically smooth" (but still turbulent; see (I.115) in /5/) the subroutine RTSI is called, where the calculation of TW1, TSCHA, TSCHB and TLINER is repeated using the equations described in 2.2 of /5/.**) Otherwise, if the flow is "rough", the subroutine TELIN is finally called, in the case of a corner channel or of the wall portion of a wall subchannel with heated shroud walls, to compute the real value of the temperature TLINER and to correct the computed surface rod temperature by means of the "superposition principle" (see 2.3 of /5/). About RTRI see also flow chart of Fig.19.

Arguments:

PBT	= average pressure for the axial section (kg/cm^2)
TBT	= average temperature T_B of the whole corner central subchannel or of the whole portion of wall subchannel (^oC)
MASSI	= average mass-flow rate of the whole corner or central subchannel, or of the whole portion of wall subchannel (g/s)
DE1	= equivalent diameter of the inner zone (cm)
AREAI	= flow-area of the whole corner or central subchannel, or of the whole portion of wall subchannel (cm^2)

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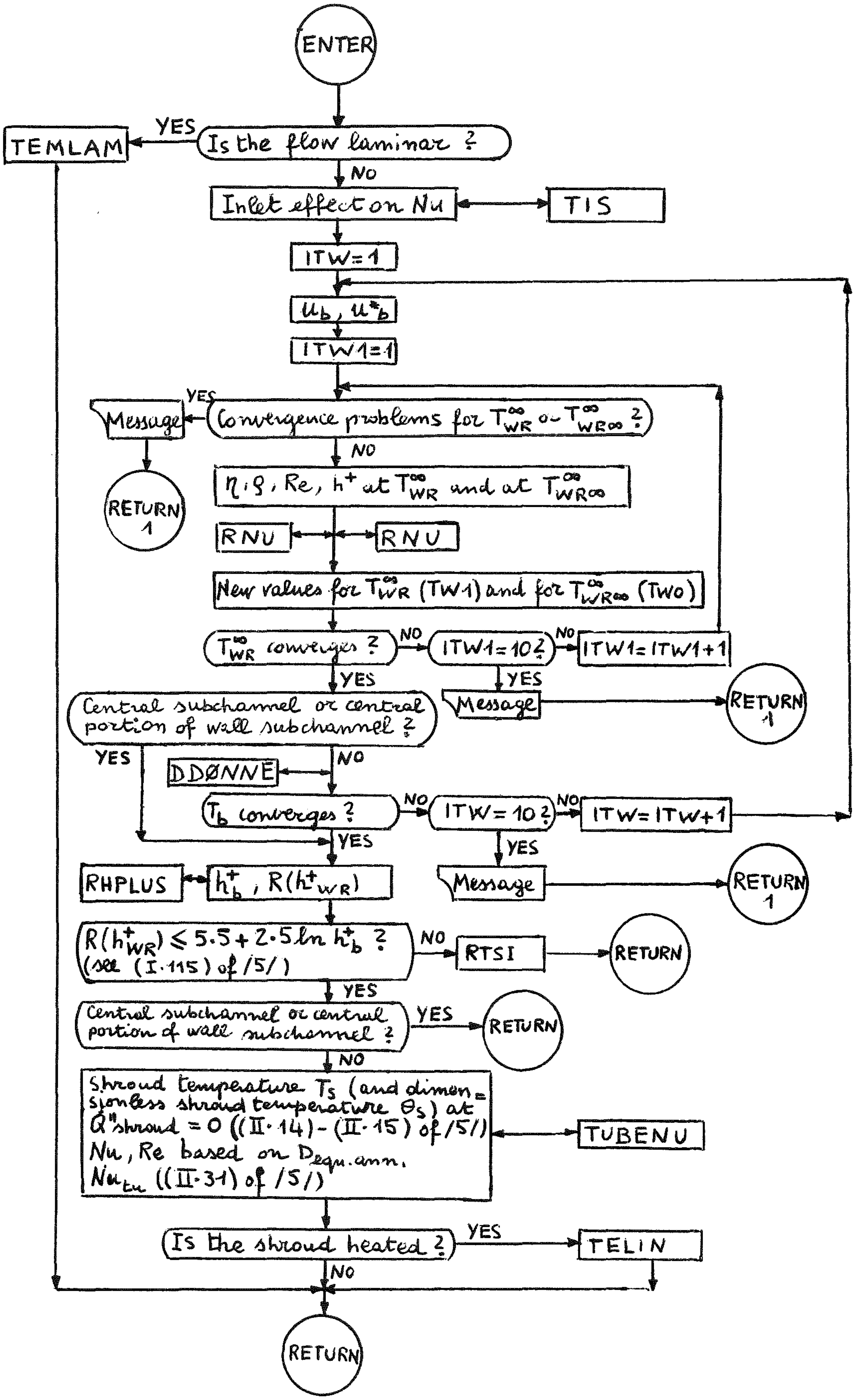
*) Coming back from TEMLAM, the calculation returns at the end of RTRI, by means of a statement RETURN1 (see Fig.19).

**) It must be pointed out, however,that the equations used in RTSI in the present version of SAGAPØ are not valid at low Reynolds numbers, such as those corresponding to "hydraulically smooth" flow (see 1.10 in /5/).

ADAB	= ratio between the flow area of the whole corner channel (or wall portion of wall subchannel) and its inner zone, in the case of corner channels or of wall portions of wall subchannels
	= 1, in the case of central subchannels or of central portions of wall subchannels
LAM1	= friction factor for the inner zone
YYI	= correction factor ($Nu_B/Nu_{B\infty}$) which takes into account the influence of the spacers on the Nusselt number
QA	= average heat flux per unit surface for the adjacent rod, in the axial section (cal/s cm^2)
FACHE	= correction factor which takes into account the inlet effect on the Nusselt number
TE	= bulk temperature for the whole bundle flow section at the bundle inlet (^oC)
RH	= height of the roughness ribs (cm)
I	= channel index
II	= I-NSTR (NSTR = number of the central channels)
M	= subchannel index
JPIN	= index of the pin which is adjacent to subchannel M of channel I
TW1	= surface pin temperature at infinite conductivity of the canning metal, computed in RTRI (^oC)
RU1DRU	= ($\rho_b u_b/\rho_B u_B$) for the corner channels and for the wall portions of the wall subchannels
	= 1 for the central subchannels and for the central portions of the wall subchannels
ITYP	= 1 for the central subchannels and for the central portions of the wall subchannels
	= 2 for the wall portions of the wall subchannels
	= 3 for the corner channels
DEI	= equivalent diameter for the whole corner channel, or for the central channel, or for the whole portion of wall subchannel (cm)
D	= volumetric diameter of the rods (cm)
YYDH	= $(r_2-r_1)/h_R$, for a corner channel and for the wall portion of a wall subchannel
	= $(r_o-r_1)/h_R$ for a central subchannel, or for the central portion of a wall subchannel



<u>Fig. 19</u> Simplified flow-chart for the subroutine RTRI
ITW1 =iteration index for the convergence of the surface pin temperature T^∞_{WR}
ITW =iteration index for the convergence of the bulk temperature T_b of the inner zone (for corner channels and for the wall portion of wall subchannels)

*	= for RETURN1, in the case of convergence problems
F2ATIP	= ratio between the whole flow area based on the tip diameter of the rods and that based on the volumetric diameter*)
F2DTIP	= ratio between the equivalent diameter based on the tip diameter of the rods and that based on the volumetric diameter *)

5.51 SUBRØUTINE RTSI

RTSI is called by the subroutine WALLTE in the case of axial sections with smooth rods and also by RTRI in the case of roughened rods but "hydraulically smooth flow" ; it performs the calculation of the surface pin temperature TWI (corresponding to an infinite conductivity of the canning metal) of a central subchannel, or of a corner channel, or of one of the two portions of a wall subchannel. As for RTRI,if the flow in subchannel M of channel I has to be considered as laminar at the iteration ITCØRR (i.e. if I2TIP (I,M) = 1, see ANGCA1, RECCA1 and TRICA1), the subroutine TEMLAM is immediately called.

Otherwise, the pin temperature TWI is computed iteratively with the equations described in 2.2.1, 2.2.2, 2.2.4 and 2.2.5 of /5/. Furthermore, in the case of a corner channel or of the wall portion of a wall subchannel, the bulk temperatures TSCHA and TSCHB of the outer and of the inner zone, together with the shroud temperature TLINER, are computed with the equations described in 2.2.1, 2.2.3 and 2.2.6 of /5/. These temperatures TSCHA, TSCHB and TLINER (as also the previously computed value of TWI) correspond to the real bulk temperature and to zero flux from the shroud (see 2.2 in /5/). If the shroud walls are heated, the subroutine TELIN is finally called (as in RTRI), to compute the real shroud temperature and to correct the surface pin temperature TWI (see flow chart, Fig.20).

*) =1 for the wall portion and for the central portion of the wall subchannels, because for them AREA and DEI are already based on the tip diameter of the rods (see RECCA1).

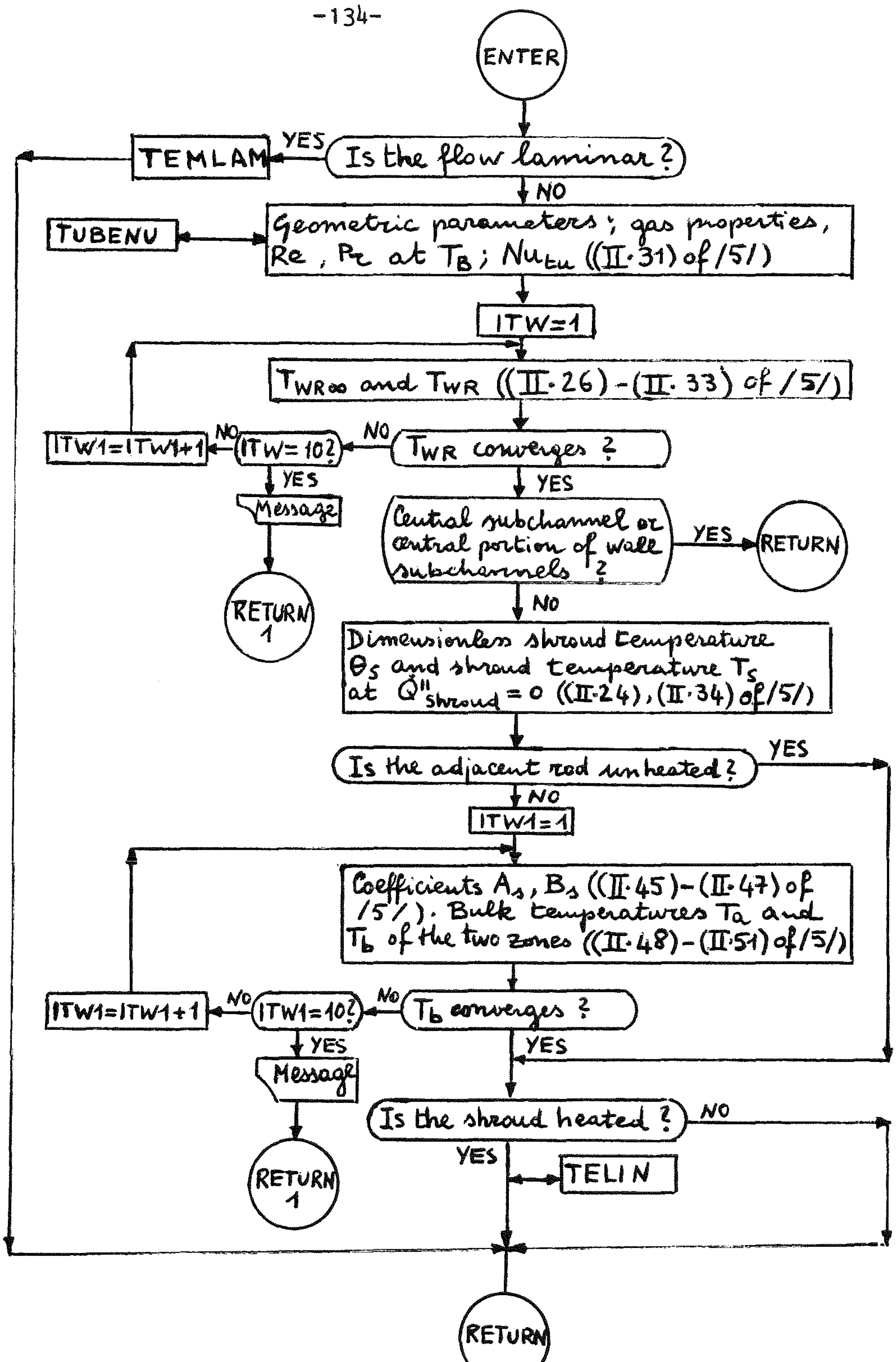


Fig.20 Simplified flow-chart for the subroutine RTSI
ITW=iteration index for the convergence of the surface pin temperature T_{WR}
ITW1=iteration index for the convergence of the bulk temperature T_b of the inner zone (for corner channels and for the wall portion of wall subchannels).

Arguments:

The arguments for RTRI are practically the same as for RTRI, thus they will not described here again. It must be only pointed out that the name for the surface pin temperature is TWI in RTSI (and not TW1), that the name for the whole equivalent diameter is DEIR (and not DEI, because in RTSI DEI is the equivalent diameter of the equivalent annulus) and that in RTSI the factor YYDH is not defined (argument XXXX in RTSI).

5.52 SUBRØUTINE SELAWA

SELAWA computes the laminar $K=\lambda Re_x$-values (see (IV.3) of /5/) for each axial portion IPA. The K-values for the central subchannels (BKAPPA (IPA, 1)) and for the central portion of the wall subchannel (AKAWC(2)) are computed by means of function GKAPPA, that for the corner channels (BKAPPA(IPA, 3)) and that for the wall portion of the wall subchannels (AKAW(1)) by means FKAPPA. The parameter β, which defines the position of the line dividing the two portions of the wall subchannels in the case of laminar flow (see 4.2.3 in /5/), is evaluated by means of the function BETAF. The K-value for the wall subchannels is finally evaluated in SELAWA by means of (IV.13) of /5/.

SELAWA is called by subroutine KAPCØR only if the value of the parameter IKAPPA (see BLØCK DATA, CØMMØN BLØCK/WAKA1/) is equal to 1. Otherwise the K-value provided in BLØCK DATA are saved (see subroutine KAPCØR).

The subroutine SELAWA has no arguments (all its parameters are provided in CØMMØN)

5.53 SUBRØUTINES SIMLA1 and SIMLA2

SIMLA1 and SIMLA2 *) are called by the subroutine TEMLAM in the case of laminar flow, if the simplified procedure for the calculation of the external channels (described in 4.6 of /5/) has to be applied. Equations (IV.89) - (IV.101) of /5/ are used in SIMLA1 and SIMLA2. SIMLA1 is called to correct the values of the pin and of the shroud temperatures corresponding to the real bulk temperature and to zero heat flux from the shroud; then, if the shroud is heated, the calculation enters from TEMLAM directly in the last part of SIMLA1, by means of the statement "ENTRY SIMLA2", and corrects the values of the pin and of the shroud temperatures corresponding to the real bulk temperature and to zero heat flux from the rod.**) ***)

Arguments for SIMLA1:

TE	= bulk temperature for the whole bundle flow section at the bundle inlet (^{o}C)
TI	= bulk temperature for the corner channel or for the wall portion of the wall subchannel (T^{*}_{Bi} in 4.6.3 of /5/) (^{o}C)
TWI	= surface pin temperature corresponding to TI and to $\dot{Q}''_{shroud}=0$ (in input: not corrected; in output: corrected) (^{o}C)
TLI	= shroud temperature corresponding to TI and to $\dot{Q}''_{shroud}=0$ (in input: not corrected; in output: corrected) (^{o}C)
NUI	= Nusselt number for the rod at $\dot{Q}''_{shroud}=0$ (in input: not corrected: in output: corrected)
TETAI	= dimensionless shroud temperature at $\dot{Q}''_{shroud}=0$ (in input: not corrected; in output: corrected)

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*) SIMLA2 is the name of the final part of SIMLA1.

**) Also in the case of the central portion of a wall subchannel, the calculation enters directly in SIMLA2, because all the necessary parameters which are computed in the first part of SIMLA1 are the same as those already computed for the wall portion.

***) Recently the option ISIMPL has been introcuded in SAGAPØ, which allows to apply the simplified procedure described in 4.6 of /5/ without correcting the Nusselt numbers and the dimensionless temperatures (case of ISIMPL$\neq$1) The value of ISIMPL must be provided in BLØCK DATA (CØMMØN BLØCK /SIMLAM/.

I = channel index

JJJ = subchannel index

TBEQ1 = temperature $\bar{T}_{BR}$ defined by (IV.95) of /5/ (^{o}C)

TBEQ2 = temperature $\bar{T}_{BS}$ defined by (IV.96) of /5/ (^{o}C)

II = I-NSTR (NSTR = number of the central channels)

Arguments for SIMLA2

TI = as for SIMLA1

TWI = as SIMLA1 *) or shroud temperature corresponding to TI and to $\dot{Q}''_{rod}$=0 (in input: not corrected; in output: corrected)**) (^{o}C)

TLI = as for SIMLA1 *) or surface pin temperature corresponding to TI and to $\dot{Q}''_{rod}$=0 (in input: not corrected; in output: corrected) **) (^{o}C)

NUI = as for SIMLA1*) or Nusselt number for the shroud, at $\dot{Q}''_{rod}$=0 (in input: not corrected; in output: corrected) **)

TETAI = as for SIMLA1*) or dimensionless surface rod temperature at $\dot{Q}''_{rod}$=0 (in input: not corrected; in output: corrected)**)

TBEQ1 = as for SIMLA1*) or temperature $\bar{T}_{BS}$ defined by (IV.96) of /5/ **) (^{o}C)

TBEQ2 = as for SIMLA1*) or temperature $\bar{T}_{BR}$ defined by (IV.95) of /5/**) (^{o}C)

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*) If SIMLA2 is called for the central portion of a wall subchannel the arguments have all the same meaning as for SIMLA1.

**) If SIMLA2 is called for the calculation of the pin and shroud temperatures corresponding to the real bulk temperature and to zero heat flux from the rods (but $\dot{Q}''_{shroud} \neq 0$), the arguments which referred to the rod in SIMLA1 refer now to the shroud and vice versa.

5.54 FUNCTIØN SMFUN1

SMFUN1 evaluates the coefficients $\sqrt{8/\lambda_{ai}}$ (SMFUN1) in the second calculation step for each sub-subchannel "i" of each corner channel (see subroutine RECANG; λ_{ai} = friction factor of the zone outside τ=0 line). SMFUN1 is called by the subroutine RECANG.

Arguments:

RHØI	= gas density ρ_{ai} for the outer zone (g/cm^3)
ETAI	= gas viscosity η_{ai} for the outer zone (g/cm s)
DETØT	= equivalent diameter for the whole bundle flow section (cm)
PRØV	= P_T (see (I.111) of /5/),in the present version of SAGAPØ.
I	= sub-subchannel index (=i)
KVIA	= 1 at the first iteration in RECANG (ITTEMP=1, ITW=1, ITW1=1)
	= 2 at the next iterations
REAI	= Reynolds number Re_{ai} for the outer zone of the sub-subchannel
DAI	= equivalent diameter for the outer zone of the sub-subchannel(cm)
SQ8LIA	= value of $\sqrt{8/\lambda_{ai}}$ at the preceeding iteration (at the first iteration,i.e. at KVIA=1,it is not defined)
RO	= radius of the τ=0 line for the annulus which is equivalent to sub-subchannel I
G	= parameter G_{ai} (see (I.92) in /5/ and flow chart for the subroutine RECANG, Fig.17)
CS	= parameter c_s (see (I.89) - (I.91) in /5/)

5.55 SUBRØUTINE SUBBAL

SUBBAL is used for the calculations of the subchannels. It computes the average mass flow rates MSCH, the average gas temperatures TSCH and some other varibales,which are partly needed for the calculations of RECCA2, i.e. the cross-flow rate WCFNS and the turbulent rates WTNS1 for the exchanges between subchannels of the same channel, the pressure losses DPNS, the terms PHII=ψ/A (see (I.81) of /5/), the terms SIGMAI=ξ/A (see (I.57) of /5/), the terms RUASN=ρu^*, etc. (see 1.6 of /5/).

The subroutine SUBCØN is called at the beginning of SUBBAL, to identify the connections between each subchannel I of each channel NS and the channels adjacent to subchannel I (see subroutine SUBCØN). At the end of SUBBAL, in the case of wall subchannel (i.e. NTYP(NS)=2), and if the flow has to be considered as turbulent in the wall channel (i.e. I2TIP(NS)=0) the subroutine RECCA2 is called, for the calculation in the two portions.
SUBBAL is called by the main program *) .

Arguments:

NSTØT	=	total number of the channels
NSTR	=	number of the central channels
INDSP	=	index for the presence of a spacer in the axial section (INDSP=1: no spacers; INDSP=2: there is a spacer)
H	=	length of the axial section (cm)
LENGTH	=	length of the axial portion (cm)
D	=	volumetric diameter of the rods (cm)
PIG	=	π=3.141593
PR1	=	inlet pressure for the axial section (kg/cm^2)
PR2	=	outlet pressure for the axial section (kg/cm^2)
PBT	=	average pressure for the axial section (kg/cm^2)
FREL	=	value of the relaxation factor at which convergence was reached in the previously performed calculation step for the channels (see flow-chart of subroutine BALA, Fig.14)
FT	=	input factor f_T (see 3.1, 21st Card)
ITCØRR	=	actual value of the iteration index in the loop for the convergence of the whole bundle friction factor (see main program , Fig.11)
DPAV	=	average pressure loss for the channels (see subroutine BALA)(kg/cm^2)

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*) As the calculation procedures used in SUBBAL are very similar to those of subroutine BALA, no flow-chart for SUBBAL will be presented in this work .

*	= for RETURN1, in the case of convergence problems
WSP	= axial width of the spacers (cm)
I1SPAC	= index of the first spacer which has been not yet overtaken by the calculation in the preceeding axial sections (I1SPAC=1 for the first spacer contained in the axial portion).

5.56 SUBRØUTINE SUBCØN

SUBCØN evaluates the number NCHC(I) of the channels which are adjacent to each subchannel I of each channel NS and identifies these channels by means of the matrix JCHC (JCHC(J,K)=index of the Mth channel J=NIS(NS,M) connected to channel NS*), which is the Kth channel adjacent to subchannel I); furthermore, by means of the matrix JSCH, SUBCØN identifies which subchannel II of the same channel NS is connected to the channel J together with I**) (JSCH(I,M)=index II of the subchannels which is adjacent to channel J together with I, for the Mth connection between channel NS and channel J). SUBCØN is called by the subroutine SUBBAL if channel NS is subdivided in more than 1 subchannel. Thus SUBCØN is never called for corner channels.

Arguments

NS	= index of the containing channel
NP	= number of the subchannels in channel NS (=number of the pins adjacent to channel NS)
NP1	= NP-1
NI	= number of the channels adjacent to channel NS.

---

*) J=NIS(NS,M) is the real index of this channel (see subroutine CØNNIJ)

**) A maximum number of two subchannels of a same channel are both connected to another channel J. If only subchannel I is adjacent to channel J, JSCH(I,M)=0 is established by SUBCØN.

5.57 SUBRØUTINE SUBDH

SUBDH halves the length of an axial section K, if in this axial section convergence problems have accured (see subroutines BALA, SUBBAL, RECCA2, RECANG, CEWA, RTRI, RTSI, TLINE, TAU). SUBDH increases by one the number N of the axial sections into which the axial portion was previously divided, rearranges the vector X (X(K)=distance from the point where the calculation is started to the inlet of the Kth axial section) and the tensor YY (YY (K, NS, M)= correction factor for the effect of the spacer grids on the Nusselt number of the Mth subchannel of channel NS, average for section K; see subroutine AXSEC)*). SUBDH is called by the main program.

Arguments:

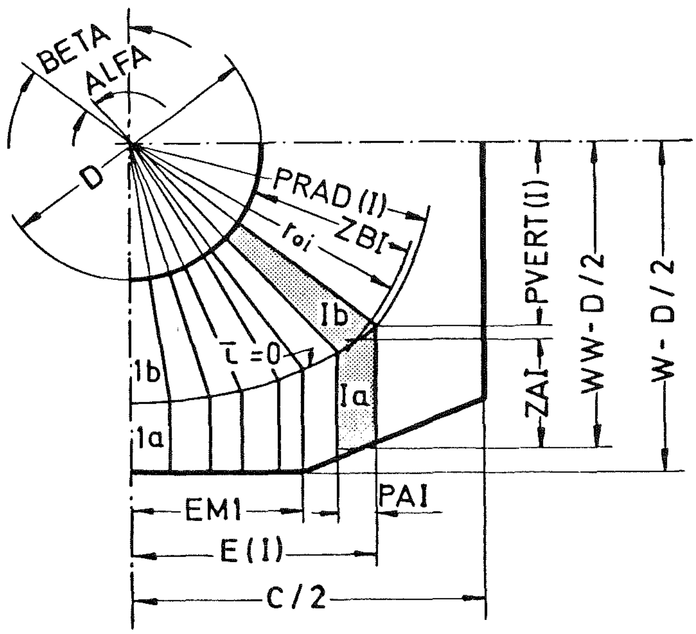
N	= number of the axial sections in the axial portion (in input: previous value; in output: input value increased by one)
K	= index of the axial section where convergence problems occur
K1	= set equal to K in SUBDH (at the beginning of an axial portion it is set = 1 in the main program, see flow chart, Fig.11)
NSTØT	= total number of the channels.

5.58 SUBRØUTINE TAU

TAU evaluates the values of the function F $(r_{oi}) = F_{ai} - F_{bi}$ (where F_{ai} (FO) and F_{bi} (F01) are defined by the equations (I.108) - (I.111) of /5/) at different values of the radius r_{oi} in the iterative procedure for the determination of the position of the τ=0 line for each "wall-type" sub-subchannel i. TAU is called by the subroutine TLINE, where the mentioned iterative procedure is organized.**) In TAU it is assumed that the

*) By halving an axial section the same YY values are assumed for the new two sections (i.e. the new real YY values are not computed, but their average value is used).

**) Convergence for this procedure is reached at the value of r_{oi} at which $F_{ai} = F_{bi}$, i.e. $F(r_{oi})=0$ (see subroutine TLINE).



τ=0 line is parallel to the shroud wall for sub-subchannel 1 (i.e. for the sub-subchannel which is at the gap between the containing corner channel- or wall portion of wall sub-channel - and its adjacent channel).

Fig.21 Geometric parameters for the "wall-type" sub-subchannels.

Arguments:

I	=	sub-subchannel index (integer form)
AI	=	sub-subchannel index (real form)
P	=	PVERT(I)/(0.5*volum.diam.of the rods) (see Fig.21)
ALFA	=	angle of the rod sector for sub-subchannel I
D	=	volumetric diameter of the rods (cm)
W	=	distance(at the gap)between the centers of the external rods and shroud + D/2 (cm)
RH	=	height of the roughness ribs (cm)
DET	=	equivalent diameter for the whole bundle flow section, in the present version of SAGAPØ(see 1.9.3 of /5/)(cm)
PRØV	=	P_T (defined by (I.111) of /5/), in the present version of SAGAPØ (see 1.9.3. of /5/)
IRH	=	index for the type of the rod surface (IRH=1 for smooth rods, IRH=2 for roughened rods)
DAI	=	value of the equivalent diameter for the outer zone of sub-subchannel I, corresponding to the actual value of r_{oi} and computed in TAU (cm)
DBI	=	value of the equivalent diameter for the inner zone of sub-subchannel I, corresponding to the actual value of r_{oi} and computed in TAU (cm)

PAI = value of the shroud heated perimeter for sub-subchannel I, corresponding to the actual value of r_{oi} and computed in TAU (cm)

F = $F_{ai}-F_{bi}$ (see above)

RHPL = $R(h^+)$ value for sub-subchannel I, computed in TAU in the case of roughened rods

TWI = surface pin temperature (^oC)

TE = bulk temperature for the whole bundle flow section at the bundle inlet (^oC)

ITTEMP = actual value of the iteration index **ITTEMP** (see flow-chart for subroutine RECANG, Fig.17)

QPLUS = $\dot{Q}''_R\ A_{bi}/\dot{m}_{bi}c_pT_E)$ (symbology see 4.4 in this work)

ETAA = gas viscosity η_{ai} for the outer zone of sub-subchannel I (g/cm s)

RHØA = gas density ρ_{ai} for the outer zone of sub-subchannel I (g/cm^3)

ETAB = gas viscosity η_{bi} for the inner zone of sub-subchannel I (g/cm s)

RHØB = gas density ρ_{bi} for the inner zone of sub-subchannel I (g/cm^3)

ETAIW = gas viscosity η_{iWR} computed at the surface pin temperature TWI (g/cm s)

RHØIW = gas density ρ_{iWR} computed at the surface pin temperature TWI (g/cm^3)

BETA = $\sum_{L=1}^{I} ALFA_L$

EM1 = (pitch of the rods - base of the blocking triangle)/2, for the wall sub-subchannels (cm)
= 0 for the corner sub-subchannels

XC1 = 0 for the sub-subchannels contained in the corner channels and in the zone of the wall portion of the wall subchannels where the sub-subchannels are defined by lines normal to the shroud walls (see Fig.21)
= $1/\sqrt{3}$ for the sub-subchannels contained in the wall portion of the wall subchannels and defined by lines which are not normal to the shroud walls(see Fig.21)

XC2 = 1 if XC1 = 0

	= 2 * XC1 if XC1 = $1/\sqrt{3}$
T1	= bulk temperature in the sub-subchannel inner zone (°C)
*	for RETURN1, in the case of convergence problems
CS	= c_s value for sub-subchannel I (see (I.89), (I.90), (I.108) in /5/).

5.59 FUNCTIØN TBFUN

TBFUN evaluates the mean shroud temperature (TBFUN) at each axial section.
TBFUN is called by the main program.

Arguments:

NSTR	= number of the central channels
NSTØT	= total number of the channels.

5.60 SUBRØUTINE TELIN

TELIN is called by the subroutines RTSI and RTRI in the case of turbulent flow and heated shroud walls. It computes the shroud Nusselt number NU2 and the dimensionless rod temperature TETA2 for the case of heated shroud and unheated rod, making use of equations (II.52)-(II.58) of /5/. Then, if the rod is heated, it applies the "superposition principle", to evaluate the Nusselt numbers and the surface temperatures of the rod and of the shroud, using equations (II.59)-(II.63) of /5/.

Arguments:

TW1	= surface pin temperature T_{WR} (at infinite conductivity of the canning metal for roughened rods) (°C)

TLINER = surface shroud temperature T_{WS} (^{o}C)

TI = bulk temperature T_B (^{o}C)

TE = bulk temperature for the whole bundle flow section at the bundle inlet (^{o}C)

TETA2 = dimensionless surface shroud temperature θ_{Sad}, corresponding to zero heat flux from the shroud walls

FTWA = dimensionless surface shroud temperature $\theta_{Sad\infty}$ corresponding to zero heat flux from the shroud walls and to fully developed flow conditions (see (II.34) of /5/)

QA = heat flux from the rod, $\dot{Q}''_R$ (average in the axial section) (cal/s cm^2)

QALIN = heat flux from the shroud, $\dot{Q}''_S$ (average in the axial section) (cal/s cm^2)

NU1 = Nussel number for the rod (in input,if the rod is heated: value corresponding to $\dot{Q}''_s = 0$ *); in output: real value defined by (II.59) of /5/)

NUTU = $Nu_{tu\infty}$, defined by (II.31) of /5/

A1 = ϕ(Pr), defined by (II.27) of /5/

KI = thermal conductivity of the gas, k (cal/s cm ^{o}C)

R1DR2 = ratio between the vol.rod radius and the inner radius of the outer wall for the equivalent annulus (=D_R/D_{2EQ}, see 2.2.2 of /5/).

DEI = equivalent diameter for the equivalent annulus, defined by (II.25) of /5/

I = channel index

JPIN = index of the pin which is adjacent to the subchannel

YYI = correction factor Y_{sp} for the Nusselt number, due to the spacer effect (see (II.10)-(II.12), (II.39)-(II.41) in /5/)

FACHE = correction factor Y_{Nu} for the Nusselt number, due to the inlet effect (see (II.35) - (II.37) of /5/)

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*) If the rod is unheated NU1 is not defined in input.

5.61 SUBRØUTINE TEMLAM

TEMLAM is called by the subroutines RTSI and RTRI in the case of laminar flow in a subchannel, to evaluate the surface pin and shroud temperatures, T_{W1} and TLINER *). The equations presented in 4.3 - 4.5 of /5/ are applied in TEMLAM. If the simplified procedure for the calculation of the external channels (described in 4.6 of /5/) has to be applied, the subroutines SIMLA1 and SIMLA2 are called by TEMLAM. About TEMLAM see flow-chart in Fig.22.

Arguments:

*	= for RETURN1 (TEMLAM returns at the end of RTRI or RTSI)
PBT	= average pressure for the axial section (kg/cm^2)
TI	= bulk temperature (^{o}C)
MASSI	= mass-flow rate (g/s)
DEIR	= equivalent diameter for the whole corner channel, or for the whole central subchannel, or for the wall portion of wall subchannel (cm)
AREAI	= flow area (cm^2)
QQ	= heat flux from the rods, $\dot{Q}''_R$ (cal/s cm^2)
QALIN	= heat flux from the shroud, $\dot{Q}''_S$ (cal/s cm^2)
TE	= bulk temperature for the whole bundle flow section at the bundle inlet (^{o}C)
I	= channel index
II	= I-NSTR (NSTR=number of the central channels)
M	= subchannel index
TW1	= surface pin temperature at the tip radius (^{o}C)
ITYP	= 1 for a central subchannel or for the central portion of a wall subchannel
	= 2 for the wall portion of a wall subchannel
	= 3 for a corner channel

*) In the case of roughened rods the computed rod temperature refers to the tip surface of the roughness ribs (see 4.1 of /5/).

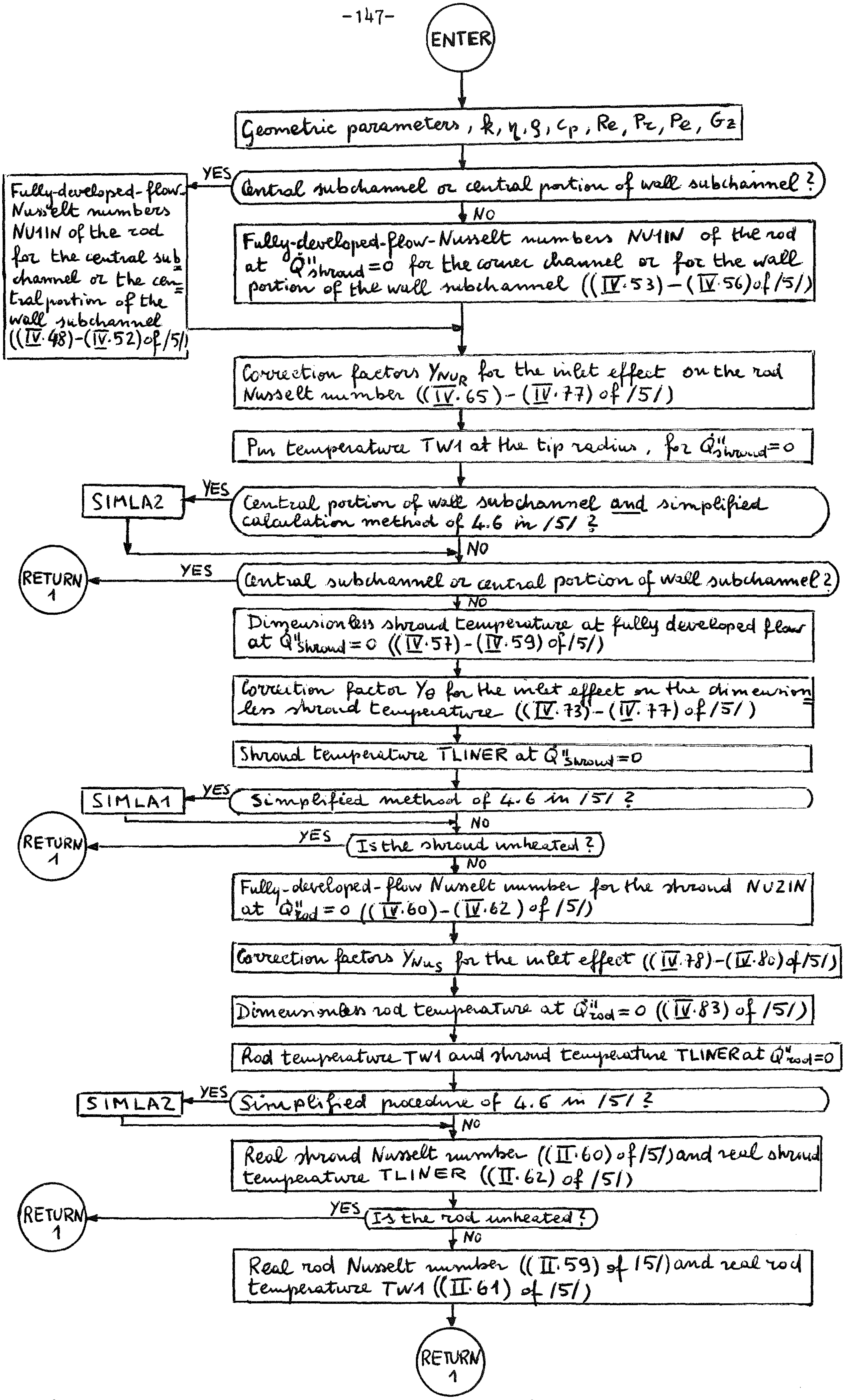

Fig. 22 Simplified flow-chart for the subroutine TEMLAM

F2ATIP = ratio between the flow area based on the tip diameter of the rods and the flow area based on the volumetric diameter (=1 for smooth rods) *)

F2DTIP = ratio between the equivalent diameter based on the tip diameter of the rods and the equivalent diameter based on the volumetric diameter (=1 for smooth rods) *)

DVØL = volumetric diameter of the rods (cm)

5.62 FUNCTIØN TIS

TIS evaluates the correction factor Y_{Nu}(TIS) for the Nusselt numbers due to the inlet effect, in the case of turbulent flow. For smooth rods equation (II.36) of /5/ is applied in TIS; as no correlation is available to take into account the inlet effect for roughened rods, in this case, TIS is set equal to 1 in the present version of SAGAPØ. The inlet effect for the shroud Nusselt number is finally taken into account by use of (II.55) of /5/. TIS is called by the subroutines RTRI, RTSI, CEWA and RECANG.

Arguments:

R1 = volumetric radius of the rods (cm)

R2 = inner radius of the outer wall for the equivalent annulus (=R1+D_{EQA}/2, see (II.25) in /5/)

INU = 1 for the calculations of Y_{Nu} for smooth rods
= 2 for the calculation of Y_{Nu_R} for roughened rods
= 3 for the calculation of Y_{Nu_S} for the shroud

*) =1 for the wall portion and for the central portion of the wall subchannels also in the case of roughened rods, because for them the flow area AREAI and the equivalent diameter DEIR are already based on the tip diameter of the rods (see RECCA1).

5.63 SUBRØUTINE TLINE

TLINE is called by the subroutine RECANG to determine the position (r_{oi}) of the τ=0 line for each sub-subchannel "i" contained in the wall portion of the wall subchannels or contained in the corner channels (for these only in the first calculation step, see RECANG). Together with the position of the τ=0 line, TLINE evaluates also the flow areas AAI and ABI for the outer and for the inner zone of the sub-subchannel, the rod wetted perimeter PBI and, by means of the function GSTAR, the parameter G (=G_{biS} or G_{biR} in 1.9.2 of /5/). For the determination of the position of the τ=0 line, TLINE looks first for two consecutive values of r_{oi} at which the function $F(r_{oi}) = F_{ai}-F_{bi}$ *) has different signs. Then TLINE applies the tangent method, starting from these two points ($\bar{r}_{oi}$, $F(\bar{r}_{oi})$), to evaluate the "zero" of the function F. The values of the function F are all computed by calling the subroutine TAU. For the meaning of the geometric parameters see Fig.21, pag. 142.

Arguments:

I	= sub-subchannel index (integer form)
AI	= sub-subchannel index (real form)
ITTEMP	= actual value of the iteration index ITTEMP (see flow-chart for subroutine RECANG, Fig. 18)
NS	= channel index
K	= index of the axial section
ALFA	= angle of the rod sector for sub-subchannel I
D	= volumetric diameter of the rods (cm)
W	= distance between the centers of the external rods and the shroud + D/2 (cm)
RH	= height of the roughness ribs (cm)
DET	= equivalent diameter for the whole bundle flow section, in the present version of SAGAPØ (see 1.9.3. of /5/) (cm)

*) F_{ai} and F_{bi} are defined by equations (I-108)-(I.111) of /5/. The position of the τ=0 line is found if F_{ai}=F_{bi}, i.e. if F=0

PRØV	= P_T (defined by (I.111) of /5/), in the present version of SAGAPØ (see 1.9.3. of /5/)
IRH	= index for the type of the rod surface (IRH=1 for smooth rods, IRH=2 for roughened rods)
DAI	= equivalent diameter for the outer zone of sub-subchannel I (computed in TAU) (cm)
DBI	= equivalent diameter for the inner zone of sub-subchannel I (computed in TAU) (cm)
AAI	= flow area of the outer zone of sub-subchannel I (computed in TLINE) (cm^2)
ABI	= flow area of the inner zone of sub-subchannel I (computed in TLINE) (cm^2)
RHPL	= $R(h^+)$ value, computed in TAU
G	= coefficient G_{biS} or G_{biR} (defined by (I.83) of (I.85) of /5/, computed in TLINE)
TWI	= surface pin temperature (at infinite conductivity of the canning metal, in the case of roughened rods) (^oC)
TE	= bulk temperature for the whole bundle flow section at the bundle inlet (^oC)
QPLUS	= $\dot{Q}''_R A_{bi}/(\dot{m}_{bi}\ c_p\ T_E)$ (symbology see 4.4 in this work)
ETAA	= gas viscosity η_{ai} for the outer zone of sub-subchannel I (g/cm s)
RHØA	= gas density ρ_{ai} for the outer zone of sub-subchannel I (g/cm^3)
ETAB	= gas viscosity η_{bi} for the inner zone of sub-subchannel I (g/cm s)
RHØB	= gas density ρ_{bi} for the inner zone of sub-subchannel I (g/cm^3)
ETAIW	= gas viscosity η_{iWR} computed at the surface pin temperature TWI (g/cm s)
RHØIW	= gas density ρ_{iWR} computed at the surface pin temperature TWI (g/cm^3)
ANGT	= $\sum_{L=1}^{I} ALFA_L$ (=argument BETA for TAU)
EM1	= (pitch of the rods-base of the blocking triangle)/2, for wall sub-subchannels (cm)
	= 0 for corner sub-subchannels

XC1	= 0 for the sub-subchannels contained in the corner channels and in the zone of the wall portion of the wall subchannels where the sub-subchannels are defined by lines normal to the shroud walls (see Fig.21)
	= $1/\sqrt{3}$ for the sub-subchannels contained in the wall portion of the wall subchannels and defined by lines normal to the shroud walls (see Fig.21)
XC2	= 1 if XC1 = 0
	= 2 * XC1 if XC1 = $1/\sqrt{3}$
T1	= bulk temperature in the sub-subchannel inner zone (^{o}C)
*	= for RETURN1, in the case of convergence problems
CS	= $\acute{c}_s$ value for sub-subchannel I (see (I.89), (I.90) and (I.108) in /5/)

5.64 SUBRØUTINE TMCF

TMCF evaluates the average cross-flow temperatures $\bar{\bar{T}}^{CF}_{Cav}$ for each channel C. Subroutine CF1 is called by TMCF, where equation (I.27) of /5/ is used for the calculation of $\bar{\bar{T}}^{CF}_{Cav}$ in the present version of SAGAPØ (see also CF1). TMCF is called by the subroutine BALA.

Arguments:

I	= channel index
NI	= number of the channels which are adjacent to channel I
TT	= cross-flow temperature $\bar{\bar{T}}^{CF}_{Iav}$, for channel I
TØTM	= $(\bar{T}\bar{\dot{m}})^{CF}_{I}$ for channel I (see CF1) (^{o}C)
MAVI	= mass-flow rate for the entire channel I (i.e. not for its considered symmetry section) (^{o}C g/s)

5.65 FUNCTIØN TME

TME evaluates the turbulent rates per unit length w^T (TME) for the exchanges between channels, for the exchanges between subchannels, and for the exchanges between the two portions of each wall subchannel. Equation (I.11) of /5/ is used in the case of the channel calculation, equation (I.44) of /5/ in the case of the subchannel calculation and an equation similar to (I.44) of /5/ also for the calculation of the two portion of the wall subchannels. TME is called by the subroutines BALA, SUBBAL and RECCA2.

Arguments:

PBT	=	average pressure for the axial section (kg/cm^2)
M1	=	mass-flow rate for the considered entire channel, or subchannel, or portion of wall subchannel (let say 1) (g/s)
M2	=	mass-flow rate for the considered entire adjacent channel, or subchannel, or portion of subchannel (let say 2) (g/s)
T1	=	bulk temperature for 1 (^oC)
T2	=	bulk temperature for 2 (^oC)
LAM1	=	friction factor for 1
LAM2	=	friction factor for 2
A1	=	flow area for the entire 1
A2	=	flow area for the entire 2
CTURB	=	factor $K_{corr} \overline{G_{12}} \overline{I_{12}} D_{12}/20\ \delta_{12}$ if 1 and 2 are channels (see subroutine INGE)
	=	factor I (G_{12} D/20 δ_{12}), if 1 and 2 are subchannels (see subroutine INGE)
	=	factor I_{WC} (G_{WC} D/20 δ_{WC}) if 1 and 2 are the two portions of a wall subchannel (see function TURBWC)

5.66 SUBRØUTINE TMPUN

TMPUN punches the Cards which are necessary to start a new calculation step, if the actual calculation step stops because the allowed calculation time TIMEPU (see 3.1, Card (39 + 4 * NSPACT)) has been **elapsed** or because the end of the axial portion IPAEND has been reached (in the case of IPAEND<7 in input, see 3.1, Card 13; see also flow-chart for the main program, Fig. 11). The variables whose values are punched have been already described in paragraph 4.6.2. TMPUN is called by the main program.

Arguments:

NSTØT	= total number of the channels
NSTR	= number of the central channels
TE	= outlet bulk temperature for the whole bundle flow section at the axial section at which the calculation has to be stopped (°C)
PE	= outlet pressure,for the axial section at which the calculation has to be stopped (kg/cm²)
PEBAR	= outlet pressure,for the axial section at which the calculation has to be stopped (bar)
TE1	= bulk temperature for the flow bundle flow section at the bundle inlet (°C)
PE1	= pressure at the bundle inlet (kg/cm²)
PE1BAR	= pressure at the bundle inlet (bar)
INDPR	= 1 if the pressure values have to be punched and read in kg/cm² *)
	= 2 if the pressure values have to be punched and read in bar *)
MFLØW	= mass-flow rate through the whole bundle flow section (g/s)
IPAST	= index of the axial portion at which the calculation stops, i.e. index of the axial portion at which the new calculation step must start
IPAEND	= input value of Card 13 (see 3 .1) for the axial portion at which the calculation must end. **)

*) It is the input value of INDPR for the performed calculation (see 3.1, Card 15)

**) see note pag. 70.

IREAD1 = 2, in order to read non-uniform mass-flow and gas-temperature distributions in the next calculation step (see 3.1 Card 13)

XLAM1(1)...XLAM1(7)
= input values for the whole bundle friction factors of Cards 10 and 11 , see 3.1)

STLEN = distance from the bundle inlet to the end point of the axial section at which the calculation has to be stopped,(cm)

* = for RETURN1 (TMPUN returns at the end of the main program)

5.67 FUNCTIØN TNU

TNU is used in the case of laminar calculations (it is called by the function RELAM). It evaluates (for the corner channels and for the wall subchannels) the value of the temperature T_x (TNU), at which the gas properties must be computed for the definition of the Reynolds number Re_x, and, consequently, for the evaluation of the friction factor $\lambda=K/Re_x$ (see (IV.3) of /5/). In the last version of the SAGAPØ code, the temperature T_x for the corner channels and for the wall subchannels is computed as the average of the pin and of shroud surface temperatures weighted by means of the corresponding wetted perimeters, according to the last results of calculations and measurements performed in the INR for annular flow sections /13/. Thus, the method suggested in /5/ is not used any more.

Arguments:

TW = surface pin temperature for the subchannel (^oC)

TL = surface shroud temperature for the subchannel (^oC)

ITYP = type of the subchannel (ITYP=2: wall; ITYP=3: corner)

PERL = shroud wetted perimeter for the subchannel (cm)

PIG = π = 3.141593

RTIP = tip radius of the rods (=outer radius in the case of smooth rods) (cm)

5.68 SUBRØUTINE TØTGEO

Two versions of TØTGEØ are available: one is used for the calculations of hexagonal bundles, the other one for the 12-rod bundles. In both versions TØTGEO evaluates the geometric parameters for the whole bundle flow section and for the three types of channels, i.e., mainly:

- the flow area for the whole bundle flow section, ATØT
- the flow area for the considered bundle symmetry section, ASEC
- the equivalent diameter for the whole bundle flow section, DETØT
- the wetted perimeter for the whole bundle flow section, PERLT
- the flow area ATC=ACH(1) for the entire channel*), the flow area AAC=ACT/6, the equivalent diameter DETC and the shroud wetted perimeter PERL(1) (obviously set =0),for the central channels
- the flow area ATW=ACH(2) for the entire channel *), the flow area AAW=ATW/2, the equivalent diameter DETW and the shroud wetted perimeter PERL(2) for the wall channels.
- the flow area ATA=ACH(3) for the entire channel *), the flow area AAA= ATA/2, the equivalent diameter DETA and the shroud wetted perimeter PERL(3) for the corner channels.
- the ratios FATIP(1), FATIP(2), FATIP(3) between the flow areas based on the tip diameter of the rods and the flow areas based on the volumetric diameter of the rods (1=central; 2=wall; 3=corner) **)
- the ratios FDTIP(1), FDTIP(2), FDTIP(3) between the equivalent diameters based on the tip diameter of the rods and the equivalent diameters based on the volumetric diameter of the rods (1= central; 2=wall; 3= corner)**)

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*) "entire channel" means the channel which is defined dividing the whole bundle flow section (and not a symmetry section of it)

**) Obviously these parameters are equal to 1 in the case of smooth rods

TØTGEØ is called by the main program, at each axial portion IPA.

Arguments:

NSEL	= index defining which portion of the whole bundle flow section must be considered (see 3.1, 9th Card)
D	= volumetric diameter of the rods (cm)
C	= pitch of the rods (cm)
Z	= distance between the centers of the external rods and the shroud, in the wall channels (cm)
PIG	= π = 3.141593
NEXCØN	= number of the rows of the rods (excluded the central rod, in the case of hexagonal bundles)
NRØDS	= number of the rods, for the whole bundle
W	= Z + D/2 (computed in TØTGEØ)
WA	= distance W for the corner channels, set equal to W in the present version of SAGAPØ *)
ZA	= distance Z for the corner channels, set equal to Z in the present version of SAGAPØ *)
EM1	= (C-base of the blocking triangles)/2 (cm)
PERLT	= wetted perimeter for the whole bundle flow section, computed in TØTGEØ (cm)
RTIP	= tip radius of the rods (cm)

5.69 SUBRØUTINE TRICA1

TRICA1 organizes the sub-subchannel calculations for the central subchannels (these calculations are performed in the subroutine CEWA, which is called by TRICA1). Furthermore TRICA1 computes the friction factors

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*) The parameters WA and ZA had been introdueed in SAGAPØ to easily allow to consider bundles with angles in shroud profile at the gaps between the corner and the wall channels, instead of angles at the center of the corner channels.

LAMSCH for the whole central subchannels, both in the case of turbulent flow (see (I.66) of /5/) and in the case of laminar flow (see (IV.3), (IV.4) and (IV.36) of /5/). Finally TRICA1 evaluates also average values of some sub-subchannel variables. TRICA1 is called by the main program. About TRICA1 see flow chart of Fig. 23.

Arguments:

K = index of the axial section

NS = channel index

NN = number of the sub-subchannels in a half of an entire central subchannel (i.e. for a rod sector of an angle $\pi/6$)

IRH = index for the type of the rod surface (IRH=1 for smooth rods, IRH=2 for roughened rods)

PRØV = P_T (see (I.111) of /5/)

PB = average pressure for the axial section (kg/cm^2)

RH = height of the roughness ribs (cm)

A(1)...A(NN)= flow areas of the sub-subchannels (cm^2)

DE(1)...DE(NN)
= equivalent diameters of the sub-subchannels (cm)

MEC(1)...MEC(NN)
= mass flow rates for the sub-subchannels, corresponding to an uniform mass-flow distribution (g/s)

AT = flow area for a half of the entire central subchannel (cm^2)

DET = equivalent diameter for the central subchannel (cm)

DETØT = equivalent diameter for the whole bundle flow section (cm)

H1 = (length of the axial section K)/ (length of the containing axial portion)

ALFA = $\frac{\pi/6}{NN}$ = angle of the rod sector for each sub-subchannel of the central subchannel

H = length of the axial section K (cm)

M = subchannel index

PR1 = inlet pressure for the axial section (kg/cm^2)

PR2 = outlet pressure for the axial section (kg/cm^2)

SQDPG = $\sqrt{|\Delta p|\, g_c}$

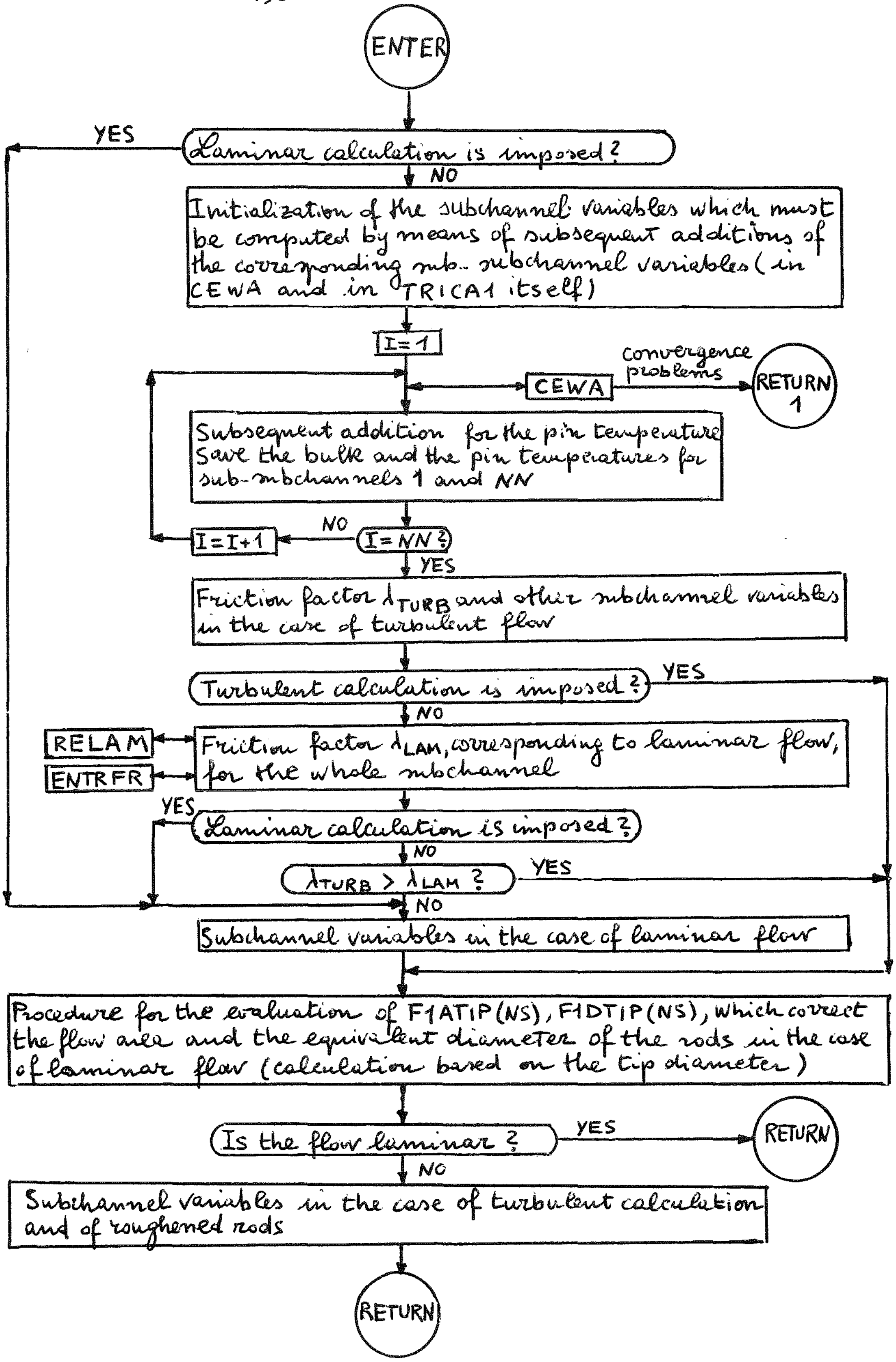

Fig.23 Simplified flow-chart for subroutine TRICA1
I=sub-subchannel index

TE	= bulk temperature for the whole bundle flow section at the bundle inlet (^{o}C)
SUR	= volumetric surface of a rod for the whole axial portion (cm^2)
D	= volumetric diameter of the rods (cm)
AMT	= summation of the computed average mass flow rates of the sub-subchannels contained in a half of the entire central subchannel (g/s)
DDDD	= summation of the computed terms $\frac{A_i}{\sqrt{\frac{\lambda_i \ \Delta x}{2D_i \ \rho_i}}}$ (see (I.66) in /5/)
ATSCH	= bulk temperature of subchannel M, computed averaging the sub-subchannel bulk temperature (^{o}C)
*	= for RETURN1, in the case of convergence problems
C	= pitch of the rods (cm)

5.70 FUNCTIØN TUBENU

TUBENU is called by the subroutines RTSI and RTRI in the case of turbulent flow. It evaluates the Nusselt number $Nu_{tu\infty}$ (TUBENU), for a smooth tube having the same Reynolds and Prandtl numbers as the annulus which is equivalent to the central subchannel or to the corner channel or to the portion of the wall subchannel, whose calculation is performed in RTSI or in RTRI. For the evaluation of $Nu_{tu\infty}$ equations (II.31)-(II.33) of /5/ are used.

Arguments:

REI	= Reynolds number
PRI	= Prandtl number

5.71 FUNCTIØN TURBWC

TURBWC evaluates the geometric factors IGD/20δ (TURBWC) for the turbulent exchange between the two portions of each wall subchannel (see 1.6 in /5/). TURBWC is called **by the subroutine** RECCA1.

Arguments:

CTU3	= input value of the mixing factor I for the turbulent exchange between the two portions of the wall subchannels (see 3.1, 21st Card)
E	= length of that segment of the boundary line dividing the two subchannels of the same wall channel, which belongs to the central portion (cm)
PRAD	= length of boundary line between the two portions + volumetric radius of the rods (cm)
D	= volumetric diameter of the rods (cm)
W	= distance (at the gap between two external channels) from the centers of the external rods to the shroud + D/2 (cm)
C	= pitch of the rods (cm)
GAMMA	= angle of the rod sector for the central portion
A1	= flow area for the wall portion (cm^2)
A2	= flow area for the central portion (cm^2)
DE1	= equivalent diameter for the wall portion(cm)
DE2	= equivalent diameter for the central portion (cm)
EM1	= (C - base of the blocking triangles)/2 (cm)

5.72 FUNCTIØN TWCTEP

TWCTEP corrects the computed surface pin temperatures to get the pin temperatures T_{WR} (TWCTEP) at the radial position RMISTW (see 3.1, Card 6), at which the thermocouples are set. In the present version of SAGAPØ this correction is performed by means of equation (II.21) of /5/, which takes into account only the conduction in the radial direction and is valid in the case of electrically heated canning metal. Equation (II.21) of /5/ is solved now in TWCTEP assuming that the thermal conductivity of the canning metal (k_c) varies linearly with the canning temperature (i.e. that k_c=D1+D2*T, see function KMET). TWCTEP is called by the subroutine CØRRTE.

Arguments:

QRMDAR = factor $\left[\frac{\bar{\dot{Q}}''_R \; r_1}{(r_1^2 - r_i^2)} \left(\frac{r_1^2 - r_{meas}^2}{2} + r_i^2 \ln \frac{r_{meas}}{r_1} \right) \right]$ for (II.21) of /5/, defined in the main program

TW = surface pin temperature (^oC)

5.73 FUNTIØN TWFUN

TWFUN evaluates the mean pin temperature (TWFUN) at each axial section. TWFUN is called by the main program.

Arguments:

NRØDS = total number of the rods (for the whole bundle)

NSTØT = total number of the channel (for the considered bundle symmetry section)

PIG = π = 3.141593

AAC = flow area for 1/6 th of an entire central channel (i.e. for a rod sector of an angle of $\pi/6$) (cm^2)

AAA = flow area for a half of an entire corner channel (i.e. for a rod sector of an angle of $\pi/6$) (cm^2)

5.74 FUNCTIØN UA

UA evaluates the average cross-flow velocities $\bar{u}^{CF}_{Cav}$ for each channel C. UA calls subroutine CF1, where equation (I.37) of /5/ is used for the calculation of $\bar{u}^{CF}_{Cav}$ in the present version of SAGAPØ (see also CF1). UA is called by the subroutine BALA.

Arguments:

I	=	channel index
NI	=	number of the channels which are adjacent to channel I
ACHI	=	flow area for the entire channel I (i.e. not for its considered symmetry section) (cm^2)
IUAV	=	option (not used in the present version of SAGAPØ) for the procedure required for the evaluation of the cross-flow velocities $\bar{u}^{FC}_{1}$ in CF1 (see CF1)

5.75 SUBRØUTINE WALLTE

WALLTE organizes the calculation of the surface pin temperatures *) for all the central subchannels (TW), for all the corner channel (TW) and for both portions of all wall subchannels (TWWC), both in the case of turbulent flow and in the case of laminar flow. The subroutine RTSI is called by WALLTE in the case of smooth rods and the subroutine RTRI in the case of roughened rods. The mean pin temperature (TW) for the wall subchannels is computed in WALLTE averaging the pin temperatures of the two portions, weighting them by means of the wetted perimeters. In the case of roughened rods the parameter YDH=$(r_2-r_1)/h_R$ for the whole wall subchannels is also evaluated in WALLTE (this parameter is used for the definition of an average value of the $G(h^+)$ parameter for the whole wall subchannel, see (III.9) and (III.22) in /5/). WALLTE is called by the main program. **)

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*) at infinite conductivity of the canning metal, in the case of roughened rods.

**) Recently the option IEXAV has been introduced in SAGAPØ, to allow the calculation of an average rod and an average shroud temperature for the external channels, instead of the single subchannel values (case of IEXAV=2). The value of IEXAV must be provided in BLØCK DATA (CØMMØN BLØCK /EXAVTW/).

Arguments:

K	=	index of the axial section
NSTØT	=	total number of the channels
NSTR	=	number of the central subchannels
RH	=	height of the roughness ribs (cm)
SUR	=	volumetric surface of each rod, for the axial section (cm^2)
D	=	volumetric diameter of the rods (cm)
PIG	=	π=3.141593
TE	=	bulk temperature for the whole bundle flow section at the bundle inlet (^oC)
PBT	=	average pressure for the axial section K (kg/cm^2)
*	=	for RETURN1, in the case of convergence problems in RTRI or in RTSI.
RTI	=	name of the subroutine which must be called by WALLTE for the calculation of the pin temperatures (RTI=RTSI in the case of smooth rods; RTI=RTRI in the case of roughened rods)

5.76 FUNCTIØN ZEIT

ZEIT is a library function of the IBM computer of the Karlsruhe Nuclear Center which is used to evaluate the time (in seconds) from the beginning of a calculation to the instant at which ZEIT is called. In SAGAPØ ZEIT is initialized at zero at the beginning of the main program and it is called by the main program at each axial section K (before starting the calculations for the axial section), to control whether the allowed computation time TIMEPU(see 3.1, Card (39+4*NSPACT))has been elapsed or not. If TIMEPU has been elapsed the subroutine TMPUN is then called by the main program.

Argument:

T	=	time elapsed from the beginning of the calculation (s)

5.77 Variables in CØMMØN BLØCKS

In this paragraph the meaning of the variables which are contained in CØMMØN BLØCKS will be explained. The names of the containing subprograms will be also cited. For the names of the variables of each CØMMØN BLØCK it will be made reference to one of the containing subprograms (sometimes the variables have different names in the various containing subprograms).*)

1) CØMMØN / ANG1/ RR2(30), ALFA12 (30)

For the definition of RR2 and ALFA12 see subroutine CEWACØ.
RR2 and ALFA1 are evaluated in CEWACØ and are used in RECANG and SMFUN1.

2) CØMMØN /ANG2/ PER(30)

For the definition of PER see subroutine CEWACØ.
PER is evaluated in CEWACØ and is used in ANGCA1.

3) CØMMØN /BIDAT/ BIK(3)

For the definition of BIK see 3.3 (BLØCK DATA).
BIK is used in KINF.

4) CØMMØN /BIDAT1/ BIE(7)

For the definition of BIE see 3.3 (BLØCK DATA). BIE is used in EINF.

5) CØMMØN /BIDE/ IBIDE

For the definition of IBIDE see 3.3 (BLØCK DATA). IBIDE is used in CORRTE.

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*)The CØMMØN BLØCKS /SIMLAM/, /EXAVTW/ and /GRAV/, which have been introduced only recently in SAGAPØ, are not included in this listing (see pag.48). /SIMLAM/ is used in BLØCK DATA and in SIMLA1. /EXAVTW/ is used in BLØCK DATA and in WALLTE. /GRAV/ is used in BLØCK DATA, in the main program, in BALA, SUBBAL and RECCA2.

6) CØMMØN /CEN1/ G(45)

For the definition of G see subroutine CEWACØ. G is evaluated in CEWACØ and is used in RECCA1 and TRICA1.

7) CØMMØN /CØLAM1/ CØLAMB

CØLAMB = factor for the correction of the friction factors. It is set equal to =1 in the main program, in the present version of SAGAPØ. It is used in CEWA, RECANG and TAU.

8) CØMMØN /CØLAM2/ CØLAMA

CØLAMA is read in the main program (see 3.1, Card 12) and is used in CSFUN, RECANG, SMFUN1 and TAU.

9) CØMMØN /CØNDO/ FCØND

For the definition of FCØND see 3.3 (BLØCK DATA). FCØND is used in INGE.

10) CØMMØN /CØND1/ CCØND (42,3)

For the definition of CCØND see subroutine INGE.
CCØND is evaluated in INGE and is used in BALA and SUBBAL.

11) CØMMØN /CØND2/ CCØND1(2)

For the definition of CCØND1 see subroutine INGE.
CCØND1 is evaluated in INGE and is used in SUBBAL.

12) CØMMØN /CØRR/ SIGMA(42), PHI(42), SBMNS

SIGMA(NS) = factor (ξ/A) for channel NS (see (I.56) in /5/)
PHI(NS) = factor (ψ/A) for channel NS (see (I.80) in /5/)

SBMNS = $\sum(\bar{\dot{m}}_{NS} - \xi_{NS})$ (see (I.71) in /5/)

SBMNS, SIGMA and PHI are computed in BALA and are used in the main program and in SUBBAL.

13) CØMMØN /CØRRE/ QHRDAR, QRMDAR, QLAMR

QHRDAR = [heat flux at the reference surface] *[height of the roughness ribs] , for the evaluation of the Biot number (see CØRRTE)
QRMDAR = input argument for function TWCTEP (see)
QLAMR = factor $\dot{Q}''_b\ r_b\ \ln \frac{r_t}{r_b}$ for the evaluation of the temperature difference between the tip and the base of the roughness ribs, in the case of laminar flow (see (IV.47) in /5/)

QHRDAR, QRMDAR and QLAMR are evaluated in the main program and are used in CØRRTE.

14) CØMMØN /CØRR1/ SIGMAI(42,3), PHII(42,3)

SIGMAI(NS,M) = factor (ξ/A) for the Mth subchannel of channel NS (see (I.57) in /5/)
PHII(NS,M) = factor (ψ/A) for the Mth subchannel of channel NS (see (I.80) in /5/)

SIGMAI and PHII are evaluated in SUBBAL and are used in the main program, in RECANG, RECCA1, RECCA2 and TRICA1.

15) CØMMØN /CØRR2/ CHI (18,2,2), PSI(18,2,2)*)

CHI(NS-NSTR,M,I)= ratio $\frac{(\xi/A)_{portion}}{(\xi/A)_{subchannel}}$ for the Ith portion of the Mth wall subchannel of channel NS (see (I.57), (I.58) in /5/)

PSI(NS-NSTR,M,I) = ratio $\frac{(\psi/A)_{portion}}{(\psi/A)_{subchannel}}$ for the Ith portion of the Mth wall subchannel of channel NS (see (I.80) in /5/)

The elements of CHI and PSI are evaluated in RECCA2 .CHI and PSI are used in the main program, in RECANG , RECCA1 and SUBBAL.

16) CØMMØN /CVREH/ ACVS(3), ACVR(3)

For the definition of ACVS and ACVR see 3.3 (BLØCK DATA). ACVS and ACVR are used in DSPDPF.

17) CØMMØN /DAT/ PIG

PIG = π=3.141593

PIG is defined in the main program and is used in ANGCA1, CEWA, RECANG, RECCA1, RELAM and TRICA1.

18) CØMMØN /DATKM/ D1(7), D2(7)

For the definition of D1 and D2 see 3.3 (BLØCK DATA). D1 and D2 are used in KMET and TWCTEP.

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*) For a hexagonal bundle with 42 channels the number of the external channel is 18 (NSTR is the number of the central channel; I=1 for the wall portion, I=2 for the central portion)

19) CØMMØN /DAT1/ A(10)

For the definition of A see 3.3 (BLØCK DATA). A is used in the main program and in GHPLUS.

20) CØMMØN /DAT2/ B(10)

For the definition of B see 3.3 (BLØCK DATA). B is used in the main program and in RHPLUS.

21) CØMMØN /DAT4/ NDEST, NDEEND

For the definition of NDEST and NDEEND see 3.3 (BLØCK DATA). NDEST and NDEEND are used in the main program.

22) CØMMØN /DAT6/ IRHPL

IRHPL = index for the definition of h^+ (see RHPLUS). The value of IRHPL is established at each axial portion in the main program. IRHPL is used in RHPLUS.

23) CØMMØN /DAT7/ CNUSS

For the definition of CNUSS see 3.3 (BLØCK DATA). CNUSS is used the main program.

24) CØMMØN /EXDAT/ EX1(7), EX2(7), EX3(7)

For the definition of EX1, EX2 and EX3 see 3.3 (BLØCK DATA). EX1, EX2 and EX3 are used in EXPCØ.

25) CØMMØN /EXDAT1/ EX4(7), EX5(7), EX6(7)

For the definition of EX4, EX5 and EX6 see 3.3 (BLØCK DATA). EX4, EX5 and EX6 are used in EXPCL.

26) CØMMØN /ENTR1/ CKAPPA(2), DEA(2), GAMMA(2),WGAMMA(2), A1

CKAPPA(1), DEA(1), GAMMA(1)
= coefficient K=λRe, equivalent diameter (cm), coefficient γ *)
in laminar flow conditions for:
- the equivalent annulus, for the corner channels
- the annulus which is equivalent to the wall portion,for the wall subchannels
- the annulus whose inner zone is equivalent to the subchannel, for the central subchannels

CKAPPA(2), DEA(2), GAMMA(2)
= coefficient K=λRe, equivalent diameter (cm), coefficient γ *)
in laminar flow conditions for the annulus whose inner zone is equivalent to the central portion, for the wall subchannels (these variables are defined only for the wall subchannels)

WGAMMA(M) *) = γ coefficient for the Mth subchannel of a wall subchannel, defined only for wall subchannels

A1 = flow area of the central or of the wall portion of the wall subchannels, based on the tip diameter of the rods, in laminar flow conditions (defined only for the wall subchannels) (cm^2).

CKAPPA, DEA, GAMMA, WGAMMA und A1 are defined in ENTRFR and are used only there. The CØMMØN BLØCK/ENTR1/ is defined in order to save the values of CKAPPA, DEA, GAMMA and A1 computed for the central portion of the wall subchannels,so that these values are available when ENTRFR is called for the calculation of the wall portion

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*) see 4.2.6 of /5/

27) CØMMØN /GAMCØ/ CGAMMA(18)

CGAMMA(NS-NSTR) = γ coefficient for the external channel NS (NSTR=number of the central channels) *)

CGAMMA is defined ENTRFR and is used in ENFRCØ.

28) CØMMØN /GEN1/ LAM(42)

LAM(NS) = friction factor for channel NS
LAM is evaluated in the main program, is eventually corrected in ENFRCØ (see)and is used in BALA.

29) CØMMØN /GEN2/ A(42)

A(NS) = flow area for channel NS, based on the volumetric diameter of the rods (cm^2).
A is defined in INQUA and is used in the main program, in BALA, ENFRCØ, INLCØN, INQUA, KAPCØR, NØRMT, RECCA1, RECCA2, SUBBAL, TMCF and TRICA1.

30) CØMMØN /GEN3/ MI(42)

MI(NS) = mass flow rate for channel NS, at the inlet of an axial section (g/s)
MI is defined in the main program (except for the first axial section of the bundle, for which it is defined in INLCØN) and is used in BALA, SUBBAL and TMPUN.

31) CØMMØN /GEN4/ TEMP(42)

TEMP(NS) = gas temperature for channel NS at the inlet of an axial section (^{o}C)
TEMP is defined in the main program (except for the first axial section of the bundle, for which it is defined in INLCØN) and is used in BALA and TMPUN.

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*) see 4.2.6 of /5/.

32) CØMMØN /GEN5/ DE(42)

DE(NS) = equivalent diameter of channel NS, based on the volumetric diameter of the rods (cm)

DE is defined in INQUA and is used in the main program, in BALA, ENFRCØ, INGE, KAPCØR, RECANG, SUBBAL and WALLTE.

33) CØMMØN /GEN6/ MO(42)

MO(NS) = summation of the mass-flow rates of the sub-subchannels contained in channel NS, at the outlet of an axial section (g/s)

MO is defined in the main program and is used only there in the present version of SAGAPØ.

34) CØMMØN /GEØO/ ACH(3) *)

For the definition of ACH see subroutine TØTGEØ.
ACH is defined in TØTGEØ and is used in BALA, INGE, RECCA2, SIMLA1, SUBBAL, TBFUN, TEMLAM, TMCF , UA and WALLTE.

35) CØMMØN /GEØ2/ ATØT, DETØT, ASEC *)

For the definition of ATØT, DETØT and ASEC see subroutine TØTGEØ.
ATØT, DETØT and ASEC are defined in TØTGEØ and are used in the main program.

36) CØMMØN /GEØ5/ ATC, DETC, ATW, DETW, ATA, DETA, AAC, AAW, AAA *)

For the definition of ATC, DETC, etc, see subroutine TØTGEØ.
These variables are defined in TØTGEØ and are used in the main program.

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*) These geometric parameters are all based on the volumetric diameter of the rods.

37) CØMMØN /GRID/ CSPC (42,3)

CSPC(NS,I) = coefficient $(K_I+K_O)/2$ for the local pressure losses at the inlet and at the outlet of the Ith spacer contained in the axial portion, for channel NS

CSPC is defined in the main program, at each axial portion (by means of the function GRIFUN), and is used in BALA.

38) CØMMØN /GRIDW / EPSWC(18,2,2,3), CSPWC(18,2,2,3)

EPSWC(NS-NSTR, M, JWC, I), CSPWC(NS-NSTR, M, JWC, I)
= blockage factor ε and coefficient $(K_I+K_O)/2$(see above), for the local pressure losses at the inlet and at the outlet of the Ith spacer contained in the axial portion, for the JWCth portion of the Mth subchannel of the external channel NS (NSTR=number of the central channels) *)

EPSWC and CSPWC are evaluated in the main program (CSPWC by means of the function GRIFUN) at each axial portion and are used also in RECCA2 .

39) CØMMØN /GRIDO/ CSPSC(42,3,3)

CSPSC(NS, M, I)= coefficient $(K_I+K_O)/2$ for the local pressure losses at the inlet and at the outlet of the Ith spacer contained in the axial portion, for the Mth subchannel of channel NS.

CSPSC is evaluated in the main program at each axial portion (by means of the function GRIFUN), and is used in RECCA2 and SUBBAL.

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*) The elements of EPSWC and CSPWC corresponding to corner channels are not defined . JWC=1 for the wall portion of a wall subchannel; JWC=2 for the central portion.

40) CØMMØN /GRID1/ EPSISC(42,3,3)

EPSISC(NS, M, I) = blockage factor ε for the Ith spacer contained in the axial portion, for the Mth subchannel of channel NS

EPSISC is defined in the main program at each axial portion and is used also in AXSEC, RECCA2 and SUBBAL.

41) CØMMØN /GRID2/ YY(100,42,3), DIST(7)

YY(K, NS, M) = correction factor Y_{sp} for the influence of the spacer grids on the Nusselt number, for the Mth subchannel of channel NS in the Kth axial section of the axial portion (see AXSEC)

DIST(I) = distance from the bundle inlet to the middle plane of spacer I (cm)

YY is defined in AXSEC. DIST is read in the main program. YY and DIST are used in CEWA, RECCANG, SUBDH and WALLTE.

42) CØMMØN /GRID3/ X(100)

X(K) = distance from the point where the calculation is started to the inlet plane of the Kth axial section of the axial portion(cm)

X is defined in AXSEC (only X(1) is established in the main program) and is used in the main program, in ENTRFR and in SUBDH.

43) CØMMØN /GRID6/ EPSIC(42,3)

EPSIC(NS, I) = blockage factor ε for the Ith spacer contained in the axial portion, for channel NS

EPSIC is defined in the main program and is used also in BALA.

44) CØMMØN /GRID7/ PGDPC(42,3)

PGDPC(NS, I) = ratio between the wetted perimeters inside and outside the Ith spacer of the axial portion, for channel NS

PGDPC is defined in the main program and is used in BALA.

45) CØMMØN /GRID8/ PGDPSC (42,3,3)

PGDPSC(NS, M, I) = ratio between the wetted perimeters inside and outside the Ith spacer of the axial portion, for the Mth sub-channel of channel NS.

PGDPSC is defined in the main program and is used in RECCA2 and SUBBAL.

46) CØMMØN /HB3/ TEMP2(42)

TEMP2 (NS) = bulk temperature at the outlet of an axial section, for channel NS (^{o}C)

TEMP2 is defined in BALA and is used also in the main program.

47) CØMMØN /HEA1/ Q(19)

Q(I) = [maximum power per unit axial length] * [length of the axial portion] for the Ith rod (input indexing for the rods, see Figs. 1,2) (cal/s)

Q is defined in the main program and is used also in HEATR.

48) CØMMØN /HEA2/ QQ(2,12), QQO

For the definition of QQ and QQO see subroutine HEATR. QQ and QQO are defined in HEATR and used in HEATI.

49) CØMMØN /HEA3/ QT(42)

For the definition of QT see subroutine HEATI.
QT is defined in HEATI and used in BALA.

50) CØMMØN /HEA5/ QQ(42,3)

For the definition of QQ see subroutine HEATI. QQ is defined in HEATI and used in the main program,in ANGCA1, CEWA, RECANG, RECCA1, TRICA1 and WALLTE.

51) CØMMØN /HEA6/ NPIN(42), JPIN(42,3)

For the definition of NPIN and JPIN see subroutine HEATI.
NPIN and JPIN are evaluated in HEATI in the version of SAGAPØ concerning hexagonal bundles. They are provided as input data in BLØCK DATA in the version for the 12-rod bundles(see 3.4).They are used in the main program, in AXSEC, BALA, ENFRCØ, ENTRFR, INLCØN, NØRMT, SIMLA1, SUBBAL, SUBCØN, SUBDH, TBFUN, TMPUN, TWFUN and WALLTE.

52) CØMMØN /HEA7/ IDPIN(2,12)

For the definition of IDPIN see subroutine HEATR.*)
IDPIN is defined in HEATR and used in HEATI.

53) CØMMØN/ HEA10/ QSCH(42,3)

For the definition of QSCH see subroutine HEATI.
QSCH is defined in HEATI and used in RECCA1, RECCA2 and SUBBAL.

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*) The CØMMØN BLØCK/HEA7/ exists only in the version of SAGAPØ concerning hexagonal bundles.

54) CØMMØN /IJ1/ NER(42) , NIS(42,3)

For the definition of NER and NIS see subroutine CØNNIJ.
NER and NIS are evaluated in CØNNIJ in the version of SAGAPØ concerning hexagonal bundles. They are provided as input data in BLØCK DATA in the version for the calculation of the 12-rod bundles (see 3.4). NER and NIS are used in the main program,in BALA, INGE, RECCA2, SUBBAL, SUBCØN, TMCF and UA.

55) CØMMØN /IND1/ NRØW(42), NUMS(42)

For the definition of NUMS and NRØW see subroutine INDEX.
NRØW and NUMS are defined in INDEX in the version of SAGAPØ concerning hexagonal bundles *). In this version they are used in CØNNIJ, HEATI, INGE and INQUA.

56) CØMMØN /ND2/ NØT (3,18)

For the definition of NØT see subroutine INDEX.
NØT is defined in INDEX in the version of SAGAPØ concerning hexagonal bundles**). NØT is used in CØNNIJ.

57) CØMMØN /IND3/ NTYP(42)

For the definition of NTYP see subroutine INDEX.
NTYP is defined in the subroutine INDEX in the version of SAGAPØ concerning

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*) The CØMMØN BLØCK /IND1/ does not exist in the version of SAGAPØ concerning the 12-rod bundles.

**) The CØMMØN BLØCK/IND2/ does not exist in the version of SAGAPØ concerning the 12-rod bundles.

hexagonal bundles. It is provided as input in BLØCK DATA in the version for the 12-rod bundles (see 3.4). NTYP is used in the main programs, in BALA, CØNNIJ, ENFRCØ, INGE, INLCØN, INQUA, KAPCØR, NØRMT, RECCA2, SIMLA1, SUBBAL, SUBCØN, TBFUN, TEMLAM, TMCF, TMPUN, TWFUN, UA and WALLTE.

58) CØMMØN /IND4/ NUM3(3), NUM6(3), NUM12(3), NUM18(3), NUM24(3), NUM30(3), NUM36(3)

NUM3(NRØ)	= number of the channels of the NRØth row contained in 1/12 th of the whole bundle flow section
NUM6(NRØ)	= number of the channels of the NRØth row contained in 1/6th of whole bundle flow section
NUM12(NRØ)	= number of the channels of the NRØth row contained in 1/3 rd of the whole bundle flow section
NUM18(NRØ)	= number of the channels of the NRØth row contained in a half of the whole bundle flow section
NUM24(NRØ)	= number of the channels of the NRØth row contained in 2/3rd of the whole bundle flow section
NUM30(NRØ)	= number of the channels of the NRØth row contained in 10/12th of the whole bundle flow section
NUM36(NRØ)	= number of the channels of the NRØth row contained in the whole bundle flow section

NUM3, NUM6, NUM12, NUM18, NUM24, NUM30 and NUM36 are defined in INDEX in the version of SAGAPØ concerning hexagonal bundles, and are used, in the version, in CØNNIJ and HEATI. The CØMMØN BLØCK /IND4/ does not exist in the version of SAGAPØ concerning the 12-rod bundles (see also /10/).

59) CØMMØN /INITL / XMHE

XMHE	= distance from the beginning of the heating to the middle plane of an axial section (cm)

XMHE is defined in the main program, at each axial section, and is used in TEMLAM and TIS.

60) CØMMØN /INPAR/ IPA

IPA = index of the axial portion

IPA is established in the main program, at each axial portion, and is used also in ANGCA1, EXPCL, EXPCØ, KAPCØR, KMET, RECCA1, RELAM, SELAWA, SIMLA1, TEMLAM, TRICA1 and TWCTEP.

61) CØMMØN / IRØSMØ/ IRH

IRH = index for the type of the rod surface (IRH=1 for smooth rods, IRH=2 for roughened rods)

IRH is fixed in the main program, at each axial portion, and is used also in CØRRTE, DSPDPF and WALLTE.

62) CØMMØN /LAMINK / BKAPPA(7,3)

For the definition of BKAPPA see 3.3 (BLØCK DATA), KAPCØR and SELAWA. BKAPPA is used also in RECCA1 and SIMLA1.

63) CØMMØN /LAMINO/ I2TIP(42,3)

I2TIP(NS,M) = index which establishes if the flow is laminar or turbulent in the Mth subchannel of channel NS (I2TIP=1 for laminar flow, I2TIP=0 for turbulent flow)

The I2TIP values are established in ANGCA1, RECCA1 and TRICA1. I2TIP is used also in the main program, in BALA, CØRRTE, RTRI, RTSI and SUBBAL.

64) CØMMØN /LAMIN1/ AKAPPA(42)

AKAPPA(NS) = $K=\lambda Re$ value for channel NS in fully developed laminar flow, in the axial portions (corrected value if the simplified procedure of 4.6 of /5/ is applied).

AKAPPA is defined in KAPCØR and is used in ANGCA1, ENFRCØ, ENTRFR, RECCA1, SIMLA1 and TRICA1.

65) CØMMØN /LAMIN2/ FATIP(3), FDTIP(3)

For the definition of FATIP and FDTIP see subroutine TØTGEØ.
FATIP and FDTIP are evaluated in the subroutine TØTGEØ and are used in ANGCA1, ENFRCØ, KAPCØR, RECCA1 and TRICA1.

66) CØMMØN /LAMIN3/ F1ATIP(42), F1DTIP(42)

F1ATIP(NS) = ratio between the real *) channel flow area and the channel flow area based on the volumetric diameter of the rods, for channel NS

F1DTIP(NS) = ratio between the real*) channel equivalent diameter and the channel equivalent diameter based on the volumetric diameter of the rods, for channel NS

The F1ATIP and F1DTIP parameters are evaluated in ANGCA1, RECCA1 and TRICA1 and are used in the main program, in BALA, NØRMT, SUBBAL and UA.

67) CØMMØN /LAMIN4/ F2ATIP(42,3), F2DTIP(42,3)

F2ATIP(NS,M) = ratio between the real *) subchannel flow area and the subchannel flow area based on the volumetric diameter of the rods, for the Mth subchannel of channel NS

F2DTIP(NS,M) = ratio between the real *) subchannel equivalent diameter and the equivalent diameter based on the volumetric diameter of the rods, for the Mth subchannel of channel NS

The F2ATIP and F2DTIP parameters are evaluated in ANGCA1, RECCA1 and TRICA1.They are used in the main program, in NØRMT, SUBBAL and WALLTE.

68) CØMMØN /LAMIN5/ RTIP(7)

RTIP(I) = tip radius of the rods in the Ith axial portion (cm)

The RTIP values are read (see 3.1, Cards 7,8)in the main program. There, they are corrected to take into account the thermal expansion of the rods.RTIP is used also in ANGCA1, RECCA1, RELAM, TEMLAM and TRICA1.

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*) If the flow is laminar in a subchannel of channel NS, the subchannel flow area must is based on the tip diameter of the rods.

69) CØMMØN /LAMIN6/ ANGLAM

ANGLAM = parameter β which defines the position of line dividing the two portions of the wall subchannels in the case of laminar flow (see 4.2.3 in /5/).

An input value of ANGLAM must be provided in BLØCK DATA (see 3.3). Then, if IKAPPA=1 (see 3.3, CØMMØN BLØCK /WAKA1/), a new value of ANGLAM is computed in SELAWA and the input value of BLØCK DATA is not used. ANGLAM is used in RECCA1.

70) CØMMØN /LAMIN7/ F1PTIP

F1PTIP = F1ATIP(NS)/F1DTIP(NS), defined in subroutines RECCA1 and TRICA1 by means of subsequent additions of subchannel variables, in the procedure for the evaluation of F1DTIP(NS)

F1PTIP is defined in RECCA1 and TRICA1 and is used only there.

71) CØMMØN /LAMIN9/ I3TIP(42,3)

For the definition of I3TIP see 3.3 (BLØCK DATA).The I3TIP values must be provided as input data in BLØCK DATA. I3TIP is used in ANGCA1, RECCA1 and TRICA1.

72) CØMMØN /MART / ITCØRR

ITCØRR = actual value of the index ITCØRR in the iteration loop for the convergence of the whole bundle friction factor (see Fig.11)

ITCØRR is defined in the main program and is used also in ANGCA1, CEWA, RECANG, RECCA1, RELAM, TAU and TRICA1.

73) CØMMØN /MART2/ NS1, NS2

For the definitions of NS1 and NS2 see 3.3 (BLØCK DATA).
NS1 and NS2 must be provided as input data in BLØCK DATA (see 3.3).
They are used in BALA, ENFRCØ, KAPCØR, SIMLA1 and TEMLAM.

74) CØMMØN /MART3/ TBEQR, TBEQL

For the definitions of TBEQR and TBEQL see subroutine SIMLA1. TBEQR and TBEQL are computed in TEMLAM by means of SIMLA1. The CØMMØN BLØCK / MART3/ is defined only for TEMLAM, to save the values of the parameters TBEQR and TBEQL for the wall subchannels, which are evaluated during the computations for the wall portion (so that their evaluation does not need to be repeated for the computation of the central portion).

75) CØMMØN /MART5/ NSTR

NSTR = number of the central channels
The CØMMØN BLØCK /MART5/ is defined in the main program (NSTR is computed in INDEX). NSTR is used in ENFRCØ.

76) CØMMØN /MØB1/ M2(42)

M2(NS) = mass flow rate at the outlet of an axial section, for channel NS (g/s)
M2 is computed in BALA and is used also in the main program.

77) CØMMØN / MØB2/ UAV(42)

UAV(NS) = velocity for channel NS (average for an axial section) (cm/s)
UAV is computed in BALA and is used also in the main program, in RECCA2, SUBBAL and UA.

78) CØMMØN /MØB4/ WCF(42)

WCF(NS) = cross-flow rate per unit length for channel NS (g/s cm)
WCF is evaluated in BALA and is used also in the main program and in SUBBAL.

79) CØMMØN /MØB5/ TAV(42)

TAV(NS) = bulk temperature of channel NS, average for an axial section (^{o}C)
TAV is computed in BALA and is used also in the main program, in NØRMT, RECCA2, SUBBAL and TMCF.

80) CØMMØN /MØB6/ MAV(42)

MAV(NS) = mass-flow rate (average for an axial section), for channel NS (g/s)
MAV is computed in BALA and is used also in the main program, in NØRMT, RECCA2, SUBBAL and TMCF.

81) CØMMØN /MØB8/ DP(42)

DP(NS) = pressure loss for channel NS, in an axial section (kg/cm^2)
DP is computed in BALA and is used also in the main program, in RECCA2, SUBBAL, TMCF and UA.

82) CØMMØN /MØB24/ WT(42,3)

WT(NS,M) = turbulent mass-flow rate per unit length exchanged between channel NS and the Mth adjacent channel (i.e. channel NIS(NS,M), see CØNNIJ) (g/s)
WT is evaluated in BALA by means of the function TME and is used also in the main program and in SUBBAL.

83) CØMMØN /MOB26/ RUAS(42)

RUAS(NS) = ρu^* (density·friction velocity) for channel NS (cm/s)
RUAS is defined in BALA and used also in SUBBAL.

84) CØMMØN /PARTB/ TEMPB(42,3), XMASSB(42,3), YDH(42,3)

TEMPB(NS,M) = bulk temperature for the whole inner zone (i.e. inside the τ=0 line) of the Mth subchannel of channel NS (^{o}C)

XMASSB(NS,M) = mass-flow rate for the whole inner zone of the Mth subchannel of channel NS (g/s)

YDH(NS,M) = [(inner radius of the outer wall for the annulus which is equivalent to the whole subchannel M of the channel NS) - (volumetric radius of the rods)] /(height of the roughness ribs)

85) CØMMØN /QPAR1/ QDEV

QDEV = [average power per unit axial length *) removed from a rod in an axial section] /[maximum rod power per unit axial length]

QDEV is defined in the main program, at each axial section, and is used also in BALA, CEWA, RECANG, RECCA1, RECCA2, SUBBAL and WALLTE.

86) CØMMØN /QPAR2/ QLINM, QLDEV

QLINM = maximum power per unit surface *) removed from the shroud (cal/s cm^2)

QLDEV = [average power per unit surface *) removed from the shroud in an axial section] /QLINM

QLINM and QLDEV are defined in the main program (QLDEV at each axial section) and are used also in BALA, RECANG, RECCA1, RECCA2 and SUBBAL.

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*) Based on the nominal lengths (see also FQDEV and MØDFQD)

87) CØMMØN /QPAR3/ PERL(3)

For the definition of PERL see subroutine TØTGEØ.
PERL is evaluated in TØTGEØ and is used in BALA, RECCA2, RELAM, SIMLA1, SUBBAL, TBFUN, TEMLAM and WALLTE.

88) CØMMØN /QSHR/ QALIN

QALIN = average power per unit surface removed from the shroud in an axial section (cal/s cm^2)

QALIN is defined in the main program, at each axial section, and is used also in RTSI and RTRI.

89) CØMMØN /REC1/ PVERT(90), PRAD(90)

PVERT(I), PRAD(I)=parameters defining the position of the τ=0 line for the Ith "wall-type" sub-subchannel (cm) (for the definition of PVERT(I) and PRAD(I) see Fig.21)

PVERT and PRAD are defined in TAU *) and are used also in ANGCA1, RECANG, RECCA1 and TLINE.

90) CØMMØN /REC2/ E(90)

E(I) = $\sum_{L=1}^{I}$ (shroud wetted perimeter of the "wall-type" sub-subchannel L) (see Fig.21) (cm)

E is defined in TAU *) and is used also in ANGCA1, RECCA1 and TLINE.

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*) Except for the last sub-subchannel of the wall portion of each wall subchannel and for the last sub-subchannel inside this portion, which is defined by lines normal to the shroud walls: for these PRAD(I), PVERT(I) and E(I) are defined in RECCA1 (see).

91) CØMMØN /REC3/ P(90)

P(I) = PVERT(I)/(volumetric radius of the rods), for the Ith "wall-type" sub-subchannel (see Fig.21)

P is evaluated in TLINE*) and is used also in ANGCA1 and RECCA1.

92) CØMMØN /RETEM/ TNY

TNY = temperature T_x at which the gas properties must be computed for the evaluation of the Reynold number Re_x, and, consequently, for the calculation of the laminar friction factor $\lambda=\gamma K/Re_x$ (see (IV.31) and (IV.35) in /5/).

TNY is computed in RELAM for each subchannel, and is used also in ENTRFR.

93) CØMMØN /SHRØUD/ TLINER (18,2)

TLINER(NS-NSTR,M)=surface shroud temperature for the Mth subchannel of channel NS (NSTR=number of the central channels) (^oC)

TLINER is defined in RTRI or in RTSI, in the case of turbulent flow and in TEMLAM,in the case of laminar flow. TLINER is used also in the main program, in ANGCA1, RECCA1, TBFUN and WALLTE.

94) CØMMØN /SUBC1/ NCHC(3), JSCH(3,3)

For the definitions of NCHC and JSCH see subroutine SUBCØN. NCHC and JSCH are defined in SUBCØN and are used in RECCA2 and SUBBAL.

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*) Except for the last sub-subchannel of the wall portion of each wall subchannel and for the last sub-subchannel inside this portion, which is defined by lines normal to the shroud walls: for these P(I) is defined in RECCA1 (see)

95) CØMMØN /SUBC2/ JCHC(3,2)

For the definition of JCHC see subroutine SUBCØN. JCHC is defined in SUBCØN and is used in RECCA2 and SUBBAL.

96) CØMMØN /SUBLA/ CLASUB

CLASUB = 1.0576 for axial portions with smooth rods
= 1 for axial portions with roughened rods

CLASUB is established in the main program, at each axial portion. It is used in GSTAR.

97) CØMMØN /SUB1/ ASCH(42,3)

For the definition of ASCH see subroutine INQUA.
ASCH is evaluated in INQUA and is used also in the main program, in ANGCA1, INLCØN, NØRMT, RECCA1, RECCA2, SIMLA1, SUBBAL, TBFUN, TEMLAM, TRICA1, TWFUN and WALLTE.

98) CØMMØN /SUB2/ TSCH(42,3), MSCH(42,3)

TSCH(NS,M) = bulk temperature (average for an axial section),for the Mth subchannel of channel NS (^{o}C)

MSCH(NS,M) = average mass flow rate (for an axial section),for the Mth subchannel of channel NS (g/s)

TSCH and MSCH are initialized in INLCØN,or in ANGCAI, or in RECCA1, or in TRICA1, are computed in SUBBAL and are used also in the main program, in NØRMT, RECCA2, SIMLA1 and WALLTE.

99) CØMMØN /SUB3/ ADAB(18,2), DETB(18,2)

ADAB(NS-NSTR,M) = (flow area for the whole corner channel or for the whole wall portion of wall subchannel)/(flow area for the corresponding zone inside the τ=0 line), for the Mth subchannel of the external channel NS*)

DETB(NS-NSTR,M) = equivalent diameter for the inner zone of a corner channel or of the wall portion of a wall subchannel, for the Mth subchannel of the external channel NS (cm)*)

The elements of ADAB and DETB are defined in ANGCA1 or in RECCA1. ADAB and DETB are used also in RECCA2, SUBBAL and WALLTE.

100) CØMMØN /SUB4/ LAMB(18,2)

LAMB(NS-NSTR,M) = friction factor for the inner zone of a corner channel or of the wall portion of a wall subchannel, for the Mth subchannel of the external channel NS *)

The elements of LAMB are computed in ANGCA1 or in RECCA1. LAMB is used also in WALLTE.

101) CØMMØN/ SUB5/ LAMSCH(42,3)

LAMSCH(NS,M) = friction factor for the Mth subchannel of channel NS.

The elements of LAMSCH are computed in ANGCA1, or in RECCA1, or in TRICA1. LAMSCH is used also in the main program, in ENFRCØ, SUBBAL and WALLTE.

102) CØMMON /SUB6/ TSCH1 (42,3)

TSCH1(NS,M) = bulk temperature at the inlet of an axial section, for the Mth subchannel of channel NS (^{o}C)

TSCH1 is read or established in INLCØN at the first axial section of the bundle and is established in the main program at the other axial sections. TSCH1 is used also in ANGCA1, SUBBAL, TMPUN and TRICA1.

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*) NSTR = number of the central channels

103) CØMMØN /SUB8/ MSCH1(42,3)

MSCH1(NS,M) = mass flow rate at the inlet of an axial section, for the Mth subchannel of channel NS (g/s)

MSCH1 is read or established in INLCØN at the first axial section of the bundle and is established in the main program at the other axial sections. MSCH1 is used also in ANGCA1, RECCA1, RECCA2, SUBBAL and TMPUN.

104) CØMMØN /SUB20/ PRØVI(18,2)

PRØVI(NS-NSTR,M)= parameter P_T defined by (I.111) of /5/ in the present version of SAGAPØ, equal for all subchannels M of all external channels NS *)

The elements of PRØVI are still defined in the main program, at each iteration ITCØRR (see Fig.11), as $P_p = \left(\frac{\dot{m}_p D_p}{A_p} \sqrt{\frac{\lambda_p}{8\rho_p}} \right)$ as in /1/ (see there equations (22) and (23)). But then, in the present version of SAGAPØ, they are all set equal to P_T as soon as RECANG is called **) (see 1.9.3 in /5/). PRØVI is used only in the main program and in RECANG.

105) CØMMØN /SUB21/ TSCHA(18,2), TSCHB(18,2)

TSCHA(NS-NSTR,M)= bulk temperature for the outer zone of a corner channel or of the wall portion of a wall subchannel, for the Mth subchannel of the external channel NS (^oC) *)

TSCHB(NS-NSTR,M)= bulk temperature for the inner zone of a corner channel or of the wall portion of a wall subchannel, for the Mth subchannel of the external channel NS (^oC) *)

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*) NSTR = number of the central channels.

**) Also in /1/ at ITCØRR=1 all P_p were set equal to P_T (see listing for RECANG).

The elements of TSCHA and TSCHB are computed in RTRI or in RTSI, in the case of turbulent flow; they are set equal to the bulk temperature of the whole corner channel or of the whole wall portion of wall subchannel in TEMLAM, in the case of laminar flow. TSCHA and TSCHB are used also in the main program in RECANG and WALLTE.

106) CØMMØN /SUB22/ TW(42,3)

TW(NS,M) = pin temperature (average in an axial section) for the Mth subchannel of channel NS (^{o}C)

TW is initialized in INLCØN. The elements of T_W are then computed in WALLTE by means of the subroutines RTRI and RTSI (these are the surface values, which correspond to an infinite conductivity of the canning metal, in the case of roughened rods *)). TW is used also in the main program, in ANGCA1, CEWA, RECANG, RECCA1, TRICA1 and TWFUN.

107) CØMMØN /SUB23/ HPLUSB(42,3), HPLUSW(42,3), QPLUS(42,3), PRB(42,3), YODH(42,3)

HPLUSB(NS,M), HPLUSW(NS,M), QPLUS(NS,M), PRB(NS,M), YODH(NS,M) =

= average values (at each axial section) of h_B^+, h_{WR}^+, Q^+, Pr_B, $\frac{(r_o-r_1)}{h_R}$, respectively, for the Mth subchannel of channel NS (for the symbology see 4.3 in this work and 3.2.3 of /5/).

The elements of HPLUSB, HPLUSW, QPLUS, PRB, YODH are evaluated in ANGCA1, or in RECCA1, or in TRICA1 and are used in the main program.

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*) Each temperature TW(NS,M) is then corrected in the subroutine CØRRTE.

108) CØMMØN /SUB31/ WCFNS(3), DPNS(3), WTNS1(3,3),WTNS2(3,2), UANS(3), RUASNS(3)

WCFNS(I) = net cross flow rate leaving the Ith subchannel of a channel (g/s cm)

DPNS(I) = pressure loss for the Ith subchannel of a channel (kg/cm^2)

WTNS1(I,II) = turbulent mass-flow rate exchanged between the Ith and the IIth subchannels of a channel (g/s cm)

WTNS2(I,K1) = turbulent mass-flow rate exchanged between the Ith subchannel of a channel and the Mth channel which is adjacent to the channel containing subchannel I *) (g/s cm)

UANS(I) = average velocity for the Ith subchannel of a channel (cm/s)

RUASNS(I) = ρu^*-value for the Ith subchannel of a channel (g/cm^2)**)

WCFNS, DPNS, WTNS1, WTNS2, UANS and RUASNS are defined in SUBBAL for each channel. They are used in RECCA2, if the channel is a wall channel.

109) CØMMØN /TRANS/ RHTU, RHSM

RHTU = value r of $R(h^+)$, obtained computing $R(h^+)$ with the equations of Dalle Donne /11/ (see RHPLUS)

RHSM = $5.5 + 2.5 \ln (h_B^+) = R(h^+)$ value in the vase of "hydraulically smooth" rods (see RHPLUS)

RHTU and RHSM are computed in RHPLUS and used also in RTRI.

110) CØMMØN /TUR1/ CTURB(42,3)

For the definition of CTURB see subroutine INGE. CTURB is defined in INGE and is used in BALA.

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*) M=JCHC(I,K1); see also subroutine SUBCØN

**) See function TME

111) CØMMØN /TUR2/ CTURB1(2)

For the definition of CTURB1 see subroutine INGE.
CTURB1 is defined in INGE and is used in SUBBAL.

112) CØMMØN /WACØ1/ XMSCHB(18,2), XMSCHA(18,2)

XMSCHB(NS-NSTR,M) = mass flow rate for the inner zone of a corner channel or of the wall portion of a wall subchannel, for the Mth subchannel of the external channel NS (NSTR=number of the central channels) (g/s)

XMSCHA(NS-NSTR,M) = mass-flow rate for the outer zone of a corner channel or of the wall portion of a wall subchannel, for the Mth subchannel of the external channel NS (NSTR=number of the external channels) (g/s)

The elements of XMSCHB and XMSCHA are defined in RECCA1 for the wall subchannels and in the main program for the corner channels. XMSCHA and XMSCHB are used also in ANGCA1, RECCA2, SUBBAL and WALLTE.

113) CØMMØN /WAKAO/ CD, WD, ZD, ZWCD, AWD2, PWWD

CD = (pitch of the rods)/(tip diameter of the rods)

WD = (distance between the centers of the external rods and the shroud + tip radius of the rods)/(tip diameter of the rods)

ZD = (distance between the centers of the external rods and the shroud)/(tip diameter of the rods)

ZWCD = (height of the blocking triangles)/(tip diameter of the rods)

AWD2 = (flow area of the wall subchannels, based on the tip diameter of the rods)/(tip diameter of the rods)^2

PWWD = (wetted perimeter of the wall subchannels, based on the tip diameter of the rods)/(tip diameter of the rods)

The parameters CD, WD, ZD, ZWCD, AWD2, PWWD are defined in TØTGEØ and are used in SELAWA.

114) CØMMØN /WAKA1/ IKAPPA

For the definition of IKAPPA see 3.3 (BLØCK DATA). IKAPPA is used in KAPCØR.

115) CØMMØN /WALLCØ/ WFCØ1(18,2), WFCØ(18,2)

WFCØ1(NS-NSTR,M) = parameter ($K^{+}_{W_1}$/K)($K^{+}_{W_1}$ is defined by (IV.100) of /5/) for the Mth subchannel of channel NS, if NS is a wall channel *)

= 1 if NS is a corner channels

WFCØ(NS-NSTR,M) = parameter (K^{+}_{W}/K) (K^{+}_{W} is defined by (IV.99) of /5/) for the Mth subchannel of channel NS, if NS is a wall channel *)

= 1 if NS is a corner channel

The elements of WFCØ1 and of WFCØ are all set equal to 1 in KAPCØR. The elements for the wall channels are then computed in RECCA1. WFCØ1 and WFCØ are used in SIMLA1.

116) CØMMØN /WALLKA/ AKAWC(2)

AKAWC(1), AKAWC(2)= K=λRe-value in fully developed laminar flow, for the wall portion and for the central portion of the wall subchannels, respectively

AKAWC(1) and AKAWC(2) are set equal to the input K-value for the wall subchannels in KAPCØR. Then, if SELAWA is called, new values for them are computed in SELAWA. AKAWC is used also in RECCA1.

117) CØMMØN /WCSE1/ DEWC(18,2,2), PHWC(18,2,2)

DEWC(NS-NSTR,M,I), (PHWC(NS-NSTR,M,I) =

= equivalent diameter and rod heated perimeter, respectively, for the Ith portion of the Mth subchannel of

---

*) NSTR = number of the central channels.

channel NS, defined only for wall channels (cm) *) **)
The elements of DEWC and PHWC are evaluated in RECCA1 for the wall subchannels. DEWC and PHWC are used also in the main program, in RECCA2 and in WALLTE.

118) CØMMØN /WCSE2/ MSCWC1(18,2,2)

MSCHWC1(NS-NSTR,M,I) =

= mass flow rate ar the inlet of an axial section for the Ith portion of the Mth subchannel of channel NS, defined only for wall channels (g/s) *)

MSCWC1 is evaluated in the main program at each axial section (only if non-uniform mass-flow and gas-temperature distributions are assumed at the inlet, at the first axial section MSCWC1 is read in INLCØN). MSCWC1 is used also in RECCA2 and TMPUN.

119) CØMMØN /WCSE3/ LAMWC(18,2,2)

LAMWC(NS-NSTR,M,I)= friction factor for the Ith portion of the Mth subchannel of channel NS, defined only for wall channels *)

The elements of LAMWC are computed in RECCA1 for the wall subchannels. LAMWC is used also in the main program,in ENFRCØ, RECCA2 and WALLTE.

120) CØMMØN /WCSE4/ CTURB2(18,2)

CTURB2(NS-NSTR,M) = parameter TURBWC for the turbulent exchange between the two portions of the Mth subchannel of channel NS, defined only for wall channels*) (see function TURBWC)

The elements of CTURB2 are evaluated in RECCA1 for the wall subchannels, by means of function TURBWC. CTURB2 is used in RECCA2.

---

*) NSTR=number of the central channels; I=1 for the wall portion, I=2 for the central portion

**) Based on the volumetric diameter of the rods in the case of turbulent flow and on the tip diameter in the case of laminar flow.

121) CØMMØN /WCSE5/ TSCWC1(18,2,2)

TSCWC1(NS-NSTR,M,I) =

= bulk temperature at the inlet of an axial section for the Ith portion of the Mth subchannel of channel NS, defined only for wall channels (^oC) *)

TSCWC1 is defined in INLCØN at the first axial section of the bundle; at the other axial sections it is defined in the main program. TSCWC1 is used also in RECCA1, RECCA2 and TMPUN.

122) CØMMØN /WCSE6/ ASCWC1(18,2,2)

ASCWC1(NS-NSTR,M,I)=flow area at the inlet of an axial section for the Ith portion of the Mth subchannel of channel NS, defined only for wall channels (cm^2) *)

ASCWC1 is defined in the main program and is used in RECCA2 **).

123) CØMMØN /WCSE7/ MAWC(18,2,2)

MAWC(NS-NSTR,M,I) = mass flow rate (average for an axial section) for the Ith portion of the Mth subchannel of channel NS, defined only for wall channels (g/s)*)

The elements MAWC are computed in RECCA2 for the wall channels in the case of turbulent flow and in SUBBAL in the case of laminar flow.
MAWC is used also in the main program, in NØRMT and WALLTE.

124) CØMMØN /WCSE8/ ASCWC(18,2,2)

ASCHWC(NS-NSTR,M,I)=flow area (average for an axial section) for the Ith

---

*) NSTR=number of the central channels; I=1 for the wall portion, I=2 for the central portion.

**) This parameter is not used in the present version of SAGAPØ: it was introduced to allow to take into account the contribution to the pressure losses which is due to the variation of the flow area. This contribution is now neglected (it is normally very small and sometimes gives origine to convergence problems).

portion of the Mth subchannel of channel NS, defined only for wall channel (cm^2) *)

The elements of ASCHWC are defined in RECCA1 for the wall subchannels (they are based on the volumetric diameter of the rods in the case of turbulent flow and on the tip diameter in the case of laminar flow).
ASCHC is used also in the main program, in NØRMT, RECCA2, SUBBAL and WALLTE.

125) CØMMØN /WCSE9 /TAVWC(18,2,2)

TAVWC(NS-NSTR,M,I)= bulk temperature (average for an axial section) for the Ith portion of the Mth subchannel of channel NS, defined only for wall channels (°C) *)

The elements of TAVWC are computed in RECCA2 for the wall subchannels, in the case of turbulent flow. They are set equal to the bulk temperature of the containg subchannel in SUBBAL, in the case of laminar flow. TAVWC is used also in the main program, in NØRMT, RECCA1 and WALLTE.

126) CØMMØN /WCSE12/ TWWC(18,2,2)

TWWC(NS-NSTR,M,I) = pin temperature for the Ith portion of the Mth subchannel of channel NS, computed only for the wall channels (°C) *)

The elements of TWWC are computed in WALLTE by means of RTRI or of RTSI, for the wall subchannels: these elements are the surface pin temperatures, (which correspond to an infinite conductivity of the canning metal ,in the case of roughened rods). The TWWC values are then corrected in the main program by means of CØRRTE.

---

*) NSTR = number of the central channels; I=1 for the wall portion, I=2 for the central portion.

127) CØMMØN /WSSCH/ T1SSC1(18,2), T2SSC1(18,2), T1SSC2(18,2), T2SSC2(18,2)

T1SSC1(NS-NSTR,M), T2SSC1(NS-NSTR,M), T1SSC2(NS-NSTR,M), T2SSC2(NS-NSTR,M) = values of the temperatures T1SSCH(1), T1SSCH(N), T2SSCH(1), T2SSCH(N), respectively (whose meaning has been explained in 4.3), for the Mth subchannel of the external channel NS (^{o}C) *)

The elements of T1SSC1, T2SSC1, T1SSC2, T2SSC2 are computed in RECANG in the case of turbulent flow; they are set equal to the bulk temperature of the containing subchannel in ANGCA1 and RECCA1, in the case of laminar flow . T1SSC1, T2SSC1, T1SSC2 and T2SSC2 are used also in the main program.

128) CØMMØN /WSSCHO/ TBSSC1(42,3), TWSSC1(42,3), TBSSC2(42,3), TWSSC2(42,3)

TBSSC1(NS,M), TWSSC1(NS,M), TBSSC2(NS,M), TWSSC2(NS,M) =
= values of the temperatures TBSSCH(1),TWSSCH(1), TBSSCH(N), TWSSCH(N) (whose meaning has been already explained in 4.3), for the Mth subchannel of channel NS (^{o}C)

The elements of TBSSC1, TWSSC1, TBSSC2 and TWSSC2 are defined in TRICA1 for the central sub-subchannels, in RECANG for the "wall-type" sub-subchannels in the case of of turbulent flow and in RECCA1 and ANGCA1 for the "wall-type" sub-subchannels in the case of laminar flow. TBSSC1, TWSSC1, TBSSC2, TWSSC2 are used also in the main program.

129) CØMMØN /WSSCH1/ DELTIE(18,2,90), DTIEAV(18,2)

DELTIE(NS-NSTR,M,I)=temperature factor $\left[\beta\left(T^{*(K-1)}_{2i} - \bar{T}^{*(K-1)}_{2}\right)\right]$, (* means normalized to the average enthalpy, see (42) in /1/) for sub-subchannel I of the Mth subchannel of the external channel NS *)**) (^{o}C)

---

*) NSTR=number of the central channels.

**) These variables were introduced for the computations of /1/.
K=index of the axial section; T_{2i}=outlet temperature for sub-subchannel i; $\bar{T}_2$=outlet temperature for the corner channel or for the portion of the wall subchannel containing sub-subchannel i; about β see 3.1, Card 22.

DTIEAV(NS-NSTR,M) = normalization factor for the temperature factors

$$\left[\beta\left(T_{2i}^{(K-1)} - \bar{T}_{2}^{(K-1)}\right)\right] = \sum\left(\beta\left(T_{2i}^{(K-1)} - \bar{T}_{2}^{(K-1)}\right)\dot{m}_{i}\right)$$

for the Mth subcahnnel of the external channel NS (^{o}C) (see (42) in /1/) *)

The elements of DELTIE are defined in the main program, whereas those of DTIEAV are computed in ANGCA1 or in RECCA1. DELTIE and DTIEAV are used also in RECANG.

130) CØMMØN /WSSCH2/ TIØ(18,2,90)

TIØ(NS-NSTR,M,I) = outlet temperature $T_{2i}^{(K)}$ at the axial section K for the Ith sub-subchannel of the Mth subchannel of the external channel NS (^{o}C) *) **)

The element of TIØ are defined in RECANG for each "wall-type" sub-subchannel and in RECCA1 for the "central-type" sub-subchannels of the wall subchannels (for these equal values of $T_{2i}^{(K)}$ are assumed). TIØ is used also in the main program.

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*) NSTR = number of the central channels

**) see the note of pag. 196.

6. REFERENCES

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7. LIST ØF FIGURES

APPENDIX 1

Listing of the version of SAGAPØ for hexagonal bundles

```
C     A. MARTELLI
C     ***********
C
C
C
C     ==================================================================
C     S A G A P O
C
C     A COMPUTER CODE FOR THE THERMO-FLUIDDYNAMIC ANALYSIS OF GAS COOLED
C     BUNDLES OF PARTLY SMOOTH AND PARTLY ROUGHENED RODS IN STEADY STATE
C     CONDITIONS
C     ==================================================================
C
C
C     THE CODE HAS BEEN WRITTEN IN FORTRAN IV FOR THE COMPUTER IBM 370-
C     168 OF THE KARLSRUHE NUCLEAR CENTER
C     DESCRIPTION OF THE PHYSICAL MODEL: KFK 2436-EUR 5508D
C     USER'S GUIDE: KFK
C
C
C     MAIN PROGRAM
C     ------------------------------------------------------------------
C     THE MAIN PROGRAM  READS MOST OF THE INPUT DATA, PRINTS AND PUNCHS
C     MOST OF THE COMPUTED RESULTS,PERFORMS SOME SIMPLE CALCULATIONS
C     AND ORGANIZES ALL THE CALCULATIONS OF SAGAPO
C
      REAL LENGTH,LAMBDM,MFLOW,MA,MSCH ,MI,MC,MEC,LAM ,MEA1,LAM1,MM2
     1     ,MSCH1,LAMSCH,MSCHB,MSCHB1,LAMBDA(100),MAV,MAWC,MSCWC1,LAMWC,
     2     NDE1,NDE2,KAPPA
      REAL*8 TITLE(4,7)/'INITIAL ','UNHEATED',' SMOOTH ','PART',
     1        'FIRST HE','ATED SMO','OTH PART',' ','FIRST UN',
     2        'HEATED R','OUGH PAR','T','ROUGH PA','RT (HEAT',
     3        'ED OR UN','HEATED)','LAST  UN','HEATED R','OUGH PAR','T',
     4        'SECOND H','EATED SM','OOTH PAR','T','LAST UNH','EATED SM',
     5        'OOTH PAR','T'/
      DIMENSION PGDPT(3),EPSIT(3),CSPT(3),DPEAR(100),PBAR(100),
     1          T(100),RHOBT(100),ETABT(100),UBT(100),REBT(100),P(100),
     2          GRI(42,3,7),IRGRI(42,3),GRIP(42,3,7),XDE1(7),XDE2(7),
     3          QPIN(42),XLAM1(7),NSPAC(7),PLEN(7),VDIAM(7),FAREL(7),
     4          CIPA(7),ZIPA(7),TWTIPA(7),TBTIPA(7),TBPIPA(7),WSP(7),
     5          PLENO(7),RHIPA(3),ACW(45),DECW(45),MEC(45),
     6          AA1(30),DEA1(30),MEA1(30),RMISTW(7),RINT(7),
     7          HPLUS1(42,3),HPLUS2(42,3),TWA(42,3),QPLUSA(42,3),
     8          PRBA  (42,3),XSTART(7),XEND(7),AMASST(42,3)
     9          ,AMASSB(42,3),TEMPBA(42,3),YCHA(42,3),TEMPTA(42,3)
      DIMENSION INDSP(100),NEXPR(7 ),PEX(10),XEXPR(10),NEXTW(7 ),
     1          XEXTW(10) ,TWTH(42,3,10),TWP(42,3),DELTIC(18,2,90),
     2          GRI1(18,2,7),GRI2(18,2,7),YOCHA(42,3),
     3          X2DPRQ(7),NDPRQ(7),QDCOI(7),QLDCOI(7),QDCC(7,7),
     4          QLDCO(7,7),XPRQ(3),BIOT(42,3),TWINF(42,3),QSECT(3)
      COMMON/GRIDWC/EPSWC(18,2,2,3),CSPWC(18,2,2,3)/CORRE/QHRDAR,QRMDAR
     1      ,QLAMR/QPAR1/QDEV/QPAR2/QLINM,QLDEV/QPAR3/PERL(3)
     2      /CORR/SIGMA(42),PHI(42),SBMNS
     3      /CORR1/SIGMAI(42,3),PHII(42,3)/CORR2/CHI(18,2,2),PSI(18,2,2)
     4      /GEN1/LAM(42)/GEN4/TEMP(42)/GEN2/A(42)/GEN5/DE(42)
     5      /GEN3/MI(42)/GEN6/MO(42)/HEA1/Q(19)/HEA5/QQ(42,3)
     6      /GRID/CSPC(42,3)/ GRIDO/CSPSC(42,3,3)
     7      /GRID1/EPSISC(42,3,3),DIST(7 )/GRID3/X(100)
     8      /GRID6/EPSIC(42,3)/GRID7/PGDPC(42,3)/GRID8/PGDPSC(42,3,3)
```

```
     9        /IND3/NTYP(42)/GEO2/ATOT,DETOT,ASEC
      COMMON/GEO5/ATC,DETC,ATW,DETW,ATA,DETA,AAC,AAW,AAA
     1        /HB3/TEMP2(42)/MOB1/MM2(42)/ MOB4/WCF(42)
     2        /MOB2/UAV(42) /MOB5/TAV(42)/MOB6/MAV(42)/MOB8/CPNS(42)
     3        /MOB24/WT(42,3)/SUB2/TSCH(42,3),MSCH(42,3)
     4        /HEA6/NPIN(42),JPIN(42,3)/SUB1/ASCH(42,3)
     5        /SUB6/TSCH1(42,3)/SUB5/LAMSCH(42,3)/SUB8/MSCH1(42,3)
     6        /SUB20/PROVI(18,2)/SUB22/TW(42,3)
     7        /SUB23/HPLUSB(42,3),HPLUSW(42,3),QPLUS(42,3),FRB  (42,3)
     8        ,YODH(42,3)/IJ1/NER(42),NIS(42,3)/MART/ITCORR /DAT/PIG
     9        /COLAM1/COLAMB/COLAM2/COLAMA/SUB21/TTSCHA(18,2),TTSCHB(18,2)
      COMMON/DAT1/O0,O1,O2,O3,O4,O5,O16,O17,O18,O19
     1        /DAT2/O6,O7,O8,O9,O10,O11,O12,O13,O14,O15/DAT4/NDEST,NDEEND
     2        /DAT6/IRHPL/DAT7/CNUSS(2)/WAC01/XMSCHB(18,2),XMSCHA(18,2)
     3        /WCSE2/MSCWC1(18,2,2)/WCSE3/LAMWC(18,2,2)/WCSE7/MAWC(18,2,2)
     4        /WCSE6/ASCWC1(18,2,2)/WCSE5/TSCWC1(18,2,2)
     5        /WCSE8/ASCHWC(18,2,2)/WCSE9/TAVWC(18,2,2)/WCSE1/DEWC(18,2,2)
     6        ,PPWWCC(18,2,2)/WCSE12/TWWC(18,2,2)/GRAV/IGRAV
     7        /PARTB/TEMPB(42,3),XMASSB(42,3),YDH(42,3)/INITL/XMHE
     8        /WSSCH/T1SSC1(18,2),T2SSC1(18,2),T1SSC2(18,2),T2SSC2(18,2)
     9        /WSSCHO/TBSSC1(42,3),TWSSC1(42,3),TBSSC2(42,3),TWSSC2(42,3)
      COMMON/WSSCH1/DELTIE(18,2,90), DTIEAV(18,2)/WSSCH2/TIC(18,2,90)
     1        /IROSMO/IRH/SUBLA/CLASUB/SHROUD/TLINER(18,2)/CSHR/QALIN
     2        /INPAR/IPA/LAMIN3/F1ATIP(42),F1DTIP(42)/LAMIN4/F2ATIP(42,3),
     3        F2DTIP(42,3)/LAMIN5/RTIP(7)/LAMINO/I2TIP(42,3)/MART5/NSTR
      EXTERNAL RTRI,RTSI
C
      CALL FSPIE
C     ..................................................................
C
C   1-READ AND WRITE INPUT DATA
C
      TIME0=0.
      TIME1=ZEIT(TIME0)
      PEXOUT=0.
      COLAMB=1.
      SQ3=SQRT(3.)
      PIG=3.141593
    1 FORMAT(8I10)
    2 FORMAT(8F10.5)
      READ(5,1)NEXCON,NRODS,NSPACT,NSPAC
      READ(5,2)C,Z,ZWC,RH,PLEN,VDIAM
      READ(5,2)AREFB,RMISTW,RINT,RTIP
      READ(5,1)NDVQ,NSEL,NSC30C,NSC30W,NSC30A
      READ(5,2)PE,PE1,TE,TE1,MFLOW,XLAM1
      READ(5,2)COLAMA
      READ(5,1)IPAST,IPAEND,IREAD1
      READ(5,2)STLEN
      READ(5,1)INDPR,INDQ
      READ(5,1) NEXPRT,NEXPR
      READ(5,1) NEXTWT,NEXTW
      READ(5,1)ITCM,ITC1,ITC2,MSUBDH
      READ(5,2)XDE1,XDE2
      READ(5,2)FT,PCORR,CTU1,CTU2,CTU3
      READ(5,2)TWPRCF,TCPRCF
      READ(5,2)CINL,COUT
      READ(5,2)FAREL
      READ(5,2)TWTIPA,TBTIPA,TBPIPA
      IF(NEXPRT.GT.0)READ(5,2)(XEXPR(I),PEX(I),I=1,NEXPRT),PEXOUT
```

```
      IF(NEXTWT.GT.0)READ(5,2)(XEXTW(I),I=1,NEXTWT)
      IF(NDVG.EQ.1)GOTO 3
      READ(5,2)(QPIN(I),I=1,NRODS)
      GOTO 5
    3 READ(5,2)QPIN(1)
      DO 4 I=1,NRODS
    4 QPIN(I)=QPIN(1)
    5 CONTINUE
      READ(5,2)QLINMT
      IF(INDQ.EQ.1)GOTO 3800
      DO 3799 I=1,NRODS
 3799 QPIN(I)=QPIN(I)/4.186
      QLINMT=QLINMT/4.186
 3800  CONTINUE
      READ(5,1)NDPRQT,NDPRC
      IF(NDPRQT.EQ.0)GOTO 3716
      READ(5,2)(X2DPRQ(I),I=1,NDPRQT)
      READ(5,1)NQDCO
        READ(5,4001)((QDCO(I,J),J=1,NQDCO),I=1,NDPRQT)
        READ(5,4001)((QLDCO(I,J),J=1,NQDCO),I=1,NDPRQT)
 4001 FORMAT(6E12.5)
 3716 CONTINUE
      HEALEN=PLEN(2)+PLEN(4)+PLEN(6)
      TOTLEN=PLEN(1)+PLEN(3)+PLEN(5)+PLEN(7)+HEALEN
      IF(ABS(PE/PE1-1.).GT.1.E-05)CINL=0.
      PEO=PE1
      IF(INDPR.EQ.1)GOTO 6529
      PE=PE/0.980665
      PEO=PE1/0.980665
 6529 CONTINUE
      PEBAR=PE*0.980665
      PEOBAR=PEO*0.980665
      WRITE(6,6)NRODS,PEO,PEOBAR,TE1,MFLOW,C,Z,ZWC,TOTLEN,HEALEN
    6 FORMAT(1H1,5X,I4,' RODS BUNDLE :'//5X,'INLET PRESSURE=',F10.7,' KG
     1/SQCM    =',F10.7,' BARS'
     1        /5X,'INLET TEMPERATURE=',F10.2,' C'/5X,'TOTAL MASS FLOW RATE
     2=',F12.6,' G/SEC'///5X,'GEOMETRY AT 20 DEGREES : '//
     3                                          5X,'ROD PITCH=',F10.6,' CM'/
     45X,'DISTANCE CENTER OF ROD - EXAGONAL WALL=',F10.6,' CM'/5X,
     5'ZWC=',F10.7,' CM'//5X,
     6  'TOTAL LENGTH=',F10.3,' CM'/5X,'HEATED LENGTH=',F10.3,' CM'/5X,
     7'LENGTH AND VOL. DIAMETERS FOR THE EXISTING PARTS :')
       DO 972 IPA=1,7
       IF(PLEN(IPA).LE.1.E-06)GOTO 972
       WRITE(6,971)IPA,PLEN(IPA),IPA,VDIAM(IPA)
  971 FORMAT(5X,'LENGTH(',I1,')=',F10.6,' CM',5X,'VOL. DIAM.(',I1,')=',
     1   F10.6,' CM')
  972 CONTINUE
      IF(PLEN(4).GT.1.E-06)
     *WRITE(6,980)RH,
     1             O16,O17,O4,O5,O0,O1,O2,O3,                   O6,O7,O8,O9
     2,O10,O11,O13,O14,O15
  980 FORMAT(//////5X,'HEIGHT OF ROUGHNESS (RH) =',F8.5,' CM'/5X,
     1'G(H+) * ((R2-R1)/RH*',F6.3,')**',F6.3,' / (PR**',F6.3,'*((TW+273.
     215)/(TB+273.15))**',F6.3,')='/5X,'=',F6.3,'*(HW+)**',F6.3,'+',F9.3
     3,'/(HW+)**' ,F6.3///5X,
     5 'R(H+)=(', F6.3,'+', F7.1,'/(HW+)**', F6.3,')**', F6.3,'+',F6.3,
     6'*LN(RH/(',F6.3,'*(R0-R1))'/12X,'+',F6.3,'/(HW+)**',F6.3,'*((TW+27
     73.16) /(TB1+273.16)-1)**',F6.3//)
```

```
      WRITE(6,3727)QLINMT,(I,QPIN(I),I=1,NRODS)
 3727 FORMAT(//5X,'MAXIMUM POWER FROM THE LINER:'//5X,'Q MAX=',E15.5,
     1    ' CAL/SEC*CM'
     2         ///5X,'MAXIMUM POWER OF RODS:'//(5X,'Q MAX(',I4,')=',E15.5,
     3    ' CAL/SEC*CM'))
      IF(NDPRQT.EQ.0)GOTO 3730
      WRITE(6,3731)
 3731 FORMAT(//5X,'COEFFICIENTS FOR THE POLYNOMIAL PROFILES OF THE ROD P
     1OWER ( 0 TAKEN AT THE BEGINNING OF THE ACTUAL PART ):'/)
      DO 3729 I=1,NDPRQT
 3729 WRITE(6,3728)X2DPRQ(I),(QDCO(I,J),J=1,NQDCO)
 3728 FORMAT(/5X,'AS FAR AS X =',F10.6,' CM :'/(5X,8E15.5))
      WRITE(6,3733)
 3733 FORMAT(//5X,'COEFFICIENTS FOR THE POLYNOMIAL PROFILE OF THE LINER
     1POWER ( 0 TAKEN AT THE BEGINNING OF THE ACTUAL PART ):'/)
      DO 3732 I=1,NDPRQT
 3732 WRITE(6,3728)X2DPRQ(I),(QLDCO(I,J),J=1,NQDCO)
 3730 CONTINUE
C     ..................................................................
C
C   2-INDEXING AND CONNECTIONS FOR THE CHANNELS
C
      CALL INDEX(NSEL,NEXCON,NSTR,NSTOT,NROM1)
      NSPER=NSTOT-NSTR
C     ..................................................................
C
C   3-READ AND WRITE INPUT DATA
C
      IF(NSPACT.EQ.0)GOTO 7
      READ(5,2)WSPO,(DIST(I),I=1,NSPACT)
      WRITE(6,970)WSPO,(I,DIST(I),I=1,NSPACT)
  970 FORMAT(//5X,'SPACERS (AT 20 DEGREES):'//5X,'WIDTH=',F10.6,' CM'//
     1(5X,'DIST(',I2,')=',F10.3,' CM'))
      WRITE(6,83)
      DO 11 I=1,NSPACT
       READ(5,981)((GRI(NS,J,I   ),J=1,3),NS=1,NSTOT)
      READ(5,981)((GRIP(NS,J,I   ),J=1,3),NS=1,NSTOT)
      READ(5,981)((GRI1(K,J,I    ),J=1,2),K=1,NSPER)
      READ(5,981)((GRI2(K,J,I    ),J=1,2),K=1,NSPER)
   11 CONTINUE
      READ(5,982)((IRGRI(NS,J),J=1,3),NS=1,NSTOT)
  981 FORMAT(6F10.5)
  982 FORMAT(6I10)
    7 CONTINUE
      READ(5,2)TIMEPU
      READ(5,1)IPUNCH
C     ..................................................................
C
C   4-CORRECTION OF THE INPUT DIMENSIONS TO TAKE INTO ACCOUNT THE
C     THERMAL EXPANSION OF THE BUNDLE STRUCTURE
C
      SPLENO=0.
      NEXPRP=0
      NEXTWP=0
      NSPACP=0
      NDPRQP=0
      DO 882 IPA=1,7
      EXFTBP=1.+EXPCL(TBPIPA(IPA))*(TBPIPA(IPA)-20.)
      EXFTWT =1.+EXPCO(TWTIPA(IPA))*(TWTIPA(IPA)-20.)
```

```
      IF(NEXPR(IPA).EQ.0)GOTO 1010
      IEXPR1=NEXPRP+1
      IEXPR2=NEXPRP+NEXPR(IPA)
      NEXPRP=IEXPR2
      DO 1009 IEXPR=IEXPR1,IEXPR2
 1009 XEXPR(IEXPR)=(XEXPR(IEXPR)-SPLENO)*EXFTBP
 1010 CONTINUE
      IF(NEXTW(IPA).EQ.0)GOTO 1012
      IEXTW1=NEXTWP+1
       IEXTW2=NEXTWP+NEXTW(IPA)
      NEXTWP=IEXTW2
      DO 1011 IEXTW=IEXTW1,IEXTW2
 1011 XEXTW(IEXTW)=(XEXTW(IEXTW)-SPLENO)*EXFTWT
 1012 CONTINUE
      IF(NDPRQ(IPA).EQ.0)GOTO 1015
      IDPRQ1=NDPRQP+1
      IDPRQ2=NDPRQP+NDPRQ(IPA)
      NDPRQP=IDPRQ2
      DO 1014 IDPRQ=IDPRQ1,IDPRQ2
      CALL MODFQD(IDPRQ,NDPRQT,NQDCO,QDCO,EXFTWT)
      CALL MODFQD(IDPRQ,NDPRQT,NQDCO,QLDCO,EXFTWT)
 1014 X2DPRQ(IDPRQ)=(X2DPRQ(IDPRQ)-SPLENO)*EXFTWT
 1015 CONTINUE
      IF(NSPAC(IPA).EQ.0)GOTO 882
      ISPAC1=1+NSPACP
      ISPAC2=NSPACP+NSPAC(IPA)
      NSPACP=ISPAC2
      WSP(IPA)=WSPO*(1.+EXPCO(TBTIPA(IPA))*(TBTIPA(IPA)-20.))
      DO 881 ISPAC=ISPAC1,ISPAC2
  881 DIST(ISPAC)=(DIST(ISPAC)-SPLENO)*EXFTBP
  882 SPLENO=SPLENO+PLEN(IPA)
      EXCON=NEXCON
      DO 983 IPA=1,7
      EXFTBP=1.+EXPCL(TBPIPA(IPA))*(TBPIPA(IPA)-20.)
      EXFTWT =1.+EXPCO(TWTIPA(IPA))*(TWTIPA(IPA)-20.)
      PLENO(IPA)=PLEN(IPA)
      PLEN(IPA)=PLEN(IPA)*EXFTBP
      RMISTW(IPA)=RMISTW(IPA)*EXFTWT
      RINT  (IPA)=RINT  (IPA)*EXFTWT
      RTIP  (IPA)=RTIP  (IPA)*EXFTWT
      VDIAM(IPA)=VDIAM(IPA)*EXFTWT
      CIPA(IPA)=C*(1.+EXPCO(TBTIPA(IPA))*(TBTIPA(IPA)-20.))
      ZIPA(IPA)=(Z+EXCON*C*SQ3*0.5)*EXFTBP-EXCON*CIPA(IPA)*SQ3*0.5
  983 CONTINUE
      SPLEN=0.
      NEXPRP=0
      NSPACP=0
      NDPRQP=0
      DO 885 IPA=1,7
      IF(NEXPR(IPA).EQ.0)GOTO 1020
      IEXPR1=NEXPRP+1
      IEXPR2=NEXPRP+NEXPR(IPA)
      NEXPRP=IEXPR2
      DO 1019 IEXPR=IEXPR1,IEXPR2
 1019 XEXPR(IEXPR)=XEXPR(IEXPR)+SPLEN
 1020 CONTINUE
      IF(NSPAC(IPA).EQ.0)GOTO 885
      ISPAC1=1+NSPACP
      ISPAC2=NSPACP+NSPAC(IPA)
```

```
      NSPACP=ISPAC2
      DO 884 ISPAC=ISPAC1,ISPAC2
  884 DIST(ISPAC)=DIST(ISPAC)+SPLEN
  885 SPLEN=SPLEN+PLEN(IPA)
      DO 8 IPA=1,7
      IF(PLEN(8-IPA).LE.1.E-06)GOTO 8
      IPAM=8-IPA
      GOTO 9
    8 CONTINUE
    9 CONTINUE
      PLEN(IPAM)=SPLEN
      IPA1=IPAM-1
      DO 10 IPA=1,IPA1
      PLEN(IPA)=PLENO(IPA)*(1.+EXPCO(TWTIPA(IPA))*(TWTIPA(IPA)-20.))
      PLEN(IPAM)=PLEN(IPAM)-PLEN(IPA)
   10 CONTINUE
      DO 886 IPA=3,5
      IF(PLEN(IPA).LE.1.E-06)GOTO 886
      RHIPA(IPA-2)=RH*(1.+EXPCO(TWTIPA(IPA))*(TWTIPA(IPA)-20.))
  886 CONTINUE
      SPLEN=0.
      NEXTWP=0
      DO 1013 IPA=1,7
      IF(NDPRQ(IPA).EQ.0)GOTO 1017
      IDPRQ1=NDPRQP+1
      IDPRQ2=NDPRQP+NDPRQ(IPA)
      NDPRQP=IDPRQ2
      DO 1016 IDPRQ=IDPRQ1,IDPRQ2
 1016 X2DPRQ(IDPRQ)=X2DPRQ(IDPRQ)+SPLEN
      X2DPRQ(IDPRQ2)=X2DPRQ(IDPRQ2)*1.1
 1017 CONTINUE
      IF(NEXTW(IPA).EQ.0)GOTO 1022
      IEXTW1=NEXTWP+1
      IEXTW2=NEXTWP+NEXTW(IPA)
      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
      X2DPRQ(I)=X2DPRQ(I+NDPRQS)-STLEN
      IF(X2DPRQ(I).LE.0.)IDPRQ1=IDPRQ1+1
      DO 6540 IQDCO=1,NQDCO
      QDCO(I,IQDCO)=QDCO(I+NDPRQS,IQDCO)
      QLDCO(I,IQDCO)=QLDCO(I+ NDPRQS,IQDCO)
 6540 CONTINUE
      NDPRQ(IPAST)=NDPRQ(IPAST)-IDPRQ1
      NDPRQT=NDPRQT-IDPRQ1
      IF( NDPRQT.EQ.0)GOTO  6539
      DO 976 I=1,NDPRQT
      X2DPRQ(I)=X2DPRQ(I+IDPRQ1)
      DO 976 IQDCO=1,NQDCO
      QDCO(I,IQDCO)=QDCO(I+IDPRQ1,IQDCO)
      QLDCO(I,IQDCO)=QLDCO(I+IDPRQ1,IQDCO)
  976 CONTINUE
 6539 CONTINUE
      IF(NSPACT.EQ.0)GOTO 6538
```

```
      ISPAC1=0
      DO 6537 I=1,NSPACT
      DIST(I)=DIST(I+NSPACS)-STLEN
      IF(DIST(I).LE.0.)ISPAC1=ISPAC1+1
      DO 2000 NS=1,NSTOT
      DO 2001 J=1,3
      GRI(NS,J,I)=GRI(NS,J ,I+NSPACS)
 2001 GRIP(NS,J,I)=GRIP(NS,J, I+NSPACS)
      IF(NS.LE.NSTR)GOTO 2000
      NSW=NS-NSTR
      DO 2002 J=1,2
      GRI1(NSW,J,I)=GRI1(NSW,J,I+NSPACS)
 2002 GRI2(NSW,J,I)=GRI2(NSW,J,I+NSPACS)
 2000 CONTINUE
 6537 CONTINUE
      NSPAC(IPAST)=NSPAC(IPAST)-ISPAC1
      NSPACT=NSPACT-ISPAC1
      IF(NSPACT.EQ.0)GOTO 6538
       DO 977 I=1,NSPACT
      DO 2003 NS=1,NSTOT
      DO 2004 J=1,3
      GRI(NS,J,I)=GRI(NS,J,I+ISPAC1)
 2004 GRIP(NS,J,I)=GRIP(NS,J,I+ISPAC1)
      IF(NS.LE.NSTR)GOTO 2003
      NSW=NS-NSTR
      DO 2005 J=1,2
      GRI1(NSW,J,I)=GRI1(NSW,J,I+ISPAC1)
 2005 GRI2(NSW,J,I)=GRI2(NSW,J,I+ISPAC1)
 2003 CONTINUE
  977 DIST(I)=DIST(I+ISPAC1)
 6538 CONTINUE
      HEALEN=PLEN(2)+PLEN(4)+PLEN(6)
      UNHLE1=PLEN(1)+PLEN(3)
      TOTLEN=UNHLE1+HEALEN+ PLEN(5)+PLEN(7)
      HRCAR=RH/AREFB
      IF(PLEN(4).GT.1.E-06)FCORLA=ALOG(RTIP(4)/(RTIP(4)-RHIPA(2)))/
     /                           (2.*PIG*PLEN(4))
C     ................................................................
C
C   6-INITIALIZATION OF VARIABLES
C
      QLINMT=QLINMT*HEALEN
      DO 3734 I=1,NRODS
 3734 QPIN(I)=QPIN(I)*HEALEN
      ANCE=NSC30C
      ANWA=NSC30W
      ANCO=NSC30A
      ALFACE=PIG/(6.*ANCE)
      ALFAWA=PIG/(6.*ANWA)
      ALFACO=PIG/(ANCO*6.)
      NSC90=3*NSC30W
      NSC45=NSC30C/2+1+NSC30C
      L=1
      T(1)=TE
      P(1)=PE
      PBAR(1)=PEBAR
      X(1)=0.
      XDEST=NDEST
      XDEEND=NDEEND
```

```
      TO=TE
      PO=PE
      INLET=1
      ISPAC=1
      II=1
      HH=0.
      IEXPR1=1
      IEXTW1=1
      IEXTWC=1
      IDPRQ=1
      SPRLEN=0.
      IRHPL=1
C     ******************************************************************
C
C     7- LOOP IPA :  A SUBDIVISION OF RODS INTO SEVEN POSSIBLE DIFFERENT
C        PARTS IS MADE ( BUT ONLY FIVE TOGETHER ARE SUPPOSED TO EXIST :
C        1) SMOOTH UNHEATED+SMOOTH HEATED+ROUGH+SMOOTH HEATED+SMOOTH
C           UNHEATED
C        2) SMOOTH UNHEATED+ROUGH UNHEATED+ROUGH HEATED+ROUGH UNHEATED+
C           SMOOTH UNHEATED)
C
C     IPA=1 : INITIAL UNHEATED SMOOTH PART
C     IPA=2 : FIRST HEATED SMOOTH PART
C     IPA=3 : FIRST UNHEATED ROUGH PART
C     IPA=4 : ROUGH PART (HEATED OR UNHEATED)
C     IPA=5 : LAST UNHEATED ROUGH PART
C     IPA=6 : SECOND HEATED SMOOTH PART
C     IPA=7 : LAST UNHEATED SMOOTH PART
C
      DO 8888 IPA=1,7
      IF(IPA.EQ.IPAEND+1)CALL TMPUN(NSTOT,NSTR,T(L),P(L),PBAR(L),
     *TE1,PE0,PE0BAR,INDPR,MFLOW,IPA,IPAEND,2,XLAM1,X(L)+STLEN,&742)
      IF(PLEN(IPA)  .LE.1.E-06)GOTO 8888
        SPLENG=SPRLEN
      IF(IPA.EQ.IPAST)SPLENG=SPLEN-STLEN
      C=CIPA(IPA)
      Z=ZIPA(IPA)
      D=VDIAM(IPA)
      LENGTH=PLEN(IPA)
      LAM1=XLAM1(IPA)
      MSPAC=NSPAC(IPA)
      NDE1=XDE1(IPA)
      NDE2=XDE2(IPA)
      FREL=FAREL(IPA)
      ZWCIPA=ZWC     *(1.+EXPCO(TBPIPA(IPA))*(TBPIPA(IPA)-20.))
      POBAR=PO*0.980665
      WRITE(6,991)(TITLE(I,IPA),I=1,4),C,Z,ZWCIPA,D,LENGTH,MSPAC,TO,PO
     1,POBAR
  991 FORMAT(1H1,5X,4A8///5X,'C=',F10.6,' CM'/5X,'Z=',F10.6,' CM'/5X,
     1'ZWC=',F10.6,' CM'/ 5X,'VOL. DIAMETER=',F10.6,' CM'/5X,'PART LENGT
     2H='  ,F10.5,' CM'/5X,'NUMBER OF SPACERS=',I3//5X,'INLET CONDITIONS
     3 :'/5X,'INLET AVERAGE TEMPERATURE=',F7.2,' C'/5X,'INLET PRESSURE='
     4,F10.7,' KG/SQCM     =',F10.7,' BARS'/////)
      IF(MSPAC.EQ.0)GOTO 968
      ISPAC2=ISPAC+MSPAC-1
      WRITE(6,967)WSP(IPA),(I,DIST(I),I=ISPAC,ISPAC2)
  967 FORMAT(5X,'SPACERS (DISTANCES ARE EVALUATED FROM THE BUNDLE ENTRAN
     1CE) :'/5X,'WIDTH=',F10.6,' CM'/(5X,'DIST(',I2,')=',F10.3,' CM'))
      WRITE(6,83)
```

```
  968 CONTINUE
      C2=C*0.5
      EM1=C2-ZWCIPA*SQ3
      X(1)=HH
      DDD=HH+LENGTH
      SUR=PIG*D*LENGTH
      IF(IPA.EQ.5)IRHPL=2
      GOTO(993,994,993,994,993,994,993),IPA
  993 PLDHL=0.
      GOTO 995
  994 PLDHL= PLEN(IPA)/HEALEN
  995 CONTINUE
      GOTO(996,996,997,997,997,996,996),IPA
  996 IRH=1
      CLASUB=1.0576
      XMAXNU=1.6
      CHSLNU=2./3.
      GOTO 998
  997 IRH=2
      CLASUB=1.
      XMAXNU=1.
      CHSLNU=.5
      RH=RHIPA(IPA-2)
      WRITE(6,990)RH
  990 FORMAT(///5X,'HEIGHT OF ROUGHNESS=',F10.7,' CM'////)
  998 CONTINUE
      CONST=CNUSS(IRH)
      QTOT=0.
      DO 992 I=1,NRODS
      Q(I)=QPIN(I)*PLDHL
  992 QTOT=QTOT+Q(I)
C
C     ..................................................................
C
C   8-SUBROUTINES HEATI,TOTGEO,INQUA, KAPCOR
C
      CALL HEATI(NSTOT,NSTR,NSEL,NEXCON,IPA)
      CALL TOTGEO(NSEL,D,C,Z,PIG,NEXCON,NRODS,WW,WA,ZA,EM1,PERLT,
     *RTIP(IPA))
      QLINM=QLINMT*PLDHL/PERLT
      CALL INQUA(NSEL,NSTOT,NEXCON,ATC,ATW,ATA,DETC,DETW,DETA)
      CALL KAPCOR(NSTOT,NSTR)
C     ..................................................................
C
C   9-DEFINITION OF THE REGIONS WHERE INDISTURBED FLOW IS ASSUMED AND
C     EVALUATION OF THE SPACER PARAMETERS
C
      DXST =XDEST*DETC
      DXEND=XDEEND*DETC
      XSTART(1)=X(1)+DXST
      XEND(MSPAC+1)=X(1)+LENGTH-DXEND
      IF(MSPAC.EQ.0)GOTO 12
      JSP=MSPAC+ISPAC-1
      IPAFD=1
      DO 4430 I=ISPAC,JSP
      I1SPAC=I-ISPAC+1
      IPAFD=IPAFD+1
      XSTART(IPAFD)=DIST(I)+DXST+WSP(IPA)*0.5
      XEND(IPAFD-1)=DIST(I)-WSP(IPA)*0.5-DXEND
```

```
      PGDPT(I1SPAC)=0.
      EPSIT(I1SPAC)=0.
      DO 5601 NS=1,NSTOT
      PGDPC(NS,I1SPAC)=0.
      EPSIC(NS,I1SPAC)=0.
      NP=NPIN(NS)
      DO 5600 J=1,NP
      DO 5599 M=1,NP
      IF(IRGRI(NS,J).NE.JPIN(NS,M))GOTO 5599
      EPSISC(NS,M,I1SPAC)=GRI(NS,J,I)
      PGDPSC(NS,M,I1SPAC)=GRIP(NS,J,I)
      EPSIC(NS,I1SPAC)=EPSIC(NS,I1SPAC)+EPSISC(NS,M,I1SPAC)*ASCH(NS,M)
      PGDPC(NS,I1SPAC)=PGDPC(NS,I1SPAC)+PGDPSC(NS,M,I1SPAC)*4.*ASCH(NS,
     *M)/DE(NS)
      IF(NTYP(NS).NE.2)GOTO 5600
      NSW=NS-NSTR
      EPSWC(NSW,M,1,I1SPAC)=GRI1(NSW,M,I)*EPSISC(NS,M,I1SPAC)
      EPSWC(NSW,M,2,I1SPAC)=GRI2(NSW,M,I)*EPSISC(NS,M,I1SPAC)
      GOTO 5600
 5599 CONTINUE
 5600 CONTINUE
      EPSIT(I1SPAC)=EPSIT(I1SPAC)+EPSIC(NS,I1SPAC)
      PGDPT(I1SPAC)=PGDPT(I1SPAC)+PGDPC(NS,I1SPAC)
      EPSIC(NS,I1SPAC)=EPSIC(NS,I1SPAC)/A(NS)
      PGDPC(NS,I1SPAC)=PGDPC(NS,I1SPAC)*DE(NS)*0.25/A(NS)
 5601 CONTINUE
      EPSIT(I1SPAC)=EPSIT(I1SPAC)/ASEC
      PGDPT(I1SPAC)=PGDPT(I1SPAC)*DETOT*0.25/ASEC
      CSPT(I1SPAC)=GRIFUN(EPSIT(I1SPAC))
      DO 5602 NS=1,NSTOT
      CSPC(NS,I1SPAC)=GRIFUN(EPSIC(NS,I1SPAC))
      NP=NPIN(NS)
      DO 5602 M=1,NP
      CSPSC(NS,M,I1SPAC)=GRIFUN(EPSISC(NS,M,I1SPAC))
      IF(NTYP(NS).NE.2)GOTO 975
      NSW=NS-NSTR
      CSPWC(NSW,M,1,I1SPAC)=GRIFUN(EPSWC(NSW,M,1,I1SPAC))
      CSPWC(NSW,M,2,I1SPAC)=GRIFUN(EPSWC(NSW,M,2,I1SPAC))
  975 CONTINUE
 5602 CONTINUE
      WRITE(6,960)I,EPSIT(I1SPAC)
  960 FORMAT(//  5X,'SPACER NR.',I5,5X,'EPSILON TOT.=',F10.7)
      DO 964 NS=1,NSTOT
      NP=NPIN(NS)
      WRITE(6,961)NS,EPSIC(NS,I1SPAC),(JPIN(NS,M),NS,M,
     *EPSISC(NS,M,I1SPAC),M=1,NP)
  961 FORMAT(/5X,'CHANNEL NR.',I5,5X,'EPSILON=',F10.7/
     1  5X,'SUBCHANNELS:'/(5X,'ROD NR.',I5,') EPSILON(',I5,',',I2,')=',
     2  F10.7))
  964 CONTINUE
      WRITE(6,83)
 4430 CONTINUE
   12 CONTINUE
C
C     ...........................................................
C  10-SUBROUTINES INGE AND CEWACO
C
      CALL INGE(NEXCON,NSEL,NSTR,NSTOT,C,Z,D,ATC,ATW,ATA,FIG,PCORR,CTU1,
     *CTU2,DETC,DETW,EM1)
```

```
      CALL CEWACO(NSC30C,NSC45,12,ALFACE,D,C2,AAC,DETC,MFLOW,ATOT,ACW,
     *            DECW,MEC)
      CALL CEWACO(NSC30A,NSC30A,3,ALFACO,D,ZA,AAA,DETA,MFLOW,ATOT,AA1,
     *            DEA1,MEA1)
      MA=MFLOW/ATOT
      PROV1=MA*DETOT
      PROV2=-1.E-03*MA**2/980.665
C     ..................................................................
C
C  11-INLET MASS FLOW RATES AND TEMPERATURES ;EVALUATION OF PRESSURE
C     LOSS AT THE BUNDLE INLET
C
      IF(INLET.NE.1)GOTO 4435
      CALL INLCON(NSTOT,MFLOW,ATOT,TE,IREAD1,NSTR)
      PI=PE
      DO 4432 I=1,10
      PO=PE+CINL*PROV2/RHO(PI,TE)*0.5
      IF(ABS(PO/PI-1.).LE.1.E-06)GOTO 4434
 4432 PI=PO
      WRITE(6,4433)PO,PI
 4433 FORMAT(1H1,5X,'CALCULATION STOPS : PO=',F10.7,'  ; PI=',F10.7)
      STOP
 4434 CONTINUE
      DPE=PO-PE
      DPEBAR=DPE*0.980665
      WRITE(6,1333)DPE,DPEBAR,CINL
 1333 FORMAT(///130('*')//5X,
     *              'PRESSURE LOSS DUE TO ENTRANCE=',F10.7,' KG/SQCM  =',
     *F10.7,' BARS ( CINL=',F4.2,')'//)
      INLET=2
      DPBAR(1)=PEOBAR-PEBAR-DPEBAR
      IF(STLEN.GT.1.E-06 .OR. IPUNCH.EQ.2)GOTO 4435
      WRITE(1,1)NSPACT
      IF(NSPACT.GT.0)WRITE(1,6069)(DIST(I),I=1,NSPACT)
      XLTOT=0.
      WRITE(1,1)IPA
      WRITE(1,6069)XLTOT,DPBAR(1)
 4435 CONTINUE
C     ..................................................................
C
C  12-EVALUATION OF SECTION LENGTHS AND CORRECTION FACTORS FOR NUSSELT
C
      CALL AXSEC(NDE1,NDE2,DETC,WSP(IPA),CONST,DDD,II,HH,MSPAC,LENGTH,N,
     *IPA,QTOT,NSTOT,XMAXNU,CHSLNU)
      WRITE(6,14)LENGTH,N,FREL
   14 FORMAT(///130('*')///
     *        5X,'TOTAL LENGTH=',F7.2,1X,'CM',5X,'NUMBER OF SECTIONS=',I3
     *,5X,'FREL=' ,F10.4///)
C     ..................................................................
C
C  13-INITIALIZATION OF VARIABLES
C
      T(1)=TO
      P(1)=PO
      PBAR(1)=PO*0.980665
      NSEFD=0
      IPAFC=1
      TM=0.
      PM=0.
```

```
      LAMBDM=0.
      REM=0.
      UM=0.
      DELTAX=0.
      TWTC=0.
      TBTC=0.
      TBPC=0.
       NSTR1=NSTR+1
      DO 5636 NS=NSTR1,NSTOT
      NP=NPIN(NS)
      DO 5636 M=1,NP
      TLINER(NS-NSTR,M)=TSCH1(NS,M)
      IF(ISTAIN.EQ.2)GOTO 978
      DO 5634 JWC=1,2
 5634 TSCWC1(NS-NSTR,M,JWC)=TSCH1(NS,M)
  978 CONTINUE
      DO 5635 I=1,NSC90
      DELTIC(NS-NSTR,M,I)=0.
 5635 TIC(NS-NSTR,M,I)=0.
 5636 CONTINUE
      IF(IRH.NE.2)GOTO 4439
      DO 4438 NS=1,NSTOT
      NP=NPIN(NS)
      DO 4438 M=1,NP
      HPLUS1(NS,M)=0.
      HPLUS2(NS,M)=0.
      TWA(NS,M)=0.
      QPLUSA(NS,M)=0.
      PREA (NS,M)=0.
      YDH(NS,M)=0.
      YODH(NS,M)=0.
      TEMPB(NS,M)=TE
      XMASSB(NS,M)=1.
      YODHA(NS,M)=0.
      YDHA(NS,M)=0.
      TEMPBA(NS,M)=0.
      AMASSE(NS,M)=0.
      TEMPTA(NS,M)=0.
      AMASST(NS,M)=0.
 4438 CONTINUE
 4439 CONTINUE
C
C     ..............................................................
C  14-THE AXIAL LOOP STARTS (K=INDEX OF THE AXIAL SECTION )
C
      K1=1
      NSUBCH=0
 8503 CONTINUE
      DO 9999 K=K1,N
C
      TIME2=ZEIT(TIME1)
      IF(TIME2.GT.TIMEPU)CALL TMPUN(NSTOT,NSTR,T(L),P(L),PBAR(L),
     *TE1,PEO,PEOBAR,INDPR,MFLOW,IPA,IPAEND,2,XLAM1,X(L)+STLEN,&742)
C
      ASECLA=ASEC
      DETCLA=DETOT
      L=K+1
      H=X(L)-X(K)
      QDEV=0.
```

```
      QLDEV=0.
      INDPRQ=1
      IF(NDPRQ(IPA).EQ.0)GOTO 3702
      XPRQ(1)=X(K)-SPLENG
      IF(X(L).LT.X2DPRQ(IDPRQ))GOTO 1018
      XPRQ(2)=X2DPRQ(IDPRQ)-SPLENG
      INDPRQ=2
 1018 XPRQ(INDPRQ+1)=X(L)-SPLENG
      DO 3402 IQDEV=1,INDPRQ
      IQDEV1=IQDEV+1
      IIQDEV=IDPRQ+IQDEV-1
      DO 3401 IQDCO=1,NQDCO
      QDCOI(IQDCO)=QDCO(IIQDEV,IQDCO)
 3401 QLDCOI(IQDCO)=QLDCO(IIQDEV,IQDCO)
      QDEV=FQDEV(QDCOI,NQDCO,XPRQ(IQDEV),XPRQ(IQDEV1))+QDEV
 3402 QLDEV=FQDEV(QLDCOI,NQDCO,XPRQ(IQDEV),XPRQ(IQDEV1))+QLDEV
      QDEV=QDEV/H
      QLDEV=QLDEV/H
 3702 CONTINUE
      QALIN=QLINM*QLDEV/LENGTH
      DO 6670 NS=NSTR1,NSTOT
      NP=NPIN(NS)
      DO 6670 M=1,NP
 6670 DTIFAV(NS-NSTR,M)=0.
      XM=(X(L)+ X(K))*0.5+STLEN
      XMHE=XM-UNHLE
      IF(NSUBDH.EQ.0)WRITE(6,8504)
 8504 FORMAT(1H1)
      WRITE(6,15)K,H,XM
   15 FORMAT(     5X,'AXIAL SECTION NR.',I4,5X,'( SECTION LENGTH=',F10.5,
     *'; HEIGHT=',F10.5,' )')
      H1=H/LENGTH
      DELTAH=(QTOT*QDEV+QLINM*PERLT*QLDEV)*H1/MFLOW
      RHO1=RHO(P(K),T(K))
      IF(NSPACT.EQ.0)GOTO 16
      IF( X(K).LT.DIST(ISPAC)) GOTO 4437
      IF(IPAFD.LE.MSPAC)IPAFD=IPAFD+1
      IF(ISPAC.EQ.NSPACT)GOTO 16
      ISPAC=ISPAC+1
 4437 CONTINUE
      IF(X(L).LT.DIST(ISPAC))GOTO 16
      INDSP(K)=2
      I1SPAC= ISPAC-II+1
      WRITE(6,4440)ISPAC
 4440 FORMAT(1H+,80X,'SPACER NR.',I3,' IS PRESENT',24('.')/5X,21('-'))
      IF(K.EQ.1)GOTO 8500
      GOTO 17
   16 INDSP(K)=1
      SBMNS=MFLOW/ATOT*ASEC
      WRITE(6,4441)
 4441 FORMAT(1H+,78X,50('.')/5X,21('-'))
   17 CONTINUE
      DO 4444 NS=1,NSTOT
      SIGMA(NS)=0.
      PHI(NS)=0.
      NP=NPIN(NS)
      DO 4443 M=1,NP
      MSCH(NS,M)=MSCH1(NS,M)
      TSCH(NS,M)=TSCH1(NS,M)
```

```
      IF(K.GT.1 .AND. NSUBDH.EQ.0)TWP(NS,M)=TW(NS,M)
      SIGMAI(NS,M)=0.
      PHII(NS,M)=0.
      IF(NS.LE.NSTR)GOTO 4443
      DO  4442 JWC=1,2
      CHI(NS-NSTR,M,JWC)=1.
      PSI(NS-NSTR,M,JWC)=1.
 4442 CONTINUE
 4443 CONTINUE
 4444 CONTINUE
      ITGLT=0
      DELTAP=0.
      T(L)=DELTAH/CP(P(K),T(K))+T(K)
      PBT=P(K)
C     ..................................................................
C
C  15-THE LOOP ITCORR STARTS
C
      DO 49  ITCORR=1,ITCM
      IF(INDSP(K).EQ.2 .AND. ITCORR.GT.2)GOTO 45
C
      LAMBDA(K)=LAM1
      DDDDT=0.
C*****CALCULATION OF DELTAP AND DELTAT FOR THE WHOLE BUNDLE FLOW SECT.*
      DO 4448 ITTE1=1,10
      TL=T(L)
      TBT=(T(L)+T(K))*0.5
      DO 4445 ITTE2=1,10
      TBT1=TBT
      TBT=DELTAH/CP(PBT,TBT)*0.5+T(K)
      IF(ABS(TBT/TBT1-1.).LE.1.E-04)GOTO 4447
 4445 CONTINUE
      WRITE(6,4446)TBT,TBT1
 4446 FORMAT(1H1,'CALCULATION STOPS: ITTE2=10 ; TBT=',E15.7,5X,'TBT1=',
     *     E15.7)
      STOP
 4447 CONTINUE
       T(L)=DELTAH/CP(PBT,TBT)+T(K)
      DO 18  ITPR=1,10
      DP=DELTAP
      PBT=P(K)+0.5*DP
      P(L)=P(K)+DP
      RHOBT(K)=RHO(PBT,TBT)
      RHO2=RHO(P(L),T(L))
      DEL1RT=(RHO1-RHO2)/RHOBT(K)**2
      DELTAP=PROV2*(LAMBDA(K)*H/(2.*RHOBT(K)*DETOLA)+DEL1RT)*(ASEC/
     /ASECLA)**2+IGRAV*RHOBT(K)*H*0.001
      ETABT(K)=ETA(PBT,TBT)
      REBT(K)=PROV1/ETABT(K)*DETOLA/DETOT*ASEC/ASECLA
      IF(INDSP(K).EQ.2)DELTAP=DELTAP+PROV2*(CSPT(I1SPAC)+DSPDPF(EPSIT(
     1 I1SPAC),DETOLA,LAMBDA(K),WSP(IPA),PGDPT(I1SPAC),REBT(K),4))/
     2  RHOBT(K)
      PLL=P(K)+DELTAP
      IF(ABS(PLL/P(L)-1.).LE.1.E-05)GOTO 20
   18 CONTINUE
      WRITE(6,19)K,ITCORR,DP,DELTAP
   19 FORMAT(1H1,5X,'CALCULATION STOPS: ITPR=10 FOR SECTION',I4,2X,'(ITC
     *ORR=',I2,') DP=',E20.5,5X,'AND DELTAP=',E20.5)
      STOP
```

```
   20 CONTINUE
        T(L)=DELTAH/CP(PBT,TBT)+T(K)
      IF(ABS(T(L)/TL-1.).LE.1.E-04)GOTO 4450
 4448 CONTINUE
      WRITE(6,4449)T(L),TL
 4449 FORMAT(1H1,5X,'CALCULATION STOPS: ITTE1=10 ; T(L)=',E15.7,5X,
     *    'TL=',E15.7)
      STOP
 4450 CONTINUE
      UBT(K)=MA/RHOBT(K)/100. *ASEC/ASECLA
      PROV=REBT(K)*ETABT(K)*SQRT(ABS(LAMBDA(K))*0.125/RHOBT(K))
      SQDPG=SQRT(ABS(DELTAP)*980665.)
      SIGMST=(SQRT(ABS(DELTAP-IGRAV*RHOBT(K)*H*0.001)*980665.)-SQDPG)/
     /SQRT(LAMBDA(K)*H/(2.*DETOLA*RHOBT(K)))
      IF(INDSP(K).EQ.2)GOTO 45
C     ****************************************************************
C
C     FOR SECTIONS WITHOUT SPACERS: SUB-SUBCHANNEL CALCULATION
C
      DO 6671 NS=NSTR1,NSTOT
      NP=NPIN(NS)
      DO 6671 M=1,NP
      DO 6671 I=1,NSC90
 6671  DELTIE(NS-NSTR,M,I)=DELTIO(NS-NSTR,M,I)-DTIEAV(NS-NSTR,M)
      ASECLA=0.
      DETOLA=0.
      DO 29 NS=1,NSTOT
      IF( ITCORR.EQ.1)SIGMA(NS)=SIGMST
      IF(NTYP(NS).EQ.3)GOTO 25
      NP=NPIN(NS)
      DDDDNS=0.
      TNS=0.
      AMNS=0.
      DO 24 M=1,NP
      IF( ITCORR.EQ.1)SIGMAI(NS,M)=SIGMST
      IF(NTYP(NS).EQ.2)GOTO 22
C
C*****SUB-SUBCHANNEL CALCULATION FOR THE CENTRAL CHANNELS*************
C
      CALL TRICAL(K,NS,NSC30C,IRH,PROV,PBT,RH,ACW,DECW,MEC,AAC,DETC,DETO
     *T,H1,ALFACE,H,M,P(K),P(L),SQDPG,TE1,SUR,D,AMT,DDDD,ATSCH,&8500,C)
      AMSCH=AMT*ASCH(NS,M)/AAC
      GOTO 23
C
   22 CONTINUE
C*****SUB-SUBCHANNEL CALCULATION FOR THE WALL CHANNELS****************
      CALL RECCAL(K,NS,NSC90,NSC45,IRH,PROV,PBT, RH,H1,ALFAWA,ACW,DECW,M
     *EC,AAW,DETW,ATOT,DETCT,MFLOW,WW,C,C,M,NSTR,H,P(K),P(L),SQDPG,TE1,
     *     SUR,AMT,DDDD,ATSCH,CTU3,EM1,&8500,ALFACE)
      NSW=NS-NSTR
      IF(K.GT.1)GOTO 4455
      DO 4451 JWC=1,2
      IF(IREAD1.EQ.1 .OR. ISTAIN.EQ.1)MSCWC1(NSW,M,JWC)=MSCH1(NS,M)/ASCH
     *(NS,M)*ASCHWC(NSW,M,JWC)/F2ATIP(NS,M)
 4451 ASCWC1(NSW,M,JWC)=ASCHWC(NSW,M,JWC)
 4455 CONTINUE
      AMSCH=AMT
   23 CONTINUE
      DDDDNS=DDDDNS+AMSCH/AMT*DDDD+ASCH(NS,M)*(SIGMAI(NS, M)-SIGMA(NS))/
```

```
     *SQDPG
      AMNS=AMNS+AMSCH
   24 TNS=TNS+ATSCH*AMSCH
      TNS=TNS/AMNS
      RHONS=RHO(PBT,TNS)
      LAM(NS)=((A(NS)/DDDDNS)**2)*2.*DE(NS)*RHONS/H *F1ATIP(NS)**2*
     *F1DTIP(NS)
      GOTO 28
C
C*****SUB-SUBCHANNEL CALCULATION FOR THE CORNER CHANNELS**************
   25 CONTINUE
      IF(ITCORR.EQ.1)SIGMAI(NS,1)=SIGMST
      CALL ANGCA1(K,NS,NSC30A,IRH,PROV,PBT,RH,H1,ALFACO,AA1,AAA,DETA,DET
     *OT,D,WA,NSTR,H,P(K),P(L),SQDPG,TEL,SUR,    AMT,DDDDNS,&8500,AMAT,
     2AMBT)
      AMNS=AMT*ASCH(NS,1)/AAA
      XMSCHA(NS-NSTR,1)=AMAT*ASCH(NS,1)/AAA
      XMSCHB(NS-NSTR,1)=AMBT*ASCH(NS,1)/AAA
      DDDDNS=DDDDNS*ASCH(NS,1)/AAA
      LAM(NS)=LAMSCH(NS,1)
   28 CONTINUE
      ASECLA=ASECLA+A(NS)*F1ATIP(NS)
      DETCLA=DETOLA+A(NS)/DE(NS)*F1ATIP(NS)/F1DTIP(NS)
      MO(NS)=2.*AMNS-MI(NS)
      DDDDT=DDDDT+DDDDNS
   29 CONTINUE
      DETOLA=ASECLA/DETOLA
C     ...............................................................
C
C  16-NEW VALUE FOR THE WHOLE BUNDLE FRICTION FACTOR
C
      IF(              ITCORR.EQ.1)GOTO 48
      DDDDT=DDDDT*(MFLOW*ASEC)/(SBMNS*ATOT)
      DPSI=-DPAV/ABS(DPAV)
      LAM1=((ASECLA/DDDDT)**2*DPSI-DEL1RT+IGRAV*RHOBT(K)*980.665*H*
     *(ASECLA *ATOT/(ASEC*MFLOW))**2)*2.*DETOLA*RHOBT(K)/H
C     ...............................................................
C
C  17-CONVERGENCE TEST FOR THE LOOP ITCORR
C
   45 CONTINUE
      IF(ITCORR.LE.ITC2)GOTO 48
      DELAM=ABS(LAMBDA(K)/LAM1-1.)
      IF(.NOT.(DELAM.LE.1.E-04 .OR. (DELAM.LE.1.E-03 .AND. ITCORR.GT.
     *   ITC1) .OR. (DELAM.LE.1.E-02 .AND. ITCORR.GT.(ITC1+5))))GOTO 48
C     ...............................................................
C
C  18-CONVERGENCE HAS BEEN REACHED: PRINT AND PUNCH RESULTS FOR SECT. K
C
      WRITE(6,46)
     *  T(L),    P(L),PBT,DELTAP,LAMBDA(K),ITCORR,ITGL,ITGLT,ITERM,FREL
   46 FORMAT(/5X,'T 2=',F10.4,5X,'P 2=',F10.6,5X,'P AV=',F10.6,5X,
     * 'DELTAP=',F11.8,5X,'LAMBDA=',F7.5/5X,'( ITCORR=',I2,
     *          5X,' ITGL=',I5,5X,'ITGL1=',I5,5X,'ITERM=',I5,5X,
     * 'FREL=',F5.2,' )'///      5X,'CHANNEL',9X,'OUTLET MASS',8X,'AVERA
     *GE MASS',7X,'OUTLET TEMP.',8X,'AVERAGE TEMP.',7X,'PRESSURE LOSS'/)
      WRITE(6,81)(NS,MM2(NS),MAV(NS),TEMP2(NS),TAV(NS),DPNS(NS),
     *  NS=1,NSTOT)
   81 FORMAT(I12,5E20.8)
```

```
      WRITE(6,83)
      DO 80 NS=1,NSTOT
      WRITE(6,78)NS,JAV(NS),NS,WCF(NS)
      IF(INDSP(K).EQ.1)WRITE(6,79)NS,MO(NS),NS,LAM(NS)
   78 FORMAT(5X,'JAV(',I3,')=',E13.5,10X,'WCF(',I3,')=',E12.3)
   79 FORMAT(1H+,T70,'MO(',I3,')=',F10.2,10X,'LAM(',I3,')=',F10.5)
   80 CONTINUE
      WRITE(6,83)
   83 FORMAT(/ )
      DO 85 NS=1,NSTOT
      NI=NER(NS)
      WRITE(6,84)(M,NS,NIS(NS,M),WT(NS,M),M=1,NI)
   84 FORMAT(3(5X,I2, ') WT(',I4,',',I4,')=',E12.3))
   85 CONTINUE
      XLTOT=X(L)+STLEN
       PBAR(L)=P(L)*0.980665
      DPBAR(L)=PEOBAR-PBAR(L)
      IF(IPUNCH.EQ.1)WRITE(1,1)IPA
      IF(IPUNCH.EQ.1)WRITE(1,6069)XLTOT,DPBAR(L)
C     ....................................................................
C
C  19-CORRECTION OF THE COMPUTED SURFACE PIN TEMPERATURES FOR THE BIOT
C     EFFECT AND FOR THE RADIAL POSITION OF THE THERMOCOUPLES
C
      IF( QTOT.LE.1.E-06)GOTO 50
      DO 53 NS=1,NSTOT
      NSW=NS-NSTR
      NP=NPIN(NS)
      DO 51 M=1,NP
      TWINF(NS,M)=TW(NS,M)
      IF(QQ(NS,M).LT.1.E-06)GOTO 51
      QHRDAR=QQ(NS,M)*QDEV*HRDAR
      RVOL=D*0.5
      IF( I2TIP(NS,M).EQ.1 .AND. IPA.EQ.4)RVOL=RTIP(4)-RH
      FCORTW=((RVOL**2-RMISTW(IPA)**2)*0.5+RINT(IPA)**2*ALOG(RMISTW(IPA)
     */RVOL))/((RVOL**2-RINT(IPA)**2)*SUR)*RVOL
      QRMDAR=QQ(NS,M)*QDEV*FCORTW
      IF(IPA.EQ.4)QLAMR=QQ(NS,M)*QDEV*FCORLA
      CALL CORRTE(TW(NS,M),TSCH(NS,M),PBT,    NS,M,0,BIOT(NS,M),TWINF(NS,
     *M))
      CALL CORRTE(TWSSC1(NS,M),TBSSC1(NS,M),PBT,    NS,M,1,BIOTI1,TWINF1)
      CALL CORRTE(TWSSC2(NS,M),TBSSC2(NS,M),PBT,    NS,M,2,BIOTI2,TWINF2)
      IF(NTYP(NS).NE.2)GOTO 51
      DO 3721 JWC=1,2
       CALL CORRTE(TWWC(NSW,M,JWC),TAVWC(NSW,M,JWC),PBT,    NS,M,JWC,BIOT
     *WC,TWINWC)
 3721 CONTINUE
   51 CONTINUE
   53 CONTINUE
      WRITE(6,86)
   86 FORMAT(                              //5X,'CHANNEL',3(2X,'ROD',4X,'TEMP
     *ERATURE',5X,'HEAT POWER')/)
      IF(IPUNCH.EQ.1)WRITE(1,6069)XM
      DO 88 NS=1,NSTOT
      NP=NPIN(NS)
      DO 3723 M=1,NP
 3723 QSECT(M)=QQ(NS,M)*QDEV*H1
      WRITE(6,87)NS,(JPIN(NS,M),TW(NS,M),QSECT(M),M=1,NP)
   87 FORMAT(I12,3(I5,2E15.5))
```

```
      IF(IPUNCH.EQ.1)WRITE(1,6069)(TW(NS,M),M=1,NP)
      IF(NS.LE.NSTR)GOTO 88
      NSW=NS-NSTR
      IF(IPUNCH.EQ.1)WRITE(1,6069)(TLINER(NSW,M),M=1,NP)
 6069 FORMAT( 3E15.5)
   88 CONTINUE
      GOTO 50
C     ...............................................................
C
C  20-CALCULATION IN THE CHANNELS, IN THE SUBCHANNELS AND IN THE TWO
C     PORTIONS OF THE WALL SUBCHANNELS
C
   48 CONTINUE
      CALL BALA(K,NSTOT,INDSP(K),ASECLA,H,LENGTH,P(K),P(L),PBT,FREL,FT,
     *ITCORR,ITCM,DPAV,ITERM,ITGL,&8500,WSP(IPA),I1SPAC)
      ITGLT=ITGLT+ITGL
      CALL SUBBAL(NSTOT,NSTR,INDSP(K),H,LENGTH,D,PIG,P(K),P(L),PBT,FREL,
     *FT,ITCORR,DPAV,&8500,WSP(IPA),I1SPAC)
      CALL NORMT(NSTOT,NSTR,TBT,ATOT,ASEC,MFLOW)
      IF(IRH.EQ.1 .AND. QTOT.GT.1.E-06)CALL WALLTE
     *        (K,NSTOT,NSTR,RH,SUR,D,PIG, TE1 ,PBT,&8500,RTSI)
      IF(IRH.EQ.2 .AND. QTOT.GT.1.E-06)CALL WALLTE
     *        (K,NSTOT,NSTR,RH,SUR,D,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 PRCVI(NSW,M)=MSCH(NS,M)*DE(NS )/ASCH(NS,M)*SQRT(LAMSCH(NS,M)*0.125
     */RHO(PBT,TSCH(NS,M)))
      GOTO 7034
 7033 PRCVI(NSW,M)=MAWC(NSW,M,1)*DEWC(NSW,M,1)/ASCHWC(NSW,M,1)*
     *SQRT(LAMWC(NSW,M,1)*0.125/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 STOPS: 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)*0.980665
      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)=(TIO(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))*TWPFCF
   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,PIG,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(IRF.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
      YDHA(NS,M)=YDHA(NS,M)+YDH(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
      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(NTYP(NS))*ASCH(NS,M)/A(NS)*H1
      WRITE(6,8886)M,JPIN(NS,M),MSCH1(NS,M),TSCH1(NS,M),LAMSCH(NS,M)
     *,SCREB,SCREW
 8886 FORMAT(5X,I2,'-(ROD NR.',I4,')',T27,'OLT. MASS',F10.6,T52,'OLT. TE
     1MP.=',F7.2,T75,'LAMBDA=',F10.5,T99,'REB=',F7.0,T112,'REW=',F7.0)
      WRITE(6,3725)QLINSC
 3725 FORMAT(T27,'Q LINER=',E15.5)
      IF(IRH.EQ.2 .AND. QTOT.GT.1.E-06 .AND. I2TIP(NS,M).NE.1)
     *                                  WRITE(6,3724)BIOT(NS,M)
 3724 FORMAT(1H+,T52,'BIOT=',F10.5)
      IF(QTOT.GT.1.E-06)WRITE(6,3722) TWINF(NS,M)
 3722 FORMAT(1H+,                    T75,'TW  INF.=',F10.2)
      IF(QTOT.GT.1.E-06 .AND. NTYP(NS).NE.1)WRITE(6,3740)TLINER(NSW,M)
 3740 FORMAT(1H+,T99,'T   AT LINER=',F10.2)
        IF(INDSP(K).EQ.2)GOTO 91
      IF(IRH.EQ.1 .OR. I2TIP(NS,M).EQ.1)GOTO 3726
      RHPLM=RHPLUS(HPLUSB(NS,M),TW(NS,M),TE1 ,QPLUS(NS,M),HPLUSW(NS,M),
     *TEMPB(NS,M),YODH(NS,M))
      WRITE(6,8883)HPLUSB(NS,M),HPLUSW(NS,M),RHPLM
 8883 FORMAT(T27,'HB+ =',E12.5,T52,'HW+ =',E12.5,T75,'R( H+ )=',E12.5)
      IF(QQ(NS,M).LE. 1.E-06)GOTO 91
      GHPLM=GHPLUS(HPLUSW(NS,M),TW(NS,M),TSCH(NS,M),PRB (NS,M),YDH(NS,M)
     1,10000.,0.)
      TWDTEM=(TW(NS,M)+273.16)/(TE+273.16)
      TWDTBM=(TW(NS,M)+273.16)/(TSCH(NS,M)+273.16)
      PHIM=GHPLM/(PRB (NS,M)**O4 * TWDTBM**O5)*(O16*YDH(NS,M))**O17
      WRITE(6,94)GHPLM,SCNUSS      ,TWDTBM,TWDTEM,YDH(NS,M),O4,O5,O16,
     1      O17,PHIM
   94 FORMAT(1H+,T99,'G( HW+ )=',E12.5/T27,'NU =',E13.6,T52,'TW/TB=',E13
     1.5,T75,'TW/TE=',E13.5,T99,'Y/RH=',E13.5/T27,'G( HW+ )/( PR**',F4.2
     2,' * (TW/TB)**',F4.2,' ) * (',F6.3,'*Y/RH)**',F6.3,' =',E13.6)
```

```
 3726 IF(CC(NS,M).LE.1.E-06)GOTO 91
      IF(IRF.EQ.1 .OR. I2TIP(NS,M).EQ.1)WRITE(6,4242)SCNLSS
 4242 FORMAT(1H+,T52,'NU =',E13.6)
      WRITE(6,6685)TBSSC1(NS,M),TWSSC1(NS,M),TBSSC2(NS,M),TWSSC2(NS,M)
 6685 FORMAT(T27,'TBSSCH(1)=',F7.2,T52,'TWSSCH(1)=',F7.2,T75,'TBSSCH(N)=
     1',F7.2,T99,'TWSSCH(N)=',F7.2)
      IF(NTYP(NS).EQ.1)GOTO 91
      WRITE(6,6640)TTSCHA(NSW,M),TTSCHB(NSW,M),TEMPB(NS,M)
 6640 FORMAT(T27,'TA=',F7.2,T52,'TB=',F7.2,T75,'TBC=',F7.2)
      IF(NTYP(NS).EQ.2)WRITE(6,6644)TWWC(NSW,M,1),TWWC(NSW,M,2)
 6644 FORMAT(T27,'TW(1)=',F7.2,T52,'TW(2)=',F7.2)
      WRITE(6,6645)T1SSC1(NSW,M),T2SSC1(NSW,M),T1SSC2(NSW,M),
     *                T2SSC2(NSW,M)
 6645 FORMAT(T27,'T1SSCH(1)=',F7.2,T52,'T2SSCH(1)=',F7.2,T75,'T1SSCH(N)=
     1',F7.2,T99,'T2SSCH(N)=',F7.2)
   91 CONTINUE
      IF(NTYP(NS).NE.2)GOTO 8887
      WRITE(6,90)(JWC,MSCWC1(NSW,M,JWC),JWC,TSCWC1(NSW,M,JWC),JWC,ASCWC1
     *(NSW,M,JWC),JWC,LAMWC(NSW,M,JWC),JWC=1,2)
   90 FORMAT(T27,'MOUT(',I1,')=',E13.6,T52,'TOUT(',I1,')=',E13.6,T75,
     1        'AREA(',I1,')=',E13.6,T99,'LAMBDA(',I1,')=',E13.6)
 8887 CONTINUE
 9999 CONTINUE
      GOTO 8499
C     ..................................................................
C
C  24-POINT REACHED IN THE CASE OF CONVERGENCE PROBLEMS (LOOP K ENDS
C     AT LABEL 9999)
 8500 CONTINUE
      NSUBDH=NSUBDH+1
      IF(NSUBDH.LE.MSUBDH)GOTO 8502
      WRITE(6,8501)MSUBDH
 8501 FORMAT(//' STOP DUE TO REACHED MAXIMUM NUMBER OF SUBDIVISIONS FOR
     *AXIAL PITCH: NSUBDH=',I2)
      STOP
C
 8502 CALL SUBDH(N,K,K1,NSTOT)
      GOTO 8503
C     ..................................................................
C
C  25-VALUES OF VARIABLES FOR THE WHOLE BUNDLE FLOW SECTION
C
 8499 CONTINUE
      DEPTOT=P(L)-P(1)
      WRITE(6,8889)
 8889 FORMAT(1H1,4X,'VARIABLES FOR THE WHOLE BUNDLE'/5X,30('-')////
     *  5X,'A) INLET VALUES OF TEMPERATURE AND PRESSURE'//5X,'SECTION NR
     *.' ,T26,'HEIGHT (CM)',T43,'TEMPERATURE ( C)',T63,'PRESSURE (KG/SQC
     *M)',T86,'PRESSURE (BARS)'/)
      WRITE(6,8890)(I,X(I),T(I),P(I),PBAR(I),I=1,L)
 8890 FORMAT(7X,I3,15X,F9.4,13X,F7.2,11X,F9.5,12X,F9.5)
      WRITE(6,8891)
 8891 FORMAT(/////5X,'B) VALUES AVERAGED OVER AXIAL SECTIONS'//5X,'SECTI
     *ON NR.',T23,'DENSITY (G/CCM)',T41,'VISCOSITY(G/CM*SEC)',T64,'VELOC
     *ITY (M/SEC)',T85,'REYNOLDS NR.',T99,'FRICTION FACTOR'/)
      WRITE(6,8892)(I,RHOBT(I),ETABT(I),UBT(I),REBT(I),LAMBDA(I),I=1,N)
 8892 FORMAT(7X,I3,17X,F7.5,12X,F9.7,12X,F7.3,11X,F9.2,6X,F7.5)
      WRITE(6,8878)DEPTOT
 8878 FORMAT(///5X,'TOTAL PRESSURE DROP=',F9.6,' KG/SQCM')
```

```
C      ..........................................................
C
C   26-EVALUATION AND PRINTING OF AVERAGE VALUES OF VARIABLES FOR THE
C       REGIONS WHERE INDISTURBED FLOW IS ASSUMED
C
       IF(NSEFD.EQ.0)GOTO 8897
       TM=TM/DELTAX
       PM=PM/DELTAX
       PMBAR=PM*0.980665
       LAMBDM=LAMBDM/DELTAX
       RHOM=RHO(PM,TM)
       ETAM=ETA(PM,TM)
       REM=REM/DELTAX
       UM=UM/DELTAX
       WRITE(6,8893) TM,PM,PMBAR,RHOM,ETAM,UM,REM,LAMBDM
 8893 FORMAT(////5X,'C) TOTAL MEAN VALUES AVERAGED IN PARTS WHERE UNDIST
     *URBED FLOW IS SUPPOSED'//                5X,'TEMPERATURE',T22,'=',F9.
     *2,' C'/5X,'PRESSURE',T22,'=',F9.4,' KG/SQCM    =',F9.4,' BARS'
     *                                               /5X,'DENSITY',T22,'=',
     *  F9.5,' G/CCM'/5X,'VISCOSITY',T22,'=',F9.7,' G/CM*SEC'/5X,
     *'VELOCITY',T22,'=',F9.3,' M/SEC'/5X,'REYNOLDS NR.',T22,'=',F9.2/5X
     *    ,'FRICTION FACTOR',T22,'=',F9.5//)
       IF(IRF.EQ.1)GOTO 8897
       WRITE(6,83)
       DO 8876 NS=1,NSTOT
       NP=NPIN(NS)
       DO 8874 M=1,NP
       IF(I2TIP(NS,M).EQ.1)GOTO 8897
       WRITE(6,8885)NS
       HPLUS1(NS,M)=HPLUS1(NS,M)/DELTAX
       HPLUS2(NS,M)=HPLUS2(NS,M)/DELTAX
       QPLUSA(NS,M)=QPLUSA(NS,M)/DELTAX
       PRBA (NS,M)=PRBA (NS,M)/DELTAX
       TWA(NS,M)=TWA(NS,M)/DELTAX
       YDHA(NS,M)=YDHA(NS,M)/DELTAX
       YODHA(NS,M)=YODHA(NS,M)/DELTAX
       TEMPTA(NS,M)=TEMPTA(NS,M)/AMASST(NS,M)
       TEMPBA(NS,M)=TEMPBA(NS,M)/AMASSB(NS,M)
       RHPLA=RHPLUS(HPLUS1(NS,M),TWA(NS,M),TE1,QPLUSA(NS,M),HPLUS2(NS,M),
      1TEMPBA(NS,M),YODHA(NS,M))
       WRITE(6,8875)M,JPIN(NS,M),HPLUS1(NS,M),HPLUS2(NS,M),RHPLA
 8875 FORMAT(5X,I2,'-(ROD NR.',I4,')',T27,'HB+ =',E12.5,T52,'HW+ =',E12.
      15,T75,'R( H+ )=',E12.5)
       IF(GG(NS,M).LE.1.E-06)GOTO 8874
       TWDTEA=(TWA(NS,M)+273.16)/(TE+273.16)
       TWDTBA=(TWA(NS,M)+273.16)/(TEMPTA(NS,M)+273.16)
       GHPLA=GHPLUS(HPLUS2(NS,M),TWA(NS,M),TEMPTA(NS,M),PRBA (NS,M),
      1YDHA(NS,M),10000.,0.)
       PHIA=GHPLA/(PRBA (NS,M)**C4 * TWDTBA**C5)*(C16*YDHA(NS,M))**C17
       WRITE(6,94)GHPLA,QPLUSA(NS,M),TWDTBA,TWDTEA,YDHA(NS,M),C4,C5,C16,
      1C17,PHIA
 8874 CONTINUE
 8876 CONTINUE
 8897 CONTINUE
C      ..........................................................
C
C   27-COMPARISON BETWEEN THE INPUT AND THE COMPUTED AVERAGE
C       TEMPERATURES OF THE GAS, OF THE SHROUD AND OF THE FINS IN THE
C       AXIAL PORTION
```

```
C
      TWTC=TWTC/LENGTH
      TBTC=TBTC/LENGTH
      TBPC=TBPC/LENGTH
      WRITE(6,69) TWTIPA(IPA),TWTC,TBTIPA(IPA),TBTC,TBPIPA(IPA),TBPC
   69 FORMAT(///5X,'COMPARISON OF INPUT TEMPERATURES WITH COMPUTED VALUE
     1S'//T17,'INPUT',T26,'COMPUTED'/5X,'TWTIPA',2F11.2/5X,'TBTIPA',2F11
     2.2/5X,'TBPIPA',2F11.2)
C     ..............................................................
C
C  28-COMPARISON BETWEEN THE EXPERIMENTAL AND THE COMPUTED PRESSURE
C     LOSSES
C
      IF(NEXPR(IPA).GT.0 .OR. NEXTW(IPA).GT.0)WRITE(6,1023)
 1023 FORMAT(////5X,'COMPARISON WITH EXPERIMENTAL RESULTS'/5X,36('-')//)
      IF(NEXPR(IPA).EQ.0)GOTO 1040
      GOTO (1069,1070),INDPR
 1069 WRITE(6,1072)
      GOTO 1071
 1070 WRITE(6,1073)
 1071 CONTINUE
 1072 FORMAT(5X, '1) PRESSURES (KG/SQCM)'//)
 1073 FORMAT(5X, '1) PRESSURES (BARS)'//)
      IEXPR2=IEXPR1+NEXPR(IPA)-1
      K1=1
      DO 1037 IEXPR=IEXPR1,IEXPR2
      DO 1024 K=K1,N
      K2=K
      IF(XEXPR(IEXPR).GE.X(K) .AND. XEXPR(IEXPR).LT.X(K+1))GOTO 1025
 1024 CONTINUE
      GOTO 1040
 1025 K1=K2
      IF(INDSP(K).EQ.2)GOTO 1026
      KK=K2
      GOTO 1027
 1026 KK=K2-1
      IF(KK.EQ.0)KK=2
 1027 CONTINUE
      GOTO (1028,1029),INDPR
 1028 PR1=P(KK)
      PR2= P(KK+1)
      GOTO 1030
 1029  PR1=PBAR(KK)
      PR2=PBAR(KK+1)
 1030 PTH=(PR2-PR1)/(X(KK+1)-X(KK))*( XEXPR(IEXPR)-X(KK))+PR1
      DPEX=PEX(IEXPR)-PE1
      DPTH=PTH-PE1
      PTMPEX=PTH-PEX(IEXPR)
      DPERR=(DPTH-DPEX)/DPEX*100.
      WRITE(6,1031)IEXPR,XEXPR(IEXPR),PEX(IEXPR),DPEX,PTH,DPTH,PTMPEX,
     *DPERR
 1031 FORMAT(5X,I2,')HEIGHT=',F10.5,' CM',5X,'P EX.=',F10.5,5X,'P EX.-PE
     *1=',F10.7,5X,'P TH.=',F10.5,5X,'P TH.-PE1=',F10.7/33X,'P TH.-P EX.
     *=',F10.7,5X,'(DP TH.-DP EX.)/DP EX. *100 =',F7.3/)
 1037 CONTINUE
 1040 CONTINUE
C     ..............................................................
C
C  29-PRINT OF THE PIN TEMPERATURES AT SPECIAL AXIAL POSITIONS
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```
C
      IF(NEXTW(IPA).EQ.0)GOTO 1060
      WRITE(6,1041)
 1041 FORMAT(///5X,'2) COMPUTED ROD TEMPERATURES ( C)'//)
      IEXTW2=IEXTW1+NEXTW(IPA)-1
      DO 1050 IEXTW=IEXTW1,IEXTW2
      WRITE(6,1045)IEXTW,XEXTW(IEXTW)
      DO 1044 NS=1,NSTOT
      NP=NPIN(NS)
      WRITE(6,1046)(M,NS, JPIN(NS,M),TWTH(NS,M,IEXTW),M=1,NP)
 1044 CONTINUE
 1045 FORMAT(/5X,I2,')HEIGHT=',F10.5,' CM'/)
 1046 FORMAT(3(5X,I2,') TW TH.(',I5,',',I5,')=',F10.3,' C'))
 1050 CONTINUE
 1060 CONTINUE
C     ..............................................................
C
C  30-STARTING VALUES OF VARIABLES FOR THE NEXT AXIAL PORTION
C
      IF(X(L).GT.DIST(ISPAC) .AND. ISPAC.NE.NSPACT)ISPAC=ISPAC+1
      TO=T(L)
      PO=P(L)
      DPBAR(1)=DPBAR(L)
      II=II+NSPAC(IPA)
      IEXPR1=IEXPR1+NEXPR(IPA)
      IEXTW1=IEXTW1+NEXTW(IPA)
      SPRLEN=SPRLEN+PLEN(IPA)
      HH=SPRLEN
      IF(NDPRQ(IPA).GT.0)IDPRQ=IDPRQ+1
      ISTAIN=1
 8888 CONTINUE
C     ..............................................................
C
C  31-END OF THE LOOP IPA; CALCULATION OF THE PRESSURE RECOVERY AT THE
C     OUTLET OF THE BUNDLE
C
      DEPOUT=-COUT*PROV2/RHO2*0.5
      POUT=PO+DEPOUT
      POBAR=POUT*0.980665
      WRITE(6,8896)DEPOUT,POUT,POBAR,COUT
 8896 FORMAT(////5X,'PRESSURE RECAPTURE DUE TO EXIT=',F7.5,' KG/SQCM',5X
     *   ,'PRESSURE OUTSIDE=',F10.5,' KG/SQCM    =',F10.5,' BARS  ( COUT=
     *',F4.2,' )')
      DPOBAR=PEOBAR-POBAR
      IF(IPUNCH.EQ.1)WRITE(1,6069)DPOBAR
      IF(PEXOUT.LE.1.E-06)STOP
      IF(INDPR.EQ.2)POUT=POBAR
      DPEX=PEXOUT-PE1
      DPTH=POUT-PE1
      DPERR=( DPTH-DPEX)/DPEX*100.
      WRITE(6,1008)PEXOUT,DPTH,DPEX,DPERR
 1008 FORMAT(/5X,'EXP. PRESSURE OUTSIDE=',F10.5/5X,'P TH.-PE1=',F10.7/5X
     *,'P EX.-PE1=',F10.7/5X,'(DP TH.- DP EX.)/DP EX.*100=',F6.3)
  742 STOP
      END
```

```
      BLOCK DATA
C-----------------------------------------------------------------------
C     BLOCK DATA FOR THE 19-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/BIE(7)/BIDE/IBIDE
     3       /LAMINK/BKAPPA(7,3)/LAMIN9/I3TIP(42,3)/CONDO/FCOND/MART2/
     4       NS1,NS2/WAKA1/IKAPPA/CVREH/ACVS(3),ACVR(3)/LAMIN6/ANGLAM
     5       /GRAV/IGRAV/SIMLAM/ISIMPL/EXAVTW/IEXAV
      DATA A/3.813,0.274,0.,1.,0.44,0.5,0.01,0.053,10.,10./
      DATA B/2.71,5100.,3.,1.,0.4,0.01,0.,5.,0.5,2./
      DATA NDEST,NDEEND/10,2/
      DATA CNUSS/5.55,3.55/
      DATA D1,D2/7*2.997E-02,7*3.87E-05/
      DATA EX1,EX2,EX3/0.1665E-04,5*0.16E-04,0.1665E-04,0.667E-08,
     *                 5*0.25E-08,0.667E-08,7*0./
      DATA EX4,EX5,EX6/7*0.1665E-04,7*0.667E-08,7*0./
      DATA BIK/1.,2*0./
      DATA BIE/0.,1.,2*0.,1.,2*0./
      DATA IBIDE/2/
      DATA BKAPPA/2*118.5,3*115.5,2*118.5,7*93.2,2*93.9,3*92.3,2*93.9/
C     ..................................................................
C     TURBULENT CALCULATION IS IMPOSED FOR ALL SUBCHANNELS
C
      DATA I3TIP/126*2/
      DATA NS1,NS2/0,0/
C
      DATA FCOND/1./
      DATA ANGLAM/1./
      DATA ACVS,ACVR/5.93,5000.,0.8,3*0./
C     ..................................................................
C     IF THE DIRECTION OF THE FLOW IS COINCIDENT TO THAT OF THE
C     GRAVITATIONAL FORCE IGRAV=1; IF IT IS OPPOSITE IGRAV=-1
C     IF THE GRAVITATIONAL FORCE IS NOT TAKEN INTO ACCOUNT IGRAV=0
C     ISIMPL=2 IN THE CASE OF LAMINAR FLOW, IF THE NUSSELT NUMBERS
C     OF THE EXTERNAL CHANNELS "NS" ( NS1-1<NS<NS2+1 ), I.E. IF IT MUST
C     BE  CO1,CO2#1 IN SIMLA1. IN THE OTHER CASES ISIMPL=1
C     IEXAV=2 IF AN AVERAGE VALUE OF THE PIN TEMPERATURES AND AN AVERAGE
C     VALUE OF THE SHROUD TEMPERATURES MUST BE COMPUTED IN WALLTE FOR
C     THE EXTERNAL CHANNELS INSTEAD OF THE REAL VALUES. OTHERWISE
C     IEXAV=1
C
      DATA IKAPPA,IGRAV,ISIMPL,IEXAV/1,0,2*1/
      END




      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=0.7982+0.3421*ALOG(PHI)
```

```
      GOTO 4
    2 IF(PHI.GE.0.05)GOTO 3
      A=-0.C5033+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=C.64/R1DR2**0.0738
      RETURN
      END



      SUBROUTINE ANGCA1(K,NS,N,IRH,PROV,PB,   RH,H1,ALFA,A,AT,DET,DETCT,
     *D,W,NSTR,H,PR1,PR2,SQDPG,TE,SUR,          AMT,DDDD,*, AMA,AMB)
C-----------------------------------------------------------------------
C     SUBROUTINE ANGCA1 CALCULATES FRICTION FACTORS AND APPROXIMATE
C     OUTLET MASS FLOW RATES AND TEMPERATURES FOR CORNER CHANNELS
C
      REAL LAMSCH,LAMB,MSCH1,KAPPA,MSCH,LAMLAM
      DIMENSION A(30)
      COMMON/WACO1/XMSCHB(18,2),XMSCHA(18,2)/DAT/PIG/ANG2/FA(30)
     0        /SUB3/ADAB(18,2),DETB(18,2)/SUB4/LAMB(18,2)/SUB1/ASCH(42,3)
     1        /SUB2/TSCH(42,3),MSCH(42,3)/SUB5/LAMSCH(42,3)/INPAR/IPA
     2        /SUB6/TSCH1(42,3)/SUB22/TW(42,3)/MART/ITCORR
     3        /SUB8/MSCH1(42,3)/SUB23/HPLUSB(42,3),HPLUSW(42,3)
     4        ,QPLUS(42,3),PRB  (42,3),YODH(42,3)/HEA5/QQ(42,3)
     5        /LAMIN0/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)/WSSCH1/DELTIE(18,2,90),DTIEAV(18,2)
     8        /REC1/       PVERT(90),PRAD(90)/REC2/E(90)/REC3/P(90)
     9        /WSSCH/T1SSC1(18,2),T2SSC1(18,2),T1SSC2(18,2),T2SSC2(18,2)
      COMMON/WSSCH0/TBSSC1(42,3),TWSSC1(42,3),TBSSC2(42,3),TWSSC2(42,3)
     0        /LAMIN9/I3TIP(42,3)/SHROUD/TLINER(18,2)/LAMIN5/RTIP(7)
      III=NS-NSTR
      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=C.
      CS=1.
      AMA1=MSCH1(NS,1)/AT
      ANGT=C.
      AMT=0.
      TT=0.
      AMB=C.
      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,SQDPC,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,SQDPC,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
      F1ATIP(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
       DDDD=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(IRF.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




      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
      COMMON/HEA6/NPIN(42),JPIN(42,3)/GRID1/EPSISC(42,3,3),DIST(7)
     1       /GRID2/YY(100,42,3)/GRID3/X(100)
      DIMENSION      B(42,3),        AA(42,3),SLOPE(42,3),YYM(3,42,3)
      X1=NDE1*DETC
      IF(MSPAC.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*********************
C***********************************************************************
      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
      RETURN
C***********************************************************************
C*****HEATED PART WITH SPACERS: AXIAL STEPS FIT CORR. PROF. FOR NU*****
C***********************************************************************
    2 CONTINUE
      ZETA1=2./(1.+XMAXNU)
      JSPAC=MSPAC+II-1
C
      AMM=8./NDE2+0.5
      MM=AMM
      BMM=MM
      NDE2=8./BMM
      X2=NDE2*DETC
C
C     (NOTE THAT 8/NDE2 MUST BE AN INTEGER TO FIT CORR. PROF. FOR NU)
      DE11W=11.*DETC-WSP*0.5
      NPSEC=0
```

```
      K=0
      M1=NPSEC+1
      M2=M1+MM+3
      M3=M2+1
C
C
      DO 16 ISPAC=II,JSPAC
      I1SPAC=ISPAC-II+1
      DO 3 NS=1,NSTOT
      NP=NPIN(NS)
      DO 3 NN=1,NP
      B(NS,NN)=CONST*EPSISC(NS,NN,I1SPAC)**2
      YYM(1,NS,NN)=1.+0.75*ZETA1*B(NS,NN)
      YYM(2,NS,NN)=(1.+B(NS,NN)*0.5*(1.+ZETA1))*(XMAXNU-1.)+(2.-XMAXNU)*
     *(1.+0.5*B(NS,NN)*(1.+CHSLNU+(1.-CHSLNU)/(3.-XMAXNU)))
      YYM(3,NS,NN)=1.+0.5*B(NS,NN)*(2.*CHSLNU+(1.-CHSLNU)/(3.-XMAXNU))
      AA(NS,NN)=1.+CHSLNU*B(NS,NN)
    3 SLOPE(NS,NN)=CHSLNU*B(NS,NN)*0.125/DETC
      XXX1=DIST(ISPAC)-WSP*0.5-DETC
      IF(ISPAC.EQ.II .AND. HH.GE.XXX1)GOTO 11
    4 K=K+1
      L=K+1
      IF(K.NE.NPSEC+1)GOTO 10
C
C*****AXIAL STEPS WHERE NO EFFECT OF SPACERS ON NU IS PRESENT**********
      DX=XXX1-HH
      SEC=DX/X1+1.
      NSEC=SEC
      SEC=NSEC
      H=DX/SEC
      M1=NSEC+NPSEC+1
      M2=M1+MM+3
      M3=M2+1
    7 CONTINUE
      DO 8 NS=1,NSTOT
      NP=NPIN(NS)
      DO 8 NN=1,NP
    8 YY(K,NS,NN)=1.
      X(L)=X(K)+H
      GOTO 4
   10 IF(K-M1)7,11,13
   11 CONTINUE
C
C****AXIAL STEPS (DIST(ISPAC)-WSP/2-DETC)-(DIST(ISPAC)-WSP/2+3*DETC) **
      XXX2=X(K)-XXX1
C     XXX2#C IF DETC > DISTANCE BETWEEN THE FIRST SPACER AND THE INLET
C     OF THE PART
      X(L)=X(K)+DETC-XXX2
      DO 12 NS=1,NSTOT
      NP=NPIN(NS)
      DO 12 NN=1,NP
   12 YY(K,NS,NN)=1.+0.25*B(NS,NN)*(1.+XXX2/DETC)*ZETA1
      DO 60 J=1,3
      K=K+1
      L=K+1
      X(L)=X(K)+DETC
      DO 59 NS=1,NSTOT
      NP=NPIN(NS)
      DO 59 NN=1,NP
```

```
   59 YY(K,NS,NN)=YYM(J,NS,NN)
      IF(X(L).GT.DDD)GOTO 61
   60 CONTINUE
      LL=L
      GOTO 4
C
C*****PART ENDS BEFORE (DIST(ISPAC)-WSP/2+3*DETC ) IS REACHED *********
   61 CONTINUE
      X(L)=DDD
      N=K
      RETURN
C
   13 IF(K.EQ.M3)GOTO 15
C
C*****AXIAL STEPS WHERE INFLUENCE OF SPACERS IS DECREASING*************
      X(L)=X(K)+X2
      DO 14 NS=1,NSTOT
      NP=NPIN(NS)
      DO 14 NN=1,NP
   14 YY(K,NS,NN)=AA(NS,NN)-(X(K)+X2*0.5-X(LL))*SLOPE(NS,NN)
      GOTO 4
   15 CONTINUE
C
C      END OF INFLUENCE OF THE SPACER.
      NPSEC=M2
      K=K-1
      HH=DIST(ISPAC)+DEL1W
   16 CONTINUE
C
C      ALL SPACERS HAVE BEEN CONSIDERED.
      IF(HH.GT.DDD)GOTO 21
C*****END OF SMOOTH OR ROUGH PART NOT YET REACHED*********************
      DX=DDD-HH
      SEC=DX/X1+1.
      NSEC=SEC
      SEC=NSEC
      H=DX/SEC
      K1=K+1
      N=K+NSEC
      DO 20 K=K1,N
      L=K+1
      X(L)=X(K)+H
      DO 19 NS=1,NSTOT
      NP=NPIN(NS)
      DO 19 NN=1,NP
   19 YY(K,NS,NN)=1.
   20 CONTINUE
      RETURN
C
C*****END OF SMOOTH OR ROUGH PART OVERTAKEN: CORRECTION TO FIT END POINT
   21 CONTINUE
      DX=DDD-X(LL)
      SEC=DX/X2+1.
      NSEC=SEC
      SEC=NSEC
      H=DX/SEC
      N=LL+NSEC-1
      DO 25 K=LL,N
      L=K+1
```

```
      X(L)=X(K)+H
      DO 24 NS=1,NSTOT
      NP=NPIN(NS)
      DO 24 NN=1,NP
   24 YY(K,NS,NN)=AA(NS,NN)-(X(K)+H*0.5-X(LL))*SLOPE(NS,NN)
   25 CONTINUE
      RETURN
      END



      SUBROUTINE BALA(K,NSTOT,INDSP,ASEC,H,LENGTH,PR1,PR2,PET,    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
      DIMENSION WCF1(42),EP1(42),A(42),DE(42),
     1          TA(42),  RHOAV(42),RHO1(42),XMEM(42),I1TIP(42)
      COMMON/GEDO/ACH(3)/HEA6/NPIN(42),JJROD(42,3)/GRID/CSPAC(42,3)
     1        /CORR/SIGMA(42),PHI(42),SBMNS/LAMINO/I2TIP(42,3)
     2        /TJ1/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)/MOB1/M2(42)/MOB2/UAV(42)/MOB8/CP(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(42,3)
     8        /GRID7/PGDP(42,3)/COND1/CCOND(42,3)/MART2/NNSS1,NNSS2
     9        /GRAV/IGRAV
C     ..................................................................
C     APPROXIMATE METHOD FOR THE LAMINAR CALCULATIONS
C
      IENFR=1
      DO 1001 NS=1,NSTOT
      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,NSTOT
      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,FREL,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
      DO 7 ITERM=1,20
      DO 3 NS=1,NSTOT
      THEX=0.
      CONHE=0.
      NI=NER(NS)
      ACH1=ACH(NTYP(NS))
      MAV1=MAV(NS)*ACH1/AZ(NS)
      DO 2 M=1,NI
      J=NIS(NS,M)
      ACH2=ACH(NTYP(J))
      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))
      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 TEMP2(NS)=TEMP(NS)+H/(MAV(NS)*CP(PBT,TA(NS)))*((QT(NS)*QDEV+QLINM*
     *PERL(NTYP(NS))*AZ(NS)/ACH1*QLDEV)/LENGTH+THEX+CFHEX+CONHE)
      PHI(NS)=(THEX+CFHEX+CONHE)*H/AZ(NS)
      TAV(NS)=(M2(NS)*TEMP2(NS)+MI(NS)*TEMP(NS))*0.5/MAV(NS)
    3 CONTINUE
      IF(ITGL.EQ.1)GOTO 9
      DO 4 NS=1,NSTOT
```

```
      IF(ABS(TAV (NS)/TA(NS)-1.).GT.1.E-04)GOTC 5
    4 CONTINUE
      GOTO 9
    5 CONTINUE
      DO 6 NS=1,NSTOT
    6 TA(NS)=TAV(NS)
    7 CONTINUE
C     ..................................................................
C     END OF LOOP ITERM
C
       WRITE(6,8)ITGL,ITCORR,(TAV(NS),NS=1,NSTOT)
    8 FORMAT(    5X,'   CHANNEL CALCULATION STOPS IN LOOP ITERM AT ITGL=
     $',I6,/5X ,'ITCORR=',I5/5X,'TEMPERATURES='/(8E15.5))
      RETURN 1
C     ..................................................................
C     CALCULATION OF PRESSURE LOSSES FOR CHANNELS
C
    9 CONTINUE
      DO 10 NS=1,NSTOT
      RHOAV(NS)=RHO(PBT,TAV(NS))
   10 UAV(NS)=MAV(NS)/(A(NS)*RHOAV(NS))
      DPAV=0.
      SMA=0.
      DO 13 NS=1,NSTOT
      TMOEX=0.
      NI=NER(NS)
      ACH1=ACH(NTYP(NS))
      DO 11 M=1,NI
      J=NIS(NS,M)
      TMOEX=TMOEX-(UAV(NS)-UAV(J))*WT(NS,M)
   11 CONTINUE
      TMOEX=FT*TMOEX/A(NS)*H
      IF(ITGL.GT.1)GOTO 103
      CFMOEX=0.
      GOTO 104
  103 UCFAV=UA(NS,NI,ACH1,1)
      CFMOEX=(2.*UAV(NS)-UCFAV)*WCF(NS)/A(NS) *H
  104 CONTINUE
      XMEM(NS)=LAM(NS)*H/(2.*DE(NS)*RHOAV(NS))
      RE=MAV(NS)*DE(NS)/(A(NS)*ETA(PBT,TAV(NS)))
      IF(INDSP.EQ.2)XMEM(NS)=XMEM(NS)+(CSPAC(NS,I1SPAC)+CSPDPF(EPS(NS,I1
     *SPAC), DE(NS),LAM(NS),WSP,PGDP(NS,I1SPAC),RE,NTYP(NS)))/RHOAV(NS)
   12 DP(NS)=XX*(-(MAV(NS)/A(NS))**2*(XMEM(NS)-(RHO(PR2,TEMP2(NS))-RHO1(
     *NS))/RHOAV(NS)**2)+TMOEX+CFMOEX+IGRAV*RHOAV(NS)*980.665*H)
      DPAV=DPAV+DP(NS)*MI(NS)
      SMA=SMA+MI(NS)
   13 CONTINUE
      DPAV=DPAV/SMA
C     ..................................................................
C     TEST OF CONVERGENCE FOR THE CHANNEL PRESSURE LOSSES
C
      DO 14 NS=1,NSTOT
      IF(ABS(DP(NS)/DPAV-1.).GT.1.E-02)GOTO 15
      IF(ABS(DP(NS)/DPAV-1.).GT.1.E-03 .AND. ITGL.LT.40)GOTO 15
   14 CONTINUE
      IF(IVIA.EQ.2)GOTO 17
      DO 301 NS=1,NSTOT
      IF(M2(NS).LE.0.)GOTO 302
  301 CONTINUE
```

```
      IVIA=2
   15 CONTINUE
C     ..................................................................
C     END OF LOOP ITGL
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 ITGL 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
      RUAS(NS)=MAV(NS)*SQRT(LAM(NS)*0.125)/AZ(NS)*ACH(NTYP(NS))
      BMNS=SQRT(ABS(DPAV)/(XX*XMEM(NS)))*A(NS)
      SIGMA(NS)=(MAV(NS)-BMNS)/AZ(NS)
      SBMNS=SBMNS+BMNS
   21 CONTINUE
      RETURN
      END



      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)+(-1.71985+1.2139*P)*W
      RETURN
      END



      SUBROUTINE CEWA(K,NS,IRH,PROV,PB,RH,AA,DD,GG,AM1,DETOT,H1,ALFA,
     *I,JJJ,H,PR1,PR2,SQDPG,AMT,TT,DDDD,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)/CAT/PIG/MART/ITCORR
     1        /QPAR1/QDEV/COLAM1/COLAMB/SUB22/TW(42,3)
C
      IF(IRH.EQ.1)GOTO 1000
C
C     IN THE CASE OF SMOOTH RODS SINGLE VALUES OF THE SUE-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
C
      DO 4 IT=1,50
      DELTAT=(Q+PHI*AA)/(AM1*CP(PB,TI))
      TI=TIE+0.5*DELTAT
      IF(ITW.EQ.1 .AND. I.EQ.1) TWI=TI
      ETAI=ETA(PB,TI)
      RHOI=RHO(PB,TI)
      REI=AM1*DD/(AA*ETAI)
      ETAIW=ETA(PB,TWI)
      RHOIW=RHO(PB,TWI)
      REIW=(ETAI*RHOIW)/(ETAIW*RHOI)*REI
      IF(IT.EQ.1 .AND. ITW.EQ.1) GOTO 30
C     .................................................................
C     AFTER 1.ST ITERATION FRICTION FACTORS ARE EVALUATED FROM THE
C     VALUES OBTAINED IN THE PRECEEDING ITERATION
C
      IF(REI.GT.0. .AND. SQ8LI.GT.0.)GOTO 700
 1001 WRITE(6,699)NS,JJJ,I,REI,SQ8LI
  699 FORMAT(//5X,'NS=',I5,5X,'M=',I2,5X,' I=',I3/5X,'RE=',E15.5,5X,'SQRT
     *(8/LAMBDA)=',E15.5)
      RETURN 1
  700 CONTINUE
      IF(IRH.EQ.2)GOTO 1
      SQ8LI=2.5*ALOG(REI/SQ8LI)+5.5-GG
      GOTO 3
    1 IF(SQ8LI.LE.0.)GOTO 1001
      HPLUSB=RH/DD*REI/SQ8LI
      HPLUSW=HPLUSB*REIW/REI
      GOTO 31
C     .................................................................
C     1.ST ITERATION: FRICTION FACTORS ARE EVALUATED BY MEANS OF THE
C     EQUATION (LAMBDAI*RHOI*UI**2/DI) = (LAMBDA*RHO*U**2/D) TOT.
C
   30 IF(IRH.EQ.2)GOTO 2
      SQ8LI=2.5*ALOG(PROV/ETAI*SQRT((DD/DETOT)**3*RHOI))+5.5-GG
      GOTO 3
```

```
    2 HPLUSB=RH/DETOT*PROV/ETAI*SQRT(DD/DETOT*RHOI)
      HPLUSW=RH/DETOT*PROV/ETAIW*SQRT(DD/DETCT*RHOIW)
C
   31 CONTINUE
      QPLUS=QA*AA/(AM1*(TE+273.16)*CP(PB,TI))
      RHPL=RHPLUS(HPLUSB,TWI,TE,QPLUS,HPLUSW,TI,YDH)
      SQ8LI=2.5*ALOG(DD/RH)+RHPL-GG
    3 LAMI=8./SQ8LI**2*COLAMB
      SSS=AA/SQRT(LAMI*H/(2.*RHOI*DD))
      AM2=SSS*SQDPG+SIGMA*AA
      IF(IT.EQ.1 .AND. ITW.EQ.1)GOTO 50
      IF(ABS(PLAMI/LAMI-1.).LE.1.E-04)GOTO 6
      PLAM1=PLAMI
      AM3=AM1
   50 PLAMI=LAMI
    4 AM1=AM2
C     ..............................................................
C     END OF LOOP IT
C
      WRITE(6,5)I,NS,K,ITW,ITCORR,AA,DD,ALFA,LAMI,PLAM1,AM3,AM2,TI,TIE,
     1TWI,PHI,SIGMA
    5 FORMAT(1H1,5X,'CALCULATION STOPS: IT=10 FOR SUBCH.',I3,2X,'(CHANNE
     *L NR.',I4,2X,'AXIAL SECTION NR.',I3,')',2X,'ITW=',I2,2X,'ITCORR=',
     *I4/5X,'AA=',E15.5/5X,'DD=',E15.5/5X,'ALFA=',E15.5/5X,'LAMI=',E15.5
     */5X,'PLAMI=',E15.5/5X,'AM1=',E15.5/5X,'AM2=',E15.5/5X,'TI=',E15.5/
     *5X,'TIE=',E15.5/5X,'TWI=',E15.5/5X,'PHI=',E15.5/5X,'SIGMA=',E15.7)
      RETURN 1
C
    6 IF(QQ(NS,JJJ).LE.1.E-06)GOTO 12
      IF(IRH.EQ.1)GOTO 13
C     ..............................................................
C     ITERATION 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/DD*FACHE
      TIW=TI+QA/ALFAI
      IF(ABS(TIW/TWI-1.).LE.1.E-04)GOTO12
   10 TWI=TIW
C     ..............................................................
C     END OF LOOP ITW
C
      WRITE(6,11)I,JJJ,NS
   11 FORMAT(    5X,'CALCULATION 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



      SUBROUTINE CEWACO(N,NN,NTYP,ALFA,D,X,AT,DET,MFLOW,ATOT,AREA,DE,ME)
C-----------------------------------------------------------------------
C     SUBROUTINE CEWACO 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)
      DELTAE=E2-E1
      AREA(I)=X*DELTAE*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)/(PEROD+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



      SUBROUTINE CF1(X1,X2,Y1,Y2,DP1,DP2,ITVIA,XYT,YT)
C-----------------------------------------------------------------------
C     CF1 IS USED IN THE CALCULATION OF THE AVERAGE CROSS-FLOW TEMPERA=
C     TURES AND VELOCITIES
```

```
C
      XYT=X1*Y1+X2*Y2+XYT
      YT=Y1+Y2+YT
      RETURN
      END



      SUBROUTINE CONNIJ(NSTR,NSTOT,NROMA,NSEL)
C-----------------------------------------------------------------------
C     CONNIJ EVALUATES FOR EACH CHANNEL I THE NUMBER  NER(I) OF
C     INTERACTIONS WITH OTHER CHANNELS J AND WHICH  CHANNELS INTERACT
C     WITH I.
C
      COMMON/IND1/NROW(42),NUMS(42)/IND2/NOT(3,18)/IND3/NTYP(42)
     1      /IND4/NUM3(3),NUM6(3),NUM12(3),NUM18(3),NUM24(3),NUM30(3),
     2      NUM36(3)/IJ1/NER(42),NIS(42,3)
      NAN=NROMA+2
      NBN=1
      NCN=-1
      DO 43 NS=1,NSTOT
      NRO=NROW(NS)
      NUM=NUMS(NS)
      NUMA3=NUM3(NRO)
      NUMA6=NUM6(NRO)
      NUMA12=NUM12(NRO)
      NUMA18=NUM18(NRO)
      NUMA24=NUM24(NRO)
      NUMA30=NUM30(NRO)
      NUMA36=NUM36(NRO)
      IF(NS.GT.NSTR)GOTO 29
      IF(NUM.GT.1)GOTO 5
      IF(NSEL-2)1,2,4
    1 NER(NS)=3
      NIS(NS,3)=NOT(NRO,NUMA36)
      GOTO 3
    2 NER(NS)=2
    3 NIS(NS,1)=NS+1
      GOTO 13
    4 IF(NRO.GT.1)GOTO 2
      NER(1)=1
      NIS(1,1)=3
      GOTO 43
    5 IF(NSEL-2)6,7,8
    6 NUMSP=NUMA36
      GOTO 9
    7 NUMSP=NUMA18
      GOTO 9
    8 NUMSP=NUMA3
    9 IF(NUM.EQ.NUMSP)GOTO 10
      NER(NS)=3
      NIS(NS,3)=NS+1
      GOTO 12
   10 IF(NSEL.EQ.1)GOTO 11
      NER(NS)=2
      GOTO 12
   11 NER(NS)=3
      NIS(NS,3)=NOT(NRO,1)
```

```
12  NIS(NS,1)=NS-1
13  IF(NUM.GT.NUMA6)GOTO 14
    NAM=NUM
    GOTO 19
14  IF(NUM.GT.NUMA12)GOTO 15
    NAM=NUM-NUMA6
    GOTO 19
15  IF(NUM.GT.NUMA18)GOTO 16
    NAM=NUM-NUMA12
    GOTO 19
16  IF(NUM.GT.NUMA24)GOTO 17
    NAM=NUM-NUMA18
    GOTO 19
17  IF(NUM.GT.NUMA30)GOTO 18
    NAM=NUM-NUMA24
    GOTO 19
18  NAM=NUM-NUMA30
19  IF(NAM.EQ.(NAM/2*2))GOTO 21
    I1=1
    IF(NRO.EQ.NROMA)GOTO 20
    I2=1
    I3=0
    GOTO 22
20  I2=2
    I3=1
    GOTO 22
21  I1=-1
    I2=1
    I3=0
22  NRO1=NRO+I1
    IF(NUM.GT.NUMA6)GOTO 23
    NUMA=(NUM+I1)/I2+I3
    GOTO 28
23  IF(NUM.GT.NUMA12)GOTO 24
    NUMA=(NUM+I1-NUMA6)/I2    +NUM6(NRO1)
    GOTO 28
24  IF(NUM.GT.NUMA18)GOTO 25
    NUMA=(NUM+I1-NUMA12)/I2    +NUM12(NRO1)
    GOTO 28
25  IF(NUM.GT.NUMA24)GOTO 26
    NUMA=(NUM+I1-NUMA18)/I2    +NUM18(NRO1)
    GOTO 28
26  IF(NUM.GT.NUMA30)GOTO 27
    NUMA=(NUM+I1-NUMA24)/I2    +NUM24(NRO1)
    GOTO 28
27  NUMA=(NUM+I1-NUMA30)/I2    +NUM30(NRO1)
28  NIS(NS,2)=NOT(NRO1,NUMA)
    GOTO 43
29  IF(NUM.GT.1)GOTO 32
    IF(NSEL.EQ.1)GOTO 30
    NER(NS)=1
    GOTO 31
30  NER(NS)=2
    NIS(NS,2)=NSTOT
31  NIS(NS,1)=NS+1
    GOTO 43
32  IF(NSEL-2)33,34,40
33  NUMSP=NUMA36
    GOTO 35
```

```
   34 NUMSP=NUMA18
   35 IF(NUM.EQ.NUMSP)GOTO 37
      NIS(NS,1)=NS+1
      NIS(NS,2)=NS-1
      IF(NUM.EQ.NAN)GOTO 36
      NER(NS)=3
      NUMA=(NUM-NBN)*2+NCN
      NIS(NS,3)=NOT(NRO-1,NUMA)
      GOTO 43
   36 NER(NS)=2
      NAN=NAN+NRO
      NBN=NBN+NRO
      NCN=NCN+2*NROMA-1
      GOTO 43
   37 IF(NSEL.EQ.1)GOTO 38
      NER(NS)=1
      GOTO 39
   38 NER(NS)=2
      NIS(NS,2)=NOT(NRO,1)
   39 NIS(NS,1)=NS-1
      GOTO 43
   40 IF(NUM.EQ.NUMA3)GOTO 41
      NER(NS)=3
      NIS(NS,3)=NS+1
      GOTO 42
   41 NER(NS)=2
   42 NIS(NS,1)=NS-1
      NUMA=(NUM-1)*2-1
      NIS(NS,2)=NOT(NRO-1,NUMA)
   43 CONTINUE
      DO 100  NS=1,NSTOT
      NI=NER(NS)
      WRITE(6,200)NS,NTYP(NS),(NIS(NS,M),M=1,NI)
  200 FORMAT(5X,'NS=',I2,5X,'TYPE=',I1,5X,'CHANNELS CONNECTED:',3I5)
  100 CONTINUE
      RETURN
      END



      SUBROUTINE CORRTE(TW,TB,PB,     NS,M,I,BIOT,TWINF)
C---------------------------------------------------------------------
C     CORRTE CORRECTS THE COMPUTED TEMPERATURES FOR THE BIOT EFFECT AND
C     THE POSITION OF THE THERMOCOUPLE INSIDE THE CANNING
C
      COMMON/IROSMO/IRH/BIDE/IBIDE/CORRE/QHRCAR,QRMDAR,QLAMR/LAMINC/
     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
      BIOT=QHRDAR/((TWBI -TB) *KMET(TWBI))
      TW=DTWINF/KINF(BIOT)+TB
      IF(ABS(TWP/TW-1.).LE.1.E-04)GOTO 13
   10 CONTINUE
      WRITE(6,12)NS,M,I,BIOT,TWP,TW
   12 FORMAT(1H1,5X,'CALCULATION STOPS IN SUBROUTINE CORRBI: NS=',I5,' M
     *=',I2,' I=',I3/5X,'BIOT=',E15.5,5X,'TWP=',E15.5,5X,'TW=',E15.5)
      STOP
C
   13 IF(QRMDAR.LE.1.E-06)TW=DTWINF/EINF(BIOT)+TB
C     ..............................................................
C     FOR SMOOTH AND ROUGHENED RODS, TURBULENT AND LAMINAR FLOW
C
  100 TW=TWCTEP(QRMDAR,TW)
      RETURN
      END



      FUNCTION CP(P,T)
C-------------------------------------------------------------------
C     FUNCTION CP EVALUATES THE SPECIFIC HEAT OF THE COOLANT (CAL/G K)
C
C     CASE OF HELIUM COOLANT
C
      CP=1.242
      RETURN
      END



      SUBROUTINE CRFL1(ITGL,DPJAV,FREL,AJT,JMAX,AJ,MJ,DPJ,WCFJ,WCF1J,
     *EP1J)
C-------------------------------------------------------------------
C     CRFL1 EVALUATES THE CROSS FLOW SOLUTIONS
C
      REAL MJ
      DIMENSION AJ(JMAX),MJ(JMAX),DPJ(JMAX),WCFJ(JMAX),WCF1J(JMAX),
     *EP1J(JMAX)
      IF(ITGL-2)1,3,5
C     ..............................................................
C     FIRST ITERATION : ASSUMED WCFJ(J)=0
C
    1 CONTINUE
      DO 2 J=1,JMAX
      WCFJ(J)=0.
    2 WCF1J(J)=0.
      RETURN
C     ..............................................................
```

```
C      SECOND ITERATION : ASSUMED WCFJ(J)=-0.5*(DPJ(J)-DPJ AV)*
C                                            MJ(J)/DPJ(J)
C
     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
C      ..............................................................
C      ITGL>2: WCFJ(J) ARE OBTAINED BY USE OF THE TANGENT METHOD
C
       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
C      ..............................................................
C      NORMALIZATION OF THE WCF(J): THEIR SUMMATION MUST BE =0
C
       WCFJT=WCFJT/AJT
       DO 8 J=1,JMAX
     8 WCFJ(J)=WCFJ(J)-WCFJT*AJ(J)
       RETURN
       END


       FUNCTION CSFUN(IRH,REAI,SQ8LIA,SQ8LIB,GA)
C-------------------------------------------------------------------
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(IRH.EQ.2)GOTO 1
       CSFUN=1.
       RETURN
     1 PROV=SQRT(1.056+0.005*(SQ8LIA/SQ8LIB)**2)
       SQ8LIA=ABS(SQ8LIA)
       SQ8LIA=(2.5*ALOG(REAI/(SQ8LIA*PROV))+5.5*COLAMA-5.659)     /PROV
       SQ8LIA=ABS(SQ8LIA)
       CSFUN=(SQ8LIA-5.5*COLAMA)/(2.5*ALOG(REAI/SQ8LIA)-GA)
       RETURN
       END


       SUBROUTINE DDONNE(TWO,TBT,GHPL,RODR2,R1DR2,YDH,R2MRCH,FF,T2,T1,TE)
C-------------------------------------------------------------------
```

```
C     DDONNE EVALUATES THE TEMPERATURES T1 AND T2 OF THE TWO REGIONS OF
C     CORNER CHANNELS AND OF THE 'WALL PART' OF WALL SUBCHANNELS
C
      R0DR22=R0DR2**2
      R1DR22=R1DR2**2
      F1=1.-R0DR22
      F2=1.-R1DR22
      F3=R0DR22-R1DR22
      T2=TWO-FF*(GHPL+2.5/F1*(F2*ALOG(YDH+R2MROH)-F3*ALOG(YDH)-0.5*(1.+
     +2.*R1DR2-R0DR22-2.*R1DR2*R0DR2)))
      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



      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/IROSMO/IRH/CVREH/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



      FUNCTION EINF(BIOT)
C     EINF EVALUATES THE E INFINITE VALUE
C-----------------------------------------------------------------------
C
      COMMON/BIOAT1/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


      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)/INC3/NTYP(42)
     2       /MART2/NS1,NS2/HEA6/NPIN(42),JPIN(42,3)/GAMCO/CGAMMA(18)
     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


      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(18)
     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=    GKAPPA(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
```

```
      FUNCTION ETA(P,T)
C------------------------------------------------------------------------
C     ETA EVALUATES THE DYNAMIC VISCOSITY OF THE COOLANT (G/CM S)
C
C     CASE OF HELIUM COOLANT
C
      ETA=18.84E-05*((T+273.16)/273.16)**0.66
      RETURN
      END
```

```
      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
```

```
      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
```

```
      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
```

```
      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
```

```
      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
```

```
      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



      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



      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



      SUBROUTINE HEATI(NSTOT,NSTR,NSEL,NROMA,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
C                VERSION FOR HEXAGONAL BUNDLES
C     ..................................................................
      COMMON/IND1/NROW(42),NUMS(42)/HEA2/Q(2,12),Q0/HEA3/QT(42)
     1       /HEA5/ QQ(42,3)/HEA6/NPIN(42),JPIN(42,3)/HEA7/IDPIN(2,12)
     2       /IND4/NUM3(3),NUM6(3),NUM12(3),NUM18(3),NUM24(3),NUM30(3),
     3       NUM36(3)/HEA10/QSCH(42,3)
C
      CALL HEATR(NROMA)
C
      NAN=1
      NBN=-NROMA
      NN=1-NROMA
      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*NRO
      N2=N1-2
      GOTO 6
    3 IF(NUM.GT.NUM24(NRO))GOTO 4
      NAM=NUM-NUM18(NRO)
      N1=3*NRO
      N2=N1-3
      GOTO 6
    4 IF(NUM.GT.NUM30(NRO))GOTO 5
      NAM=NUM-NUM24(NRO)
      N1=4*NRO
      N2=N1-4
      GOTO 6
    5 NAM=NUM-NUM30(NRO)
      N1=5*NRO
      N2=N1-5
    6 IF(NAM.EQ. NAM/2*2 )GOTO 8
      NUR=(NAM+1)/2+N1
      Q1=Q(NRO,NUR)
      JPIN(NS,1)=IDPIN(NRO,NUR)
      IF(NUR.EQ.6*NRO) NUR=0
      Q2=Q(NRO,NUR+1)
      JPIN(NS,3)=IDPIN(NRO,NUR+1)
      IF(NRO.EQ.1)GOTO 7
      NUR=(NAM+1)/2+N2
      IF(NUR.EQ. 6*NRO-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(NRO-1,NUR)
      JPIN(NS,1)=IDPIN(NRO-1,NUR)
      IF(NUR.EQ.6*NRO-6) NUR=0
      Q2=Q(NRO-1,NUR+1)
      JPIN(NS,3)=IDPIN(NRO-1,NUR+1)
      NUR=(NAM+2)/2+N1
      Q3=Q(NRO,NUR)
      JPIN(NS,2)=IDPIN(NRO,NUR)
    9 CONTINUE
```

```
      QQ(NS,1)=Q1
      QQ(NS,2)=Q3
      QQ(NS,3)=Q2
      IF(NSEL.EQ.3 .AND. NUM.EQ.NRO)GOTO 10
      NPIN(NS)=3
      GOTO 11
   10 Q2=0.
      Q3=Q3/2.
      NPIN(NS)=2
   11 QT(NS)=(Q1+Q2+Q3)/6.
      QSCH(NS,1)=Q1/6.
      QSCH(NS,2)=Q3/6.
      QSCH(NS,3)=Q2/6.
      GOTO 15
C
C
   12 IF(NUM.LT.NAN)GOTO 14
C
C     CORNER CHANNELS
      NN=NN+NROMA
      NAN=NAN+NRO
      NBN=NBN+NRO
      NPIN(NS)=1
      QQ(NS,1)=Q(NROMA,NN)
      JPIN(NS,1)=IDPIN(NROMA,NN)
      IF(NSEL.EQ.3)GOTO 13
      IF((NSEL.EQ.2 .AND. NUM.EQ.1).OR.(NSEL.EQ.2 .AND. NUM.EQ.NUM18(NRO
     *)))GOTO 13
      QT(NS)=Q(NROMA,NN)/6.
      GOTO 29
   13 QT(NS)=Q(NROMA,NN)/12.
   29 QSCH(NS,1)=QT(NS)
      GOTO 15
C
C     WALL CHANNELS AND SUBCHANNELS
   14 NUR=NUM-NBN+NN-1
      Q1=Q(NROMA,NUR)
      JPIN(NS,1)=IDPIN(NROMA,NUR)
      IF(NS.EQ.NSTOT .AND. NSEL.EQ.1) NUR=0
      Q2=Q(NROMA,NUR+1)
      JPIN(NS,2)=IDPIN(NROMA,NUR+1)
      QQ(NS,1)=Q1
      QQ(NS,2)=Q2
      IF(NSEL.EQ.3 .AND. NUM.EQ.(NRO/2+1) .AND. NRO.EQ.NRO/2*2)GOTO 30
      NPIN(NS)=2
      GOTO 31
   30 Q2=0.
      NPIN(NS)=1
   31 CONTINUE
      QT(NS)=(Q1+Q2)/4.
      QSCH(NS,1)=Q1*0.25
      QSCH(NS,2)=Q2*0.25
   15 CONTINUE
      IF(IPA.NE.IPA/2*2)RETURN
C
C
      WRITE(6,16)
   16 FORMAT(////5X,'RESULTS OF HEATI'////8X,'CHANNEL',3(21X,'ROD',2X)/)
      DO 19 NS=1,NSTOT
```

```
      NP=NPIN(NS)
      WRITE(6,18)NS,(M,NS,M,JPIN(NS,M),M=1,NP)
   18 FORMAT(2X,I10,3(3X,I1,') JPIN(',I5,',',I2,')=',I5))
   19 CONTINUE
      RETURN
      END



      SUBROUTINE HEATR(NROMA)
C-----------------------------------------------------------------------
C     HEATR PROVIDES INDICES TO THE ROD HEAT FLUXES ( Q(NRO,NUM) ) AND
C     IDENTIFIES THE PINS BY MEANS OF THE MATRIX IDPIN
C
C                EXISTS ONLY IN THE VERSION FOR HEXAGONAL BUNDLES
C     ..................................................................
      COMMON/HEA1/Q(19)/HEA2/QQ(2,12),QQ0/HEA7/IDPIN(2,12)
      I=1
      QQ0=Q(1)
      DO 2 NRO=1,NROMA
      NR36=6*NRO
      DO 1 NUM=1,NR36
      I=I+1
      IDPIN(NRO,NUM)=I
    1 QQ(NRO,NUM)=Q(I)
    2 CONTINUE
      RETURN
      END



      SUBROUTINE INDEX(NSEL,NROMA,NSTR,NSTCT,NRO)
C-----------------------------------------------------------------------
C     INDEX PROVIDES INDICES TO THE CHANNELS
C
C                 VERSION FOR HEXAGONAL BUNDLES
C     ..................................................................
      COMMON/IND1/NROW(42),NUMS(42)/IND2/NOT(3,18)/IND3/NTYP(42)/IND4/
     1     NUM3(3),NUM6(3),NUM12(3),NUM18(3),NUM24(3),NUM30(3),NUM36(3)
      NS=1
      DO  6 NRO=1,NROMA
      NUM3(NRO)=NRO
      NUM6(NRO)=2*NRO-1
      NUM12(NRO)=2*NUM6(NRO)
      NUM18(NRO)=3*NUM6(NRO)
      NUM24(NRO)=4*NUM6(NRO)
      NUM30(NRO)=5*NUM6(NRO)
      NUM36(NRO)=6*NUM6(NRO)
      IF(NSEL-2)1,2,3
    1 NUMSP=NUM36(NRO)
      GOTO4
    2 NUMSP=NUM18(NRO)
      GOTO4
    3 NUMSP=NUM3(NRO)
    4 CONTINUE
      DO 5 NUM=1,NUMSP
      NUMS(NS)=NUM
```

```
      NROW(NS)=NRO
      NOT(NRO,NUM)=NS
      NTYP(NS)=1
    5 NS=NS+1
    6 CONTINUE
      NSTR=NS-1
      NRO=NROMA+1
      NUM3(NRO)=NRO/2+1
      NUM6(NRO)=NRO+1
      NUM12(NRO)=NUM6(NRO)+NRO
      NUM18(NRO)=NUM12(NRO)+NRO
      NUM24(NRO)=NUM18(NRO)+NRO
      NUM30(NRO)=NUM24(NRO)+NRO
      NUM36(NRO)=NUM30(NRO)+NROMA
      IF(NSEL-2)7,8,9
    7 NUMSP=NUM36(NRO)
      GOTO 10
    8 NUMSP=NUM18(NRO)
      GOTO 10
    9 NUMSP=NUM3(NRO)
   10 NAN=1
      DO 13 NUM=1,NUMSP
      IF(NUM.EQ.NAN)GOTO 11
      NTYP(NS)=2
      GOTO 12
   11 NTYP(NS)=3
      NAN=NAN+NRO
   12 NUMS(NS)=NUM
      NROW(NS)=NRO
      NOT(NRO,NUM)=NS
   13 NS=NS+1
      NSTOT=NS-1
      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//)
      CALL CONNIJ(NSTR,NSTOT,NROMA,NSEL)
      RETURN
      END




      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 HEXAGONAL BUNDLES
C      .................................................................
      COMMON/IND1/NROW(42),NUMS(42)/IND3/NTYP(42)/IJ1/NER(42),NIS(42,3)
     1       /TUR1/CTURB(42,3)/GEN5/DE(42)/GEOO/ACH(3)/TUR2/CTURB1(2)
     2       /CONDO/FCOND/COND1/CCOND(42,3)/COND2/CCOND1(2)
      REAL NGAPS(42)
      DIMENSION SUM(42)
      SQ3=SQRT(3.)
```

```
      R=D*0.5
      A2=A**2
      A3=A*A2
      R2=R**2
      R3=R*R2
      APIN=PIG*R2
      EM2=C*0.5-EM1
      ZWC=EM2/SQ3
      ATW3=EM2*ZWC
      GAP1=C-D
      GAP2=GAP1*0.5
      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
      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
      NI=NER(I)
      DO 23 M=1,NI
      J=NIS(I,M)
      IF(I.GT.NSTR)GOTO 16
      IF(NSEL.EQ.3 .AND. NUMS(I).EQ.NROW(I))GOTO 12
   11 GAP      =GAP1
      GOTO 14
```

```
   12 IF(NUMS(J).EQ.NROW(J) .OR. NTYP(J).EQ.2)GOTO 13
      GOTO 11
   13 GAP     =GAP2
   14 IF(NTYP(J).EQ.2)GOTO 15
      DELTA     =DELTA1
      RAPPA=RA1
      GOTO 22
   15 DELTA     =DELTA2
      RAPPA=RA2
      GOTO 22
   16 IF(NTYP(I).EQ.3)GOTO 20
      IF(NTYP(J)-2)17,19,20
   17 IF(NUMS(J).EQ.NROW(J) .AND. NSEL.EQ.3)GOTO 18
      GAP     =GAP1
      GOTO 15
   18 GAP     =GAP2
      GOTO 15
   19 DELTA     =DELTA3
      RAPPA=RA3
      GOTO 21
   20 DELTA     =DELTA4
      RAPPA=RA4
   21 GAP     =GAP3
   22 CONTINUE
      AREAI= ACH(NTYP(I))
      AREAJ= ACH(NTYP(J))
      DEIJ=(AREAI+AREAJ)/(AREAI/DE(I)+AREAJ/DE(J))
      YH  =   1.14*SQRT((NGAPS(I)+NGAPS(J))/(SUM(I)+SUM(J)))*RAPPA**2
      CTURB( I,M)=YH*GAP/DELTA*DEIJ*0.05*PCORR
      CCOND(I,M)=GAP/DELTA*FCOND*0.5
   23 CONTINUE
   24 CONTINUE
      DELSC1=C-(7.*C**3/48.-R3)/(0.25*C**2-PIG*R2*SQ3/6.)
      DELSC2=C-2.*XBWS
      CTURB1(1)=CTU1*0.05*DETC*YBC/DELSC1
      CTURB1(2)=CTU2*0.05*DETW*(A-ZWC)/DELSC2
      CCOND1(1)=YBC/DELSC1*FCOND*0.5
      CCOND1(2)=(A-ZWC)/DELSC2*FCOND*0.5
      RETURN
      END


      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



      SUBROUTINE INQUA(NSEL,NSTOT,NROMA,ATC,ATW,ATA,DETC,DETW,DETA)
C-----------------------------------------------------------------------
C     INQUA PROVIDES INDICES TO CHANNEL FLOW AREAS AND EQUIVALENT
C     DIAMETERS AND TO SUBCHANNEL  FLOW AREAS
C
C                 VERSION FOR THE EXAGONAL BUNDLES
C     .................................................................
      COMMON/IND1/NROW(42),NUMS(42)/IND3/NTYP(42)/SUB1/ASCH(42,3)
     1        /GEN2/A(42)/GEN5/DE(42)
      II=0
      KK=0
      DO 10 NS=1,NSTOT
      IF(NTYP(NS)-2)1,3,6
C***** CENTRAL CHANNELS AND SUBCHANNELS**********************************
    1 DE(NS)=DETC
      ASCH(NS,1)=ATC/3.
      IF((NSEL.EQ.3).AND.(NROW(NS).EQ.NUMS(NS)))GOTO 2
      A(NS)=ATC
```

```
      ASCH(NS,2)=ASCH(NS,1)
      ASCH(NS,3)=ASCH(NS,1)
      GOTO 10
    2 CONTINUE
      A(NS)=ATC/2.
      ASCH(NS,2)=ATC/6.
      GOTO 10
C***** WALL    CHANNELS AND SUBCHANNELS**********************************
    3 DE(NS)=DETW
      ASCH(NS,1)=ATW*0.5
      IF(NSEL.NE.3)GOTO 4
      IF(NROMA.EQ.(NROMA/2*2))GOTO 4
      IF(NUMS(NS).EQ.(NROMA+1)/2+1)GOTO 5
    4 CONTINUE
      A(NS)=ATW
      ASCH(NS,2)=ASCH(NS,1)
      GOTO 10
    5 CONTINUE
      A(NS)=ATW /2.
      GOTO 10
C***** CORNER  CHANNELS AND SUBCHANNELS**********************************
    6 DE(NS)=DETA
      IF(NSEL.EQ.1)GOTO 7
      IF(NSEL.EQ.3)GOTO 9
      IF(II.EQ.0 .OR. KK.EQ.2) GOTO 8
      KK=KK+1
    7 CONTINUE
      A(NS)=ATA
      ASCH(NS,1)=A(NS)
      GOTO 10
    8 II=1
    9 CONTINUE
      A(NS)=ATA /2.
      ASCH(NS,1)=A(NS)
   10 CONTINUE
      RETURN
      END




      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),FDTIP(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 5
      DO 4 I=1,2
      WFCO (NS-NSTR,I)=1.
```

```
    4 WFCO1(NS-NSTR,I)=1.
    5 AKAPPA(NS)=BKAPPA(IPA,NTYP(NS))
      IF(NS1.EQ.0 .AND. NS2.EQ.0)GOTO 35
      IF(NS1.GT.NSTR .AND. NS2.LE.NSTOT)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
   20 AKAPPA(NS)=(DE(NS)*FDTIP(NTYP(NS)))**2*PP
   35 CONTINUE
      WRITE(6,30)(NS,AKAPPA(NS)     ,BKAPPA(IPA,NTYP(NS)),NS=1,NSTOT)
   30 FORMAT(     5X,'CHANNEL',I5,' : USED KAPPA=',F10.3,' (INPUT KAPPA='
     *       ,F10.3,')')
      RETURN
      END




      REAL FUNCTION KAPPA(P,T)
C-----------------------------------------------------------------------
C     KAPPA EVALUATES THE THERMAL CONDUCTIVITY OF THE COOLANT
C     (CAL/CM S K)
C
C     CASE OF HELIUM COOLANT
C
      KAPPA=35.1E-05*((T+273.16)/273.16)**0.66
      RETURN
      END




      REAL FUNCTION KINF(BIOT)
C-----------------------------------------------------------------------
C     KINF EVALUATES THE K INFINITE VALUE
C
      COMMON/BIDAT/BI1,BI2,BI3
      KINF=BI1+BI2*BIOT+BI3*BIOT**2
      RETURN
      END




      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




      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




      SUBROUTINE NEWTON(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




      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)/HEA6/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
      ASCH(M)=ASCHZ(NS,M)*F2ATIP(NS,M)
    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



      SUBROUTINE RECANG(I,AI,NS,K,IVIA,IRH,ALFA,AMA1,TI,PB,D,W,RH,DETOT
     *,PROV,DAI,DBI,AAI,ABI,G,SSSA,SSSB, AMTI,NTYP,H1,H,PR1,PR2,SQDPG,JJ
     *J,TE,SUR,TW1,AMAI,TAI,AMBI,TBI,III,TIE,TIAV,HPLUSB,HPLUSW,ANGT,EM1
     *,XC1,XC2,*,DEPA,CS)
C-----------------------------------------------------------------------
C     SUBROUTINE RECANG EVALUATES FRICTION FACTORS AND APPROXIMATE MASS
C     FLOW RATES AND TEMPERATURES FOR WALL-TYPE SUB-SUBCHANNELS.
C
      REAL LAMIA,LAMIB,KI, KAPPA,NUI,NUO
      COMMON/CORR1/SIGMAI(42,3),PHII(42,3)/COLAM1/COLAMB/COLAM2/COLAMA
     1        /CORR2/CHI(18,2,2),PSI(18,2,2)/GRID2/YY(100,42,3)
     2        /ANG1/RA2(60)/HEA5/QQ(42,3)/DAT/PIG/REC1/PVERT(90),PRAD(90)
     3        /SUB20/PROVI(18,2)/GEN5/DE(42)/SUB22/TW(42,3)/MART/ITCORR
     4        /SUB21/TSCHA(18,2),TSCHB(18,2)/QPAR1/QDEV/QPAR2/QLINM,QLDEV
     5        /WSSCH1/DELTIE(18,2,90), DTIEAV(18,2)/WSSCH2/TIO(18,2,90)
     6        /WSSCH/T1SSC1(18,2),T2SSC1(18,2),T1SSC2(18,2),T2SSC2(18,2)
     7        /WSSCH0/TBSSC1(42,3),TWSSC1(42,3),TBSSC2(42,3),TWSSC2(42,3)
C
      ICS=1
      IF(I.GT.1)TWI=TW1
```

```
      IF(ITCORR.EQ.1)PROVI(III,JJJ)=PROV
      PROVI(III,JJJ)=PROV
      DEPA=DETOT
      QROD=QQ(NS,JJJ)*QDEV
      Q=QROD*ALFA/(2.*PIG)*H1
      QA=QROD/SUR
      QLIN=QLINM*H1*QLDEV
      AMABI=AMA1
C     ..................................................................
C     LOOP ITW1 STARTS (CALCULATION OF THE BULK TEMPERATURES OF THE
C     TWO ZONES DIVIDED BY THE TAU=0 LINE, TAI AND TBI)
C
      DO 2000 ITW1=1,10
C     ..................................................................
C     LOOP ITW STARTS (CALCULATION OF THE PIN TEMPERATURE TWI)
C
       DO 14 ITW=1,20
C     ..................................................................
C     LOOP ITTEMP STARTS (CALCULATION OT THE FRICTION FACTORS AND OF
C     THE MASS FLOW RATES FOR THE TWO ZONES DIVIDED BY THE TAU=0 LINE
C     AND OF THE BULK TEMPERATURE TI FOR THE WHOLE SUB-SUBCHANNEL)
C
      DO 7 ITTEMP=1,60
      IF(ITW1.GT.1)GOTO 1998
      IF(                 ITCORR .GT.1 .AND. QQ(NS,JJJ).GT. 1.E-06)GOTO 25
      TAI=TI
      TBI=TI
      GOTO 26
   25 CONTINUE
      TAI=TSCHA(III,JJJ)
      TBI=TSCHB(III,JJJ)
      TI=TIAV
   26 CONTINUE
      IF(ITW.EQ.1 .AND. I.EQ.1)TWI=TBI
      IF(ITW.EQ.1)TWO=TWI
 1998 CONTINUE
      ETAA=ETA(PB,TAI)
      ETAB=ETA(PB,TBI)
      RHOA=RHO(PB,TAI)
      RHOB=RHO(PB,TBI)
      ETAIW=ETA(PB,TWI)
      RHOIW=RHO(PB,TWI)
      QPLUS=QA/(AMABI*CP(PB,TBI)*(TE+273.16))
C
      IF(IVIA.EQ.2 .OR. ITW1.GT.1)GOTO 1
C     ..................................................................
C     CALCULATION OF THE POSITION OF THE TAU=0 LINE
C
      CALL TLINE(I,AI,ITTEMP,NS,K,ALFA,D,W,RH,DEPA   ,PROVI(III,JJJ),IRH,
     *DAI,DBI,AAI,ABI,RHPL,G,TWI,TE,QPLUS,ETAA,RHOA,ETAB,RHOB,ETAIW,
     *RHOIW,ANGT,EM1,XC1,XC2,TBI,&8500,CS)
C
    1 CONTINUE
      PAI=4.*AAI/DAI
      RO=0.5*SQRT(D**2+D*DBI)
      YDH=(RO-0.5*D)/RH
      IF(ITTEMP.EQ.1 .AND. ITW.EQ.1 .AND. ITW1.EQ.1)GOTO 30
C     ..................................................................
C     AFTER THE FIRST ITERATION THE FRICTION FACTORS ARE EVALUATED
```

```
C      BY MEANS OF THE REYNOLDS NUMBERS AND OF THE FRICTION FACTORS
C      COMPUTED AT THE PRECEEDING ITERATION
C
       REAI=AMAI*DAI/(AAI*ETAA)
       REBI=AMBI*DBI/(ABI*ETAB)
       REIW=(ETAB*RHOIW)/(ETAIW*RHOB)*REBI
       IF(REAI.GT.0. .AND. REBI.GT.0. .AND. SQ8LIA.GT.0. .AND. SQ8LIB.GT.
      *0.)GOTO 700
       WRITE(6,699)NS, JJJ,I,REAI,SQ8LIA,REBI,SQ8LIB,ITCORR,ICS
  699 FORMAT(//5X,'NS=',I5,5X,'M=',I2,5X,'I=',I3/5X,'RE A=',E15.5,5X,'SQ
     *RT(8/LAMBDA) A=',E15.5/5X,'RE B=',E15.5,5X,'SQRT(8/LAMBDA) B=',E15
     *.5/5X,'ITCORR=',I5,5X,'ICS=',I2)
 8500 RETURN 1
C
  700 CONTINUE
       IF(IRH.EQ.2)GOTO 27
       SQ8LIB=2.5*ALOG(REBI/SQ8LIB)+5.5-G
       GA=6.0737
       GOTO 28
   27 HPLUSB=RH/DBI*REBI /SQ8LIB
       HPLUSW=HPLUSB*REIW/REBI
       RHPL=RHPLUS(HPLUSB,TWI,TE,QPLUS,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)
       GOTO 6
C      ..................................................................
C      FIRST ITERATION : THE FRICTION FACTORS ARE EVALUATED BY MEANS
C      OF THE EQUATION (LAMBDAI*RHOI**2/DI) = (LAMBDA*RHO*L**2/D) TOT.
C
   30 IF(IRH.EQ.2)GOTO 2
       SQ8LIB=2.5*ALOG(PROV/ETAB*SQRT((DBI/DETOT)**3*RHOB))+5.5-G
       GA=6.0737
       GOTO 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,QPLUS,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
       GOTO 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*H/(2.*RHOA*DAI))
       SSSB=ABI/SQRT(LAMIB*H/(2.*RHOB*DBI))
       AMBI=SSSB*SQDPG+ABI*SIGMAI(NS,JJJ)*CHI(III,JJJ,1)
       AMAI=SSSA*SQDPG+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)
      TIC(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-R0)/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))
      HPLUSC=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,LAMIB,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
C
 1999 U1STAR=AMBI/(RHOB*ABI)*SQRT(LAMIB*0.125)
      FF=QA/(RHOI*CPI*U1STAR)
      RODR2=RO/R2
      CALL DDONNE(TWO,TI,GHPL,RODR2,R1DR2,YDH,R2MROH,FF,TAI,TIB,TE)
      IF(ABS(TBI/TIB-1.).LE.1.E-04)GOTO 2002
 2000 TBI=TIB
C     ..................................................................
C     END OF LOOP ITW1: POINT REACHED IN THE CASE OF CONVERGENCE
C     PROBLEMS
C
       WRITE(6,2001)I,NS,JJJ,ITCORR,TBI,TAI,TI,TWI,TWO
 2001 FORMAT(/5X,'STOP IN RECANG (LOOP ITW1) I=',I3,' NS=',I5,' M=',I2,
     1 ' ITCORR=',I3/5X,'TBI=',E15.5,5X,'TAI=' ,E15.5,5X,'TI=',E15.5,5X,
     2 'TWI=',E15.5,5X,'TWO=',E15.5)
      RETURN 1
C     ..................................................................
C     CONVERGENCE  IS REACHED IN THE LOOP ITW1
C
  600 TWI=TW(NS,JJJ)
C
 2002 CONTINUE
      TBSSC2(NS ,JJJ)=TI
      T1SSC2(III,JJJ)=TBI
      T2SSC2(III,JJJ)=TAI
      TWSSC2( NS,JJJ)=TWI
      IF(I.GT.1)RETURN
C
      TBSSC1( NS,JJJ)=TI
```

```
      T1SSC1(III,JJJ)=TBI
      T2SSC1(III,JJJ)=TAI
      TWSSC1( NS,JJJ)=TWI
      RETURN
      END



      SUBROUTINE RECCA1(K,NS,N,NSC45,IRH,PROV,PB,   RH,H1,ALFA,A,DE,MEC,
     *AT,DET,ATOT,DETOT,MFLOW,W,D,C, JJJ,NSTR,H,PR1,PR2,SCDPG,TE,SUR,
     *AMT,DDDD,ATSCH,CTU3,EM1,*,ALFACE)
C-----------------------------------------------------------------------
C     SUBROUTINE RECCA1 CALCULATES FRICTION FACTORS  AND APPROXIMATE
C     OUTLET MASS FLOW RATES AND TEMPERATURES FOR WALL CHANNELS AND SUBC
C
      REAL MEC,MFLOW,LAMB,LAMSCH,LAMWC,MSCH1,KAPPA,LAMLAM,MSCH,
     1    MWC1L,MWC2L
      DIMENSION A(45),DE(45),MEC(45)
      COMMON/WACO1/XMSCHB(18,2),XMSCHA(18,2)/DAT/PIG/CEN1/G(45)
     0        /REC1/       PVERT(90),PRAD(90)/REC2/E(90)/REC3/P(90)
     1        /SUB1/ASCH(42,3)/SUB2/TSCH(42,3),MSCH(42,3)/SUB3/ADAB(18,2),
     2        DETB(18,2)/SUB4/LAMB(18,2)/SUB5/LAMSCH(42,3)
     3        /SUB8/MSCH1(42,3)/SUB23/HPLUSB(42,3),HPLUSW(42,3)
     4        ,QPLUS(42,3),PRB  (42,3),YODH(42,3)/HEA5/QQ(42,3)/INPAR/IPA
     5        /SUB22/TW(42,3)/WCSE1/DEWC(18,2,2),PHWC(18,2,2)
     6        /LAMIN0/I2TIP(42,3)/LAMIN1/AKAPPA(42) /LAMIN2/FATIP(3),
     7        FDTIP(3)/LAMIN3/F1ATIP(42),F1DTIP(42)/LAMIN4/F2ATIP(42,3),
     8        F2DTIP(42,3)/LAMIN5/RTIP(7)/LAMIN6/ANGLAM/LAMIN7/F1PTIP
     9        /WSSCH1/DELTIE(18,2,90), DTIEAV(18,2)/WSSCH2/TIO(18,2,90)
      COMMON/LAMINK/BKAPPA(7,3)/QPAR1/QDEV/QPAR2/QLINM,QLDEV/HEA10/
     1        QSCH(42,3)/WALLCO/WFCO1(18,2),WFCO(18,2)/WALLKA/AKAWC(2)
     2        /WCSE3/LAMWC(18,2,2)/WCSE4/CTURB2(18,2)/WCSE8/ASCHWC(18,2,2)
     3        /WCSE5/TSCWC1(18,2,2)/WCSE9/TAVWC(18,2,2)/GEN2/ACHA(42)
     4        /CORR1/SIGMAI(42,3),PHII(42,3)/CORR2/CHI(18,2,2),PSI(18,2,2)
     5        /WSSCH/T1SSC1(18,2),T2SSC1(18,2),T1SSC2(18,2),T2SSC2(18,2)
     6        /WSSCH0/TBSSC1(42,3),TWSSC1(42,3),TBSSC2(42,3),TWSSC2(42,3)
     7        /LAMIN9/I3TIP(42,3)/SHROUD/TLINER(18,2)/MART/ITCORR
      IF(JJJ.GT.1)GOTO 2998
      F1ATIP(NS)=0.
      F1PTIP=0.
 2998 CONTINUE
      III=NS-NSTR
      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,D,W,RH,DETOT,PROV,
     *DAI,DBI,AAI,ABI,GG,SSSA,SSSB,AMTI,2,H1,H,PR1,PR2,SCCFG,JJJ,TE,SUR,
     *TWI,AMAI,TAI,AMBI,TBI,III,TSCWC1(III,JJJ,1),TAVWC(III,JJJ,1),
     *HPLUS1,HPLUS2,ANGT,EM1,XC1,XC2,&777,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
      DEWC(III,JJJ,1)=4.*ASCHWC(III,JJJ,1)/(PHWC(III,JJJ,1)+(EMAX-EM1)*
     *  XC2+EM1)
      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)*RHCTE/H
      AMTAE=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)
      STOP
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,PB,RH,AA,DD,GG,AM1,DETOT,H1,ALFA1,L,JJJ,H,
     *PR1,PR2,SQDPG,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
      AA=A(I)
      DD=DE(I)
      GG=G(I)
      AM1=MEC(I)
      LL=L+J
      CALL CEWA(K,NS,IRH,PROV,PB,RH,AA,DD,GG,AM1,DETOT,H1,ALFC,LL,JJJ,H,
     *PR1,PR2,SQDPG,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*ALFC
   13 CONTINUE
C     ..................................................................
C     THE CALCULATION OF THE "CENTRAL-TYPE" SUB-SUBCHANNELS HAS BEEN
C     COMPLETED: CALCULATION OF AVERAGE SUB-SUBCHANNEL VARIABLES FOR THE
C     WHOLE CENTRAL PORTION AND FOR THE WHOLE WALL SUBCHANNEL
C
      TWIAV=TWIAV*2./PIG
      PHWC(III,JJJ,2)=GAMMA*D*0.5
      ASCHWC(III,JJJ,2)=AT-ASCHWC(III,JJJ,1)
      DEWC(III,JJJ,2)=4.*ASCHWC(III,JJJ,2)/PHWC(III,JJJ,2)
      TSCHC=(TT-TTAB)/(AMT-AMTAB)
      RHOTC=RHO(PB,TSCHC)
      DDDDC=DDDD-DDDDAB
      LAMWC(III,JJJ,2)=((ASCHWC(III,JJJ,2)/DDDDC)**2)*2.*DEWC(III,JJJ,2)
     *                 *RHOTC/H
       ATSCH=TT/AMT
      RHOT=RHO(PB,ATSCH)
      DO 14 JWC=1,2
   14 DDDD=DDDD+ASCHWC(III,JJJ,JWC)*SIGMAI(NS,JJJ)*(CHI(III,JJJ,JWC)-1.)
     */SQDPC
      LAMSCH(NS,JJJ)=((AT/DDDD)**2)*2.*DET*RHOT/H
      CTURB2(III,JJJ)=TURBWC(CTU3,PVERT(II),PRAD(II),D,W,C,GAMMA,ASCHWC
     *(III,JJJ,1),ASCHWC(III,JJJ,2),DEWC(III,JJJ,1),DEWC(III,JJJ,2),EM1)
      I2TIP(NS,JJJ)=0
      F2ATIP(NS,JJJ)=1.
      F2DTIP(NS,JJJ)=1.
      IF(I3TIP(NS,JJJ).EQ.2)GOTO 3000
      IF(ITCORR.GT.1)GOTO 2999
      MSCH(NS,JJJ)=AMT
      TSCH(NS,JJJ)=ATSCH
      TW(NS,JJJ)=TWIAV
C     ..................................................................
C     ..................................................................
C     FOR I3TIP=1 OR I3TIP=3
C
 2999 CONTINUE
      ZWC=(C*0.5-EM1)/SQRT(3.)
      PPPP=(W-0.5*D-ZWC)*ANGLAM
      OMEGA=ATAN(PPPP*2. /C)
      PHWC1L=(PIG*0.5-OMEGA)*RTIP(IPA)
      PHWC2L=OMEGA*RTIP(IPA)
      AWC2L=            C*0.25*PPPP-RTIP(IPA)**2*0.5*OMEGA
      AWC1L=ASCH(NS,JJJ)*FATIP(2)-AWC2L
      PHWCTL=PHWC1L+2.*ZWC+EM1
      DEWC1L=4.*AWC1L/PHWCTL
      DEWC2L=4.*AWC2L/PHWC2L
      MWC1L=MSCH(NS,JJJ)*AWC1L/(ASCH(NS,JJJ)*FATIP(2))
      MWC2L=MSCH(NS,JJJ)-MWC1L
      R1DR2L=1./SQRT(1.+ 2.*AWC1L/(PHWC1L*RTIP(IPA)))
      R21WA=RTIP(IPA)/R1DR2L
      RO2WA=SQRT(RTIP(IPA)**2+2.*RTIP(IPA)*AWC2L/PHWC2L)
      PHWCTE=1.
      PHWC1E=1.
      IF(QQ(NS,JJJ).LE.1.E-06)GOTO 4444
      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*H/(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.
      YOCH(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
```

```
      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
      IF(IRH.EQ.1 .OR.     I2TIP(NS,JJJ).EQ.1)RETURN
C     ..............................................................
C     ONLY FOR TURBULENT FLOW AND ROUGHENED RODS
C
      ATBC=ATB+ASCHWC(III,JJJ,2)
      HPLUSB(NS,JJJ)=HPLUSB(NS,JJJ)/ATBC
      HPLUSW(NS,JJJ)=HPLUSW(NS,JJJ)/ATBC
      AMTBC=AMT-SRAMIA
      TSCHBC=(TT-TTA)/AMTBC
      CPTBC=CP(PB,TSCHBC)
      QPLUS(NS,JJJ)=QQ(NS,JJJ)*ATBC/(SUR*AMTBC*CPTBC*(TE+273.16))
      PRB(NS,JJJ)=ETA(PB,ATSCH)*CP(PB,ATSCH)/KAPPA(PB,ATSCH)
      YODH(NS,JJJ)=0.5*(SQRT(D**2+16.*ATBC/PIG)-D)/RH
      RETURN
  777 RETURN 1
      END




      SUBROUTINE RECCA2  (NS,III,NP,INDSP,H,LENGTH,PR1,PR2,PBT,FRELI,FT,
     *ITCORR,PIG,D,DPAV,*,WSP,I1SFAC)
C-----------------------------------------------------------------------
C     SUBROUTINE SUBBAL EVALUATES MASS FLOW RATES AND TEMPERATURES FOR
C     THE TWO PARTS OF WALL SUBCHANNEL
C
      REAL LENGTH,LAMWC,MAWC,M1WC(2),M2WC(2),MSCWC1,MSCH,MSCH1,MAVCF(2),
     *     MAV,MAVJT
      DIMENSION WCFUD(2),WCFWC(2),WCF1WC(2),EP1WC(2),QWCL(2),T1WC(2),
     1          TAWC(2),T2WC(2),RHO1(2),RHOAV(2),RUASWC(2),AWC(2),
     2          TMOEX(2),TACF(2),UACF(2),ACF(2),WTWC2(2),WTWC3(2)
     3          ,XMEM(2),DELTAA(2),IPAWC(2),CLINWC(2),THEX(2),DPWC(2),
     4          UWC(2)
      COMMON/CORR1/SIGMAI(42,3),PHII(42,3)/CORR2/CHI(18,2,2),PSI(18,2,2)
     1     /GRID0/CSPAC(42,3,3)/IJ1/NER(42),NIS(42,3)/INC3/NTYP(42)
     2     /GEN2/A(42)/MOB2/UAV(42)/MOB5/TAV(42)/MOB6/MAV(42)
     3     /MOB8/DP(42)/SUBC2/JCHC(3,2)/SUB1/ASCH(42,3)/SUB2/TSCH(42,3)
     4     ,MSCH(42,3)/SUB8/MSCH1(42,3)/SUB31/WCFNS(3),DFNS(3),WTNS1(3,
     5     3),WTNS2(3,2),UNS(3),RUASNS(3)/HEA10/QSCH(42,3)
     6     /WCSE1/DEWC(18,2,2),PHWC(18,2,2)/WCSE2/MSCWC1(18,2,2)/WCSE5/
     7     TSCWC1(18,2,2)/ WCSE3/LAMWC(18,2,2)/WCSE4/CTURB(18,2)
     8     /WCSE6/ASCWC1(18,2,2)/WCSE7/MAWC(18,2,2)
     9     /WCSE8/ASCHWC(18,2,2)/WCSE9/TAVWC(18,2,2)
      COMMON /SUBC1/NCHC(3),JSCH(3,3)/GEO0/ACH(3)
     1     /GRID1/EPS(42,3,3),DISTS(7)/GRID8/PGDP(42,3,3)
     2     /SUB3/ADAB(18,2),CDBB(18,2)/WACO1/XMSCHB(18,2),XMSCHA(18,2)
     3     /QPAR1/QDEV/QPAR2/QLINM,QLDEV/QPAR3/FERL(3)
     4     /GRIDWC/EPSWC(18,2,2,3),CSPWC(18,2,2,3)/GRAV/IGRAV
      XX=1./980665.
      DO 70 I=1,NP
      FRELWC=FRELI
      NCHCI=NCHC(I)
C
C     IW IS THE OTHER SUBCHANNEL OF WALL CHANNEL NS; NCHCI IS THE NUMBER
C     OF CHANNELS CONNECTED TO SUBCHANNEL I
C
```

```
      IW=3-I
C
C     PORTICN 1 IS CONNECTED TO AN EXTERNAL CHANNEL; PORTICN 2 TO A
C     CENTRAL CHANNEL ( PORTICN INDEX = IPAWC )
C
      DO 101 K1=1,NCHCI
      J=NIS(NS,JCHC(I,K1))
      IPAWC(K1)=3-NTYP(J)+NTYP(J)/3
  101 CONTINUE
      DC 3 JWC=1,2
      WCFUD(JWC)=WCFNS(I)*ASCHWC(III,I,JWC)/ASCH(NS,I)
      MIWC(JWC)=MSCWC1(III,I,JWC)
      AWC(JWC)=ASCHWC(III,I,JWC)
      DELTAA(JWC)=0.
      QWCL(JWC)=QSCH(NS,I)*PHWC(III,I,JWC)/(LENGTH*C.25*PIG*D)*QDEV
      QLINWC(3-JWC)=QLINM*PERL(JWC)*0.5*QLDEV/LENGTH
      TIWC(JWC)=TSCWC1(III,I,JWC)
      RHO1(JWC)=RHO(PR1,TSCWC1(III,I,JWC))
    3 CONTINUE
C     ...................................................................
C     ITERATION ON THE RELAXATION FACTOR (LOOP ITFREL)
C
      DO 50 ITFREL=1,98
      IVIA=1
C     ...................................................................
C     CALCULATION OF THE PRESSURE LOSSES (LOCP ITGL)
C
      DC 49 ITGL=1,60
C
C-----EVALUATION OF THE CROSS FLOW SOLUTION
      CALL CRFL1(ITGL,DPWCAV,FRELWC,ASCH(NS,I),2,AWC,MIWC,DPWC,WCFWC,
     *     WCF1WC,EP1WC)
      DC 5 JWC=1,2
      WCFWC(JWC)=WCFWC(JWC)+WCFUD(JWC)
      M2WC(JWC)=MIWC(JWC)-H*WCFWC(JWC)
      MAWC(III,I,JWC)=(M2WC(JWC)+MIWC(JWC))*0.5
      TAWC(JWC)=TSCH(NS,I)
      RUASWC(JWC)=MAWC(III,I,JWC)*SQRT(LAMWC(III,I,JWC)*C.125)
    5 CONTINUE
C
      IF(ITGL.GT.1 .AND. IVIA.EQ.1 )GOTO 30
C     ...................................................................
C     CALCULATION OF THE AVERAGE GAS TEMPERATURES (LCOP ITERM)
C
      DO 25 ITERM=1,20
C
C  A) TURBOLENT EXCHANGE BETWEEN THE TWO PARTS OF SUBCHANNEL
C
      IF(TAWC(1).LE.0. .OR. TAWC(1).GT.3000. .OR. TAWC(2).LE.C. .OR.
     * TAWC(2).GT.3000.)GOTO 99
      WTWC1=TME(PBT,MAWC(III,I,1),MAWC(III,I,2),TAWC(1),TAWC(2),LAMWC(II
     *I,I,1),LAMWC(III,I,2),AWC(1),AWC(2),CTURB(III,I))
      TA12=(MAWC(III,I,1)*TAWC(1)+MAWC(III,I,2)*TAWC(2))/MSCH(NS,I)
      THEX(1)=-(TAWC(1)-TAWC(2))*WTWC1*CP(PBT,TA12)
      THEX(2)=-THEX(1)
C
C  B) TURBCLENT EXCHANGE WITH CHANNELS
C
      DO 8 K1=1,NCHCI
```

```
      IWC=IPAWC(K1)
      J=NIS(NS,JCHC(I,K1))
      MAVJT=MAV(J)*ACH(NTYP(J))/A(J)
      WTWC2(IWC)=WTNS2(I,K1)
      TAIJ=(TAWC(IWC)*MAWC(III,I,IWC)+TAV(J)*MAVJT )/(MAWC(III,I,IWC)+
     *       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) TURBULENT 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)
      J=NIS(NS,JCHC(I,K1))
      MAVJT=MAV(J)*ACH(NTYP(J))/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)
      T2WC(JWC)=TSCWC1(III,I,JWC)+H/(MAWC(III,I,JWC)*CP(PBT,TAWC(JWC)))*
     *           (QWCL(JWC)+QLINWC(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)=(M2WC(JWC)*T2WC(JWC)+M1WC(JWC)*TSCWC1(III,I,JWC))
     *               *0.5   /MAWC(III,I,JWC)
   20 CONTINUE
      IF(ITCL.EQ.1)GOTO 30
      DO 21 JWC=1,2
      IF(ABS(TAWC(JWC)/TAVWC(III,I,JWC)-1.).GT.1.E-04)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
      J=NIS(NS,JCHC(I,K1))
      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(IW))*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,UACF(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)
      J=NIS(NS,JCHC(I,K1))
      AJT=ACH(NTYP(J))
      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),UNS(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))
      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)-WCFUD(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
       BMWC=SQRT(ABS(DPAV) /(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



       FUNCTION RELAM(A,D,P,TB,TW,M,TLINER,ITYP,R1DR2L,PHICPH)
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*D /(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



       FUNCTION RHO(P,T)
C-----------------------------------------------------------------------
C      RHO EVALUATES THE DENSITY OF THE COOLANT (G/CCM)
C
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
       END
```

```
      FUNCTION RHPLUS(HPLUSB,TW,TE,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/(C.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(RHFL.GT.RHSM)RHPL=RHSM
      RHPLUS=RHPL
      RETURN
      END



      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)*U1DU/FF
      NUI=STI*REI*PRI*YYI
      RETURN
      END



      SUBROUTINE RTRI(PBT,TBT,MASSI,DE1,AREAI,ACAB,LAM1,YYI,QA,FACHE,TE,
     * RH,I,II,M,JPIN,TW1,RU1DRU,ITYP,DEI,D,YYDH,*,F2ATIF,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,NUO,NUTU
      COMMON/SUB21/TSCHA(18,2),TSCHB(18,2)/SHROUD/TLINER(18,2)
     1       /QSHR/QALIN/TRANS/RHTU,RHSM/LAMINO/I2TIP(42,3)
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: CALCULATICN PERFORMED ASSUMING ROUGH FLOW
C     ***************************************************************
C
      R1=D*C.5
      RO=0.5*SQRT(D**2+DE1*D)
      R2=SQRT(D**2+ADAB*DE1*D)*0.5
C     ...............................................................
C     INLET EFFECT ON THE NUSSELT NUMBER OF THE RODS
C
      FACHE=TIS(R1,R2,2)
C
      YDH=(RO-R1)/RH
      R2MROH=(R2-RO)/RH
      YYDH=YDH+R2MROH
      RODR2=RO/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
      TWO=TBT
      TB1=TBT
C     ...............................................................
C     CALCULATION OF THE BULK TEMPERATURES OF THE TWO ZONES DIVIDED BY
C     THE TAU=0 LINE ( LOOP ITW )
C
      DC 7 ITW=1,10
      RHO1=RHO(PBT,TB1)
      U1CU=RU1DRU*RHOI/RHO1
      U1=U1CU*UI
      U1STAR=U1*SQRT(LAM1*0.125)
C     ...............................................................
C     CALCULATION OF THE SURFACE PIN TEMPERATURE AT INFINITE CONDUCTI=
C     VITY CF THE CANNING METAL AND AT (Q'')SHROUD = 0 ( LOOP ITW1 )
C
      DO 30 ITW1=1,10
      IF(ABS(TWO).LT.3000..AND. ABS(TWALL).LT.3000.)GOTO 29
      WRITE(6,28)I,JPIN,TWO,TWALL
   28 FORMAT(     5X,'STOP IN RTRI: NS=',I5,5X,'PIN=',I5/5X,'TWO=',E15.5,
     15X,'TWALL=',E15.5)
      RETURN 1
   29 CONTINUE
      ETAW=ETA(PBT,TWALL)
      RHOW=RHO(PBT,TWALL)
```

```
      REW=U1*DE1*RHOW/ETAW
      REWO=REW*ETAW*RHO(PBT,TWO)/(RHOW*ETA(PBT,TWO))
      HPLUSW=RH*REW*SQRT(LAM1*0.125)/DE1
      HPLUSO=HPLUSW*REWO/REW
      CALL RNU(HPLUSW,TWALL,LAM1,REI,PRI,TBT,YDH,R1DR2,R2MROH,U1DU,REW,
     1      YYI,NUI,GHPL)
      CALL RNU(HPLUSO,TWO   ,LAM1,REI,PRI,TBT,YDH,R1DR2,R2MROH,U1DU,REWO,
     1       1.,NUO,GHPL)
      ALFAI=NUI*KI/DEI*FACHE
      ALFAO=NUO*KI/DEI
      TW1=TBT+QA/ALFAI
      TWO=TBT+QA/ALFAO
      IF(ABS(TW1/TWALL-1.).LE.1.E-04)GOTO 32
   30 TWALL=TW1
C     ..................................................................
C     END OF LOOP ITW1: POINT REACHED IN THE CASE OF CONVERGENCE
C     PROBLEMS
C
      WRITE(6,31)I,JPIN,TW1
   31 FORMAT(1H1,5X,'STOP IN RTRI (LOOP ITW1) NS=',I5,5X,'PIN=',I5,5X,
     *'TW1=',E15.5)
      RETURN 1
C     ..................................................................
C     CONVERGENCE HAS BEEN REACHED FOR THE PIN TEMPERATURE
C
   32 CONTINUE
      IF(ITYP.EQ.1)GOTO 9
C     ..................................................................
C     ONLY FOR THE CORNER CHANNELS AND FOR THE WALL PORTION OF THE WALL
C     SUBCHANNELS
C
      FF=QA/(RHOI*CPI*U1STAR)
      CALL DDONNE(TWO,TBT,GHPL,RODR2,R1DR2,YDH,R2MROH,FF,TSCHA(II,M),
     1   TSCHB(II,M),TE)
      IF(ABS(TSCHB(II,M)/TB1-1.).LE.1.E-04)GOTO 9
      TB1=TSCHB(II,M)
    7 CONTINUE
C     ..................................................................
C     END OF LOOP ITW: POINT REACHED IN THE CASE OF CONVERGENCE
C     PROBLEMS
C
      WRITE(6,8)I,JPIN,TB1
    8 FORMAT(1H1,5X,'STOP IN RTRI (LOOP ITW) I=',I5,5X,'PIN=',I5,5X,'TB1
     $=',E15.5)
      RETURN 1
C     ..................................................................
C     CONVERGENCE HAS BEEN REACHED FOR THE BULK TEMPERATURES OF THE
C     TWO ZONES DIVIDED BY THE TAU=0 LINE; THE ASSUMPTION OF ROUGH FLOW
C     IF TESTED ( THIS POINT IS REACHED ALSO BY THE CALCULATION FOR THE
C     CENTRAL SUBCHANNELS AND THE CENTRAL PORTION OF THE WALL SUBCHANNEL
C
    9 CONTINUE
      ETA1=ETA(PBT,TB1)
      HPLUSB=HPLUSW*RHO1*ETAW/(ETA1*RHOW)
      RHPL=RHPLUS(HPLUSB,TWALL,TE,XYXYX,HPLUSW,TB1,YCH)
      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 CALCULATICN RETURNS  IMMEDIATELY AFTER COMING BACK
C       FROM RTSI
C       ****************************************************************
C
        CALL RTSI(PBT,TBT,MASSI,DE1,AREAI,ADAB,LAM1,YYI,QA,FACHE,TE,RH,I,
       &II,M,JPIN,TW1,RU1DRU,ITYP,DEI,D,YYCH,&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 ( VALLE 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)
        NUTU=TUBENU(REI,PRI)
        PEI=REI*PRI
        FTWA=22.*(0.27*R1DR2**2-1.)/(PEI**0.87*PRI**0.18)*R1DR2
        IF(QALIN.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


         SUBROUTINE RTSI(PBT,TI,MASSI,DE1,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,NUI0,NUI,KI,KAPPA,MASSI,LAM1
        COMMON/SUB21/TSCHA(18,2),TSCHB(18,2)/SHROUD/TLINER(18,2)
       *        /QSHR/QALIN/LAMINO/I2TIP(42,3)
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)
C       ****************************************************************
C       THE FLOW IS TURBULENT
```

```
C     ****************************************************************
       R1=D*0.5
      R0=0.5*SQRT(D**2+DE1*D)
      R2=SQRT(D**2+ADAB*DE1*D)*0.5
      DEI=2.*(R2-R1)
      R0DR2=R0/R2
      R1DR2=R1/R2
      R1DR0=R1/R0
C     ................................................................
C     INLET EFFECT ON THE NUSSELT NUMBER OF THE RODS
C
      FACHE=TIS(R1,R2,1)
C
      TWI0=TWI
      KI=KAPPA(PBT,TI)
      ETAI=ETA(PBT,TI)
      RHOI=RHO(PBT,TI)
      CPI=CP(PBT,TI)
      REI=MASSI*DEI/(AREAI*ETAI)
      PRI=ETAI*CPI/KI
      A1=0.45/(2.4+PRI)
      A2=0.16*PRI**(-0.15)
      A3=1.
      IF(R1DR2.LT.0.2)A3=1.+(7.5*(1./R1DR2-5.)/REI)**0.6
      NUTU=TUBENU(REI,PRI)
      FNU=(1.-A1)/R1DR2**A2  *A3*(TE+273.16)**0.2*NUTU
C     ................................................................
C     CALCULATION OF THE SURFACE PIN TEMPERATURE AT (Q")SHROUD = 0
C     ( LOOP ITW )
C
      DO 5 ITW=1,10
      TWALL=TWI
      NUI=FNU/(TWI+273.16)**0.2*YYI*FACHE
      NUI0=FNU/(TWI0+273.16)**0.2
      ALFAI0=NUI0*KI/DEI
      ALFAI=NUI*KI/DEI
      TWI=TI+QA/ALFAI
      TWI0=TI+QA/ALFAI0
      IF(ABS(TWALL/TWI-1.).LE.1.E-04)GOTO 7
    5 CONTINUE
C     ................................................................
C     END OF LOOP ITW: POINT REACHED IN THE CASE OF CONVERGENCE
C     PROBLEMS
C
      WRITE(6,6)I,JPIN,TWI,TWALL
    6 FORMAT(1H1,5X,'STOP IN RTSI (CHANNEL',I5,' , PIN',I5,') : TW=',
     *E15.7,5X,'TWALL=',E15.7)
        RETURN 1
C     ................................................................
C     CONVERGENCE HAS BEEN REACHED FOR THE PIN TEMPERATURE
C
    7 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
      PEI=REI*PRI
      FTWA=22.*(0.27*R1DR2**2-1.)/(PEI**0.87*PRI**0.18)*R1DR2
```

```
      TLINER(II,M)=FTWA*QA*DEI/KI+TI
      IF(TLINER(II,M).LE.TE)TLINER(II,M)=TE
      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*R1DR0+0.5)/(R1DR0+1.)
      UI=MASSI/(AREAI*RHOI)
      F1=R0**2-R1**2
      F2=R2**2-R0**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((R0-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(QALIN.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


      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)/WAKAC/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



      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)/GPAR3/PERL(3)
     1       /SUB1/ASCH(42,3)/GEOO/ACH(3)/MART2/NS1,NS2/INPAR/IPA
     2       /LAMINK/BKAPPA(7,3)/LAMIN1/AKAPPA(42)/WALLCC/WFCC1(18,2),
     3       WFCO(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.
      AVRAKF=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



      FUNCTION SMFUN1(RHOI,ETAI,DETCT,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/(DETCT*SQRT(RHOI))
      SMFUN1=CS*(2.5*ALOG((R2(I)-RO)*RHOI/ETAI*UAST2)-G)+5.5*COLAMA
      RETURN
      END
```

```
      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,MINS(3),M2NS(3),
     1     MAV1,MAV2 ,MAWC,KAPPA
      DIMENSION RHO1(3),TINS(3),WCFUD(3),WCF1NS(3),EP1NS(3),TANS(3),
     1          T2NS(3),RHOAV(3),ANS(3),XMEM(3),DE(3) ,A(42)
      COMMON/CORR/SIGMA(42),PHI(43)/CORR1/SIGMAI(42,3),PHII(42,3)
     1      /GRID0/CSPAC(42,3,3)/IJ1/NER(42),NIS(42,3)/INC3/NTYP(42)
     2      /GEN2/AZ(42)/GEN3/MI(42)/GEN5/DEZ(42)/MOB2/UAV(42)
     3      /MOB4/WCF(42)/MOB5/TAV(42)/MOB6/MAV(42)/MOB8/CP(42)
     4      /SUBC1/NCHC(3),JSCH(3,3)/SUBC2/JCHC(3,2)/SUB1/ASCH(42,3)
     5      /SUB2/TSCH(42,3),MSCH(42,3)/SUB5/LAMSCH(42,3)
     6      /SUB6/TSCH1(42,3)/SUB8/MSCH1(42,3)/HEA10/QSCH(42,3)
     7      /SUB31/WCFNS(3),DPNS(3),WTNS1(3,3),WTNS2(3,2),LNS(3),RUASNS(
     8      3)/MOB24/WT(42,3)/MOB26/RUAS(42)/TUR2/CTURB1(2)
     9      /HEA6/NPIN(42),JPIN(42,3)/GEO0/ACH(3)
      COMMON/GRID1/EPS(42,3,3),DISTSP(7)/GRID8/PGDP(42,3,3)
     1      /SUB3/ADAB(18,2),DDTBB(18,2)/WAC01/XMSCHB(18,2),XMSCHA(18,2)
     2      /QPAR1/QDEV/QPAR2/QLINM,QLDEV/CPAR3/PERL(3)
     3      /LAMIN0/          I2TIP(42,3) /LAMIN3/F1ATIP(42),F1DTIP(42)
     4      /LAMIN4/F2ATIP(42,3),F2DTIP(42,3)/WCSE7/MAWC (18,2,2)
     5      /WCSE9/TAVWC(18,2,2)/CORR2/CHI(18,2,2),PSI(18,2,2)
     6      /WCSE8/ASCHWC(18,2,2)/CCND1/CCCNC(42,3)/CONC2/CCOND1(2)
     7      /GRAV/IGRAV
C
      XX=1./980665.
C     ..................................................................
C     CORRECTION OF THE CHANNEL FLOW AREAS TO TAKE INTO ACCOUNT THAT
C     THE SUBCHANNEL GEOMETRIC PARAMETERS MUST BE BASED ON THE TIP
C     DIAMETER OF THE RODS IN THE CASE OF LAMINAR FLOW
C
      DO 1000 NS=1,NSTOT
 1000 A(NS)=AZ(NS)*F1ATIP(NS)
C     ..................................................................
C     LOOP "NS" STARTS ( NS = CHANNEL INDEX )
C
C
      DO 80 NS=1,NSTOT
      III=NS-NSTR
      FRELI=FREL
      NP=NPIN(NS)
      IF(NPIN(NS).EQ.1)GOTO 65
C     ******************************************************************
C     ONLY FOR CHANNELS WITH MORE THAN 1 SUBCHANNEL
C
      NI=NER(NS)
      NP1=NP-1
      ITYP=NTYP(NS)
      NSCH=4-ITYP
      SCH=NSCH
      AREASC=ACH(ITYP)/SCH
C     ..................................................................
C     CONNECTIONS BETWEEN THE SUBCHANNELS OF CHANNEL "NS" AND THE
C     CHANNELS ADJACENT TO "NS"
C
```

```
      CALL SUBCON(NS,NP,NP1,NI)
C
      DO 1 I=1,NP
      RHO1(I)=RHO(PR1,TSCH1(NS,I))
      MINS(I)=MSCH1(NS,I)
      ANS(I)=ASCH(NS,I)*F2ATIP(NS,I)
      DE(I)=DEZ(NS)*F2DTIP(NS,I)
      TINS(I)=TSCH1(NS,I)
    1 WCFUD(I)=WCF(NS)*ANS(I)/A(NS)
C     ..................................................................
C     ITERATION ON THE RELAXATION FACTOR (LOOP ITFREL)
C
      DO 48 ITFREL=1,98
      IVIA=1
C     ..................................................................
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)+WCFUD(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
      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
      WTNS1(I,II)=TME(PBT,MAV1,MAV2,TANS(I),TANS(II),LAMSCH(NS,I),
     *LAMSCH(NS,II),AREASC,AREASC,CTURB1(ITYP))
      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)
      MAV2=MAV(J)*ACH( NTYP(J))/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,M)*(KAPPA(PBT,TANS(I))+KAPPA(PBT,
     *TAV(J)))
      IF((ACH(ITYP)/AZ(NS).LE.1.1 .OR. ACH(NTYP(J))/AZ(J).LE.1.1) .AND.
     *(NTYP(NS).EQ.1 .OR. NTYP(J).EQ.1))CONHEP=CONHEP*0.5
      CONHE=CONHE-CONHEP
    6 THEX=THEX-(TANS(I)-TAV(J))*WTNS2(I,K1)*CP(PBT,TAIJ)
C
C     C) CROSS FLOW HEAT EXCHANGE SUBCHANNEL-SUBCHANNEL
C
    7 CONTINUE
      TACF=0.
      MAVCF=0.
      DO 8 II=1,NP
      IF(I.EQ.II)GOTO 8
      MAV2=MSCH(NS,II)*AREASC/ASCH(NS,II)
      CALL CF1(TANS(I),TANS(II),MAV1,MAV2,DPNS(I),DPNS(II),
     *    ITGL,TACF,MAVCF)
C
C     D) CROSS FLOW HEAT EXCHANGE  SUBCHANNEL-CHANNEL
C
    8 CONTINUE
      IF(NCHCI.EQ.0)GOTO 12
      DO 11 K1=1,NCHCI
      M=JCHC(I,K1)
      J=NIS(NS,M)
      MAV2=MAV(J)*ACH(NTYP(J))/AZ(NS)
      CALL CF1(TANS(I),TAV(J),MAV1,MAV2,DPNS(I),DP(J),ITGL,TACF,MAVCF)
   11 CONTINUE
   12 CONTINUE
C
C
      TACF=TACF/MAVCF
      TAICF=(TANS(I)*MAV1+TACF*MAVCF)/(MAV1+MAVCF)
      CFHEX=WCFNS(I)*(TANS(I)-TACF)*CP(PBT,TAICF)
      PHII(NS,I)=(THEX+CFHEX+CONHE)*H/ASCH(NS,I)
      T2NS(I)=TSCH1(NS,I)+H/(MSCH(NS,I)*CP(PBT,TANS(I)))*((QSCH(NS,I)*QD
     +EV+ QLINM*PERL(NTYP(NS))*0.5*QLDEV)/LENGTH+THEX+CFHEX+CONHE)
      TSCH(NS,I)=(M2NS(I)*T2NS(I)+MSCH1(NS,I)*TSCH1(NS,I))*0.5/
     *    MSCH(NS,I)
   16 CONTINUE
      IF(ITGL.EQ.1)GOTO 25
C
```

```
C      TEST OF CONVERGENCE FOR THE GAS TEMPERATURES
C
       DO 17 I=1,NP
       IF(ABS(TANS(I)/TSCH(NS,I)-1.).GT.1.E-04)GOTO  18
   17 CONTINUE
       GOTO 25
   18 CONTINUE
       DO 19 I=1,NP
   19 TANS(I)=TSCH(NS,I)
   20 CONTINUE
C      ..................................................................
C      END OF LOOP ITERM: POINT REACHED IN THE CASE OF CONVERGENCE
C      PROBLEMS
C
       WRITE(6,21)NS,(TANS(I),I=1,NP),ITCORR
   21 FORMAT(    5X,'SUBCHANNEL CALCULATION STOPS IN LOOP ITERM  OF CHAN
      *NEL',I6,5X,'TEMPERATURES='/5X,3E15.7/5X,'ITCORR=',I5)
       RETURN 1
C      ..................................................................
C      CONVERGENCE HAS BEEN REACHED FOR THE ENERGY EQUATIONS; THE CALCU=
C      LATION OF THE PRESSURE DROPS STARTS
C
   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=0.
       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 CCNTINUE
C
C     CROSS-FLOW EXCHANGE SUBCHANNEL-CHANNEL
C
      IF(NCHCI.EQ.0)GOTO 36
      DC 35 K1=1,NCHCI
      M=JCHC(I,K1)
      J=NIS(NS,M)
      AREAJ=ACH(NTYP(J))*FLATIP(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))
      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,PGDP(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+CFMCEX+IGRAV*RHCAV(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)-WCFUD(I)
   47 CONTINUE
C     ....................................................................
C     END CF 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 CF 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
      BMI=SQRT(ABS(DPAV) /(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 MSCH(NS,1)=MAV(NS)
      TSCH(NS,1)=TAV(NS)
      SIGMAI(NS,1)=SIGMA(NS)
      PHII(NS,1)=PHI(NS)
      IF(NTYP(NS).NE.3)GOTO 70
      EPSM=MSCH(NS,1)-(XMSCHA(III,1)+XMSCHB(III,1))
      XMSCHA(III,1)=XMSCHA(III,1)+EPSM*(1.-1./ADAB(III,1))
      XMSCHB(III,1)=XMSCHB(III,1)+EPSM /ADAB(III,1)
C
   70 CONTINUE
      IF(NTYP(NS).NE.2)    GOTO 80
C      *****************************************************************
C      ONLY FOR THE WALL SUBCHANNELS
C
      I2TTIP=0
      DO 4000 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)
C      .................................................................
C      RECCA2 IS CALLED ONLY IF THE FLOW IS TURBULENT IN THE WHOLE WALL
C      CHANNEL
C
      IF(I2TTIP.EQ.0)
     *CALL      RECCA2  (NS,III,NP,INDSP,H,LENGTH,PR1,PR2,PBT,FRELI,FT,
     *ITCORR,PIG,D,DPAV,&777,WSP,IISPAC)
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
```

```
      SUBROUTINE SUBCON(NS,NP,NP1,NI)
C-----------------------------------------------------------------------
C     SUBROUTINE SUBCON 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))GOTO 2
    1 CONTINUE
      GOTO 3
    2 NCHC(I)=NCHC(I)+1
      JCHC(I,NCHC(I))=M
      JSCH(I,M)=0
    3 CONTINUE
    4 CONTINUE
C
      DO 9 I=1,NP1
      IF(NCHC(I).EQ.0)GOTO 9
      NCHCI=NCHC(I)
      DO 8 K1=1,NCHCI
      I1=I+1
      DO 6 II=I1,NP
      IF(NCHC(II).EQ.0)GOTO 6
      NCHCII=NCHC(II)
      DO 5 K2=1,NCHCII
      IF(JCHC(I,K1).EQ.JCHC(II,K2))GOTO 7
    5 CONTINUE
    6 CONTINUE
      GOTO 8
    7 JSCH(I,JCHC(I,K1))=II
      JSCH(II,JCHC(I,K1))=I
    8 CONTINUE
    9 CONTINUE
      RETURN
      END
```

```
      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



      SUBROUTINE TAU(I,AI,P,ALFA,D,W,RH,DET,PROV,IRH,DAI,DBI,PAI,F,
     *RHPL,TWI,TE,ITTEMP,QPLUS,ETAA,RHCA,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-C.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
      FO=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
      FO1=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)
      FO1=SQRT(DBI*RHOA/(DAI*RHOB))*(2.5*ALOG(ZBI/RH)+RHPL)
C
C
    4 F=FO-FO1
      RETURN
      END



      FUNCTION TBFUN(NSTR,NSTOT)
C-----------------------------------------------------------------------
C     TBFUN EVALUATES THE MEAN LINER TEMPERATURE IN THE AXIAL SECTION
C
      COMMON/SHROUD/TLINER(18,2)/GPAR3/PERL(3)/IND3/NTYP(42)
     1       /HEA6/NPIN(42),JPIN(42,3)/SUB1/ASCH(42,3)/GEOC/ACH(3)
C
      NSTR1=NSTR+1
      TBPIPA=0.
      PERLT=0.
      DO 10 NS=NSTR1,NSTOT
      NP=NPIN(NS)
      DO 10 M=1,NP
      PERLSC=PERL(NTYP(NS))*ASCH(NS,M)/ACH(NTYP(NS))
      PERLT=PERLT+PERLSC
   10 TBPIPA=TBPIPA+TLINER(NS-NSTR,M)*PERLSC
      TBFUN=TBPIPA/PERLT
      RETURN
```

```
      END



      SUBROUTINE TELIN(TW1,TLINER,TI,TE,TETA2,FTWA,QA,QALIN,NU1,NUTU,
     1 A1,KI,R1DR2,DEI,I,JPIN,YYI,FACHE)
C-----------------------------------------------------------------------
C     TELIN COMPUTES THE LINER TEMPERATURES AND CORRECTS THE PIN TEMPERA
C     OF THE EXTERNAL CHANNELS IN THE CASE OF HEATED LINER (TURB. FLOW)
C
      REAL NUTU,NU1,NU2,KI
C     ..................................................................
C     INLET EFFECT ON THE LINER NUSSELT NUMBER
C
      R1=DEI*R1DR2*0.5/(1.-R1DR2)
      R2=R1+0.5*DEI
      FACHE=TIS(R1,R2,3)
C
      FNU=(1.-A1*R1DR2**0.6)*NUTU*(TI+273.16)**0.5*YYI*FACHE
C     ..................................................................
C     ITERATION FOR THE CALCULATION OF THE LINER TEMPERATURE AT
C     (Q")ROD = 0 ( LOOP ITW1 )
C
      DO 1 ITW=1,10
      TW2=TLINER
      NU2=FNU/(TW2+273.16)**0.5
      ALFA2=NU2*KI/DEI
      TLINER=TI+QALIN/ALFA2
      IF(ABS(TLINER/TW2-1.).LE.1.E-04)GOTO 5
    1 CONTINUE
C     ..................................................................
C     CONVERGENCE PROBLEMS IN THE LOOP ITW1
C
      WRITE(6,2)I,JPIN,TW2
    2 FORMAT(1H1,5X,'STOP IN TELIN: I=',I5,5X,'PIN=',I5,5X,'TLINER=',
     1E15.5)
      STOP
C     ..................................................................
C     CONVERGENCE IN LOOP ITW1; CALCULATION OF THE ROD TEMPERATURE AT
C     (Q")ROD = 0
C
    5 TW1 =FTWA/R1DR2*QALIN*DEI/KI+TI
      IF(TW1 .LE.TE)TW1 =TE
      TETA1=(TW1 -TI)*KI/(QALIN*DEI)
        IF(QA.LE.1.E-06)GOTO 10
C     ..................................................................
C     REAL ROD TEMPERATURE IN THE CASE OF HEATED ROD AND HEATED SHROUD
C
      NU1=NU1/(1.+QALIN/QA*TETA1*NU1)
      ALFA1=NU1*KI/DEI
      TW1=TI+QA/ALFA1
C     ..................................................................
C     REAL SHROUD TEMPERATURE IN THE CASE OF HEATED ROD AND HEATED SHROU
C
   10 NU2=NU2/(1.+QA/QALIN*TETA2*NU2)
      ALFA2=NU2*KI/DEI
      TLINER=TI+QALIN/ALFA2
      RETURN
```

```
      END



       SUBROUTINE TEMLAM(*,PBT,TI,MASSI,DEIR,AREAI,QQ,QALIN,TE,I,II,M,
     & TW1,ITYP,F2ATIP,F2DTIP,DVOL)
C     ------------------------------------------------------------------
C     TEMLAM COMPUTES THE PIN TEMPERATURES AND THE TEMPERATURE  OF THE
C     LINER IN THE SUBCHANNELS WHERE THE FLOW IS LAMINAR ( THE VELOCITY
C     PROFILE IS ASSUMED TO BE ALREADY DEVELOPED AT THE POSITION WHERE T
C     HEATING STARTS)
C         ITYP=1 : CENTRAL SUBCHANNELS AND CENTRAL PART OF WALL SUBCHANN
C         ITYP=2 : WALL PART OF WALL SUBCHANNELS
C         ITYP=3 : CORNER CHANNELS
C
      REAL MASSI,KI,KAPPA,NU1,NU1IN,NU2,NU2IN
      COMMON/INPAR/IPA/LAMIN5/RTIP(7)/QPAR3/PERL(3)/IND3/NTYP(42)
     1       /SUB1/ASCH(42,3)/GEOO/ACH(3)/INITL/X/SHROUD/TLINER(18,2)
     2       /SUB21/TSCHA(18,2),TSCHB(18,2)/MART2/NS1,NS2/MART3/TBEQR,
     3       TBEQL
C
      QA=QQ*DVOL/RTIP(IPA)*0.5
      TSCHA(II,M)=TI
      TSCHB(II,M)=TI
      PW=4.*AREAI*F2ATIP/(DEIR*F2DTIP)
      PH=PW-PERL(ITYP)*ASCH(I,M)/ACH(NTYP(I))
      R2=SQRT(RTIP(IPA)**2+2.*RTIP(IPA)*AREAI*F2ATIP/PH)
      DEI=2.*(R2-RTIP(IPA))
      RAS=RTIP(IPA)/R2
      KI=KAPPA(PBT,TI)
      ETAI=ETA(PBT,TI)
      RHOI=RHO(PBT,TI)
      CPI=CP(PBT,TI)
      REI=MASSI*DEI/(AREAI*F2ATIP*ETAI)
      PRI=ETAI*CPI/KI
      PEI=REI*PRI
      GRI=X/(DEI*PEI)
C
C-------- (NU 1)INF IF (Q)LIN =0
C
      IF(ITYP.EQ.1)GOTO 1
      NU1IN=4.07+1.237/RAS**0.80272
      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)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)RCD =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
      GOTO 12
   11 YNU2=1.+0.060344/GRI**0.506*EXP(-49.*GRI)
   12 NU2=NU2IN*YNU2
      NU2=NU2*0.967
C
C-------- (TETA 1)
C
      TETA1=TETA2P/RAS
```

```
      TW1=TETA1*QALIN*DEI/KI+TI
      ALFA2=NU2*KI/DEI
      TLINER(II,M)=TI+QALIN/ALFA2
      IF(I.GE.NS1 .AND. I.LE.NS2)CALL SIMLA2(TI,TLINER(II,M),TW1,NU2,
     *     TETA1,TBEQL,TBEQR)
      IF (TW1.LE.TE)TW1=TE
      TETA1=(TW1-TI)*KI/(QALIN*DEI)
C
C---------GENERAL CASE OF HEATED LINER AND ROD (CORNER CHANNELS AND WALL
C---------PART OF THE WALL SUBCHANNELS)
C
      NU2=NU2/(1.+QA/QALIN*TETA2*NU2)
      ALFA2=NU2*KI/DEI
      TLINER(II,M)=TI+QALIN/ALFA2
      IF(QA.LE.1.E-06)RETURN 1
C
      NU1=NU1/(1.+QALIN/QA*TETA1*NU1)
      ALFA1=NU1*KI/DEI
      TW1=TI+QA/ALFA1
      RETURN 1
      END



      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+0.8*(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



      SUBROUTINE TLINE(I,AI,ITTEMP,NS,K,ALFA,D,W,RH,DET,FRCV,IRH,DAI,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=C LINE FOR EACH
C     "WALL-TYPE" SUB-SUBCHANNEL
C
      COMMON/REC1/      PVERT(90),PRAD(90)/REC2/E(90)/REC3/P(90)
      NNN=20
      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.)
      XX=-0.04
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=DAI*PAI*0.25
      ABI=DBI*PBI*0.25
      P(I)=PP
      EPS=SQRT(1.+DBI/D)
      G=GSTAR(EPS)
      RETURN
      END



      SUBROUTINE TMCF(I,NI,TT,TOTM,MAVI)
C------------------------------------------------------------------
C     TMCF EVALUATES THE AVERAGE CROSS-FLOW TEMPERATURES  FOR THE
C     CROSS-FLOW EXCHANGE BETWEEN CHANNELS
C
      REAL MAV,MAVI,MAVJ
      COMMON/IJ1/NER(42),NIS(42,3)/MOB5/T(42)/MOB8/DP(42)/MOB6/MAV(42)
     1      /GEO0/ACH(3)/IND3/NTYP(42)/GEN2/A(42)
      TT=0.
      TOTM=0.
      DO 2 M=1,NI
      J=NIS(I,M)
      MAVJ=MAV(J)*ACH( NTYP(J))/A(J)
      CALL CF1(T(I),T(J),MAVI,  MAVJ,  DP(I),DP(J),2,TT,TOTM)
    2 CONTINUE
      TT =TT/TOTM
      RETURN
      END



      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)
      RHC12=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



      SUBROUTINE TMPUN(NSTOT,NSTR,TE,PE,PEBAR,TE1,PE1,PE1BAR,
     *INDPR,MFLOW,IPAST,IPAEND,IREAD1,XLAM1,STLEN,*)
C     ------------------------------------------------------------------
C     TMFUN PUNCHS THE CARDS WHICH MUST BE CHANGED TO START A NEW
C     CALCULATION STEP (PUNCHING UNITY=1)
C     THE ACTUAL CALCULATION STEP IS STOPPED BECAUSE THE ALLOWED
C     CALCULATION TIME TIMEPU HAS BEEN ELAPSED  OR BECAUSE THE END
C     OF THE AXIAL PORTION IPAEND (IPAEND<7) HAS BEEN OVERTAKEN
C
      REAL MFLOW,MI,MSCH1,MSCWC1
      DIMENSION XLAM1(7)
      COMMON/GEN3/MI(42)/GEN4/TEMP(42)/SUB6/TSCH1(42,3)/SUB8/MSCH1(42,3)
     1       /WCSE2/MSCWC1(18,2,2)/WCSE5/TSCWC1(18,2,2)/INC3/NTYP(42)
     2       /HEA6/NPIN(42),JPIN(42,3)
C
C     10TH CARD:
      IF(INDPR.EQ.1)GOTO 1
      PE=PEBAR
      PE1=PE1BAR
    1 WRITE(1,2)PE,PE1,TE,TE1,MFLOW,(XLAM1(I),I=1,3)
    2 FORMAT(8F10.5)
C
C     13TH CARD
      WRITE(1,3)IPAST,IPAEND,IREAD1
    3 FORMAT(3I10)
C
C     14TH CARD
      WRITE(1,2)STLEN
C
C     LAST BLOCK OF CARDS
      WRITE(1,4)(MI(NS),TEMP(NS),NS=1,NSTOT)
      DO 5 NS=1,NSTOT
      NSW=NS-NSTR
      NP=NPIN(NS)
      WRITE(1,4)(MSCH1(NS,M),TSCH1(NS,M),M=1,NP)
      IF(NTYP(NS).EQ.2)WRITE(1,4)((MSCWC1(NSW,M,JWC),TSCWC1(NSW,M,JWC),
     *                    JWC=1,2),M=1,2)
    4 FORMAT(8F10.5)
    5 CONTINUE
      RETURN 1
      END



      FUNCTION TNU(TW,TL,ITYP,PERL,PIG,RTIP)
```

```
C      ----------------------------------------------------------------------
C      TNU EVALUATES THE TEMPERATURE AT WHICH THE GAS PROPERTIES MUST BE
C      COMPUTED IN THE CASE OF LAMINAR FLOW FOR THE DEFINITION OF THE
C      REYNOLDS NUMBER USED FOR THE CALCULATION OF THE FRICTION FACTORS
C      OF THE CORNER AND WALL SUBCHANNELS
C
       LPIG=ITYP**2-ITYP
       PHR=RTIP*PIG/LPIG*2.
       TNU=(TL*PERL+TW*PHR)/(PERL+PHR)
       RETURN
       END



       SUBROUTINE TOTGEO(NSEL,D,C,Z,PIG,NEXCON,NRODS,W,WA,ZA,EM1,PERLT,
      &RTIP)
C-----------------------------------------------------------------------
C      TOTGEO CALCULATES FLOW AREAS , EQUIVALENT DIAMETERS AND OTHER
C      GEOMETRIC DATA FOR THE WHOLE BUNDLE FLOW SECTION , FOR THE
C      CHANNELS AND FOR THE SUBCHANNELS
C
C                  VERSION FOR HEXAGONAL BUNDLES
C      ......................................................................
       COMMON/GEO0/ACH(3)/LAMIN2/FATIP(3),FDTIP(3)/CPAR3/PERL(3)
      1       /GEO2/ATOT,DETOT,ASEC/GEO5/ATC,DETC,ATW,DETW,ATA,DETA,AAC,
      2       AAW,AAA/WAKAO/CD,WD,ZD,ZWCD,AWD2,PWWD
       SQ3=SQRT(3.)
       W=Z+D*0.5
       WA=W
       ZA=Z
       EXCON=NEXCON
       RODS=NRODS
       EM2=C*0.5-EM1
       ZWC=EM2/SQ3
       DTIP=RTIP*2.
       SIDE=EXCON*C+(2.*W-D)/SQ3
       RPER=RODS*PIG*D
       PERLT=6.*SIDE-12.*EM2+24.*ZWC
       ATOT=3.*SQ3/2.*SIDE**2-RPER*D/4.-6.*EM2*ZWC
       DETOT=4.*ATOT/(RPER+PERLT)
       GOTO(20,21,22),NSEL
    20 ASEC=ATOT
       GOTO 23
    21 ASEC=ATOT*0.5
       GOTO 23
    22 ASEC=ATOT/12.
    23 CONTINUE
       ATC=(C**2*SQ3-PIG*D**2/2.)/4.
       DETC=4.*ATC/(PIG*D/2.)
       ATW=C*(W-D/2.)-D**2*PIG/8.-EM2*ZWC
       DETW=4.*ATW/(PIG*D*0.5+2.*EM1+4.*ZWC)
       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-0.5*PIG*D
      PERL(3)=4.*ATA/DETA-PIG*D/6.
      FATIP(1)=(C**2*SQ3-PIG*DTIP**2*0.5)*C.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*0.5+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
      ZD=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



      SUBROUTINE TRICA1(K,NS,NN,IRH,PROV,PB,   RH,A,DE,MEC,AT,DET,DETOT,
     *H1,ALFA, H,M,PR1,PR2,SQDPG,TE,SUR,D,AMT,DDDD,ATSCH,*,C)
C-----------------------------------------------------------------------
C     SUBROUTINE TRICA1 CALCULATES FRICTION FACTORS AND APPROXIMATE
C     OUTLET MASS FLOW RATES AND TEMPERATURES FOR CENTRAL SUBCHANNELS
C
      REAL MEC,LAMSCH,KAPPA,LAMLAM,MSCH
      COMMON/SUB5/LAMSCH(42,3)/CEN1/G(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      ,QPLUS(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 CALCULATICN MUST BE PERFORMEC
C
        TWIAV=0.
        AMT=0.
        TT=0.
        DCCD=0.
        HPLUS1=0.
        HPLUS2=0.
C       ...................................................................
C       SUB-SUBCHANNEL CALCULATIONS ( I = SUB-SUBCHANNEL INCEX )
C
        DO 1 I=1,NN
        AM1=MEC(I)
        AA=A(I)
        DD=DE(I)
        GG=G(I)
        CALL CEWA(K,NS,IRH,PROV,PE,RH,AA,CC,GG,AM1,DETOT,H1,ALFA,I,M,H,PRI
       *,PR2,SQDPG,AMT,TT,DDDD,TE,SUR,1,III,HPLUS1,HPLUS2,TSCH1(NS,M),
       *SIGMAI(NS,M),PHII(NS,M),8777,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 CALCULATICN MUST BE ALSC PERFCRMEC
C
        IF(ITCCRR.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(IPA),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)=QQ(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




      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(CTU3,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*(0.5*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*0.5)/(12.*A2)
      XB2=(E2*C-D3*(1.-COSGAM)*0.5)/(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



      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



      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



      FUNCTION UA(I,NI,ACHI,IUAV)
C-----------------------------------------------------------------------
C     UA EVALUATES THE AVERAGE CROSS-FLOW VELOCITIES FOR THE CROSS-FLOW
C     EXCHANGE BETWEEN CHANNELS
C
      COMMON/IJ1/NER(42),NIS(42,3)/MOB8/DP(42)/MOB2/U(42)
     1       /GEOO/ACH(3)/IND3/NTYP(42)/LAMIN3/F1ATIP(42),F1DTIP(42)
      UU=0.
      AA=0.
      ACHN=ACHI*F1ATIP(I)
      DO 2 M=1,NI
      J=NIS(I,M)
      ACHJ=ACH(NTYP(J))*F1ATIP(J)
      CALL CF1(U(I),U(J),ACHN,ACHJ,DP(I),DP(J),IUAV,UU,AA)
    2 CONTINUE
      UA=UU/AA
      RETURN
      END



       SUBROUTINE WALLTE(K,NSTOT,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/HEA5/QQ(42,3)/HEA6/NPIN(42),JPIN(42,3)/GEN5/CE(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)/GEOO/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/IRCSMC/IRH
C     ..........................................................
```

```
C      I=CHANNEL INDEX
C
       DO 11 I=1,NSTOT
       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
      IF(IEXAV.EQ.1)RETURN
C     ****************************************************************
C     IF AN AVERAGE VALUE IS DESIRED FOR THE PIN AND FOR THE SHROUD
C     TEMPERATURES OF THE EXTERNAL CHANNELS
C
      PERLT=0.
      PERRT=0.
      TLM=0.
      TWM=0.
      NSTR1=NSTR+1
      DO 20 I=NSTR1,NSTOT
      NP=NPIN(I)
      DO 20 M=1,NP
      PERLSC=PERL(NTYP(I  ))*ASCH(I,M)/ACH(NTYP(I))
      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
```

APPENDIX 2

Data for a turbulent calculation for the 19-rod bundle

(Test 1 for the 19-rod bundle of /5/)

```
         2        19         3         0         2         0         0         0
         1         0
2.61      1.479347  0.        0.03      27.       117.8     0.        75.
0.        4.2       4.        1.83      1.83      1.836763  1.836763  1.836763
1.83      1.83
530.144   0.915     0.915     0.915     0.9183815  0.915    0.915     0.915
0.822     0.822     0.822     0.822     0.822     0.822     0.822     0.915
0.915     0.945     0.945     0.945     0.915     0.915
         1         3        10        10        10
39.90999  39.90999  189.89    189.89    1207.199950.023     0.023     0.096
0.096     0.096     0.023     0.023
1.
         1         7         1
0.
         2         2
         5         0         2         0         3         0         0         0
         0         0         0         0         0         0         0
        40         3         3        10
2.5       2.5       2.5       2.5       2.5       2.5       2.5       2.
2.        2.        2.        2.        2.        2.
1.        0.5        1.       1.        1.
0.        0.
1.2       0.
1.        1.        1.        1.        1.        1.        1.
189.89    284.79    0.        277.14    0.        333.04    255.72    189.89
208.01    0.        237.67    0.        249.85    250.50    189.89    195.45
0.        226.25    0.        230.63    240.96
109.3     39.82713  132.8     39.81885  165.8     39.76389  189.3     39.72250
212.8     39.68298  39.66524
101.63
0.
         3         0         1         0         1         0         1         0
144.8     219.8     224.
         1
1.          1.          1.
1.          1.          1.
0.8       62.9      142.9     222.9
.2028     .1893               .1893     .1893     .2028
.1893     .2028               .22937
.206256   .206256
1.        1.        1.         1.         1.      1.
1.        1.        1.        1.        1.        1.
1.        1.        1.
1.        1.        1.         1.
1.        1.        1.         1.
.2028     .1893               .1893     .1893     .2028
.1893     .2028               .22937
.206256   .206256
1.        1.        1.         1.         1.      1.
1.        1.        1.         1.         1.      1.
1.        1.        1.
1.        1.        1.         1.
1.        1.        1.         1.
.2028     .1893               .1893     .1893     .2028
.1893     .2028               .22937
.206256   .206256
1.        1.        1.         1.         1.      1.
1.        1.        1.         1.         1.      1.
1.        1.        1.
```

1.	1.	1.	1.			
1.	1.	1.	1.			
	1	2		2	8	9
	2	9		8		
	8	9				
630.						
	2					

APPENDIX 3

Parts of a printed output (Test 1 for the 19-rod bundle of /5/)

```
19 RODS BUNDLE :

INLET PRESSURE=40.6968536 KG/SQCM    =39.9099731 BARS
INLET TEMPERATURE=    189.89 C
TOTAL MASS FLOW RATE= 1207.19995  G/SEC


GEOMETRY AT 20 DEGREES :

ROD PITCH=  2.610000 CM
DISTANCE CENTER OF ROD - EXAGONAL WALL=  1.479347 CM
ZWC= 0.0        CM

TOTAL LENGTH=   228.000 CM
HEATED LENGTH=   197.000 CM
LENGTH AND VOL. DIAMETERS FOR THE EXISTING PARTS :
LENGTH(1)= 27.000000 CM     VOL. DIAM.(1)=  1.830000 CM
LENGTH(2)=117.800003 CM     VOL. DIAM.(2)=  1.830000 CM
LENGTH(4)= 75.000000 CM     VOL. DIAM.(4)=  1.836763 CM
LENGTH(6)=  4.200000 CM     VOL. DIAM.(6)=  1.830000 CM
LENGTH(7)=  4.000000 CM     VOL. DIAM.(7)=  1.830000 CM




HEIGHT OF ROUGHNESS (RH) = 0.03000 CM
G(H+) * ((R2-R1)/RH* 0.010)** 0.053 / (PR** 0.440*((TW+273.15)/(TB+273.15))** 0.500)=
= 3.813*(HW+)** 0.274+    0.0  /(HW+)** 1.000


R(H+)=( 2.710+ 5100.0/(HW+)** 3.000)** 1.000+ 0.400*LN(RH/( 0.010*(RO-R1))
       + 5.000/(HW+)** 0.500*((TW+273.16) /(TB1+273.16)-1)** 2.000


MAXIMUM POWER FROM THE LINER:

Q MAX=     0.0          CAL/SEC*CM


MAXIMUM POWER OF RODS:

Q MAX(    1)=    0.24279E+02 CAL/SEC*CM
Q MAX(    2)=    0.24279E+02 CAL/SEC*CM
Q MAX(    3)=    0.24279E+02 CAL/SEC*CM
Q MAX(    4)=    0.24279E+02 CAL/SEC*CM
Q MAX(    5)=    0.24279E+02 CAL/SEC*CM
Q MAX(    6)=    0.24279E+02 CAL/SEC*CM
Q MAX(    7)=    0.24279E+02 CAL/SEC*CM
Q MAX(    8)=    0.24279E+02 CAL/SEC*CM
Q MAX(    9)=    0.24279E+02 CAL/SEC*CM
Q MAX(   10)=    0.24279E+02 CAL/SEC*CM
Q MAX(   11)=    0.24279E+02 CAL/SEC*CM
Q MAX(   12)=    0.24279E+02 CAL/SEC*CM
Q MAX(   13)=    0.24279E+02 CAL/SEC*CM
Q MAX(   14)=    0.24279E+02 CAL/SEC*CM
Q MAX(   15)=    0.24279E+02 CAL/SEC*CM
Q MAX(   16)=    0.24279E+02 CAL/SEC*CM
Q MAX(   17)=    0.24279E+02 CAL/SEC*CM
Q MAX(   18)=    0.24279E+02 CAL/SEC*CM
Q MAX(   19)=    0.24279E+02 CAL/SEC*CM
```

COEFFICIENTS FOR THE POLYNOMIAL PROFILES OF THE ROD POWER (0 TAKEN AT THE BEGINNING OF THE ACTUAL PART):

AS FAR AS X =144.800003 CM :
0.10000E+01

AS FAR AS X =219.800003 CM :
0.10000E+01

AS FAR AS X =224.000000 CM :
0.10000E+01

COEFFICIENTS FOR THE POLYNOMIAL PROFILE OF THE LINER POWER (0 TAKEN AT THE BEGINNING OF THE ACTUAL PART):

AS FAR AS X =144.800003 CM :
0.10000E+01

AS FAR AS X =219.800003 CM :
0.10000E+01

AS FAR AS X =224.000000 CM :
0.10000E+01

RESULTS OF INDEX

NROWS= 3 TYPE OF SECTION=3 NR. OF CENTRAL CHANNELS= 3 TOTAL NUMBER OF CHANNELS= 5

NS= 1	TYPE=1	CHANNELS CONNECTED:	3	
NS= 2	TYPE=1	CHANNELS CONNECTED:	3	5
NS= 3	TYPE=1	CHANNELS CONNECTED:	2	1
NS= 4	TYPE=3	CHANNELS CONNECTED:	5	
NS= 5	TYPE=2	CHANNELS CONNECTED:	4	2

SPACERS (AT 20 DEGREES):

WIDTH= 0.800000 CM

DIST(1)= 62.900 CM
DIST(2)= 142.900 CM
DIST(3)= 222.900 CM

INITIAL UNHEATED SMOOTH PART

C= 2.617942 CM
Z= 1.483950 CM
ZWC= 0.0 CM
VOL. DIAMETER= 1.835568 CM
PART LENGTH= 27.08215 CM
NUMBER OF SPACERS= 0

INLET CONDITIONS :
INLET AVERAGE TEMPERATURE= 189.89 C
INLET PRESSURE=40.6968536 KG/SQCM =39.9099731 BARS

TOTAL FLOW AREA= 75.19 SQCM
TOTAL EQUIVALENT DIAMETER= 2.0 CM
FLOW AREA OF SECTION= 6.27 SQCM

FLOW AREAS OF CHANNELS:
CENTRAL= 1.64
WALL= 2.56
CORNER= 0.83

EQUIVALENT DIAMETERS
CENTRAL= 2.3
WALL= 1.9
CORNER= 1.2

****
CHANNEL 1 : USED KAPPA= 118.740 (INPUT KAPPA= 118.740)
CHANNEL 2 : USED KAPPA= 118.740 (INPUT KAPPA= 118.740)
CHANNEL 3 : USED KAPPA= 118.740 (INPUT KAPPA= 118.740)
CHANNEL 4 : USED KAPPA= 92.790 (INPUT KAPPA= 92.790)
CHANNEL 5 : USED KAPPA= 91.962 (INPUT KAPPA= 91.962)

****

GEOMETRY OF CENTRAL CHANNELS (REFERENCE TO 1/6)

TOTAL FLOW AREA= 0.27 SQCM TOTAL EQUIVALENT DIAMETER= 2.3 CM

SECTION NR.	FLOW AREA (SQCM)	EQUIV. DIAMETER(CM)
1	0.02285	1.902
2	0.02309	1.922
3	0.02359	1.964
4	0.02436	2.027
5	0.02540	2.114
6	0.02675	2.227

7	0.02845	2.368
8	0.03052	2.540
9	0.03303	2.749
10	0.03605	3.001

****

GEOMETRY OF ANGULAR CHANNELS (REFERENCE TO 1/2)

TOTAL FLOW AREA= 0.42 SQCM   TOTAL EQUIVALENT DIAMETER= 1.2 CM

SECTION NR.	FLOW AREA (SQCM)	EQUIV. DIAMETER(CM)
1	0.03564	1.133
2	0.03596	1.139
3	0.03660	1.152
4	0.03759	1.171
5	0.03893	1.196
6	0.04067	1.227
7	0.04284	1.264
8	0.04550	1.308
9	0.04873	1.359
10	0.05262	1.415

****

PRESSURE LOSS DUE TO ENTRANCE=-0.0384827 KG/SQCM =-0.0377386 BARS (CINL=1.20)

****

TOTAL LENGTH= 27.08 CM   NUMBER OF SECTIONS= 5   FREL= 1.0000

```
AXIAL SECTION NR.   1     ( SECTION LENGTH=   5.41643; HEIGHT=   2.70821 )....................................................
---------------------

T 2=  189.8900       P 2= 40.656815      P AV= 40.657593      DELTAP=-0.00153973      LAMBDA=0.01760
( ITCORR= 5       ITGL=     7      ITGL1=   28      ITERM=    1      FREL= 1.00 )

CHANNEL          OUTLET MASS          AVERAGE MASS          OUTLET TEMP.          AVERAGE TEMP.          PRESSURE LOSS

      1       0.13242749E+02       0.13222527E+02       0.18989000E+03       0.18988985E+03       -0.15398581E-02
      2       0.26484879E+02       0.26444733E+02       0.18989000E+03       0.18988992E+03       -0.15398590E-02
      3       0.13242744E+02       0.13222519E+02       0.18989000E+03       0.18988995E+03       -0.15398546E-02
      4       0.65423727E+01       0.66033974E+01       0.18989000E+03       0.18988992E+03       -0.15398900E-02
      5       0.41087250E+02       0.41106812E+02       0.18989000E+03       0.18988988E+03       -0.15398527E-02

UAV(  1)=  0.39236E+04          WCF(  1)=  -0.747E-02          MO(  1)=      13.23          LAM(  1)=   0.01757
UAV(  2)=  0.39236E+04          WCF(  2)=  -0.148E-01          MO(  2)=      26.47          LAM(  2)=   0.01757
UAV(  3)=  0.39236E+04          WCF(  3)=  -0.747E-02          MO(  3)=      13.23          LAM(  3)=   0.01757
UAV(  4)=  0.38818E+04          WCF(  4)=   0.225E-01          MO(  4)=       6.54          LAM(  4)=   0.01970
UAV(  5)=  0.39158E+04          WCF(  5)=   0.722E-02          MO(  5)=      41.06          LAM(  5)=   0.01715

 1) WT(   1,    3)=    0.397E-01
 1) WT(   2,    3)=    0.795E-01       2) WT(    2,    5)=    0.534E-01
 1) WT(   3,    2)=    0.795E-01       2) WT(    3,    1)=    0.397E-01
 1) WT(   4,    5)=    0.255E-01
 1) WT(   5,    4)=    0.255E-01       2) WT(    5,    2)=    0.534E-01

CHANNEL NR.    1
 1-(ROD NR.    2)     OUT. MASS  8.828499      OUT. TEMP.= 189.89     LAMBDA=    0.01757       REB=137453.  REW=137453.
                      Q LINER=     0.0
 2-(ROD NR.    1)     OUT. MASS  4.414248      OUT. TEMP.= 189.89     LAMBDA=    0.01757       REB=137453.  REW=137453.
                      Q LINER=     0.0
CHANNEL NR.    2
 1-(ROD NR.    8)     OUT. MASS  8.828194      OUT. TEMP.= 189.89     LAMBDA=    0.01757       REB=137451.  REW=137451.
                      Q LINER=     0.0
 2-(ROD NR.    2)     OUT. MASS  8.828468      OUT. TEMP.= 189.89     LAMBDA=    0.01757       REB=137453.  REW=137453.
                      Q LINER=     0.0
 3-(ROD NR.    9)     OUT. MASS  8.828209      OUT. TEMP.= 189.89     LAMBDA=    0.01757       REB=137451.  REW=137451.
                      Q LINER=     0.0
CHANNEL NR.    3
 1-(ROD NR.    2)     OUT. MASS  8.828484      OUT. TEMP.= 189.89     LAMBDA=    0.01757       REB=137453.  REW=137453.
                      Q LINER=     0.0
 2-(ROD NR.    9)     OUT. MASS  4.414246      OUT. TEMP.= 189.89     LAMBDA=    0.01757       REB=137453.  REW=137453.
                      Q LINER=     0.0
CHANNEL NR.    4
 1-(ROD NR.    8)     OUT. MASS  6.542372      OUT. TEMP.= 189.89     LAMBDA=    0.01970       REB= 74004.  REW= 74004.
                      Q LINER=     0.0
CHANNEL NR.    5
 1-(ROD NR.    8)     OUT. MASS 20.543045      OUT. TEMP.= 189.89     LAMBDA=    0.01715       REB=111982.  REW=111982.
                      Q LINER=     0.0
                      MOUT(1)= 0.162240E+02    TOUT(1)= 0.189890E+03  AREA(1)= 0.101249E+01   LAMBDA(1)= 0.171790E-01
                      MOUT(2)= 0.431901E+01    TOUT(2)= 0.189890E+03  AREA(2)= 0.268267E+00   LAMBDA(2)= 0.176096E-01
 2-(ROD NR.    9)     OUT. MASS 20.544174      OUT. TEMP.= 189.89     LAMBDA=    0.01715       REB=111985.  REW=111985.
                      Q LINER=     0.0
                      MOUT(1)= 0.162251E+02    TOUT(1)= 0.189890E+03  AREA(1)= 0.101249E+01   LAMBDA(1)= 0.171789E-01
                      MOUT(2)= 0.431903E+01    TOUT(2)= 0.189890E+03  AREA(2)= 0.268267E+00   LAMBDA(2)= 0.176096E-01
```

AXIAL SECTION NR. 5 (SECTION LENGTH= 5.41643; HEIGHT= 24.37392)..

T 2= 189.8900 P 2= 40.650650 P AV= 40.651413 DELTAP=-0.00153785 LAMBDA=0.01757
(ITCORR= 5 ITGL= 7 ITGL1= 30 ITERM= 1 FREL= 1.00)

CHANNEL	OUTLET MASS	AVERAGE MASS	OUTLET TEMP.	AVERAGE TEMP.	PRESSURE LOSS
1	0.13387742E+02	0.13370834E+02	0.18988991E+03	0.18988982E+03	-0.15377472E-02
2	0.26762085E+02	0.26730515E+02	0.18989006E+03	0.18988985E+03	-0.15377530E-02
3	0.13387403E+02	0.13370583E+02	0.18989003E+03	0.18988988E+03	-0.15377172E-02
4	0.61297894E+01	0.61759348E+01	0.18989084E+03	0.18989073E+03	-0.15379728E-02
5	0.40932907E+02	0.40952057E+02	0.18989030E+03	0.18989011E+03	-0.15377293E-02

UAV(1)= 0.39682E+04	WCF(1)= -0.624E-02	MO(1)= 13.39	LAM(1)= 0.01752
UAV(2)= 0.39666E+04	WCF(2)= -0.117E-01	MO(2)= 26.77	LAM(2)= 0.01752
UAV(3)= 0.39682E+04	WCF(3)= -0.621E-02	MO(3)= 13.39	LAM(3)= 0.01752
UAV(4)= 0.36310E+04	WCF(4)= 0.170E-01	MO(4)= 6.13	LAM(4)= 0.02000
UAV(5)= 0.39016E+04	WCF(5)= 0.707E-02	MO(5)= 40.94	LAM(5)= 0.01717

1) WT(1, 3)= 0.402E-01	
1) WT(2, 3)= 0.803E-01	2) WT(2, 5)= 0.535E-01
1) WT(3, 2)= 0.803E-01	2) WT(3, 1)= 0.402E-01
1) WT(4, 5)= 0.250E-01	
1) WT(5, 4)= 0.250E-01	2) WT(5, 2)= 0.535E-01

CHANNEL NR. 1
1-(ROD NR. 2) OUT. MASS 8.925117 OUT. TEMP.= 189.89 LAMBDA= 0.01752 REB=138994. REW=138994.
Q LINER= 0.0
2-(ROD NR. 1) OUT. MASS 4.462580 OUT. TEMP.= 189.89 LAMBDA= 0.01752 REB=138995. REW=138995.
Q LINER= 0.0
CHANNEL NR. 2
1-(ROD NR. 8) OUT. MASS 8.918846 OUT. TEMP.= 189.89 LAMBDA= 0.01752 REB=138912. REW=138912.
Q LINER= 0.0
2-(ROD NR. 2) OUT. MASS 8.924004 OUT. TEMP.= 189.89 LAMBDA= 0.01752 REB=138980. REW=138980.
Q LINER= 0.0
3-(ROD NR. 9) OUT. MASS 8.919136 OUT. TEMP.= 189.89 LAMBDA= 0.01752 REB=138916. REW=138916.
Q LINER= 0.0
CHANNEL NR. 3
1-(ROD NR. 2) OUT. MASS 8.924950 OUT. TEMP.= 189.89 LAMBDA= 0.01752 REB=138992. REW=138992.
Q LINER= 0.0
2-(ROD NR. 9) OUT. MASS 4.462414 OUT. TEMP.= 189.89 LAMBDA= 0.01752 REB=138991. REW=138991.
Q LINER= 0.0
CHANNEL NR. 4
1-(ROD NR. 8) OUT. MASS 6.129787 OUT. TEMP.= 189.89 LAMBDA= 0.02000 REB= 69213. REW= 69213.
Q LINER= 0.0
CHANNEL NR. 5
1-(ROD NR. 8) OUT. MASS 20.455124 OUT. TEMP.= 189.89 LAMBDA= 0.01717 REB=111510. REW=111510.
Q LINER= 0.0
MOUT(1)= 0.161115E+02 TOUT(1)= 0.189891E+03 AREA(1)= 0.101248E+01 LAMBDA(1)= 0.172040E-01
MOUT(2)= 0.434363E+01 TOUT(2)= 0.189891E+03 AREA(2)= 0.268269E+00 LAMBDA(2)= 0.175831E-01
2-(ROD NR. 9) OUT. MASS 20.477646 OUT. TEMP.= 189.89 LAMBDA= 0.01716 REB=111613. REW=111613.
Q LINER= 0.0
MOUT(1)= 0.161333E+02 TOUT(1)= 0.189891E+03 AREA(1)= 0.101248E+01 LAMBDA(1)= 0.171998E-01
MOUT(2)= 0.434425E+01 TOUT(2)= 0.189891E+03 AREA(2)= 0.268269E+00 LAMBDA(2)= 0.175826E-01

VARIABLES FOR THE WHOLE BUNDLE

A) INLET VALUES OF TEMPERATURE AND PRESSURE

SECTION NR.	HEIGHT (CM)	TEMPERATURE (C)	PRESSURE (KG/SQCM)	PRESSURE (BARS)
1	0.0	189.89	40.65837	39.87224
2	5.4164	189.89	40.65681	39.87071
3	10.8329	189.89	40.65527	39.86920
4	16.2493	189.89	40.65373	39.86769
5	21.6657	189.89	40.65219	39.86618
6	27.0821	189.89	40.65065	39.86467

B) VALUES AVERAGED OVER AXIAL SECTIONS

SECTION NR.	DENSITY (G/CCM)	VISCOSITY(G/CM*SEC)	VELOCITY (M/SEC)	REYNOLDS NR.	FRICTION FACTOR
1	0.00410	0.0002669	39.176	119605.37	0.01760
2	0.00410	0.0002669	39.178	119605.37	0.01761
3	0.00410	0.0002669	39.179	119605.37	0.01760
4	0.00410	0.0002669	39.181	119605.37	0.01758
5	0.00410	0.0002669	39.182	119605.37	0.01757

TOTAL PRESSURE DROP=-0.007721 KG/SQCM

COMPARISON OF INPUT TEMPERATURES WITH COMPUTED VALUES

	INPUT	COMPUTED
TWTIPA	189.89	189.89
TBTIPA	189.89	189.89
TBPIPA	189.89	189.89

FIRST HEATED SMOOTH PART

```
C=  2.618104 CM
Z=  1.484203 CM
ZWC=  0.0       CM
VOL. DIAMETER=  1.838098 CM
PART LENGTH= 118.32127 CM
NUMBER OF SPACERS=  2

INLET CONDITIONS :
INLET AVERAGE TEMPERATURE= 189.89 C
INLET PRESSURE=40.6506500 KG/SQCM     =39.8646698 BARS



SPACERS (DISTANCES ARE EVALUATED FROM THE BUNDLE ENTRANCE) :
WIDTH=  0.802484 CM
DIST( 1)=     63.095 CM
DIST( 2)=    143.347 CM




RESULTS OF HEATI


   CHANNEL                          ROD                          ROD                          ROD

      1   1) JPIN(     1, 1)=     2    2) JPIN(     1, 2)=     1
      2   1) JPIN(     2, 1)=     8    2) JPIN(     2, 2)=     2    3) JPIN(     2, 3)=     9
      3   1) JPIN(     3, 1)=     2    2) JPIN(     3, 2)=     9
      4   1) JPIN(     4, 1)=     8
      5   1) JPIN(     5, 1)=     8    2) JPIN(     5, 2)=     9


TOTAL FLOW AREA=        75.08 SQCM
TOTAL EQUIVALENT DIAMETER=          2.0 CM
FLOW AREA OF SECTION=        6.26 SQCM

FLOW AREAS OF CHANNELS:
CENTRAL=         1.64
WALL=       2.56
CORNER=        0.83

EQUIVALENT DIAMETERS
CENTRAL=         2.3
WALL=       1.9
CORNER=        1.2


*****************************************************************************************************************************************
 CHANNEL     1 : USED KAPPA=    118.579 (INPUT KAPPA=    118.579)
 CHANNEL     2 : USED KAPPA=    118.579 (INPUT KAPPA=    118.579)
 CHANNEL     3 : USED KAPPA=    118.579 (INPUT KAPPA=    118.579)
 CHANNEL     4 : USED KAPPA=     92.792 (INPUT KAPPA=     92.792)
 CHANNEL     5 : USED KAPPA=     91.938 (INPUT KAPPA=     91.938)
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SPACER NR.     1      EPSILON TOT.= 0.2012529

CHANNEL NR.     1      EPSILON= 0.1937999
SUBCHANNELS:
ROD NR.     2) EPSILON(     1, 1)= 0.1893000
ROD NR.     1) EPSILON(     1, 2)= 0.2028000

CHANNEL NR.     2      EPSILON= 0.1937999
SUBCHANNELS:
ROD NR.     8) EPSILON(     2, 1)= 0.1893000
ROD NR.     2) EPSILON(     2, 2)= 0.1893000
ROD NR.     9) EPSILON(     2, 3)= 0.2028000

CHANNEL NR.     3      EPSILON= 0.1937999
SUBCHANNELS:
ROD NR.     2) EPSILON(     3, 1)= 0.1893000
ROD NR.     9) EPSILON(     3, 2)= 0.2028000

CHANNEL NR.     4      EPSILON= 0.2293699
SUBCHANNELS:
ROD NR.     8) EPSILON(     4, 1)= 0.2293700

CHANNEL NR.     5      EPSILON= 0.2062559
SUBCHANNELS:
ROD NR.     8) EPSILON(     5, 1)= 0.2062560
ROD NR.     9) EPSILON(     5, 2)= 0.2062560


SPACER NR.     2      EPSILON TOT.= 0.2012529

CHANNEL NR.     1      EPSILON= 0.1937999
SUBCHANNELS:
ROD NR.     2) EPSILON(     1, 1)= 0.1893000
ROD NR.     1) EPSILON(     1, 2)= 0.2028000

CHANNEL NR.     2      EPSILON= 0.1937999
SUBCHANNELS:
ROD NR.     8) EPSILON(     2, 1)= 0.1893000
ROD NR.     2) EPSILON(     2, 2)= 0.1893000
ROD NR.     9) EPSILON(     2, 3)= 0.2028000

CHANNEL NR.     3      EPSILON= 0.1937999
SUBCHANNELS:
ROD NR.     2) EPSILON(     3, 1)= 0.1893000
ROD NR.     9) EPSILON(     3, 2)= 0.2028000

CHANNEL NR.     4      EPSILON= 0.2293699
SUBCHANNELS:
ROD NR.     8) EPSILON(     4, 1)= 0.2293700

CHANNEL NR.     5      EPSILON= 0.2062559
SUBCHANNELS:
ROD NR.     8) EPSILON(     5, 1)= 0.2062560
ROD NR.     9) EPSILON(     5, 2)= 0.2062560
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GEOMETRY OF CENTRAL CHANNELS (REFERENCE TO 1/6)

TOTAL FLOW AREA= 0.27 SQCM   TOTAL EQUIVALENT DIAMETER= 2.3 CM

SECTION NR.	FLOW AREA (SQCM)	EQUIV. DIAMETER(CM)
1	0.02279	1.894
2	0.02304	1.915
3	0.02354	1.957
4	0.02430	2.020
5	0.02535	2.107
6	0.02670	2.219
7	0.02839	2.360
8	0.03046	2.532
9	0.03298	2.741
10	0.03600	2.992

GEOMETRY OF ANGULAR CHANNELS (REFERENCE TO 1/2)

TOTAL FLOW AREA= 0.41 SQCM   TOTAL EQUIVALENT DIAMETER= 1.2 CM

SECTION NR.	FLOW AREA (SQCM)	EQUIV. DIAMETER(CM)
1	0.03561	1.131
2	0.03593	1.138
3	0.03657	1.150
4	0.03755	1.169
5	0.03890	1.194
6	0.04064	1.225
7	0.04281	1.263
8	0.04548	1.307
9	0.04871	1.357
10	0.05259	1.414

TOTAL LENGTH= 118.32 CM   NUMBER OF SECTIONS= 27   FREL= 1.0000

AXIAL SECTION NR. 1 (SECTION LENGTH= 5.55632; HEIGHT= 29.86031)...

T 2= 191.5919 P 2= 40.648819 P AV= 40.649734 DELTAP=-0.0018220C LAMBDA=0.01756
(ITCORR= 6 ITGL= 7 ITGL1= 38 ITERM= 2 FREL= 1.00)

CHANNEL	OUTLET MASS	AVERAGE MASS	OUTLET TEMP.	AVERAGE TEMP.	PRESSURE LOSS
1	0.13409843E+02	0.13398788E+02	0.19190704E+03	0.19089931E+03	-0.18215324E-02
2	0.26800903E+02	0.26781494E+02	0.19190430E+03	0.19089769E+03	-0.18209950E-02
3	0.13409286E+02	0.13398338E+02	0.19190724E+03	0.19089944E+03	-0.18216036E-02
4	0.60501060E+01	0.60899477E+01	0.19136937E+03	0.19062535E+03	-0.18229147E-02
5	0.40929764E+02	0.40931335E+02	0.19121362E+03	0.19055191E+03	-0.18222283E-02

UAV(1)= 0.39932E+04	WCF(1)= -0.398E-02	MO(1)= 13.42	LAM(1)= 0.01752
UAV(2)= 0.39908E+04	WCF(2)= -0.699E-02	MO(2)= 26.81	LAM(2)= 0.01753
UAV(3)= 0.39931E+04	WCF(3)= -0.394E-02	MO(3)= 13.42	LAM(3)= 0.01752
UAV(4)= 0.35889E+04	WCF(4)= 0.143E-01	MO(4)= 6.05	LAM(4)= 0.02007
UAV(5)= 0.39091E+04	WCF(5)= 0.563E-03	MO(5)= 40.94	LAM(5)= 0.01718

1) WT(1, 3)= 0.403E-01	
1) WT(2, 3)= 0.805E-01	2) WT(2, 5)= 0.535E-01
1) WT(3, 2)= 0.805E-01	2) WT(3, 1)= 0.403E-01
1) WT(4, 5)= 0.250E-01	
1) WT(5, 4)= 0.250E-01	2) WT(5, 2)= 0.535E-01

CHANNEL	ROD	TEMPERATURE	HEAT POWER	ROD	TEMPERATURE	HEAT POWER	ROD	TEMPERATURE	HEAT POWER
1	2	0.24884E+03	0.13430E+03	1	0.24884E+03	0.13430E+03			
2	8	0.24888E+03	0.13430E+03	2	0.24885E+03	0.13430E+03	9	0.24888E+03	0.13430E+03
3	2	0.24884E+03	0.13430E+03	9	0.24884E+03	0.13430E+03			
4	8	0.25460E+03	0.13430E+03						
5	8	0.25027E+03	0.13430E+03	9	0.25021E+03	0.13430E+03			

CHANNEL NR. 1				
1-(ROD NR. 2)	OUT. MASS 8.939842	OUT. TEMP.= 191.91	LAMBDA= 0.01752	REB=138893. REW=114422.
	Q LINER= 0.0	NU = 0.329867E+03	TW INF.= 248.84	
	TBSSCH(1)= 191.31	TWSSCH(1)= 248.84	TBSSCH(N)= 190.52	TWSSCH(N)= 248.84
2-(ROD NR. 1)	OUT. MASS 4.469950	OUT. TEMP.= 191.91	LAMBDA= 0.01752	REB=138894. REW=114423.
	Q LINER= 0.0	NU = 0.329870E+03	TW INF.= 248.84	
	TBSSCH(1)= 191.31	TWSSCH(1)= 248.84	TBSSCH(N)= 190.52	TWSSCH(N)= 248.84
CHANNEL NR. 2				
1-(ROD NR. 8)	OUT. MASS 8.931190	OUT. TEMP.= 191.90	LAMBDA= 0.01753	REB=138777. REW=114313.
	Q LINER= 0.0	NU = 0.329651E+03	TW INF.= 248.88	
	TBSSCH(1)= 191.31	TWSSCH(1)= 248.88	TBSSCH(N)= 190.52	TWSSCH(N)= 248.88
2-(ROD NR. 2)	OUT. MASS 8.938011	OUT. TEMP.= 191.91	LAMBDA= 0.01752	REB=138870. REW=114400.
	Q LINER= 0.0	NU = 0.329824E+03	TW INF.= 248.85	
	TBSSCH(1)= 191.31	TWSSCH(1)= 248.85	TBSSCH(N)= 190.52	TWSSCH(N)= 248.85
3-(ROD NR. 9)	OUT. MASS 8.931602	OUT. TEMP.= 191.90	LAMBDA= 0.01753	REB=138783. REW=114318.
	Q LINER= 0.0	NU = 0.329661E+03	TW INF.= 248.88	
	TBSSCH(1)= 191.31	TWSSCH(1)= 248.88	TBSSCH(N)= 190.52	TWSSCH(N)= 248.88
CHANNEL NR. 3				
1-(ROD NR. 2)	OUT. MASS 8.939568	OUT. TEMP.= 191.91	LAMBDA= 0.01752	REB=138890. REW=114419.
	Q LINER= 0.0	NU = 0.329861E+03	TW INF.= 248.84	
	TBSSCH(1)= 191.31	TWSSCH(1)= 248.84	TBSSCH(N)= 190.52	TWSSCH(N)= 248.84
2-(ROD NR. 9)	OUT. MASS 4.469679	OUT. TEMP.= 191.91	LAMBDA= 0.01752	REB=138887. REW=114416.
	Q LINER= 0.0	NU = 0.329856E+03	TW INF.= 248.84	
	TBSSCH(1)= 191.31	TWSSCH(1)= 248.84	TBSSCH(N)= 190.52	TWSSCH(N)= 248.84
CHANNEL NR. 4				
1-(ROD NR. 8)	OUT. MASS 6.050108	OUT. TEMP.= 191.37	LAMBDA= 0.02007	REB= 68134. REW= 55070.

	Q LINER= 0.0	NU = 0.162970E+03	TW INF.= 254.60	T AT LINER= 189.89
	TBSSCH(1)= 190.63	TWSSCH(1)= 254.60	TBSSCH(N)= 190.63	TWSSCH(N)= 254.60
	TA= 190.17	TB= 191.34	TBC= 191.34	
	T1SSCH(1)= 191.34	T2SSCH(1)= 190.17	T1SSCH(N)= 191.34	T2SSCH(N)= 190.17
CHANNEL NR. 5				
1-(ROD NR. 8)	OUT. MASS 20.449387	OUT. TEMP.= 191.22	LAMBDA= 0.01718	REB=111243. REW= 91120.
	Q LINER= 0.0	NU = 0.261840E+03	TW INF.= 250.27	T AT LINER= 189.89
	TBSSCH(1)= 190.46	TWSSCH(1)= 250.27	TBSSCH(N)= 190.46	TWSSCH(N)= 250.27
	TA= 190.08	TB= 190.96	TBC= 190.94	
	TW(1)= 250.54	TW(2)= 249.73		
	T1SSCH(1)= 190.96	T2SSCH(1)= 190.08	T1SSCH(N)= 190.96	T2SSCH(N)= 190.08
	MOUT(1)= 0.161507E+02	TOUT(1)= 0.191033E+03	AREA(1)= 0.101143E+01	LAMBDA(1)= 0.172007E-01
	MOUT(2)= 0.429867E+01	TOUT(2)= 0.191904E+03	AREA(2)= 0.268077E+00	LAMBDA(2)= 0.176370E-01
2-(ROD NR. 9)	OUT. MASS 20.480240	OUT. TEMP.= 191.21	LAMBDA= 0.01717	REB=111389. REW= 91256.
	Q LINER= 0.0	NU = 0.262104E+03	TW INF.= 250.21	T AT LINER= 189.89
	TBSSCH(1)= 190.46	TWSSCH(1)= 250.21	TBSSCH(N)= 190.46	TWSSCH(N)= 250.21
	TA= 190.08	TB= 190.96	TBC= 190.94	
	TW(1)= 250.47	TW(2)= 249.68		
	T1SSCH(1)= 190.96	T2SSCH(1)= 190.08	T1SSCH(N)= 190.96	T2SSCH(N)= 190.08
	MOUT(1)= 0.161775E+02	TOUT(1)= 0.191031E+03	AREA(1)= 0.101143E+01	LAMBDA(1)= 0.171956E-01
	MOUT(2)= 0.430272E+01	TOUT(2)= 0.191902E+03	AREA(2)= 0.268081E+00	LAMBDA(2)= 0.176330E-01

AXIAL SECTION NR. 8 (SECTION LENGTH= 2.27383; HEIGHT= 63.83086) SPACER NR. 1 IS PRESENT.......................

T 2= 201.4946 P 2= 40.629578 P AV= 40.634216 DELTAP=-0.00927372 LAMBDA=0.01752
(ITCORR= 4 ITGL= 4 ITGL1= 12 ITERM= 2 FREL= 1.00)

CHANNEL	OUTLET MASS	AVERAGE MASS	OUTLET TEMP.	AVERAGE TEMP.	PRESSURE LOSS
1	0.13554733E+02	0.13530540E+02	0.20358151E+03	0.20317104E+03	-0.92484429E-02
2	0.27068527E+02	0.27016418E+02	0.20342177E+03	0.20302238E+03	-0.92472918E-02
3	0.13552408E+02	0.13528000E+02	0.20357193E+03	0.20316241E+03	-0.92484243E-02
4	0.57099829E+01	0.57175236E+01	0.20024408E+03	0.19992282E+03	-0.92488974E-02
5	0.40714157E+02	0.40807312E+02	0.19901585E+03	0.19873676E+03	-0.92481077E-02

UAV(1)= 0.41392E+04 WCF(1)= -0.213E-01
UAV(2)= 0.41311E+04 WCF(2)= -0.458E-01
UAV(3)= 0.41384E+04 WCF(3)= -0.215E-01
UAV(4)= 0.34373E+04 WCF(4)= 0.663E-02
UAV(5)= 0.39666E+04 WCF(5)= 0.819E-01

1) WT(1, 3)= 0.407E-01
1) WT(2, 3)= 0.813E-01 2) WT(2, 5)= 0.537E-01
1) WT(3, 2)= 0.813E-01 2) WT(3, 1)= 0.407E-01
1) WT(4, 5)= 0.246E-01
1) WT(5, 4)= 0.246E-01 2) WT(5, 2)= 0.537E-01

CHANNEL	ROD	TEMPERATURE	HEAT POWER	ROD	TEMPERATURE	HEAT POWER	ROD	TEMPERATURE	HEAT POWER
1	2	0.27018E+03	0.54962E+02	1	0.26952E+03	0.54962E+02			
2	8	0.27008E+03	0.54962E+02	2	0.27018E+03	0.54962E+02	9	0.26944E+03	0.54962E+02
3	2	0.27018E+03	0.54962E+02	9	0.26952E+03	0.54962E+02			
4	8	0.27647E+03	0.54962E+02						
5	8	0.26914E+03	0.54962E+02	9	0.26892E+03	0.54962E+02			

CHANNEL NR. 1
1-(ROD NR. 2) OUT. MASS 9.079338 OUT. TEMP.= 203.58 LAMBDA= 0.01755 REB=138190. REW=111247.
Q LINER= 0.0 TW INF.= 270.18
2-(ROD NR. 1) OUT. MASS 4.475296 OUT. TEMP.= 203.58 LAMBDA= 0.01755 REB=137208. REW=110676.
Q LINER= 0.0 TW INF.= 269.52
CHANNEL NR. 2
1-(ROD NR. 8) OUT. MASS 9.060631 OUT. TEMP.= 203.34 LAMBDA= 0.01756 REB=137928. REW=110987.
Q LINER= 0.0 TW INF.= 270.08
2-(ROD NR. 2) OUT. MASS 9.072380 OUT. TEMP.= 203.53 LAMBDA= 0.01756 REB=138088. REW=111149.
Q LINER= 0.0 TW INF.= 270.18
3-(ROD NR. 9) OUT. MASS 8.935310 OUT. TEMP.= 203.39 LAMBDA= 0.01756 REB=136975. REW=110445.
Q LINER= 0.0 TW INF.= 269.44
CHANNEL NR. 3
1-(ROD NR. 2) OUT. MASS 9.077736 OUT. TEMP.= 203.57 LAMBDA= 0.01755 REB=138168. REW=111226.
Q LINER= 0.0 TW INF.= 270.18
2-(ROD NR. 9) OUT. MASS 4.474588 OUT. TEMP.= 203.57 LAMBDA= 0.01755 REB=137181. REW=110650.
Q LINER= 0.0 TW INF.= 269.52
CHANNEL NR. 4
1-(ROD NR. 8) OUT. MASS 5.709980 OUT. TEMP.= 200.24 LAMBDA= 0.02041 REB= 63135. REW= 49311.
Q LINER= 0.0 TW INF.= 276.47 T AT LINER= 189.89
CHANNEL NR. 5
1-(ROD NR. 8) OUT. MASS 20.323990 OUT. TEMP.= 199.04 LAMBDA= 0.01721 REB=109502. REW= 87088.
Q LINER= 0.0 TW INF.= 269.14 T AT LINER= 189.89
MOUT(1)= 0.160426E+02 TOUT(1)= 0.198237E+03 AREA(1)= 0.101372E+01 LAMBDA(1)= 0.172484E-01
MOUT(2)= 0.428138E+01 TOUT(2)= 0.202034E+03 AREA(2)= 0.265793E+00 LAMBDA(2)= 0.176551E-01
2-(ROD NR. 9) OUT. MASS 20.389847 OUT. TEMP.= 198.99 LAMBDA= 0.01720 REB=109906. REW= 87453.

Q LINER= 0.0		TW INF.= 268.92	T AT LINER= 189.89
MOUT(1)= 0.161053E+02	TOUT(1)= 0.198178E+03	AREA(1)= 0.101370E+01	LAMBDA(1)= 0.172305E-01
MOUT(2)= 0.428446E+01	TOUT(2)= 0.202031E+03	AREA(2)= 0.265807E+00	LAMBDA(2)= 0.176521E-01

AXIAL SECTION NR. 26 (SECTION LENGTH= 2.27383; HEIGHT= 144.08276) SPACER NR. 2 IS PRESENT.......................

T 2= 226.0762 P 2= 40.593155 P AV= 40.598038 DELTAP=-0.00976815 LAMBDA=0.01749
(ITCORR= 4 ITGL= 8 ITGL1= 24 ITERM= 2 FREL= 1.00)

CHANNEL	OUTLET MASS	AVERAGE MASS	OUTLET TEMP.	AVERAGE TEMP.	PRESSURE LOSS
1	0.13650595E+02	0.13652657E+02	0.23221092E+03	0.23180798E+03	-0.97021684E-02
2	0.27213531E+02	0.27202911E+02	0.23096353E+03	0.23058278E+03	-0.97015239E-02
3	0.13642043E+02	0.13642715E+02	0.23199384E+03	0.23159608E+03	-0.97020306E-02
4	0.54937172E+01	0.54400740E+01	0.22297421E+03	0.22268927E+03	-0.96952803E-02
5	0.40599625E+02	0.40661148E+02	0.21916522E+03	0.21887852E+03	-0.97009465E-02

UAV(1)= 0.44283E+04 WCF(1)= 0.182E-02
UAV(2)= 0.44011E+04 WCF(2)= -0.935E-02
UAV(3)= 0.44232E+04 WCF(3)= 0.595E-03
UAV(4)= 0.34288E+04 WCF(4)= -0.472E-01
UAV(5)= 0.41225E+04 WCF(5)= 0.541E-01

1) WT(1, 3)= 0.412E-01
1) WT(2, 3)= 0.822E-01 2) WT(2, 5)= 0.539E-01
1) WT(3, 2)= 0.822E-01 2) WT(3, 1)= 0.412E-01
1) WT(4, 5)= 0.244E-01
1) WT(5, 4)= 0.244E-01 2) WT(5, 2)= 0.539E-01

CHANNEL	ROD	TEMPERATURE	HEAT POWER	ROD	TEMPERATURE	HEAT POWER	ROD	TEMPERATURE	HEAT POWER
1	2	0.30035E+03	0.54962E+02	1	0.29974E+03	0.54962E+02			
2	8	0.29906E+03	0.54962E+02	2	0.29977E+03	0.54962E+02	9	0.29854E+03	0.54962E+02
3	2	0.30022E+03	0.54962E+02	9	0.29950E+03	0.54962E+02			
4	8	0.30635E+03	0.54962E+02						
5	8	0.29351E+03	0.54962E+02	9	0.29285E+03	0.54962E+02			

```
CHANNEL NR.    1
 1-(ROD NR.   2)   OUT. MASS  9.144966    OUT. TEMP.= 232.20   LAMBDA=   0.01765     REB=134190.  REW=108787.
                   Q LINER=   0.0                              TW INF.=   300.35
 2-(ROD NR.   1)   OUT. MASS  4.505417    OUT. TEMP.= 232.25   LAMBDA=   0.01766     REB=133162.  REW=108155.
                   Q LINER=   0.0                              TW INF.=   299.75
CHANNEL NR.    2
 1-(ROD NR.   8)   OUT. MASS  9.107307    OUT. TEMP.= 230.62   LAMBDA=   0.01767     REB=133823.  REW=108345.
                   Q LINER=   0.0                              TW INF.=   299.06
 2-(ROD NR.   2)   OUT. MASS  9.126411    OUT. TEMP.= 231.48   LAMBDA=   0.01766     REB=133999.  REW=108563.
                   Q LINER=   0.0                              TW INF.=   299.77
 3-(ROD NR.   9)   OUT. MASS  8.979317    OUT. TEMP.= 230.81   LAMBDA=   0.01767     REB=132856.  REW=107778.
                   Q LINER=   0.0                              TW INF.=   298.54
CHANNEL NR.    3
 1-(ROD NR.   2)   OUT. MASS  9.138847    OUT. TEMP.= 232.02   LAMBDA=   0.01766     REB=134121.  REW=108711.
                   Q LINER=   0.0                              TW INF.=   300.22
 2-(ROD NR.   9)   OUT. MASS  4.502977    OUT. TEMP.= 231.96   LAMBDA=   0.01766     REB=133119.  REW=108097.
                   Q LINER=   0.0                              TW INF.=   299.50
CHANNEL NR.    4
 1-(ROD NR.   8)   OUT. MASS  5.493715    OUT. TEMP.= 222.98   LAMBDA=   0.02085     REB= 58236.  REW= 45037.
                   Q LINER=   0.0                              TW INF.=   306.35     T  AT LINER=    209.80
CHANNEL NR.    5
 1-(ROD NR.   8)   OUT. MASS 20.228012    OUT. TEMP.= 219.31   LAMBDA=   0.01734     REB=105890.  REW= 83941.
                   Q LINER=   0.0                              TW INF.=   293.51     T  AT LINER=    207.11
                   MOUT(1)= 0.159743E+02  TOUT(1)= 0.218050E+03  AREA(1)= 0.101458E+01  LAMBDA(1)= 0.173711E-01
                   MOUT(2)= 0.425311E+01  TOUT(2)= 0.224066E+03  AREA(2)= 0.264932E+00  LAMBDA(2)= 0.177932E-01
 2-(ROD NR.   9)   OUT. MASS 20.370895    OUT. TEMP.= 219.03   LAMBDA=   0.01731     REB=106781.  REW= 84732.
```

Q LINER= 0.0 TW INF.= 292.85 T AT LINER= 226.87
MOUT(1)= 0.161102E+02 TOUT(1)= 0.217712E+03 AREA(1)= 0.101454E+01 LAMBDA(1)= 0.173293E-01
MOUT(2)= 0.426057E+01 TOUT(2)= 0.224024E+03 AREA(2)= 0.264966E+00 LAMBDA(2)= 0.177852E-01

AXIAL SECTION NR. 27 (SECTION LENGTH= 0.18373; HEIGHT= 145.31152)..

T 2= 226.1324 P 2= 40.593079 P AV= 40.593109 DELTAP=-0.00006423 LAMBDA=0.01754
(ITCORR= 5 ITGL= 6 ITGL1= 23 ITERM= 2 FREL= 1.00)

CHANNEL	OUTLET MASS	AVERAGE MASS	OUTLET TEMP.	AVERAGE TEMP.	PRESSURE LOSS
1	0.13650736E+02	0.13650665E+02	0.23227899E+03	0.23224599E+03	-0.64219377E-04
2	0.27213623E+02	0.27213577E+02	0.23102826E+03	0.23099680E+03	-0.64219494E-04
3	0.13642170E+02	0.13642105E+02	0.23206088E+03	0.23202835E+03	-0.64219043E-04
4	0.54929743E+01	0.54933453E+01	0.22302957E+03	0.22300342E+03	-0.64271284E-04
5	0.40599991E+02	0.40599808E+02	0.21921568E+03	0.21919156E+03	-0.64219785E-04

UAV(1)= 0.44320E+04 WCF(1)= -0.769E-03 MO(1)= 13.65 LAM(1)= 0.01766
UAV(2)= 0.44069E+04 WCF(2)= -0.520E-03 MO(2)= 27.22 LAM(2)= 0.01767
UAV(3)= 0.44273E+04 WCF(3)= -0.694E-03 MO(3)= 13.65 LAM(3)= 0.01767
UAV(4)= 0.34650E+04 WCF(4)= 0.404E-02 MO(4)= 5.49 LAM(4)= 0.02077
UAV(5)= 0.41193E+04 WCF(5)= -0.206E-02 MO(5)= 40.61 LAM(5)= 0.01734

1) WT(1, 3)= 0.412E-01
1) WT(2, 3)= 0.822E-01 2) WT(2, 5)= 0.538E-01
1) WT(3, 2)= 0.822E-01 2) WT(3, 1)= 0.412E-01
1) WT(4, 5)= 0.244E-01
1) WT(5, 4)= 0.244E-01 2) WT(5, 2)= 0.538E-01

CHANNEL	ROD	TEMPERATURE	HEAT POWER	ROD	TEMPERATURE	HEAT POWER	ROD	TEMPERATURE	HEAT POWER
1	2	0.29670E+03	0.44396E+01	1	0.29602E+03	0.44396E+01			
2	8	0.29532E+03	0.44396E+01	2	0.29608E+03	0.44396E+01	9	0.29476E+03	0.44396E+01
3	2	0.29655E+03	0.44396E+01	9	0.29576E+03	0.44396E+01			
4	8	0.29941E+03	0.44396E+01						
5	8	0.28896E+03	0.44396E+01	9	0.28836E+03	0.44396E+01			

CHANNEL NR. 1
1-(ROD NR. 2) OUT. MASS 9.144707 OUT. TEMP.= 232.27 LAMBDA= 0.01764 REB=134408. REW=110274.
Q LINER= 0.0 NU = 0.280152E+03 TW INF.= 296.70
TBSSCH(1)= 232.25 TWSSCH(1)= 296.70 TBSSCH(N)= 232.23 TWSSCH(N)= 296.70
2-(ROD NR. 1) OUT. MASS 4.505808 OUT. TEMP.= 232.31 LAMBDA= 0.01770 REB=132438. REW=108887.
Q LINER= 0.0 NU = 0.283320E+03 TW INF.= 296.02
TBSSCH(1)= 232.29 TWSSCH(1)= 296.02 TBSSCH(N)= 232.27 TWSSCH(N)= 296.02
CHANNEL NR. 2
1-(ROD NR. 8) OUT. MASS 9.106956 OUT. TEMP.= 230.67 LAMBDA= 0.01765 REB=134133. REW=109918.
Q LINER= 0.0 NU = 0.279844E+03 TW INF.= 295.32
TBSSCH(1)= 230.66 TWSSCH(1)= 295.32 TBSSCH(N)= 230.63 TWSSCH(N)= 295.32
2-(ROD NR. 2) OUT. MASS 9.126091 OUT. TEMP.= 231.54 LAMBDA= 0.01765 REB=134262. REW=110092.
Q LINER= 0.0 NU = 0.279977E+03 TW INF.= 296.08
TBSSCH(1)= 231.53 TWSSCH(1)= 296.08 TBSSCH(N)= 231.50 TWSSCH(N)= 296.08
3-(ROD NR. 9) OUT. MASS 8.980064 OUT. TEMP.= 230.87 LAMBDA= 0.01771 REB=132222. REW=108599.
Q LINER= 0.0 NU = 0.283089E+03 TW INF.= 294.76
TBSSCH(1)= 230.86 TWSSCH(1)= 294.76 TBSSCH(N)= 230.83 TWSSCH(N)= 294.76
CHANNEL NR. 3
1-(ROD NR. 2) OUT. MASS 9.138527 OUT. TEMP.= 232.08 LAMBDA= 0.01765 REB=134350. REW=110208.

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                      Q LINER=      0.0         NU = 0.280072E+03     TW INF.=      296.55
                      TBSSCH(1)= 232.07         TWSSCH(1)= 296.55     TBSSCH(N)= 232.04         TWSSCH(N)= 296.55
 2-(ROD NR.     9)    OUT. MASS  4.503416       OUT. TEMP.= 232.02    LAMBDA=    0.01770        REB=132416.  REW=108850.
                      Q LINER=      0.0         NU = 0.283312E+03     TW INF.=      295.76
                      TBSSCH(1)= 232.00         TWSSCH(1)= 295.76     TBSSCH(N)= 231.98         TWSSCH(N)= 295.76
CHANNEL NR.     4
 1-(ROD NR.     8)    OUT. MASS  5.492975       OUT. TEMP.= 223.03    LAMBDA=    0.02077        REB= 58782.  REW= 46421.
                      Q LINER=      0.0         NU = 0.130477E+03     TW INF.=      299.41      T   AT LINER=     210.23
                      TBSSCH(1)= 223.00         TWSSCH(1)= 299.41     TBSSCH(N)= 223.00         TWSSCH(N)= 299.41
                      TA= 215.06                TB= 235.59            TBC= 235.59
                      T1SSCH(1)= 235.59         T2SSCH(1)= 215.06     T1SSCH(N)= 235.59         T2SSCH(N)= 215.06
CHANNEL NR.     5
 1-(ROD NR.     8)    OUT. MASS 20.228073       OUT. TEMP.= 219.36    LAMBDA=    0.01735        REB=105737.  REW= 85031.
                      Q LINER=      0.0         NU = 0.215777E+03     TW INF.=      288.96      T   AT LINER=     207.42
                      TBSSCH(1)= 218.07         TWSSCH(1)= 288.96     TBSSCH(N)= 218.07         TWSSCH(N)= 288.96
                      TA= 211.07                TB= 227.45            TBC= 226.15
                      TW(1)= 289.11             TW(2)= 288.64
                      T1SSCH(1)= 227.45         T2SSCH(1)= 211.07     T1SSCH(N)= 227.45         T2SSCH(N)= 211.07
                      MOUT(1)= 0.159747E+02     TOUT(1)= 0.218095E+03 AREA(1)= 0.101457E+01     LAMBDA(1)= 0.173794E-01
                      MOUT(2)= 0.425327E+01     TOUT(2)= 0.224114E+03 AREA(2)= 0.264938E+00     LAMBDA(2)= 0.178211E-01
 2-(ROD NR.     9)    OUT. MASS 20.371201       OUT. TEMP.= 219.08    LAMBDA=    0.01732        REB=106524.  REW= 85733.
                      Q LINER=      0.0         NU = 0.216823E+03     TW INF.=      288.36      T   AT LINER=     207.16
                      TBSSCH(1)= 217.74         TWSSCH(1)= 288.36     TBSSCH(N)= 217.74         TWSSCH(N)= 288.36
                      TA= 210.78                TB= 227.05            TBC= 225.89
                      TW(1)= 288.29             TW(2)= 288.51
                      T1SSCH(1)= 227.05         T2SSCH(1)= 210.78     T1SSCH(N)= 227.05         T2SSCH(N)= 210.78
                      MOUT(1)= 0.161104E+02     TOUT(1)= 0.217759E+03 AREA(1)= 0.101455E+01     LAMBDA(1)= 0.173460E-01
                      MOUT(2)= 0.426074E+01     TOUT(2)= 0.224075E+03 AREA(2)= 0.264963E+00     LAMBDA(2)= 0.178147E-01
```

VARIABLES FOR THE WHOLE BUNDLE

A) INLET VALUES OF TEMPERATURE AND PRESSURE

SECTION NR.	HEIGHT (CM)	TEMPERATURE (C)	PRESSURE (KG/SQCM)	PRESSURE (BARS)
1	27.0822	189.89	40.65065	39.86467
2	32.6385	191.59	40.64882	39.86287
3	38.1948	193.29	40.64699	39.86107
4	43.7511	195.00	40.64516	39.85928
5	49.3074	196.70	40.64331	39.85747
6	54.8638	198.40	40.64146	39.85565
7	60.4201	200.10	40.63962	39.85385
8	62.6939	200.80	40.63885	39.85310
9	64.9678	201.49	40.62958	39.84399
10	67.2416	202.19	40.62881	39.84325
11	69.5154	202.89	40.62805	39.84250
12	74.0631	204.28	40.62653	39.84100
13	78.6108	205.67	40.62500	39.83951
14	83.1584	207.07	40.62346	39.83800
15	87.7061	208.46	40.62192	39.83649
16	93.0027	210.08	40.62012	39.83472
17	98.2993	211.70	40.61832	39.83296
18	103.5959	213.33	40.61652	39.83119
19	108.8925	214.95	40.61470	39.82941
20	114.1890	216.57	40.61288	39.82762
21	119.4856	218.19	40.61107	39.82585
22	124.7822	219.82	40.60924	39.82405
23	130.0788	221.44	40.60741	39.82225
24	135.3754	223.06	40.60558	39.82047
25	140.6720	224.68	40.60373	39.81865
26	142.9459	225.38	40.60294	39.81787
27	145.2197	226.08	40.59315	39.80827
28	145.4034	226.13	40.59308	39.80821

B) VALUES AVERAGED OVER AXIAL SECTIONS

SECTION NR.	DENSITY (G/CCM)	VISCOSITY(G/CM*SEC)	VELOCITY (M/SEC)	REYNOLDS NR.	FRICTION FACTOR
1	0.00409	0.0002672	39.314	119338.19	0.01756
2	0.00408	0.0002679	39.458	119050.06	0.01756
3	0.00406	0.0002685	39.602	118763.69	0.01755
4	0.00405	0.0002692	39.746	118479.12	0.01754
5	0.00403	0.0002698	39.890	118196.25	0.01754
6	0.00402	0.0002705	40.034	117915.00	0.01753
7	0.00401	0.0002709	40.135	117717.87	0.01752
8	0.00400	0.0002712	40.198	117603.56	0.01752
9	0.00399	0.0002714	40.262	117489.87	0.01751
10	0.00399	0.0002717	40.321	117376.44	0.01751
11	0.00398	0.0002721	40.409	117206.50	0.01750
12	0.00397	0.0002726	40.527	116981.06	0.01750
13	0.00396	0.0002731	40.645	116756.69	0.01750
14	0.00394	0.0002737	40.763	116533.37	0.01749
15	0.00393	0.0002742	40.891	116292.87	0.01749
16	0.00392	0.0002748	41.029	116035.50	0.01749
17	0.00391	0.0002754	41.166	115779.50	0.01749
18	0.00389	0.0002761	41.304	115524.94	0.01748
19	0.00388	0.0002767	41.441	115271.87	0.01748
20	0.00387	0.0002773	41.579	115020.00	0.01748

21	0.00385	0.0002779	41.716	114769.69	0.01749
22	0.00384	0.0002785	41.854	114520.69	0.01749
23	0.00383	0.0002791	41.992	114272.94	0.01749
24	0.00382	0.0002797	42.129	114026.62	0.01749
25	0.00381	0.0002801	42.228	113851.37	0.01749
26	0.00380	0.0002804	42.291	113746.37	0.01749
27	0.00380	0.0002805	42.328	113689.87	0.01754

TOTAL PRESSURE DROP=-0.057571 KG/SQCM

C) TOTAL MEAN VALUES AVERAGED IN PARTS WHERE UNDISTURBED FLOW IS SUPPOSED

```
TEMPERATURE      =   215.76 C
PRESSURE         =  40.6137 KG/SQCM   =  39.8285 BARS
DENSITY          =  0.00388 G/CCM
VISCOSITY        =0.0002767 G/CM*SEC
VELOCITY         =   41.441 M/SEC
REYNOLDS NR.     =115276.31
FRICTION FACTOR =  0.01749
```

COMPARISON OF INPUT TEMPERATURES WITH COMPUTED VALUES

	INPUT	COMPUTED
TWTIPA	284.79	284.24
TBTIPA	208.01	208.01
TBPIPA	195.45	195.29

COMPARISON WITH EXPERIMENTAL RESULTS
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1) PRESSURES (BARS)

```
 1)HEIGHT= 109.64131 CM     P EX.=  39.82713     P EX.-PE1=-0.0828552     P TH.=  39.82915     P TH.-PE1=-0.0808411
                            P TH.-P EX.= 0.0020142      (DP TH.-DP EX.)/DP EX. *100 = -2.431

 2)HEIGHT= 133.21532 CM     P EX.=  39.81885     P EX.-PE1=-0.0911407     P TH.=  39.82118     P TH.-PE1=-0.0888062
                            P TH.-P EX.= 0.0023346      (DP TH.-DP EX.)/DP EX. *100 = -2.562
```

ROUGH PART (HEATED OR UNHEATED)

C= 2.619426 CM
Z= 1.485490 CM
ZWC= C.C CM
VOL. DIAMETER= 1.844646 CM
PART LENGTH= 75.32185 CM
NUMBER OF SPACERS= 0

INLET CONDITIONS :
INLET AVERAGE TEMPERATURE= 226.13 C
INLET PRESSURE=40.5930786 KG/SQCM =39.8082123 BARS

HEIGHT OF ROUGHNESS= 0.0301287 CM

RESULTS OF HEATI

CHANNEL		ROD		ROD		RCD
1	1) JPIN(1, 1)=	2	2) JPIN(1, 2)=	1		
2	1) JPIN(2, 1)=	8	2) JPIN(2, 2)=	2	3) JPIN(2, 3)=	5
3	1) JPIN(3, 1)=	2	2) JPIN(3, 2)=	9		
4	1) JPIN(4, 1)=	8				
5	1) JPIN(5, 1)=	8	2) JPIN(5, 2)=	9		

TOTAL FLOW AREA= 74.87 SQCM
TOTAL EQUIVALENT DIAMETER= 2.0 CM
FLOW AREA OF SECTION= 6.24 SQCM

FLOW AREAS OF CHANNELS:
CENTRAL= 1.63
WALL= 2.55
CORNER= 0.83

EQUIVALENT DIAMETERS
CENTRAL= 2.3
WALL= 1.9
CORNER= 1.2

****

CHANNEL 1 : USED KAPPA= 114.799 (INPUT KAPPA= 114.799)
CHANNEL 2 : USED KAPPA= 114.799 (INPUT KAPPA= 114.799)
CHANNEL 3 : USED KAPPA= 114.799 (INPUT KAPPA= 114.799)
CHANNEL 4 : USED KAPPA= 92.840 (INPUT KAPPA= 92.840)
CHANNEL 5 : USED KAPPA= 88.730 (INPUT KAPPA= 88.730)

****

GEOMETRY OF CENTRAL CHANNELS (REFERENCE TO 1/6)

TOTAL FLOW AREA= 0.27 SQCM   TOTAL EQUIVALENT DIAMETER= 2.3 CM

SECTION NR.	FLOW AREA (SQCM)	EQUIV. DIAMETER(CM)
1	0.02268	1.878
2	0.02293	1.899
3	0.02343	1.940
4	0.02419	2.004
5	0.02524	2.090
6	0.02659	2.203
7	0.02828	2.343
8	0.03036	2.515
9	0.03287	2.723
10	0.03590	2.974

****

GEOMETRY OF ANGULAR CHANNELS (REFERENCE TO 1/2)

TOTAL FLOW AREA= 0.41 SQCM   TOTAL EQUIVALENT DIAMETER= 1.2 CM

SECTION NR.	FLOW AREA (SQCM)	EQUIV. DIAMETER(CM)
1	0.03555	1.127
2	0.03587	1.134
3	0.03652	1.146
4	0.03750	1.165
5	0.03885	1.190
6	0.04059	1.221
7	0.04276	1.259
8	0.04544	1.303
9	0.04867	1.354
10	0.05256	1.411

****

TOTAL LENGTH= 75.32 CM   NUMBER OF SECTIONS= 14   FREL= 1.0000

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AXIAL SECTION NR.    1      ( SECTION LENGTH=   5.38013; HEIGHT= 148.09338 )..........................................................
---------------------

T 2=  227.7806      P 2= 40.584320      P AV= 40.588695      DELTAP=-0.00874786      LAMBDA=0.08919
( ITCORR= 4       ITGL=     8     ITGL1=    24      ITERM=     2      FREL= 1.00 )

CHANNEL           OUTLET MASS          AVERAGE MASS        OUTLET TEMP.          AVERAGE TEMP.         PRESSURE LOSS

        1       0.13243714E+02       0.13447220E+02       0.23421809E+03       0.23329709E+03       -0.87441429E-02
        2       0.26424240E+02       0.26318924E+02       0.23285312E+03       0.23199046E+03       -0.87441504E-02
        3       0.13236246E+02       0.13439201E+02       0.23393468E+03       0.23304680E+03       -0.87440647E-02
        4       0.58368950E+01       0.56649342E+01       0.22423528E+03       0.22372682E+03       -0.87424479E-02
        5       0.41858383E+02       0.41229187E+02       0.22078230E+03       0.22007530E+03       -0.87442920E-02

UAV(  1)=  0.43921E+04             WCF(  1)=    0.757E-01             MO(  1)=      13.25              LAM(  1)=    0.12159
UAV(  2)=  0.43686E+04             WCF(  2)=    0.147E+00             MO(  2)=      26.43              LAM(  2)=    0.12159
UAV(  3)=  0.43874E+04             WCF(  3)=    0.754E-01             MO(  3)=      13.24              LAM(  3)=    0.12158
UAV(  4)=  0.35823E+04             WCF(  4)=  -0.639E-01              MO(  4)=       5.84              LAM(  4)=    0.05841
UAV(  5)=  0.41973E+04             WCF(  5)=  -0.234E+00              MO(  5)=      41.88              LAM(  5)=    0.06353

 1) WT(    1,    3)=    0.106E+00
 1) WT(    2,    3)=    0.213E+00       2) WT(    2,    5)=    0.119E+00
 1) WT(    3,    2)=    0.213E+00       2) WT(    3,    1)=    0.106E+00
 1) WT(    4,    5)=    0.462E-01
 1) WT(    5,    4)=    0.462E-01       2) WT(    5,    2)=    0.119E+00

CHANNEL  ROD      TEMPERATURE      HEAT POWER  ROD      TEMPERATURE       HEAT POWER  ROD      TEMPERATURE       HEAT POWER

        1    2      0.26623E+03     0.13006E+03     1      0.26656E+03     0.13006E+03
        2    8      0.26472E+03     0.13006E+03     2      0.26547E+03     0.13006E+03     9      0.26516E+03      0.13006E+03
        3    2      0.26604E+03     0.13006E+03     9      0.26625E+03     0.13006E+03
        4    8      0.26473E+03     0.13006E+03
        5    8      0.25833E+03     0.13006E+03     9      0.25785E+03     0.13006E+03

CHANNEL NR.     1
 1-(ROD NR.    2)        OUT. MASS  8.849361       OUT. TEMP.= 234.34       LAMBDA=    0.12157        REB=131590.  REW=118608.
                         Q LINER=     0.0          BIOT=    0.07767         TW INF.=     266.23
                         HB+ = 0.21869E+03         HW+ = 0.19726E+03        R( H+ )= 0.34701E+01     G( HW+ )= 0.15485E+02
                         NU = 0.526450E+03         TW/TB=   0.10650E+01     TW/TE=  0.11649E+01     Y/RH=  0.15035E+02
                         G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.162221E+02
                         TBSSCH(1)= 233.60         TWSSCH(1)= 268.06        TBSSCH(N)= 232.89        TWSSCH(N)= 263.45
 2-(ROD NR.    1)        OUT. MASS  4.393618       OUT. TEMP.= 234.38       LAMBDA=    0.12157        REB=130151.  REW=117209.
                         Q LINER=     0.0          BIOT=    0.07697         TW INF.=     266.56
                         HB+ = 0.21630E+03         HW+ = 0.19493E+03        R( H+ )= 0.34702E+01     G( HW+ )= 0.15439E+02
                         NU = 0.521895E+03         TW/TB=   0.10656E+01     TW/TE=  0.11656E+01     Y/RH=  0.15035E+02
                         G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.161694E+02
                         TBSSCH(1)= 233.66         TWSSCH(1)= 268.45        TBSSCH(N)= 232.93        TWSSCH(N)= 263.72
CHANNEL NR.     2
 1-(ROD NR.    8)        OUT. MASS  8.822838       OUT. TEMP.= 232.70       LAMBDA=    0.12157        REB=131393.  REW=118353.
                         Q LINER=     0.0          BIOT=    0.07752         TW INF.=     264.72
                         HB+ = 0.21836E+03         HW+ = 0.19684E+03        R( H+ )= 0.34701E+01     G( HW+ )= 0.15479E+02
                         NU = 0.525820E+03         TW/TB=   0.10655E+01     TW/TE=  0.11616E+01     Y/RH=  0.15035E+02
                         G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.162125E+02
                         TBSSCH(1)= 231.99         TWSSCH(1)= 266.58        TBSSCH(N)= 231.28        TWSSCH(N)= 261.92
 2-(ROD NR.    2)        OUT. MASS  8.833229       OUT. TEMP.= 233.43       LAMBDA=    0.12157        REB=131472.  REW=118461.
                         Q LINER=     0.0          BIOT=    0.07758         TW INF.=     265.47
                         HB+ = 0.21850E+03         HW+ = 0.19702E+03        R( H+ )= 0.34701E+01     G( HW+ )= 0.15482E+02
                         NU = 0.526073E+03         TW/TB=   0.10653E+01     TW/TE=  0.11632E+01     Y/RH=  0.15035E+02
                         G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.162166E+02
                         TBSSCH(1)= 232.78         TWSSCH(1)= 267.30        TBSSCH(N)= 232.09        TWSSCH(N)= 262.69
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 3-(ROD NR.    9)   OUT. MASS  8.767647      OUT. TEMP.= 232.83      LAMBDA=    C.12157        REB=13003C.  REW=117033.
                    Q LINER=     0.0           BIOT=    C.07697          TW INF.=     265.16
                    HB+ = 0.21610E+03          HW+ = C.19464E+03        R( H+ )= 0.34702E+01     G( HW+ )= 0.15435E+02
                    NU = 0.521502E+03          TW/TB=  C.1066CE+01      TW/TE=  C.11625E+01      Y/RH=  0.15035E+02
                    G( HW+ )/( PR**0.44 * (TW/TB)**C.50 ) * ( 0.010*Y/RH)** 0.053 = 0.161628E+02
                    TBSSCH(1)= 232.15          TWSSCH(1)= 267.06        TBSSCH(N)= 231.44        TWSSCH(N)= 262.29
CHANNEL NR.    3
 1-(ROD NR.    2)   OUT. MASS  8.842247      OUT. TEMP.= 234.09      LAMBDA=    0.12157        REB=131526.  REW=118537.
                    Q LINER=     0.0           BICT=    0.07763          TW INF.=     266.04
                    HB+ = 0.21860E+03          HW+ = C.19715E+03        R( H+ )= 0.34701E+01     G( HW+ )= 0.15484E+02
                    NU = 0.526246E+03          TW/TB=  C.10651E+01      TW/TE=  0.11644E+01      Y/RH=  0.15035E+02
                    G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.162197E+C2
                    TBSSCH(1)= 233.36          TWSSCH(1)= 267.84        TBSSCH(N)= 232.66        TWSSCH(N)= 263.24
 2-(ROD NR.    9)   OUT. MASS  4.393766      OUT. TEMP.= 234.C2      LAMBDA=    0.12157        REB=130173.  REW=117218.
                    Q LINER=     0.0           BIOT=    C.C7697          TW INF.=     266.25
                    HB+ = 0.21633E+03          HW+ = 0.19494E+03        R( H+ )= 0.34702E+01     G( HW+ )= 0.15440E+02
                    NU = 0.521963E+03          TW/TB=  0.10657E+01      TW/TE=  C.11649E+01      Y/RH=  0.15035E+02
                    G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.161696E+C2
                    TBSSCH(1)= 233.35          TWSSCH(1)= 268.16        TBSSCH(N)= 232.63        TWSSCH(N)= 263.42
CHANNEL NR.    4
 1-(ROD NR.    8)   OUT. MASS  5.836893      OUT. TEMP.= 224.38      LAMBDA=    0.05841        REB= 60449.  REW= 53045.
                    Q LINER=     0.0           BICT=    0.06250          TW INF.=     264.73     T  AT LINER=     219.20
                    HB+ = 0.17419E+03          HW+ = C.15373E+03        R( H+ )= 0.34528E+01     G( HW+ )= 0.14319E+02
                    NU = 0.234645E+03          TW/TB=  C.10825E+01      TW/TE=  0.11616E+01      Y/RH=  0.21161E+02
                    G( HW+ )/( PR**0.44 * (TW/TB)**C.50 ) * ( 0.010*Y/RH)** 0.053 = 0.151508E+C2
                    TBSSCH(1)= 223.85          TWSSCH(1)= 267.02        TBSSCH(N)= 223.41        TWSSCH(N)= 261.15
                    TA= 219.92                 TB= 225.39               TBC= 225.39
                    T1SSCH(1)= 225.46          T2SSCH(1)= 219.57        T1SSCH(N)= 224.78        T2SSCH(N)= 220.C4
CHANNEL NR.    5
 1-(ROD NR.    8)   OUT. MASS 20.856400      OUT. TEMP.= 221.05      LAMBDA=    0.06353        REB=107026.  REW= 94677.
                    Q LINER=     0.0           BIOT=    C.06765          TW INF.=     258.33     T  AT LINER=     215.93
                    HB+ = 0.19736E+03          HW+ = C.17556E+03        R( H+ )= 0.33964E+01     G( HW+ )= 0.14796E+02
                    NU = 0.380051E+03          TW/TB=  C.10772E+01      TW/TE=  0.11478E+01      Y/RH=  0.21626E+C2
                    G( HW+ )/( PR**0.44 * (TW/TB)**C.50 ) * ( 0.010*Y/RH)** 0.053 = 0.157122E+C2
                    TBSSCH(1)= 220.55          TWSSCH(1)= 266.66        TBSSCH(N)= 219.61        TWSSCH(N)= 251.27
                    TA= 216.58                 TB= 221.59               TBC= 221.11
                    TW(1)= 259.32              TW(2)= 257.19
                    T1SSCH(1)= 222.36          T2SSCH(1)= 215.96        T1SSCH(N)= 220.83        T2SSCH(N)= 217.27
                    MOUT(1)= 0.133952E+02      TOUT(1)= 0.220706E+03  AREA(1)= C.817941E+00    LAMBDA(1)= 0.510209E-01
                    MOUT(2)= 0.746114E+01      TOUT(2)= 0.221677E+03  AREA(2)= 0.459501E+00    LAMBDA(2)= 0.103140E+00
 2-(ROD NR.    9)   OUT. MASS 21.001236      OUT. TEMP.= 220.77      LAMBDA=    0.06351        REB=107817.  REW= 95429.
                    Q LINER=     0.0           BICT=    0.06804          TW INF.=     257.85     T  AT LINER=     215.66
                    HB+ = 0.19880E+03          HW+ = 0.17694E+03        R( H+ )= 0.33963E+01     G( HW+ )= 0.14826E+02
                    NU = 0.382201E+03          TW/TB=  0.10769E+01      TW/TE=  C.11468E+01      Y/RH=  0.21626E+02
                    G( HW+ )/( PR**0.44 * (TW/TB)**C.50 ) * ( 0.010*Y/RH)** 0.053 = 0.157460E+C2
                    TBSSCH(1)= 220.22          TWSSCH(1)= 265.94        TBSSCH(N)= 219.30        TWSSCH(N)= 250.83
                    TA= 216.31                 TB= 221.28               TBC= 220.82
                    TW(1)= 258.79              TW(2)= 256.77
                    T1SSCH(1)= 222.01          T2SSCH(1)= 215.67        T1SSCH(N)= 220.52        T2SSCH(N)= 216.98
                    MOUT(1)= 0.135049E+02      TOUT(1)= 0.220395E+03  AREA(1)= 0.817929E+00    LAMBDA(1)= 0.505907E-01
                    MOUT(2)= 0.749638E+01      TOUT(2)= 0.221456E+03  AREA(2)= 0.459513E+00    LAMBDA(2)= 0.103139E+00
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AXIAL SECTION NR.  14      ( SECTION LENGTH=    5.38013; HEIGHT= 218.03503 )...................................................
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T 2=  249.2070      P 2= 40.469910      P AV= 40.474350      DELTAP=-0.00888595      LAMBDA=0.08670
( ITCORR= 4      ITGL=     6      ITGL1=    18      ITERM=     2      FREL= 1.00 )

CHANNEL          OUTLET MASS        AVERAGE MASS        OUTLET TEMP.        AVERAGE TEMP.       PRESSURE LOSS

      1        0.11822899E+02     0.11833458E+02     0.26228198E+03     0.26121167E+03     -0.88857003E-02
      2        0.24099304E+02     0.24110809E+02     0.25755200E+03     0.25663940E+03     -0.88858865E-02
      3        0.11868471E+02     0.11877365E+02     0.26067041E+03     0.25966919E+03     -0.88852011E-02
      4        0.66624165E+01     0.66592607E+01     0.24093082E+03     0.24030748E+03     -0.88855289E-02
      5        0.46146194E+02     0.46118378E+02     0.23973051E+03     0.23903751E+03     -0.88867657E-02

UAV(  1)=  0.40873E+04          WCF(  1)=   0.393E-02          MO(  1)=     11.82          LAM(  1)=    0.12157
UAV(  2)=  0.41288E+04          WCF(  2)=   0.428E-02          MO(  2)=     24.10          LAM(  2)=    0.12157
UAV(  3)=  0.40908E+04          WCF(  3)=   0.331E-02          MO(  3)=     11.87          LAM(  3)=    0.12157
UAV(  4)=  0.43626E+04          WCF(  4)=  -0.117E-02          MO(  4)=      6.66          LAM(  4)=    0.05783
UAV(  5)=  0.48875E+04          WCF(  5)=  -0.103E-01          MO(  5)=     46.14          LAM(  5)=    0.06321

 1) WT(   1,    3)=    0.938E-01
 1) WT(   2,    3)=    0.189E+00       2) WT(   2,    5)=    0.120E+00
 1) WT(   3,    2)=    0.189E+00       2) WT(   3,    1)=    0.938E-01
 1) WT(   4,    5)=    0.521E-01
 1) WT(   5,    4)=    0.521E-01       2) WT(   5,    2)=    0.120E+00

CHANNEL  ROD     TEMPERATURE      HEAT POWER  ROD     TEMPERATURE      HEAT POWER  ROD     TEMPERATURE      HEAT POWER

      1    2     0.29744E+03     0.13006E+03    1     0.29760E+03     0.13006E+03
      2    8     0.29167E+03     0.13006E+03    2     0.29360E+03     0.13006E+03    9     0.29207E+03     0.13006E+03
      3    2     0.29603E+03     0.13006E+03    9     0.29554E+03     0.13006E+03
      4    8     0.27616E+03     0.13006E+03
      5    8     0.27432E+03     0.13006E+03    9     0.27403E+03     0.13006E+03

CHANNEL NR.     1
 1-(ROD NR.    2)       OUT. MASS  7.883114        OUT. TEMP.= 262.24      LAMBDA=    0.12155        REB=111386.  REW= 99952.
                        Q LINER=      0.0          BICT=    0.06848        TW INF.=     297.44
                        HB+ = 0.18498E+03          HW+ = 0.16612E+03       R( H+ )= 0.34708E+01     G( HW+ )= 0.14793E+02
                        NU = 0.461486E+03          TW/TB=  0.10679E+01     TW/TE=  0.12323E+01      Y/RH=  0.15035E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.154761E+02
                        TBSSCH(1)= 261.61          TWSSCH(1)= 300.05       TBSSCH(N)= 260.76        TWSSCH(N)= 293.96
 2-(ROD NR.    1)       OUT. MASS  3.939476        OUT. TEMP.= 262.40      LAMBDA=    0.12155        REB=111310.  REW= 99883.
                        Q LINER=      0.0          BICT=    0.06844        TW INF.=     297.60
                        HB+ = 0.18485E+03          HW+ = 0.16600E+03       R( H+ )= 0.34708E+01     G( HW+ )= 0.14790E+02
                        NU = 0.461239E+03          TW/TB=  0.10679E+01     TW/TE=  0.12326E+01      Y/RH=  0.15035E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.154731E+02
                        TBSSCH(1)= 261.76          TWSSCH(1)= 300.23       TBSSCH(N)= 260.91        TWSSCH(N)= 294.12
CHANNEL NR.     2
 1-(ROD NR.    8)       OUT. MASS  8.069176        OUT. TEMP.= 256.90      LAMBDA=    0.12156        REB=114696.  REW=102999.
                        Q LINER=      0.0          BICT=    0.07001        TW INF.=     291.67
                        HB+ = 0.19050E+03          HW+ = 0.17120E+03       R( H+ )= 0.34707E+01     G( HW+ )= 0.14912E+02
                        NU = 0.472302E+03          TW/TB=  0.10674E+01     TW/TE=  0.12198E+01      Y/RH=  0.15035E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.156043E+02
                        TBSSCH(1)= 256.39          TWSSCH(1)= 294.11       TBSSCH(N)= 255.62        TWSSCH(N)= 288.34
 2-(ROD NR.    2)       OUT. MASS  7.971920        OUT. TEMP.= 258.54      LAMBDA=    0.12155        REB=113104.  REW=101505.
                        Q LINER=      0.0          BIOT=    0.06925        TW INF.=     293.60
                        HB+ = 0.18784E+03          HW+ = 0.16870E+03       R( H+ )= 0.34708E+01     G( HW+ )= 0.14855E+02
                        NU = 0.467104E+03          TW/TB=  0.10678E+01     TW/TE=  0.12240E+01      Y/RH=  0.15035E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.155417E+02
                        TBSSCH(1)= 258.00          TWSSCH(1)= 296.12       TBSSCH(N)= 257.22        TWSSCH(N)= 290.19
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3-(ROD NR.   9)    OUT. MASS  8.057472    OUT. TEMP.= 257.28     LAMBDA=   0.12156       REB=114482.  REW=102803.
                   Q LINER=     0.0       BIOT=    0.06991       TW INF.=     292.07
                   HB+ = 0.19014E+03      HW+ = 0.17087E+03      R( H+ )= 0.34707E+01    G( HW+ )= 0.14904E+02
                   NU = 0.471604E+03      TW/TB=  0.10674E+01    TW/TE=  0.12207E+01     Y/RH=  0.15035E+02
                   G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.155961E+02
                   TBSSCH(1)= 256.76      TWSSCH(1)= 294.53      TBSSCH(N)= 255.99       TWSSCH(N)= 288.74
CHANNEL NR.    3
 1-(ROD NR.   2)   OUT. MASS  7.906517    OUT. TEMP.= 260.84     LAMBDA=   0.12155       REB=111891.  REW=100399.
                   Q LINER=     0.0       BIOT=    0.06870       TW INF.=     296.03
                   HB+ = 0.18586E+03      HW+ = 0.16699E+03      R( H+ )= 0.34708E+01    G( HW+ )= 0.14812E+02
                   NU = 0.463138E+03      TW/TB=  0.10679E+01    TW/TE=  0.12292E+01     Y/RH=  0.15035E+02
                   G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.154958E+02
                   TBSSCH(1)= 260.14      TWSSCH(1)= 298.50      TBSSCH(N)= 259.35       TWSSCH(N)= 292.49
 2-(ROD NR.   9)   OUT. MASS  3.961634    OUT. TEMP.= 260.38     LAMBDA=   0.12155       REB=112179.  REW=100664.
                   Q LINER=     0.0       BIOT=    0.06883       TW INF.=     295.54
                   HB+ = 0.18628E+03      HW+ = 0.16729E+03      R( H+ )= 0.34708E+01    G( HW+ )= 0.14821E+02
                   NU = 0.464080E+03      TW/TB=  0.10679E+01    TW/TE=  0.12282E+01     Y/RH=  0.15035E+02
                   G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.155059E+02
                   TBSSCH(1)= 259.87      TWSSCH(1)= 298.17      TBSSCH(N)= 259.04       TWSSCH(N)= 292.13
CHANNEL NR.    4
 1-(ROD NR.   8)   OUT. MASS  6.662415    OUT. TEMP.= 240.94     LAMBDA=   0.05783       REB= 69536.  REW= 62214.
                   Q LINER=     0.0       BIOT=    0.07069       TW INF.=     276.16      T  AT LINER=     236.46
                   HB+ = 0.20053E+03      HW+ = 0.18027E+03      R( H+ )= 0.34519E+01    G( HW+ )= 0.14870E+02
                   NU = 0.262574E+03      TW/TB=  0.10698E+01    TW/TE=  0.11863E+01     Y/RH=  0.21161E+02
                   G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.158265E+02
                   TBSSCH(1)= 240.49      TWSSCH(1)= 277.68      TBSSCH(N)= 240.10       TWSSCH(N)= 273.73
                   TA= 237.07             TB= 241.73             TBC= 241.73
                   T1SSCH(1)= 241.84      T2SSCH(1)= 236.92      T1SSCH(N)= 241.30       T2SSCH(N)= 237.18
CHANNEL NR.    5
 1-(ROD NR.   8)   OUT. MASS 23.018295    OUT. TEMP.= 239.85     LAMBDA=   0.06321       REB=116912.  REW=104793.
                   Q LINER=     0.0       BIOT=    0.07220       TW INF.=     274.32      T  AT LINER=     234.06
                   HB+ = 0.21505E+03      HW+ = 0.19397E+03      R( H+ )= 0.33959E+01    G( HW+ )= 0.15145E+02
                   NU = 0.401736E+03      TW/TB=  0.10686E+01    TW/TE=  0.11823E+01     Y/RH=  0.21626E+02
                   G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.161476E+02
                   TBSSCH(1)= 238.18      TWSSCH(1)= 277.83      TBSSCH(N)= 237.32       TWSSCH(N)= 266.71
                   TA= 234.64             TB= 239.04             TBC= 240.33
                   TW(1)= 272.92          TW(2)= 275.93
                   T1SSCH(1)= 239.69      T2SSCH(1)= 234.35      T1SSCH(N)= 238.45       T2SSCH(N)= 235.18
                   MOUT(1)= 0.149942E+02  TOUT(1)= 0.238363E+03  AREA(1)= 0.818463E+00   LAMBDA(1)= 0.506324E-01
                   MOUT(2)= 0.802413E+01  TOUT(2)= 0.242635E+03  AREA(2)= 0.458979E+00   LAMBDA(2)= 0.103204E+00
 2-(ROD NR.   9)   OUT. MASS 23.126938    OUT. TEMP.= 239.63     LAMBDA=   0.06319       REB=117498.  REW=105335.
                   Q LINER=     0.0       BIOT=    0.07236       TW INF.=     274.03      T  AT LINER=     233.76
                   HB+ = 0.21600E+03      HW+ = 0.19488E+03      R( H+ )= 0.33958E+01    G( HW+ )= 0.15164E+02
                   NU = 0.402629E+03      TW/TB=  0.10685E+01    TW/TE=  0.11817E+01     Y/RH=  0.21626E+02
                   G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.161683E+02
                   TBSSCH(1)= 237.83      TWSSCH(1)= 277.19      TBSSCH(N)= 236.98       TWSSCH(N)= 266.25
                   TA= 234.33             TB= 238.71             TBC= 240.13
                   TW(1)= 272.40          TW(2)= 275.90
                   T1SSCH(1)= 239.33      T2SSCH(1)= 234.04      T1SSCH(N)= 238.10       T2SSCH(N)= 234.85
                   MOUT(1)= 0.150976E+02  TOUT(1)= 0.238040E+03  AREA(1)= 0.818448E+00   LAMBDA(1)= 0.506056E-01
                   MOUT(2)= 0.802938E+01  TOUT(2)= 0.242628E+03  AREA(2)= 0.458994E+00   LAMBDA(2)= 0.103203E+00
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VARIABLES FOR THE WHOLE BUNDLE

A) INLET VALUES OF TEMPERATURE AND PRESSURE

SECTION NR.	HEIGHT (CM)	TEMPERATURE (C)	PRESSURE (KG/SQCM)	PRESSURE (BARS)
1	145.4034	226.13	40.59308	39.80821
2	150.7836	227.78	40.58432	39.79962
3	156.1637	229.43	40.57555	39.79102
4	161.5438	231.08	40.56677	39.78241
5	166.9239	232.73	40.55800	39.77380
6	172.3041	234.37	40.54924	39.76521
7	177.6842	236.02	40.54048	39.75662
8	183.0643	237.67	40.53171	39.74802
9	188.4444	239.32	40.52293	39.73941
10	193.8246	240.97	40.51414	39.73080
11	199.2047	242.61	40.50534	39.72217
12	204.5848	244.26	40.49652	39.71352
13	209.9650	245.91	40.48767	39.70483
14	215.3451	247.56	40.47881	39.69614
15	220.7252	249.21	40.46991	39.68742

B) VALUES AVERAGED OVER AXIAL SECTIONS

SECTION NR.	DENSITY (G/CCM)	VISCOSITY(G/CM*SEC)	VELOCITY (M/SEC)	REYNOLDS NR.	FRICTION FACTOR
1	0.00379	0.0002808	42.523	113251.06	0.08919
2	0.00378	0.0002814	42.671	113005.31	0.08903
3	0.00377	0.0002820	42.818	112761.00	0.08872
4	0.00375	0.0002827	42.966	112518.00	0.08837
5	0.00374	0.0002833	43.114	112276.31	0.08803
6	0.00373	0.0002839	43.261	112035.94	0.08773
7	0.00371	0.0002845	43.409	111796.81	0.08748
8	0.00370	0.0002851	43.557	111559.06	0.08728
9	0.00369	0.0002857	43.705	111322.50	0.08712
10	0.00368	0.0002863	43.853	111087.19	0.08699
11	0.00366	0.0002869	44.001	110853.19	0.08689
12	0.00365	0.0002875	44.150	110620.37	0.08681
13	0.00364	0.0002881	44.298	110388.75	0.08675
14	0.00363	0.0002887	44.446	110158.44	0.08670

TOTAL PRESSURE DROP=-0.123169 KG/SQCM

C) TOTAL MEAN VALUES AVERAGED IN PARTS WHERE UNDISTURBED FLOW IS SUPPOSED

```
TEMPERATURE     =   240.97 C
PRESSURE        =  40.5141 KG/SQCM   =   39.7307 BARS
DENSITY         =  0.00368 G/CCM
VISCOSITY       =0.0002860 G/CM*SEC
VELOCITY        =   43.779 M/SEC
REYNOLDS NR.    =111207.87
FRICTION FACTOR =  0.08713
```

```
CHANNEL NR.     1
 1-(ROD NR.     2)      HB+ = 0.19027E+03          HW+ = 0.17072E+03         R( H+ )= 0.34707E+01     G( HW+ )= 0.14909E+02
                        NU = 0.495272E-03          TW/TB=  0.10686E+01       TW/TE=  0.12105E+01      Y/RH=  0.15035E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.155923E+02
CHANNEL NR.     1
 2-(ROD NR.     1)      HB+ = 0.19018E+03          HW+ = 0.17064E+03         R( H+ )= 0.34708E+01     G( HW+ )= 0.14907E+02
                        NU = 0.495439E-03          TW/TB=  0.10686E+01       TW/TE=  0.12107E+01      Y/RH=  0.15035E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.155904E+02
CHANNEL NR.     2
 1-(ROD NR.     8)      HB+ = 0.19425E+03          HW+ = 0.17437E+03         R( H+ )= 0.34706E+01     G( HW+ )= 0.14993E+02
                        NU = 0.487359E-03          TW/TB=  0.10682E+01       TW/TE=  0.12016E+01      Y/RH=  0.15035E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.156831E+02
CHANNEL NR.     2
 2-(ROD NR.     2)      HB+ = 0.19213E+03          HW+ = 0.17239E+03         R( H+ )= 0.34707E+01     G( HW+ )= 0.14948E+02
                        NU = 0.491941E-03          TW/TB=  0.10685E+01       TW/TE=  0.12049E+01      Y/RH=  0.15035E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.156340E+02
CHANNEL NR.     2
 3-(ROD NR.     9)      HB+ = 0.19402E+03          HW+ = 0.17416E+03         R( H+ )= 0.34707E+01     G( HW+ )= 0.14988E+02
                        NU = 0.487787E-03          TW/TB=  0.10682E+01       TW/TE=  0.12022E+01      Y/RH=  0.15035E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.156779E+02
CHANNEL NR.     3
 1-(ROD NR.     2)      HB+ = 0.19082E+03          HW+ = 0.17120E+03         R( H+ )= 0.34707E+01     G( HW+ )= 0.14920E+02
                        NU = 0.494402E-03          TW/TB=  0.10686E+01       TW/TE=  0.12086E+01      Y/RH=  0.15035E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.156044E+02
CHANNEL NR.     3
 2-(ROD NR.     9)      HB+ = 0.19102E+03          HW+ = 0.17139E+03         R( H+ )= 0.34707E+01     G( HW+ )= 0.14925E+02
                        NU = 0.494002E-03          TW/TB=  0.10686E+01       TW/TE=  0.12079E+01      Y/RH=  0.15035E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.156090E+02
CHANNEL NR.     4
 1-(ROD NR.     8)      HB+ = 0.19978E+03          HW+ = 0.17919E+03         R( H+ )= 0.34518E+01     G( HW+ )= 0.14856E+02
                        NU = 0.476079E-03          TW/TB=  0.10713E+01       TW/TE=  0.11749E+01      Y/RH=  0.21161E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.158006E+02
CHANNEL NR.     5
 1-(ROD NR.     8)      HB+ = 0.21433E+03          HW+ = 0.19287E+03         R( H+ )= 0.33959E+01     G( HW+ )= 0.15132E+02
                        NU = 0.412683E-03          TW/TB=  0.10700E+01       TW/TE=  0.11694E+01      Y/RH=  0.21626E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.161223E+02
CHANNEL NR.     5
 2-(ROD NR.     9)      HB+ = 0.21533E+03          HW+ = 0.19382E+03         R( H+ )= 0.33958E+01     G( HW+ )= 0.15151E+02
                        NU = 0.410887E-03          TW/TB=  0.10699E+01       TW/TE=  0.11687E+01      Y/RH=  0.21626E+02
                        G( HW+ )/( PR**0.44 * (TW/TB)**0.50 ) * ( 0.010*Y/RH)** 0.053 = 0.161441E+02


COMPARISON OF INPUT TEMPERATURES WITH COMPUTED VALUES

             INPUT     COMPUTED
TWTIPA      277.14      277.26
TBTIPA      237.67      237.67
TBPIPA      226.25      225.71


COMPARISON WITH EXPERIMENTAL RESULTS
------------------------------------


1) PRESSURES (BARS)

 3)HEIGHT= 166.33174 CM      P EX.=  39.76389     P EX.-PE1=-0.1461029     P TH.=  39.77475     P TH.-PE1=-0.1352386
                             P TH.-P EX.= 0.0108643      (DP TH.-DP EX.)/DP EX. *100 = -7.436

 4)HEIGHT= 189.91974 CM      P EX.=  39.72250     P EX.-PE1=-0.1874847     P TH.=  39.73705     P TH.-PE1=-0.1729431
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```
                       P TH.-P EX.= 0.0145416      (DP TH.-DP EX.)/DP EX. *100 = -7.756

5)HEIGHT= 213.50775 CM    P EX.=  39.68298     P EX.-PE1=-0.2270050     P TH.=  39.69910     P TH.-PE1=-0.2108917
                          P TH.-P EX.= 0.0161133     (DP TH.-DP EX.)/DP EX. *100 = -7.098
```

SECOND HEATED SMOOTH PART

```
C=  2.619970 CM
Z=  1.485062 CM
ZWC=  0.0       CM
VOL. DIAMETER=  1.839642 CM
PART LENGTH=   4.22213 CM
NUMBER OF SPACERS=  1

INLET CONDITIONS :
INLET AVERAGE TEMPERATURE= 249.21 C
INLET PRESSURE=40.4699097 KG/SQCM     =39.6874237 BARS



SPACERS (DISTANCES ARE EVALUATED FROM THE BUNDLE ENTRANCE) :
WIDTH=  0.803056 CM
DIST( 3)=   223.646 CM



RESULTS OF HEATI


   CHANNEL                          ROD                              ROD                              ROD

       1    1) JPIN(     1, 1)=     2    2) JPIN(      1, 2)=     1
       2    1) JPIN(     2, 1)=     8    2) JPIN(      2, 2)=     2    3) JPIN(     2, 3)=     9
       3    1) JPIN(     3, 1)=     2    2) JPIN(      3, 2)=     9
       4    1) JPIN(     4, 1)=     8
       5    1) JPIN(     5, 1)=     8    2) JPIN(      5, 2)=     9


TOTAL FLOW AREA=       75.16 SQCM
TOTAL EQUIVALENT DIAMETER=        2.0 CM
FLOW AREA OF SECTION=       6.26 SQCM

FLOW AREAS OF CHANNELS:
CENTRAL=       1.64
WALL=      2.56
CORNER=      0.83

EQUIVALENT DIAMETERS
CENTRAL=       2.3
WALL=      1.9
CORNER=      1.2


****************************************************************************************************
CHANNEL    1 : USED KAPPA=   118.563 (INPUT KAPPA=    118.563)
CHANNEL    2 : USED KAPPA=   118.563 (INPUT KAPPA=    118.563)
CHANNEL    3 : USED KAPPA=   118.563 (INPUT KAPPA=    118.563)
CHANNEL    4 : USED KAPPA=    92.792 (INPUT KAPPA=     92.792)
CHANNEL    5 : USED KAPPA=    91.924 (INPUT KAPPA=     91.924)

SPACER NR.    3     EPSILON TOT.= 0.2012520
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```
CHANNEL NR.    1     EPSILON= 0.1937999
SUBCHANNELS:
ROD NR.    2) EPSILON(    1, 1)= 0.1893000
ROD NR.    1) EPSILON(    1, 2)= 0.2028000

CHANNEL NR.    2     EPSILON= 0.1937999
SUBCHANNELS:
ROD NR.    8) EPSILON(    2, 1)= 0.1893000
ROD NR.    2) EPSILON(    2, 2)= 0.1893000
ROD NR.    9) EPSILON(    2, 3)= 0.2028000

CHANNEL NR.    3     EPSILON= 0.1937999
SUBCHANNELS:
ROD NR.    2) EPSILON(    3, 1)= 0.1893000
ROD NR.    9) EPSILON(    3, 2)= 0.2028000

CHANNEL NR.    4     EPSILON= 0.2293699
SUBCHANNELS:
ROD NR.    8) EPSILON(    4, 1)= 0.2293700

CHANNEL NR.    5     EPSILON= 0.2062559
SUBCHANNELS:
ROD NR.    8) EPSILON(    5, 1)= 0.2062560
ROD NR.    9) EPSILON(    5, 2)= 0.2062560
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****

GEOMETRY OF CENTRAL CHANNELS (REFERENCE TO 1/6)

TOTAL FLOW AREA= 0.27 SQCM   TOTAL EQUIVALENT DIAMETER= 2.3 CM

SECTION NR.	FLOW AREA (SQCM)	EQUIV. DIAMETER(CM)
1	0.02282	1.895
2	0.02307	1.916
3	0.02357	1.957
4	0.02433	2.021
5	0.02538	2.108
6	0.02673	2.220
7	0.02843	2.361
8	0.03050	2.533
9	0.03302	2.742
10	0.03605	2.994

****

GEOMETRY OF ANGULAR CHANNELS (REFERENCE TO 1/2)

TOTAL FLOW AREA= 0.42 SQCM   TOTAL EQUIVALENT DIAMETER= 1.2 CM

SECTION NR.	FLOW AREA (SQCM)	EQUIV. DIAMETER(CM)
1	0.03564	1.132
2	0.03596	1.138
3	0.03660	1.150
4	0.03759	1.169
5	0.03893	1.194
6	0.04067	1.225
7	0.04285	1.263
8	0.04552	1.307
9	0.04875	1.358
10	0.05264	1.414

****

TOTAL LENGTH= 4.22 CM   NUMBER OF SECTIONS= 3   FREL= 1.0000

AXIAL SECTION NR. 1 (SECTION LENGTH= 0.24431; HEIGHT= 220.84741)..

T 2= 249.2819 P 2= 40.469818 P AV= 40.469864 DELTAP=-0.00008925 LAMBDA=0.01762
(ITCORR= 6 ITGL= 9 ITGL1= 48 ITERM= 2 FREL= 1.00)

CHANNEL	OUTLET MASS	AVERAGE MASS	OUTLET TEMP.	AVERAGE TEMP.	PRESSURE LOSS
1	0.11826693E+02	0.11824791E+02	0.26238989E+03	0.26233960E+03	-0.89173875E-04
2	0.24109604E+02	0.24104446E+02	0.25764844E+03	0.25760376E+03	-0.89210283E-04
3	0.11872449E+02	0.11870453E+02	0.26077515E+03	0.26072632E+03	-0.89257737E-04
4	0.66572065E+01	0.66598110E+01	0.24099841E+03	0.24096835E+03	-0.89232984E-04
5	0.46133316E+02	0.46139755E+02	0.23979404E+03	0.23976546E+03	-0.89253357E-04

UAV(1)= 0.40723E+04	WCF(1)= -0.156E-01	MO(1)= 11.83	LAM(1)= 0.01837
UAV(2)= 0.41143E+04	WCF(2)= -0.422E-01	MO(2)= 24.12	LAM(2)= 0.01827
UAV(3)= 0.40759E+04	WCF(3)= -0.163E-01	MO(3)= 11.88	LAM(3)= 0.01835
UAV(4)= 0.43602E+04	WCF(4)= 0.213E-01	MO(4)= 6.66	LAM(4)= 0.01999
UAV(5)= 0.48839E+04	WCF(5)= 0.527E-01	MO(5)= 46.14	LAM(5)= 0.01697

1) WT(1, 3)= 0.364E-01	
1) WT(2, 3)= 0.734E-01	2) WT(2, 5)= 0.557E-01
1) WT(3, 2)= 0.734E-01	2) WT(3, 1)= 0.364E-01
1) WT(4, 5)= 0.278E-01	
1) WT(5, 4)= 0.278E-01	2) WT(5, 2)= 0.557E-01

CHANNEL	ROD	TEMPERATURE	HEAT POWER	ROD	TEMPERATURE	HEAT POWER	ROD	TEMPERATURE	HEAT POWER
1	2	0.34840E+03	0.59004E+01	1	0.34860E+03	0.59004E+01			
2	8	0.34145E+03	0.59004E+01	2	0.34392E+03	0.59004E+01	9	0.34193E+03	0.59004E+01
3	2	0.34678E+03	0.59004E+01	9	0.34619E+03	0.59004E+01			
4	8	0.32453E+03	0.59004E+01						
5	8	0.31601E+03	0.59004E+01	9	0.31550E+03	0.59004E+01			

CHANNEL NR. 1				
1-(ROD NR. 2)	OUT. MASS 7.885649	OUT. TEMP.= 262.34	LAMBDA= 0.01837	REB=111454. REW= 87150.
	Q LINER= 0.0	NU = 0.201701E+03	TW INF.= 348.40	
	TBSSCH(1)= 262.31	TWSSCH(1)= 348.40	TBSSCH(N)= 262.27	TWSSCH(N)= 348.40
2-(ROD NR. 1)	OUT. MASS 3.940744	OUT. TEMP.= 262.50	LAMBDA= 0.01837	REB=111373. REW= 87084.
	Q LINER= 0.0	NU = 0.201575E+03	TW INF.= 348.60	
	TBSSCH(1)= 262.48	TWSSCH(1)= 348.60	TBSSCH(N)= 262.43	TWSSCH(N)= 348.60
CHANNEL NR. 2				
1-(ROD NR. 8)	OUT. MASS 8.072975	OUT. TEMP.= 256.98	LAMBDA= 0.01825	REB=114852. REW= 89987.
	Q LINER= 0.0	NU = 0.206890E+03	TW INF.= 341.45	
	TBSSCH(1)= 256.96	TWSSCH(1)= 341.45	TBSSCH(N)= 256.92	TWSSCH(N)= 341.45
2-(ROD NR. 2)	OUT. MASS 7.974781	OUT. TEMP.= 258.63	LAMBDA= 0.01830	REB=113230. REW= 88582.
	Q LINER= 0.0	NU = 0.204470E+03	TW INF.= 343.92	
	TBSSCH(1)= 258.60	TWSSCH(1)= 343.92	TBSSCH(N)= 258.56	TWSSCH(N)= 343.92
3-(ROD NR. 9)	OUT. MASS 8.061104	OUT. TEMP.= 257.36	LAMBDA= 0.01826	REB=114630. REW= 89804.
	Q LINER= 0.0	NU = 0.206550E+03	TW INF.= 341.93	
	TBSSCH(1)= 257.34	TWSSCH(1)= 341.93	TBSSCH(N)= 257.30	TWSSCH(N)= 341.93
CHANNEL NR. 3				
1-(ROD NR. 2)	OUT. MASS 7.909172	OUT. TEMP.= 260.93	LAMBDA= 0.01835	REB=111980. REW= 87557.
	Q LINER= 0.0	NU = 0.202540E+03	TW INF.= 346.78	
	TBSSCH(1)= 260.90	TWSSCH(1)= 346.78	TBSSCH(N)= 260.86	TWSSCH(N)= 346.78
2-(ROD NR. 9)	OUT. MASS 3.962954	OUT. TEMP.= 260.48	LAMBDA= 0.01834	REB=112280. REW= 87809.
	Q LINER= 0.0	NU = 0.202997E+03	TW INF.= 346.19	
	TBSSCH(1)= 260.45	TWSSCH(1)= 346.19	TBSSCH(N)= 260.41	TWSSCH(N)= 346.19
CHANNEL NR. 4				
1-(ROD NR. 8)	OUT. MASS 6.657207	OUT. TEMP.= 241.00	LAMBDA= 0.01999	REB= 69564. REW= 54267.

	Q LINER= 0.0	NU = 0.116402E+03	TW INF.= 324.53	T AT LINER= 230.20
	TBSSCH(1)= 240.97	TWSSCH(1)= 324.53	TBSSCH(N)= 240.97	TWSSCH(N)= 324.53
	TA= 234.27	TB= 251.55	TBC= 251.55	
	T1SSCH(1)= 251.55	T2SSCH(1)= 234.27	T1SSCH(N)= 251.55	T2SSCH(N)= 234.27
CHANNEL NR. 5				
1-(ROD NR. 8)	OUT. MASS 23.011703	OUT. TEMP.= 239.91	LAMBDA= 0.01698	REB=117012. REW= 93144.
	Q LINER= 0.0	NU = 0.191884E+03	TW INF.= 316.01	T AT LINER= 230.43
	TBSSCH(1)= 239.88	TWSSCH(1)= 316.01	TBSSCH(N)= 239.88	TWSSCH(N)= 316.01
	TA= 233.66	TB= 248.18	TBC= 245.02	
	TW(1)= 317.96	TW(2)= 311.97		
	T1SSCH(1)= 248.18	T2SSCH(1)= 233.66	T1SSCH(N)= 248.18	T2SSCH(N)= 233.66
	MOUT(1)= 0.182370E+02	TOUT(1)= 0.239897E+03	AREA(1)= 0.101512E+01	LAMBDA(1)= 0.169970E-01
	MOUT(2)= 0.477469E+01	TOUT(2)= 0.239957E+03	AREA(2)= 0.265785E+00	LAMBDA(2)= 0.174713E-01
2-(ROD NR. 9)	OUT. MASS 23.120651	OUT. TEMP.= 239.69	LAMBDA= 0.01696	REB=117598. REW= 93677.
	Q LINER= 0.0	NU = 0.192665E+03	TW INF.= 315.50	T AT LINER= 230.25
	TBSSCH(1)= 239.65	TWSSCH(1)= 315.50	TBSSCH(N)= 239.65	TWSSCH(N)= 315.50
	TA= 233.46	TB= 247.93	TBC= 244.78	
	TW(1)= 317.44	TW(2)= 311.48		
	T1SSCH(1)= 247.93	T2SSCH(1)= 233.46	T1SSCH(N)= 247.93	T2SSCH(N)= 233.46
	MOUT(1)= 0.183233E+02	TOUT(1)= 0.239676E+03	AREA(1)= 0.101512E+01	LAMBDA(1)= 0.169789E-01
	MOUT(2)= 0.479732E+01	TOUT(2)= 0.239737E+03	AREA(2)= 0.265791E+00	LAMBDA(2)= 0.174525E-01

AXIAL SECTION NR. 3 (SECTION LENGTH= 1.70313; HEIGHT= 224.09583) SPACER NR. 3 IS PRESENT.......................

T 2= 250.4992 P 2= 40.458908 P AV= 40.463943 DELTAP=-0.0100629C LAMBDA=0.01764
(ITCORR= 4 ITGL= 10 ITGL1= 32 ITERM= 2 FREL= 1.00)

CHANNEL	OUTLET MASS	AVERAGE MASS	OUTLET TEMP.	AVERAGE TEMP.	PRESSURE LOSS
1	0.12258911E+02	0.12060417E+02	0.26393237E+03	C.26349585E+03	-C.10038078E-C1
2	0.24962204E+02	0.24582809E+02	0.25886597E+03	0.25854150E+03	-C.10035343E-C1
3	0.12301395E+02	0.12105309E+02	C.26228687E+03	0.26185425E+03	-0.10037113E-C1
4	0.63291492E+01	0.64693851E+01	C.24198700E+03	0.24164182E+03	-C.10041427E-C1
5	0.44747574E+02	C.45381317E+C2	C.24059857E+03	0.24034846E+03	-0.10042079E-01

UAV(1)= 0.41637E+04	WCF(1)= -C.233E+CC
UAV(2)= 0.42048E+04	WCF(2)= -0.446E+CC
UAV(3)= 0.41666E+04	WCF(3)= -C.23CE+CC
UAV(4)= 0.42425E+04	WCF(4)= 0.165E+0C
UAV(5)= 0.48106E+04	WCF(5)= 0.744E+CC

1) WT(1, 3)= 0.371E-01	
1) WT(2, 3)= 0.749E-C1	2) WT(2, 5)= C.555E-C1
1) WT(3, 2)= 0.749E-01	2) WT(3, 1)= 0.371E-C1
1) WT(4, 5)= 0.272E-01	
1) WT(5, 4)= 0.272E-01	2) WT(5, 2)= 0.555E-C1

CHANNEL	ROD	TEMPERATURE	HEAT POWER	ROD	TEMPERATURE	HEAT POWER	ROD	TEMPERATURE	HEAT POWER
1	2	0.33913E+C3	C.41133E+C2	1	0.33860E+03	0.41133E+02			
2	8	0.33199E+03	0.41133E+02	2	0.33471E+03	0.41133E+02	9	0.33189E+03	0.41133E+02
3	2	0.33752E+03	0.41133E+02	9	C.33621E+03	0.41133E+C2			
4	8	0.31452E+C3	0.41133E+02						
5	8	0.30822E+03	0.41133E+02	9	0.30774E+03	0.41133E+02			

```
CHANNEL NR.    1
 1-(ROD NR.    2)    OUT. MASS  8.211918     OUT. TEMP.= 263.64   LAMBDA=   0.01836      REB=113783.  REW= 91528.
                     Q LINER=     0.0                             TW INF.=    339.13
 2-(ROD NR.    1)    OUT. MASS  4.046690     OUT. TEMP.= 263.84   LAMBDA=   0.01837      REB=112891.  REW= 90991.
                     Q LINER=     0.0                             TW INF.=    338.60
CHANNEL NR.    2
 1-(ROD NR.    8)    OUT. MASS  8.404167     OUT. TEMP.= 257.74   LAMBDA=   0.01824      REB=117363.  REW= 94573.
                     Q LINER=     C.0                             TW INF.=    331.99
 2-(ROD NR.    2)    OUT. MASS  8.294498     OUT. TEMP.= 259.88   LAMBDA=   0.01830      REB=115550.  REW= 92982.
                     Q LINER=     0.0                             TW INF.=    334.72
 3-(ROD NR.    9)    OUT. MASS  8.262779     OUT. TEMP.= 258.34   LAMBDA=   0.01825      REB=116192.  REW= 93798.
                     Q LINER=     0.0                             TW INF.=    331.90
CHANNEL NR.    3
 1-(ROD NR.    2)    OUT. MASS  8.234043     OUT. TEMP.= 262.22   LAMBDA=   0.01835      REB=114313.  REW= 91949.
                     Q LINER=     0.0                             TW INF.=    337.52
 2-(ROD NR.    9)    OUT. MASS  4.067022     OUT. TEMP.= 261.76   LAMBDA=   0.01833      REB=113788.  REW= 91723.
                     Q LINER=     0.0                             TW INF.=    336.21
CHANNEL NR.    4
 1-(ROD NR.    8)    OUT. MASS  6.329151     OUT. TEMP.= 241.76   LAMBDA=   0.02001      REB= 67516.  REW= 54274.
                     Q LINER=     0.0                             TW INF.=    314.52      T  AT LINER=    230.60
CHANNEL NR.    5
 1-(ROD NR.    8)    OUT. MASS 22.326736     OUT. TEMP.= 240.53   LAMBDA=   0.01698      REB=115012.  REW= 93761.
                     Q LINER=     0.0                             TW INF.=    308.22      T  AT LINER=    230.74
                     MOUT(1)= 0.176883E+02   TOUT(1)= 0.240354E+03  AREA(1)= 0.101512E+01  LAMBDA(1)= C.17CC39E-01
                     MOUT(2)= 0.463838E+01   TOUT(2)= 0.241220E+03  AREA(2)= 0.265786E+00  LAMBDA(2)= 0.174805E-01
 2-(ROD NR.    9)    OUT. MASS 22.419815     OUT. TEMP.= 240.28   LAMBDA=   0.01697      REB=115568.  REW= 94270.
```

```
Q LINER=     0.0                                       TW INF.=     307.75     T  AT LINER=     230.54
MOUT(1)= 0.177630E+02     TOUT(1)= 0.240103E+03  AREA(1)= 0.101512E+01   LAMBDA(1)= 0.169853E-01
MOUT(2)= 0.465687E+01     TOUT(2)= 0.240978E+03  AREA(2)= 0.265791E+00   LAMBDA(2)= 0.174626E-01
```

VARIABLES FOR THE WHOLE BUNDLE

A) INLET VALUES OF TEMPERATURE AND PRESSURE

SECTION NR.	HEIGHT (CM)	TEMPERATURE (C)	PRESSURE (KG/SQCM)	PRESSURE (BARS)
1	220.7253	249.21	40.46991	39.68742
2	220.9696	249.28	40.46982	39.68733
3	223.2443	249.98	40.46898	39.68651
4	224.9474	250.50	40.45891	39.67664

B) VALUES AVERAGED OVER AXIAL SECTIONS

SECTION NR.	DENSITY (G/CCM)	VISCOSITY(G/CM*SEC)	VELOCITY (M/SEC)	REYNOLDS NR.	FRICTION FACTOR
1	0.00362	0.0002890	44.348	110252.81	0.01762
2	0.00362	0.0002892	44.381	110199.12	0.01763
3	0.00361	0.0002894	44.438	110114.50	0.01764

TOTAL PRESSURE DROP=-0.011002 KG/SQCM

COMPARISON OF INPUT TEMPERATURES WITH COMPUTED VALUES

	INPUT	COMPUTED
TWTIPA	333.04	332.83
TBTIPA	249.85	249.85
TBPIPA	230.63	230.55

LAST UNHEATED SMOOTH PART

C= 2.621021 CM
Z= 1.484461 CM
ZWC= 0.0 CM
VOL. DIAMETER= 1.837915 CM
PART LENGTH= 3.81876 CM
NUMBER OF SPACERS= 0

INLET CONDITIONS :
INLET AVERAGE TEMPERATURE= 250.50 C
INLET PRESSURE=40.4589081 KG/SQCM =39.6766357 BARS

TOTAL FLOW AREA= 75.31 SQCM
TOTAL EQUIVALENT DIAMETER= 2.0 CM
FLOW AREA OF SECTION= 6.28 SQCM

FLOW AREAS OF CHANNELS:
CENTRAL= 1.65
WALL= 2.56
CORNER= 0.83

EQUIVALENT DIAMETERS
CENTRAL= 2.3
WALL= 1.9
CORNER= 1.2

****

CHANNEL	1 : USED KAPPA=	118.727	(INPUT KAPPA= 118.727)
CHANNEL	2 : USED KAPPA=	118.727	(INPUT KAPPA= 118.727)
CHANNEL	3 : USED KAPPA=	118.727	(INPUT KAPPA= 118.727)
CHANNEL	4 : USED KAPPA=	92.792	(INPUT KAPPA= 92.792)
CHANNEL	5 : USED KAPPA=	91.901	(INPUT KAPPA= 91.901)

****

GEOMETRY OF CENTRAL CHANNELS (REFERENCE TO 1/6)

TOTAL FLOW AREA= 0.27 SQCM TOTAL EQUIVALENT DIAMETER= 2.3 CM

SECTION NR.	FLOW AREA (SQCM)	EQUIV. DIAMETER(CM)
1	0.02290	1.903
2	0.02314	1.924
3	0.02364	1.966
4	0.02441	2.029
5	0.02546	2.116
6	0.02681	2.229

7	0.02851	2.370
8	0.03059	2.543
9	0.03310	2.752
10	0.03613	3.004

****

GEOMETRY OF ANGULAR CHANNELS (REFERENCE TO 1/2)

TOTAL FLOW AREA= 0.42 SQCM   TOTAL EQUIVALENT DIAMETER= 1.2 CM

SECTION NR.	FLOW AREA (SQCM)	EQUIV. DIAMETER(CM)
1	0.03563	1.132
2	0.03595	1.138
3	0.03660	1.151
4	0.03758	1.169
5	0.03892	1.194
6	0.04066	1.226
7	0.04284	1.263
8	0.04550	1.307
9	0.04873	1.358
10	0.05262	1.415

****

TOTAL LENGTH= 3.82 CM   NUMBER OF SECTIONS= 1   FREL= 1.0000

AXIAL SECTION NR. 1 (SECTION LENGTH= 3.81876; HEIGHT= 226.85669)..

```
T 2=  250.4992       P 2= 40.457657      P AV= 40.458282      DELTAP=-0.00124197      LAMBDA=0.01780
( ITCORR= 5      ITGL=    3      ITGL1=   32      ITERM=    2      FREL= 1.00 )
```

CHANNEL	OUTLET MASS	AVERAGE MASS	OUTLET TEMP.	AVERAGE TEMP.	PRESSURE LOSS
1	0.12309191E+02	0.12284050E+02	0.26367969E+03	0.26367407E+03	-0.12411999E-02
2	0.25083939E+02	0.25023071E+02	0.25849731E+03	0.25855200E+03	-0.12412583E-02
3	0.12354506E+02	0.12327950E+02	0.26199390E+03	0.26200928E+03	-0.12415568E-02
4	0.62631159E+01	0.62961321E+01	0.24175224E+03	0.24174127E+03	-0.12418022E-02
5	0.44588470E+02	0.44668015E+02	0.24047887E+03	0.24042654E+03	-0.12414102E-02

```
UAV(  1)=  0.42296E+04        WCF(  1)=  -0.132E-01        MO(  1)=    12.31        LAM(  1)=   0.01822
UAV(  2)=  0.42673E+04        WCF(  2)=  -0.319E-01        MO(  2)=    25.09        LAM(  2)=   0.01813
UAV(  3)=  0.42317E+04        WCF(  3)=  -0.139E-01        MO(  3)=    12.36        LAM(  3)=   0.01820
UAV(  4)=  0.41305E+04        WCF(  4)=   0.173E-01        MO(  4)=     6.26        LAM(  4)=   0.02023
UAV(  5)=  0.47311E+04        WCF(  5)=   0.417E-01        MO(  5)=    44.60        LAM(  5)=   0.01710

 1) WT(   1,   3)=   0.376E-01
 1) WT(   2,   3)=   0.759E-01      2) WT(   2,   5)=   0.553E-01
 1) WT(   3,   2)=   0.759E-01      2) WT(   3,   1)=   0.376E-01
 1) WT(   4,   5)=   0.268E-01
 1) WT(   5,   4)=   0.268E-01      2) WT(   5,   2)=   0.553E-01

CHANNEL NR.    1
 1-(ROD NR.   2)     OUT. MASS  8.239483      OUT. TEMP.= 263.58     LAMBDA=    0.01820      REB=116199.  REW=116199.
                     Q LINER=     0.0
 2-(ROD NR.   1)     OUT. MASS  4.069401      OUT. TEMP.= 263.79     LAMBDA=    0.01826      REB=114622.  REW=114622.
                     Q LINER=     0.0
CHANNEL NR.    2
 1-(ROD NR.   3)     OUT. MASS  8.437920      OUT. TEMP.= 257.57     LAMBDA=    0.01808      REB=119838.  REW=119838.
                     Q LINER=     0.0
 2-(ROD NR.   2)     OUT. MASS  8.326977      OUT. TEMP.= 259.73     LAMBDA=    0.01815      REB=117953.  REW=117953.
                     Q LINER=     0.0
 3-(ROD NR.   9)     OUT. MASS  8.318275      OUT. TEMP.= 258.13     LAMBDA=    0.01815      REB=117896.  REW=117896.
                     Q LINER=     0.0
CHANNEL NR.    3
 1-(ROD NR.   2)     OUT. MASS  8.262493      OUT. TEMP.= 262.13     LAMBDA=    0.01819      REB=116725.  REW=116724.
                     Q LINER=     0.0
 2-(ROD NR.   9)     OUT. MASS  4.091671      OUT. TEMP.= 261.65     LAMBDA=    0.01823      REB=115524.  REW=115524.
                     Q LINER=     0.0
CHANNEL NR.    4
 1-(ROD NR.   8)     OUT. MASS  6.263113      OUT. TEMP.= 241.72     LAMBDA=    0.02023      REB= 65739.  REW= 65739.
                     Q LINER=     0.0
CHANNEL NR.    5
 1-(ROD NR.   8)     OUT. MASS 22.243851      OUT. TEMP.= 240.58     LAMBDA=    0.01711      REB=113238.  REW=113238.
                     Q LINER=     0.0
                     MOUT(1)= 0.175775E+02    TOUT(1)= 0.240505E+03  AREA(1)= 0.101349E+01   LAMBDA(1)= 0.171298E-01
                     MOUT(2)= 0.466632E+01    TOUT(2)= 0.240860E+03  AREA(2)= 0.268659E+00   LAMBDA(2)= 0.175690E-01
 2-(ROD NR.   9)     OUT. MASS 22.343552      OUT. TEMP.= 240.33     LAMBDA=    0.01709      REB=113764.  REW=113763.
                     Q LINER=     0.0
                     MOUT(1)= 0.176597E+02    TOUT(1)= 0.240256E+03  AREA(1)= 0.101348E+01   LAMBDA(1)= 0.171126E-01
                     MOUT(2)= 0.468383E+01    TOUT(2)= 0.240629E+03  AREA(2)= 0.268662E+00   LAMBDA(2)= 0.175527E-01
```

VARIABLES FOR THE WHOLE BUNDLE

A) INLET VALUES OF TEMPERATURE AND PRESSURE

SECTION NR.	HEIGHT (CM)	TEMPERATURE (C)	PRESSURE (KG/SQCM)	PRESSURE (BARS)
1	224.9474	250.50	40.45891	39.67664
2	228.7662	250.50	40.45766	39.67540

B) VALUES AVERAGED OVER AXIAL SECTIONS

SECTION NR.	DENSITY (G/CCM)	VISCOSITY(G/CM*SEC)	VELOCITY (M/SEC)	REYNOLDS NR.	FRICTION FACTOR
1	0.00361	0.0002895	44.380	110147.12	0.01780

TOTAL PRESSURE DROP=-0.001251 KG/SQCM

COMPARISON OF INPUT TEMPERATURES WITH COMPUTED VALUES

	INPUT	COMPUTED
TWTIPA	255.72	255.72
TBTIPA	250.50	250.50
TBPIPA	240.96	240.74

PRESSURE RECAPTURE DUE TO EXIT=0.0 KG/SQCM PRESSURE OUTSIDE= 40.45766 KG/SQCM = 39.67540 BARS (COUT=0.0)

EXP. PRESSURE OUTSIDE= 39.66524
P TH.-PE1=-0.2345886
P EX.-PE1=-0.2447510
(DP TH.- DP EX.)/DP EX.*100=-4.152

APPENDIX 4

Listing of the modified subprograms which are used in the calculations for the 12-rod bundles

```
      BLOCK DATA
C-----------------------------------------------------------------------
C     BLOCK DATA FOR THE 12-ROD BUNDLES ( 1/3.RD OF THE WHOLE BUNDLE
C     FLOW SECTION )
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/BIE(7)/BIDE/IBIDE
     3        /LAMINK/BKAPPA(7,3)/LAMIN9/I3TIP(42,3)/CONDO/FCOND/MART2/
     4        NS1,NS2/WAKA1/IKAPPA/CVREH/ACVS(3),ACVR(3)/LAMIN6/ANGLAM
     5        /GRAV/IGRAV/HEA6/ NPIN(42),JPIN(42,3)/IND3/NTYP(42)/IJ1/
     6        NER(42),NIS(42,3)/SIMLAM/ISIMPL/EXAVTW/IEXAV
      DATA A/4.4,0.24,0.,1.,0.44,0.5,0.01,0.053,10.,10./
      DATA B/4.7,359.,2.,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*2.897E-02,7*3.87E-05/
      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,
     $        37*0/
      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,
     $        7,9,11,3*0,4,33*0/
      DATA NER/2*2,3*3,3*2,3,2*2,31*0/
      DATA NTYP/6*1,2,3,2,3,2,31*0/
      DATA NPIN/1,2,3*3,2*2,1,2,1,2,31*0/
      DATA EX1,EX2,EX3/0.1665E-04, 5*0.1524E-04,0.1665E-04, 0.667E-08,
     *        5*0.726E-08,0.667E-08,0.,5*-0.488E-11,0./
      DATA EX4,EX5,EX6/7*0.1524E-04,7*0.726E-08,7*-0.488E-11/
      DATA BIK/1.,-1.2,0./
      DATA BIE/0.01,1.,-3.35,0.,0.995,-2.83,0./
      DATA IBIDE/1/
      DATA BKAPPA/21*1./
C     ...................................................................
C     TURBULENT CALCULATION IS IMPOSED FOR ALL SUBCHANNELS
C
      DATA I3TIP/126*2/
      DATA NS1,NS2/0,0/
C
      DATA FCOND/1./
      DATA ANGLAM/1./
      DATA ACVS,ACVR/4.75,643.,0.527,8.,3500.,0.8/
C     ...................................................................
C     IF THE DIRECTION OF THE FLOW IS COINCIDENT TO THAT OF THE
C     GRAVITATIONAL FORCE IGRAV=1; IF IT IS OPPOSITE IGRAV=-1
C     IF THE GRAVITATIONAL FORCE IS NOT TAKEN INTO ACCOUNT IGRAV=0
C     ISIMPL=2 IN THE CASE OF LAMINAR FLOW, IF THE NUSSELT NUMBERS
C     OF THE EXTERNAL CHANNELS "NS" ( NS1-1<NS<NS2+1 ), I.E. IF IT MUST
C     BE  CO1,CO2#1 IN SIMLA1. IN THE OTHER CASES ISIMPL=1
C     IEXAV=2 IF AN AVERAGE VALUE OF THE PIN TEMPERATURES AND AN AVERAGE
C     VALUE OF THE SHROUD TEMPERATURES MUST BE COMPUTED IN WALLTE FOR
C     THE EXTERNAL CHANNELS INSTEAD OF THE REAL VALUES. OTHERWISE
C     IEXAV=1
C
      DATA IKAPPA,IGRAV,ISIMPL,IEXAV/1,0,2*1/
      END
      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     VERSICN FOR THE 12-ROD BUNDLES
C
      COMMON/IROSMO/IRH/CVREH/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
      SUBROUTINE HEATI(NSTOT,NSTR,NSEL,NROMA,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
C                 VERSION FOR THE 12-ROD BUNDLES
C     ..................................................................
      COMMON/HEA1/Q(19)/HEA3/QT(42)/IND3/NTYP(42)
     1        /HEA5/QQ(42,3)/HEA6/NPIN(42),JPIN(42,3)/HEA10/QSCH(42,3)
      DO 3 NS=1,NSTOT
      NP=NPIN(NS)
      DO 2 M=1,NP
      QQ(NS,M)=Q(JPIN(NS,M))
      IF(NTYP(NS).EQ.2)GOTO 1
      QSCH(NS,M)=QQ(NS,M)/6.
      GOTO 2
    1 QSCH(NS,M)=QQ(NS,M)*0.25
    2 CONTINUE
    3 CONTINUE
      IF(NSEL.EQ.1)GOTO 4
```

```
      QSCH(2,2)=QSCH(2,2)*0.5
      QSCH(6,1)=QSCH(6,1)*0.5
    4 CONTINUE
      DO 5 NS=1,NSTOT
      NP=NPIN(NS)
      QT(NS)=0.
      DO 5 M=1,NP
    5 QT(NS)=QT(NS)+QSCH(NS,M)
      IF(IPA.NE.IPA/2*2)RETURN
C
      WRITE(6,6)
    6 FORMAT(////5X,'RESULTS OF HEATI'////8X,'CHANNEL',3(21X,'ROD',2X)/)
      DO 8 NS=1,NSTOT
      NP=NPIN(NS)
      WRITE(6,7) NS,(M,NS,M,  JPIN(NS,M),M=1,NP)
    7 FORMAT(2X,I10,3(3X,I1,') JPIN(',I5,',',I2,')=',I5))
    8 CONTINUE
      RETURN
      END
      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/NER(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,NSTOT
      NI=NER(NS)
      WRITE(6,200) NS,NTYP(NS),(NIS(NS,M),M=1,NI)
  200 FORMAT(5X,'NS=',I2,5X,'TYPE=',I1,5X,'CHANNELS CONNECTED:',3I5)
  100 CONTINUE
      RETURN
      END
      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)/GEO0/ACH(3)
     1       /GEN5/DE(42)/TUR1/CTURB(42,3)/TUR2/CTURB1(2)
     2       /COND0/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
      R1A1=AS1/AP1
      R1A2=AS2/AP2
      R1A3=AS3/AP3
      R1A4=AS4/AP4
C EACH CENTRAL CHANNEL HAS 3 GAPS. IT IS CONNECTED TO 3 CENTRAL CHANNELS
C OR TO 2 CENTRAL CHANNELS AND TO 1 WALL CHANNEL
      DO 7 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 7
    4 SUM(I)=2.*R1A4
      NGAPS(I)=2.
    7 CONTINUE
      DO 15 I=1,NSTOT
      NI=NER(I)
      DO 15 M=1,NI
      J=NIS(I,M)
      IF(I.GT.NSTR)GOTO 10
```

```
      IF(NTYP(J).EQ.2)GOTO 8
C   I=CENTRAL CHANNEL, J=CENTRAL CHANNEL
      DELTA=DELTA1
      RAPPA=RA1
      GOTO 9
C   I=CENTRAL CHANNEL, J=WALL CHANNEL (OR VICE VERSA)
    8 DELTA=DELTA2
      RAPPA=RA2
    9 GAP=GAP1
      GOTO 14
   10 IF(NTYP(I).EQ.3)GOTO 12
      IF(NTYP(J)-2)8,11,12
C   I=WALL CHANNEL , J=WALL CHANNEL
   11 DELTA=DELTA3
      RAPPA=RA3
      GOTO 13
C   I=CORNER CHANNEL, J=WALL CHANNEL (OR VICE VERSA)
   12 DELTA=DELTA4
      RAPPA=RA4
   13 GAP=GAP3
   14 YH=1.14*SQRT((NGAPS(I)+NGAPS(J))/(SUM(I)+SUM(J)))*RAPPA**2
      AREAI= ACH(NTYP(I))
      AREAJ= ACH(NTYP(J))
      DEIJ=(AREAI+AREAJ)/(AREAI/DE(I)+AREAJ/DE(J))
      CTURB(I,M)=YH*GAP/DELTA*DEIJ*0.05*PCORR
      CCOND(I,M)=GAP/DELTA*FCOND*0.5
   15 CONTINUE
      DELSC1=C-(7.*C**3/48.-R3)/(0.25*C**2-PIG*R2*SQ3/6.)
      DELSC2=C-2.*XBWS
      CTURB1(1)=CTU1*0.05*DETC*YBC/DELSC1
      CTURB1(2)=CTU2*0.05*DETW*(A-ZWC)/DELSC2
      CCOND1(1)=YBC/DELSC1*FCOND*0.5
      CCOND1(2)=(A-ZWC)/DELSC2*FCOND*0.5
      IF(NSEL.EQ.1)RETURN
      CTURB(1,1)=CTURB(1,1)*0.5
      CTURB(1,2)=CTURB(1,2)*0.5
      CTURB(2,1)=CTURB(2,1)*0.5
      CTURB(6,2)=CTURB(6,2)*0.5
      CCOND(1,1)=CCOND(1,1)*0.5
      CCOND(1,2)=CCOND(1,2)*0.5
      CCOND(2,1)=CCOND(2,1)*0.5
      CCOND(6,2)=CCOND(6,2)*0.5
      RETURN
      END
      SUBROUTINE INQUA(NSEL,NSTOT,NROMA,ATC,ATW,ATA,DETC,DETW,DETA)
C-----------------------------------------------------------------------
C     INQUA PROVIDES INDICES TO CHANNEL FLOW AREAS AND EQUIVALENT
C     DIAMETERS AND TO SUBCHANNEL  FLOW AREAS
C
C                 VERSION FOR THE THE 12-ROD BUNDLES
C     ..................................................................
      DIMENSION ACH(3),D(3)
      COMMON/GEN2/A(42)          /IND3/NTYP(42)/SUB1/ASCH(42,3)/GEN5/DE(42)
     1     /HEA6/NPIN(42),JPIN(42,3)
      ACH(1)=ATC
      ACH(2)=ATW
      ACH(3)=ATA
      D(1)=DETC
      D(2)=DETW
```

```
      D(3)=DETA
      DO 1 NS=1,NSTOT
      NP=NPIN(NS)
      NSCH=4-NTYP(NS)
      SCH=NSCH
      DE(NS)=D(NTYP(NS))
      DO 1 M=1,NP
    1 ASCH(NS,M)=ACH(NTYP(NS))/SCH
      IF(NSEL.EQ.1)GOTO 3
      ASCH(2,2)=ASCH(2,2)*0.5
      ASCH(6,1)=ASCH(6,1)*0.5
    3 CONTINUE
      DO 4 NS=1,NSTOT
      NP=NPIN(NS)
      A(NS)=0.
      DO 4 M=1,NP
    4 A(NS)=A(NS)+ASCH(NS,M)
      RETURN
      END
      SUBROUTINE TOTGEO(NSEL,D,C,Z,PIG,NEXCON,NRODS,WW,WA,ZA,EM1,PERLT,
     &RTIP)
C-----------------------------------------------------------------------
C     TOTGEO CALCULATES FLOW AREAS , EQUIVALENT DIAMETERS AND OTHER
C     GEOMETRIC DATA FOR THE WHOLE BUNDLE FLOW SECTION , FOR THE
C     CHANNELS AND FOR THE SUBCHANNELS
C
C                 VERSION FOR THE 12-ROD BUNDLES
C     ..................................................................
      COMMON/GEO0/ACH(3)/LAMIN2/FATIP(3),FDTIP(3)/QPAR3/PERL(3)
     1       /GEO2/ATOT,DETOT,ASEC/GEO5/ATC,DETC,ATW,DETW,ATA,DETA,AAC,
     2       AAW,AAA/WAKAD/CD,WD,ZD,ZWCD,AWD2,PWWD
      SQ3=SQRT(3.)
      D2=D**2
      EM2=C*0.5-EM1
      ZWC=EM2/SQ3
      DTIP=RTIP*2.
      ATC=(C**2*SQ3-PIG*D2*0.5)*0.25
      DETC=8.*ATC/(PIG*D)
      ATW=C*Z-0.125*PIG*D2-EM2*ZWC
      DETW=4.*ATW/(2.*EM1+4.*ZWC+PIG*D*0.5)
      ATA=Z**2/SQ3      -PIG*D2/24.
      DETA=4.*ATA/(  PIG*D/6.+2.*Z/SQ3)
      AAC=ATC/6.
      AAW=ATW*0.5
      AAA=ATA*0.5
      ATOT=13.*ATC+9.*ATW+6.*ATA
      DETOT=ATOT/(13.*ATC/DETC+9.*ATW/DETW+6.*ATA/DETA)
      IF(NSEL.EQ.3)GOTO 1
      ASEC=ATOT
      GOTO 2
    1 ASEC=ATOT/3.
    2 CONTINUE
      ACH(1)=ATC
      ACH(2)=ATW
      ACH(3)=ATA
      PERLT=4.*ATOT/DETOT-12.*PIG*D
      PERL(1)=0.
      PERL(2)=4.*ATW/DETW-0.5*PIG*D
      PERL(3)=4.*ATA/DETA-PIG*D/6.
```

```
      WW=Z+0.5*D
      ZA=Z
      WA=WW
      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*(WW-DTIP*0.5)-DTIP**2*PIG*0.125-EM2*ZWC
      FDTIP(2)=4.*FATIP(2)/(PIG*DTIP*0.5+2.*EM1+4.*ZWC)/DETW
      FATIP(2)=FATIP(2)/ATW
      FATIP(3)=(WA-DTIP*0.5)**2/SQ3-DTIP**2*PIG/24.
      FDTIP(3)=4.*FATIP(3)/(DTIP*PIG/6.+(WA-DTIP*0.5)*2./SQ3)/DETA
      FATIP(3)=FATIP(3)/ATA
      CD=C/DTIP
      WD=WW/DTIP
      ZD=Z/DTIP
      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=',F10.3/8X,'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
```