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MACABRE

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**PHILLIPS
PETROLEUM
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ATOMIC ENERGY DIVISION

**NATIONAL REACTOR TESTING STATION
US ATOMIC ENERGY COMMISSION**

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ABSTRACT

MACABRE is a series of codes for the IBM 7040 computer; it is capable of solving the isothermal hydraulics and the nonisothermal hydraulics and heat transfer characteristics of most plate-type reactor fuel elements cooled by pressurized water in forced convection. It has been employed in ATR and EOCR fuel element analyses.

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I. INTRODUCTION

Computer analysis of the steady state hydraulics and heat transfer in test reactors has not been necessary in the past. Cooling has been by single-phase flow through a series of parallel, continuous channels. The flow through each coolant passage must conform to the equation of continuity:

$$\left[\rho_1 V_1 A_1 = \rho_2 V_2 A_2 \right] \quad (1)$$

where the subscripts refer to any two axial position within a continuous channel. The various forms of energy that must be evaluated are the following:

(1) Kinetic energy:	$\frac{mV^2}{2g_c}$
(2) Potential energy:	$\frac{Zmg}{g_c}$
(3) Pressure energy:	Pv
(4) Internal energy:	UJ
(5) Thermal energy:	qJ
(6) Mechanical energy:	W
(7) Friction energy:	W_f

Applying the equation of continuity and following the convention that thermal energy is positive if absorbed by the system and that the mechanical and frictional terms are positive when lost from the system, a balance between the two arbitrary axial positions, designated by the subscripts 1 and 2, results in the following equation:

$$\left[\frac{m}{2g_c} \Delta(V^2) + \frac{m}{g_c} \Delta(gZ) + J\Delta U + \Delta Pv = qJ - W - W_f \right] \quad (2)$$

Assuming the coolant is a single-phase incompressible fluid and converting to a basis of one pound, yields the following:

$$\left[\frac{\Delta(V^2)}{2g_c} + \frac{\Delta(gZ)}{g_c} + \frac{J\Delta U}{m} + \frac{\Delta P}{\rho} = \frac{qJ}{m} - \bar{w} - \bar{w}_f \right] \quad (3)$$

Simultaneous solutions of Equations (1) and (3) are possible for a single coolant channel of known geometry if the thermal energy added (q) and the mechanical energy dissipated ($\bar{w}$) are known and if experimental data are available for the evaluation of the friction term. The mechanical energy term is generally assumed to be zero in a reactor coolant channel, the thermal energy generated in a fuel plate is evaluated from the total reactor power, and either local relative power is computed or a value is measured in a critical facility. There are considerable data available for evaluating the friction term.

The friction losses are divided into permanent losses due to channel contraction and expansion, at the entrance and exit, and a shear loss at the walls of the coolant channel. These are evaluated from empirical equations

$$K_{\text{ent}} \left[\frac{V_{\text{ch}}^2 - V_{\text{up}}^2}{2g_c} \right]$$

$$K_{\text{exit}} \left[\frac{(V_{\text{ch}} - V_{\text{Lp}})^2}{2g_c} \right]$$

and

$$\frac{4fLV^2}{2g_c D}$$

respectively. K_{ent} , K_{exit} , and f must be obtained from experimental data either directly or by analogy to a similar geometry for which there are published data.

Historically, the thermal-hydraulics of testing reactors has been solved by hand, assuming the heat from a given fuel plate is split between the two adjacent channels independent of axial location. This assumes that the difference in the film heat transfer coefficients and in the bulk coolant temperature rise in adjacent channels is small. It has also been assumed that the shear losses within the channel are dependent on the axially averaged bulk coolant temperature. These assumptions, together with one of the heat transfer correlations, allow hand solution of the reactor parameters at a given core pressure drop and power level. A value of the average bulk coolant temperature is assumed, and a flow rate is computed. The computed flow rate is then used to evaluate the film heat transfer coefficient (generally at the hot vertical location) and the resulting heat split and bulk coolant temperature. The computed bulk coolant temperature is then used in place of the assumed value, and the simultaneous solutions are developed through the resulting iterative process. The assumptions used have generally introduced little error since each coolant channel has been heated from both sides, and they are all about the same size. The bulk-coolant temperature increase across the core has been relatively small, minimizing the differences between adjacent channels.

The evolution of testing reactors has been toward longer fuel sections, smaller coolant channels, and higher core pressure drops. This evolutionary process increased the relative bulk temperature rise across the core (because of longer fuel elements and smaller channels) and the lateral pressure drops resulting from manufacturing irregularities. Early isothermal hydraulic tests of the ATR fuel elements indicated that the lateral pressures developed had become excessive. To relieve these pressures, it has been necessary to vent the element side plates at various locations along the axis. The vents allow the coolant from one channel to enter another channel equalizing the pressures at this location. The cross flow between channels, permitted at each vent, together with the uneven bulk temperature rise in the critical channels, Number 19 and Number 20 (channel Number 20 is heated from only one side), and the subsequent axial dependence of the heat split has made hand solutions of the fuel element thermal hydraulics impractical.

The MACABRE codes have been written to solve simultaneously, on the IBM 7040, Equation (1), Equation (3), and the Dittus-Boelter forced convection heat transfer correlation with the added requirement that the pressures in all channels be equal at a vent. The potential energy term has been disregarded since it is equal in all channels, at a given mesh point, and since pressure differences are usually measured with instruments (manometers, transducers, etc) that automatically compensate for this term. The equation of continuity applies to an individual channel only between vents. The code computes the heat split between the two coolant channels adjacent to a fuel plate allowing thermal resistances to both conduction and convection in the direction normal to both the fuel plate and the coolant flow. The axial and azimuthal conduction within the plate has been disregarded. In computing the coolant bulk temperature increase between mesh points, it has been assumed that the heat split remains unchanged between the mesh points, ie, the bulk rise, $a + j$, is computed using the average heat source for the two adjacent mesh points, $j-1$ and j ; and the heat split is computed at the upstream mesh point, j . The pressure losses are computed in the interval between mesh points, $j-1$ and j , based on the bulk temperature at j .

The accuracy of the solution to the simultaneous equations is limited only by the demanded convergence on pressure loss (at those locations where they are to be equal) and the distance between mesh points. As the mesh spacing and demanded convergence approach zero, the solution becomes exact.

The codes currently can handle two geometries: the wedge-shaped ATR geometry, in which each plate has a different span, and the rectangular geometry associated with the ETR. The codes permit changing any channel thickness at any axial location, requiring only that a mesh point be located at the position of the change. It also permits variation in heating from plate-to-plate (horizontal peaking) as well as vertically. It permits calculating the axial temperature profile in the nominal hot element or in the hot-spot hot-track element, in which the flow rate can be based either on the azimuthally averaged bulk temperature or on the hot-track bulk temperature.

The principal limitations of the code are a maximum of 19 plates (20 channels) and 64 mesh points (without linking).

II. PROGRAM DESCRIPTION

The code requires first the definition of the fuel element geometry. Either the wedge or the rectangular deck must be selected, and the geometry must be dimensioned according to Figures 1 or 2. The problem is further defined by incorporating a coolant physical property table. The code is capable of evaluating the pressure loss if the flow is known or of evaluating the flow rates if the total pressure loss (demanded pressure loss) is known. The latter case requires estimating the flow rate. The program then solves the pressure loss and corrects the flow rate until the computed pressure loss is sufficiently close (EPSLON) to the demanded pressure loss. These two cases can be solved either isothermally or with the addition of heat.

1. ISOTHERMAL CASE

An isothermal hydraulic problem requires specifying the velocities associated with the upper and lower plenums, the inlet coolant temperature, the demanded pressure loss or coolant flow rate, entrance and exit coefficients for each channel, and an initial estimate of velocity for each channel,

Fig. 1 Wedge geometry dimensionless definition.

PP Co-B-6765

Fig. 2 Rectangular geometry dimensionless definition.

in addition to defining the geometry. The hydraulic diameter is computed as two times the channel thickness, and the friction factor is calculated as $0.0024 + 0.358 \left(\frac{1}{N_{re}} \right)^{0.437[a]}$. The calculations start at the upper plenum and

progressively sum entrance, exit, and frictional losses and the conversion of pressure to kinetic energy from meshpoint to mesh point. The program demands that all channels be at the same pressure at any axial location where there is a vent and at the lower plenum. If they do not balance in the first pass, an internal converging routine guides the iterating process. The degree of convergence required is the input parameter (EPSLON) which is the percentage of the difference in the computed pressure, for a particular channel, from the average of the computed pressures for each channel.

The code for rectangular geometries has been written to handle elements with more than 19 plates. This requires dividing the element into two or more portions, each of which has 19 plates or less. The element is divided in the

[a] This is a Phillips correlation of experimental data taken in high aspect ratio fuel element channels.

center of one of the internal channels (see Figure 2). The division is possible only if it is assumed that the plates on each side of the divided channel produce equal power, ie, the heat entering channel Number 1 (the divided channel) is assumed to be twice the heat entering channel Number 1 from plate Number 1. The correct bulk temperature is computed by doubling the multiplier, CONB, for the channel(s) that is divided. This method allows calculations for cores in which fuel plates of adjacent elements are separated only by a water channel (the external channels are heated from both sides) as well as cores in which the external fuel plates are adjacent to unfueled materials (the external channels are heated from only one side). In the latter case CONB would not be doubled.

2. NONISOTHERMAL CASE

The hydraulic computations for the nonisothermal cases are the same as for the isothermal cases except that the friction factor changes from mesh point to mesh point due to its temperatures dependence and the velocity changes from mesh point to mesh point due to the temperature dependence of the fluid density. The pressure drop between two mesh points is computed based on the bulk temperature at the upstream mesh point. The bulk temperature is updated at each mesh point. The wall temperature at each mesh point is computed from the updated bulk temperature and the heat flowing through the wall at that mesh point. The film heat transfer coefficient is evaluated from the Dittus-Boelter correlation:

$$\left[\frac{hD}{k} = 0.023 \left(\frac{DV\rho}{\mu} \right)^{0.8} \left(\frac{C_p\mu}{R} \right)^{0.4} \right]$$

The heat flowing to each heat transfer surface of a fuel plate is a function not only of the total heat produced in the plate but of the resistance to conduction in each direction and the resistance to convection at each surface as influenced by the bulk temperature, coolant velocity, and hydraulic diameter of each of the adjacent coolant channels.

The accuracy of the computed results is limited only by the distance between mesh points and the demanded degree of convergence (EPSLON). To increase the accuracy of computations, a linking option has been incorporated into the programs. This allows increasing the number of mesh points from a maximum of 64 to 64 times the number of links. A link is formed by dividing a fuel element at some axial position where all pressures are equal (such as at a vent). This, in essence, makes two separate hydraulic problems linked together only by the continuity of bulk temperatures for each flow channel and the overall pressure drop.

III. INPUT DATA

The input data are divided into seven groups. For a multilink problem, Groups 3, 5, and 6 may be changed from link to link. If a particular data address is referenced, after the first link, it must be completely redefined for the link because the referencing wipes out all of the data stored from the preceding link in the referenced address. If the data address is not referenced, it is unchanged from the previous link. All groups other than 3, 5, and 6 are entered in the first link only. The data groups are:

- (1) Physical properties
- (2) Title
- (3) Fixed-point data (all integers)
- (4) Floating-point single-valued data
- (5) Floating-point array data
- (6) Vent indicator
- (7) Thermal profile data .

It is important that all cards have identification information in Columns 73-80 as error comments will print only this information to assist the user in locating mistakes.

1. PHYSICAL PROPERTIES

Preceding the data deck for each run, there is a table of the coolant physical properties (limited to 48 entries).

This table is preceded by a card with the number of entries in the table placed in Columns 1-2.

The temperature points in the table must be equally spaced, one data point per card. The properties are the following:

- (1) Column 4-8 -- TEMP -- temperature, °F
- (2) Column 13-25 -- RUERO -- density/viscosity, sec/ft²
- (3) Column 26-31 -- CAY -- thermal conductivity, Btu/hr-ft-°F
- (4) Column 37-42 -- C_p -- heat capacity, Btu/lb-°F
- (5) Column 48-53 -- RHO -- density, lb/ft³
- (6) Column 59-67 -- PN3 -- dimensionless Prandtl number raised to the 0.4 power.

2. TITLE

This is the first card of each problem. (It follows the cards listing the physical properties of the coolant.) An * must be present in Column 1 of this card. Columns 2-72 are used for title information that is to appear at the top of each page of output.

3. FIXED-POINT DATA

Fixed-point data cards are present for each link. Column 1 contains the number of data items on the card. Column 2, if nonzero, indicates the last card of this group. Columns 9-12 contain the address of the first data item on the card, and the data for this address and the next four consecutive locations in storage follow in Columns 14-24, 26-36, 38-48, 50-60, and 62-72 (this is the standard FORTRAN work sheet form). All data items must be right-adjusted.

<u>Address</u>	<u>Item</u>	<u>Definition</u>	(2I1, 6XI4, 5I12, A6, A2)
1	LINK	The link number for this set of data	
2	NDX	The number of mesh points in the link	
3	NO	The number of channels in the element	
4	LAST	The number of the last link in the problem	
5	HEAT	0, if there is no heating in the problem 1, if there is heating in the problem	
6	VERHT	The number of input points for the vertical profile curve	
7	STHEAT	The number of the first mesh point in the first link that has heat	
8	EDHEAT	The number of mesh points in the last link that have no heat	
9	NSTRT	The number of the mesh point for which output printing is to begin	
10	NOPR	The periodicity of the mesh point solutions to be printed in the output (NOPR-1 mesh points are skipped between mesh points printed)	
11	NENO	The last mesh point solution to be printed in the output.	

4. FLOATING-POINT SINGLE-VALUED DATA

The form of input for the floating-point single-valued data is the same as for the preceding data sheet. All data items must have the decimal point on the card.

The card(s) must always be present for the first link of each problem, but are not included in the subsequent link(s).

<u>Address</u>	<u>Item</u>	<u>Definition</u>	(2I1, 6XI4, 5E12.5, A6, A2)
1	THETA	The angle of the fuel element in degrees (wedge geometry only)	
2	WID	Fuel element width in inches (rectangular geometry only)	
3	SP1	The distance from the center of the side channel to the inside of the side plate in inches	
4	SP2	The same as the above for the other side plate	
5	CLTH1	The thickness of cladding in plate No. 1 in inches	
6	CLTH	The thickness of cladding in the internal plates (2 through NO-1) in inches	
7	CLTHNO	The thickness of cladding in the final plate in inches	
8	MTTH	The meat or fuel thickness in inches (all plates must have the same thickness)	
9	V1	The velocity in the upper plenum (above the fuel element) in ft/sec	
10	V2	The velocity in the lower plenum (below the fuel element) in ft/sec	
11	T1N	The bulk coolant inlet temperature in °F	
12	DLP	The demanded loss of pressure across the fuel element in psi. If the mass flow (FLOFED) is known, DLP must be input as 0	
13	FLOFED	The coolant flow rate in lb/sec (this parameter must always be greater than zero)	
14	VELS5	The initial velocity estimate for the left side channel (SP1) in ft/sec	
15	VELS6	The same as the above for the right side channel (SP2)	
16	ENK5	The entrance coefficient for the left side channel (SP1), dimensionless	
17	ENK6	The entrance coefficient for the right side channel (SP2)	
18	EXITK5	The exit coefficient for the left side channel (SP1)	
19	EXITK6	The exit coefficient for the right side channel (SP2)	

<u>Address</u>	<u>Item</u>	<u>Definition</u>	(2I1, 6XI4, 5E12.5, A6, A2)
20	MULF	A multiplier for increasing or decreasing the normal friction factor for handling roughened surfaces.	
21	QAVE	The average heat source in Btu/hr-ft ² of plate (1 ft ² of plate normally has 2 ft ² of heat transfer area). This number when multiplied by the local horizontal and vertical peaking factors yield the local heat source.	
22	KCL	The thermal conductivity of the cladding material in Btu/hr ft ² -°F/in.	
23	KMT	The thermal conductivity of the meat or fueled material	
24	MULH	A multiplier for increasing or decreasing the normal heat transfer coefficient for handling hot-spot hot-channel calculations or for handling roughened surface heat transfer.	
25	EPSLON	The degree of convergence demanded. Computed as the fractional deviation of the total pressure loss in a given channel from the average of the pressure loss in all channels, $\frac{\text{total pressure loss} - \text{average pressure loss}}{\text{total pressure loss}}$	

5. FLOATING-POINT ARRAY DATA

Floating-point array card(s) must always be present for each link of each problem. If no change is required after the first link, a blank card must be used. Column 1 contains the number of data items on the card. Column 2, if not zero, indicates the last card of this data group. Columns 7-10 contain the address of the data item(s) on the card. Columns 15-17, 35-37, and 55-57 contain the plate or channel number that pertains to the data item (when applicable). Columns 18-20, 38-40, and 58-60 contain the mesh point number that pertains to the data item (when applicable). Columns 21-30, 41-50, and 61-70 contain the data items. The decimal point must be on the card. All data items in this group (except P1, address 1 and P2, address 1217) require only one location, either a plate or channel number or a mesh point number. Only one location number can be specified for these items. If the address is referenced in multilink problems, the data item must be completely redefined for the link since referencing the address removes all previous entries.

<u>Address</u>	<u>Item</u>	<u>Definition</u>	(2I1, 4XI4, 3(4X2I3, E10.5)2X, A6, A2)
1	P1	The inner radius of each fuel plate (from the same reference as B1 and B2) in inches	
1217	P2	The outer radius of each fuel plate in inches	
2433	DX	The length of each mesh element in feet	
2497	FW	The fuel withdrawal distance for each fuel plate in inches	

<u>Address</u>	<u>Item</u>	<u>Definition</u>	(2I1, 4XI4, 3(4X2I3, E10.5)2X, A6, A2)
2516	VEL	Initial coolant velocity estimate for each channel in ft/sec	
2536	ENK	Entrance coefficient for each channel	
2556	EXITK	Exit coefficient for each channel	
2576	CONA	A bulk coolant temperature multiplier used for increasing or decreasing the computed bulk temperature. The modified coolant temperature is used only in computing coolant flow rates and/or pressure drops, eg, the velocity in a channel with a high azimuthal peaking factor can be computed based on the average coolant temperature (at the given axial location) while computing the thermal profiles in the hot track	
2596	CONB	A bulk coolant temperature multiplier (hot channel factor). Used to increase or decrease the computed bulk temperature rise	
2616	B1	The locating dimension for the inner fuel element boundary (must be nonzero) in inches	
2680	B2	The locating dimension for the outer fuel element boundary in inches	
2744	SG5	The left side channel (SP1) gap in inches	
2808	SG6	The right side channel (SP2) gap in inches.	

6. VENT INDICATOR (2I1, 16I4, 6XA6, A2)

The vent indicator card must be present for each link in each problem. A blank card must be used if no window is desired in the link. A window location must not be specified as beginning at zero; it must be specified as mesh point No. 1 of the link (zero is an illegal entry and is physically meaningless). Column 1 contains the number of windows specified on the card. Column 2, if nonzero, indicates the last card in this data group. Windows are indicated by a set of numbers indicating the first and last mesh points of the window. As many as eight sets of numbers may be placed on a card in Columns 3-72. Columns 3-72 are divided into 16 fields of 4 columns each. The integer number must be right-adjusted within the four columns.

7. THERMAL PROFILE DATA (14F5.3)

Plate and channel dependent thermal profile data cards must always be present for the first link of a problem and are not included in subsequent links. Columns 1-70 are divided into 14 sections of 5 columns each. Each multiplier is listed continuously, requiring no identification or address, until complete. The decimal points must be present on the data card. These cards must not be present in isothermal-type problems.

7.1 Horizontal Peaking

A series of terms (one number for each plate) that describe the horizontal (radial or plate-to-plate) variation of the thermal flux developed within the element. It is a dimensionless term such that when it is multiplied by the average heat source (QAVE) and the vertical profile, the result is the local source.

7.2 Vertical Profile

A series of terms describing the vertical variation of the thermal flux developed within the element. It is a dimensionless term such that when it is multiplied by the average heat source (QAVE) and the horizontal peaking term, the result is the local source. The element of the series must be equally spaced along the axis of the fuel element at one-inch intervals with a limit of 51 values (this limits the element to a maximum of 50 inches). (See Group 3, address 6.)

IV. OUTPUT DATA

The output data list the title card followed by the fixed-point data and floating-point single-valued data. Each of the floating-point array data input cards is printed followed by the horizontal peaking, the vertical peaking, and the total flow (lb/sec). The computed pressure drop across the fuel element is printed for each outer iteration as the program converges on a demanded loss of pressure.

The final output is in descriptively headed columns. The mesh points are numbered consecutively for the entire element with no regard to linking. Channel numbers are listed for each data row. The coolant velocity (ft/sec), the total pressure loss (in psid referred to the upper plenum), and the bulk coolant temperature are listed for each channel at each mesh point requested for output. The fuel plate wall temperatures (and heat fluxes for the last two plates) are tabulated in rows between the coolant channels they form. The first TWALL and Q/A printed (reading from left to right) correspond to the side of the fuel plate nearest the point of geometrical reference. The second TWALL and Q/A printed correspond to the other side of the fuel plate. The Q/A terms are printed for the last two plates only. An * under the window heading indicates a vent at the listed mesh point in the indicated channel.

After printing the solution the elapsed time is printed in hours, minutes, and seconds with two digits allowed for each; eg, 001846 is 0 hours 18 minutes and 46 seconds.

APPENDIX A -- NOMENCLATURE

APPENDIX A -- NOMENCLATURE

SYMBOLS

INTERPRETATION

A	= flow area, ft^2
C_p	= heat capacity at constant pressure, $\text{Btu}/(\text{lb-mass})(^\circ\text{F})$
D	= hydraulic diameter, ft
f	= dimensionless friction factor
g	= gravitational acceleration at given location, ft/sec^2
g_c	= gravitational acceleration standard $(\text{ft})(\text{lb-mass})/(\text{sec}^2)(\text{lb-force})$
h	= film heat transfer coefficient, $\text{Btu}/(\text{hr})(\text{ft}^2)(^\circ\text{F})$
J	= mechanical equivalent of heat $(\text{ft})(\text{lb-force})/\text{Btu}$
K	= coolant thermal conductivity, $\text{Btu}/(\text{hr})(\text{ft}^2)(^\circ\text{F}/\text{ft})$
K_{ent}	= dimensionless entrance loss coefficient
K_{exit}	= dimensionless exit loss coefficient
L	= length, ft
m	= pounds mass, lb-mass
N_{re}	= dimensionless Reynold's number
P	= pressure, $\text{lb-force}/\text{ft}^2$
q	= heat, Btu
U	= internal energy, Btu
V	= velocity, ft/sec
v	= volume, ft^3
W	= mechanical energy $(\text{ft})(\text{lb-force})$
$\bar{w}$	= mechanical energy per pound mass $(\text{ft})(\text{lb-force})/\text{lb-mass}$
W_f	= frictional energy $(\text{ft})(\text{lb-force})$
$\bar{w}_f$	= frictional energy per pound mass $(\text{ft})(\text{lb-force})/\text{lb-mass}$
Z	= height above arbitrary reference plane, ft
ρ	= density, $\text{lb-mass}/\text{ft}^3$
μ	= coolant viscosity, $\text{lb-mass}/(\text{ft})(\text{sec})$

SUBSCRIPTS

ch	= parameter within the channel
LP	= parameter in lower plenum or below the fuel element
UP	= parameter in the upper plenum or above the fuel element .

APPENDIX B -- SAMPLE PROBLEM

APPENDIX B -- SAMPLE PROBLEM

The thermal-hydraulics of a nominal-hot ATR fuel element^[a] is to be analyzed. Rather than the nominal Channel No. 20 width of 0.113 inch, the channel will be tapered from 0.063 inch at the top of the fuel element to 0.175 inch at the bottom. The coolant velocity within a channel will be assumed constant in the radial and azimuthal direction and will be calculated from the average (radially and azimuthally) bulk temperature rather than on a hot strip. This assumes complete bulk mixing. The element will be vented (2-inch-long vents) 8 to 10 inches, 12 to 14 inches, 22 to 24 inches, 26 to 28 inches, and 42 to 44 inches from the top.

1. INPUT

1.1 Physical Properties

The ATR is water cooled so a water properties table precedes the problem. The water properties, density/viscosity, thermal conductivity, heat capacity, density, and the Prandtl number to the 0.4 power, are listed for the range 100 to 570°F in 10°F intervals (48 entries). The properties table is listed at the end of this appendix.

1.2 Title

ATR Nom Hot Element Tapered Channel No. 20 -- Small at Top.

1.3 Fixed-Point Data

The fuel element has been divided into four links. It is divided at the bottom of the second vent, the bottom of the fourth vent, and through the fifth vent. It was divided to enable a reduction in the mesh spacing to 1/4 inch for increased accuracy. The mesh spacing immediately below the entrance and each vent has been reduced to a negligible distance (0.0001 ft) because this is the region of maximum lateral pressure drops, and a finite mesh spacing would give lateral pressure drops smaller than the actual values by the difference in the friction losses for adjacent channels.

The ATR fuel element has 19 fuel plates (20 channels). The fuel plates are unfueled (unheated) over the top and bottom 3/4-inch intervals. The vertical distribution of power has been measured in the ATR Critical Facility, and 51 equally spaced values will be in the input data. The output will contain solutions for every fourth mesh point, from the first through the 204th mesh point (4th link -- 25th mesh point).

The fixed-point data are shown in the input listing at the end of this appendix.

[a] The nominal-hot element is an element with nominal dimensions and fuel content running in the hottest position of the reactor core. Fabrication tolerances and other uncertainties have been excluded.

1.4 Floating-Point Single-Valued Data

The ATR fuel element, when in the reactor, has a reproducible geometry (around the fuel annulus) based on 45°. The other physical dimensions are as shown in the input listing at the end of this appendix. The upper and lower plenum velocities have been assumed to be zero (zero values need not be inserted). The thermal hydraulics will be solved for the case of 130°F bulk inlet and at a pressure loss of 100 psid. The "FLOFED", "VELS5", and "VELS6" terms are initial guesses only, with the restriction that they be nonzero, ("VELS5" and "VELS6" are assumed to be zero if there are no side channels). The entrance and exit coefficients have been experimentally evaluated as 0.5 and 0.7, respectively. The element analyzed has smooth fuel plates so "MULF" is set to unity. "QAVE" has been evaluated from the maximum source (4.37×10^6 Btu/hr-ft²), the maximum relative horizontal peaking (2.42) and the maximum relative vertical peaking (20), all of which were measured in the critical facility^[a]. Nominal (as opposed to hot-spot hot-channel) values for a smooth heat transfer surface are desired so "MULH" is set to unity. The desired convergence is 1/2 percent (EPSLON = 0.005).

1.5 Floating-Point Array Data

The physical dimensions (P1, P2, DX, and FW) are as shown in the input listing at the end of this appendix. The velocity estimates are initial guesses only, and any nonzero value will result in the solution. The more accurate estimate results in saving machine time only. The entrance and exit coefficient have been evaluated experimentally and are as listed. "CONA" values are the azimuthal average to maximum values for each plate divided by "CONB". This multiplier adjusts the bulk temperature computed for the hot strip, assuming no mixing, to the average or mixed value. The problem solution will then be the hot-strip bulk and wall temperatures, based on no mixing, as computed from velocities based on complete mixing. This approach was used to be on the safe side since the increase in velocity along the hot strip was unknown. "CONB" has been used to compensate for the unfueled portion of the channel (fuel withdrawal distance). The program calculates the bulk rise on the entire flow channel and the heated span. The assumption of no mixing requires a multiplier, $\frac{\text{Total Span}}{\text{Heated Span}}$, to correct the computed bulk rise.

"B1" remains constant but "B2" varies linearly along the full length of the element. 0.001-inch incremental steps of 0.001 inch were assumed to approximate the linear variation with sufficient accuracy. "SG5" and "SG6" remain constant over the full length of the element.

1.6 Vent Indicator

The locations of the vents are incorporated into each link and are located by the first and last mesh point of the vent. The vent indicators are shown in the input listing at the end of this appendix.

[a] Maximum values need not be used; it is just as necessary that all values be taken at the same location. The peaking terms are dimensionless terms relating local power to average power. It must be remembered that a source term is twice the surface heat flux.

1.7 Thermal Profile Data

The thermal profile data are dimensionless terms relating the local source term to the average power. The values used are shown in the input listing at the end of this appendix.

2. OUTPUT

The sample problem output is listed at the end of this appendix. To save space, some of the mesh point solutions have been omitted.

PHYSICAL PROPERTIES TABLE
LISTING FOR WATER

(See Section III.1.)

100.0	0.135000E	060.3541	0.9976	61.995	1.8283332	1
110.0	0.147000E	060.3589	0.9976	61.843	1.7445781	2
120.0	0.162000E	060.3733	0.9977	61.729	1.6711017	3
130.0	0.177000E	060.3772	0.9981	61.538	1.6062720	4
140.0	0.192000E	060.3810	0.9988	61.387	1.5476990	5
150.0	0.210000E	060.3836	0.9996	61.199	1.4965810	6
160.0	0.225000E	060.3861	1.0004	61.013	1.4450055	7
170.0	0.241000E	060.3884	1.0012	60.790	1.4026275	8
180.0	0.260000E	060.3905	1.0022	60.569	1.3582364	9
190.0	0.275000E	060.3923	1.0034	60.350	1.3221429	10
200.0	0.295000E	060.3935	1.0047	60.132	1.2872506	11
210.0	0.310000E	060.3943	1.0061	59.880	1.2622378	12
220.0	0.328000E	060.3950	1.0079	59.630	1.2335441	13
230.0	0.345000E	060.3957	1.0097	59.382	1.2038124	14
240.0	0.360000E	060.3961	1.0119	59.102	1.1823265	15
250.0	0.377000E	060.3964	1.0142	58.824	1.1602384	16
260.0	0.395000E	060.3964	1.0165	58.514	1.1407905	17
270.0	0.410000E	060.3962	1.0191	58.241	1.1208323	18
280.0	0.426000E	060.3959	1.0222	57.937	1.1003262	19
290.0	0.442000E	060.3955	1.0225	57.637	1.0827892	20
300.0	0.458000E	060.3952	1.0289	57.307	1.0684466	21
310.0	0.470000E	060.3948	1.0322	56.980	1.0538091	22
320.0	0.485000E	060.3944	1.0354	56.657	1.0388602	23
330.0	0.500000E	060.3933	1.0404	56.306	1.0274330	24
340.0	0.513000E	060.3921	1.0455	55.960	1.0158120	25
350.0	0.528000E	060.3906	1.0511	55.586	1.0079525	26
360.0	0.542000E	060.3891	1.0564	55.218	0.9971934	27
370.0	0.555000E	060.3876	1.0614	54.855	0.9891112	28
380.0	0.570000E	060.3857	1.0665	54.466	0.9821621	29
390.0	0.580000E	060.3834	1.0728	54.054	0.9759685	30
400.0	0.592000E	060.3809	1.0794	53.648	0.9701344	31
410.0	0.605000E	060.3783	1.0861	53.248	0.9642470	32
420.0	0.617000E	060.3753	1.0941	52.798	0.9600085	33
430.0	0.627000E	060.3724	1.1023	52.356	0.9561697	34
440.0	0.640000E	060.3693	1.1114	51.921	0.9527379	35
450.0	0.650000E	060.3670	1.1212	51.546	0.9484220	36
460.0	0.657000E	060.3640	1.1315	51.020	0.9462529	37
470.0	0.665000E	060.3608	1.1431	50.505	0.9445123	38
480.0	0.675000E	060.3575	1.1545	50.000	0.9427669	39
490.0	0.680000E	060.3535	1.1698	49.505	0.9436402	40
500.0	0.688000E	060.3494	1.1861	49.020	0.9458182	41
510.0	0.693000E	060.3446	1.2100	48.309	0.9501519	42
520.0	0.699000E	060.3397	1.2300	47.847	0.9544562	43
530.0	0.708000E	060.3348	1.2500	47.170	0.9587314	44
540.0	0.714000E	060.3298	1.2800	46.512	0.9587314	45
550.0	0.720000E	060.3246	1.3100	45.872	0.9713889	46
560.0	0.724800E	060.3189	1.3400	45.249	0.9796917	47
570.0	0.725000E	060.3130	1.3700	44.643	0.9878902	48

SAMPLE PROBLEM INPUT LISTING

*ATR	NOM	HQT	ELEMENT	TAPERED	CHANNEL	NO	2C-SMALL	AT TOP	
5		1		1	57		20		4
5		6		51	4		3		1
11		11		204					
5		1	45.0			0.251		0.251	C.03
3		6	0.015		0.04	0.02			
5		11	130.0		100.0	100.0		45.0	45.0
5		16	0.5		0.5	0.7		0.7	1.0
51		21	9.02		+4 1200.0	1200.0		1.0	C.005
3		1	1	13.015		2	13.173		3
3		1	4	13.429		5	13.557		6
3		1	7	13.813		8	13.941		9
3		1	10	14.197		11	14.325		12
3		1	13	14.581		14	14.709		15
3		1	16	14.965		17	15.093		18
1		1	19	15.349					
3	1217	1	13.095		2	13.223		3	13.351
3	1217	4	13.479		5	13.607		6	13.735
3	1217	7	13.863		8	13.991		9	14.119
3	1217	10	14.247		11	14.375		12	14.503
3	1217	13	14.631		14	14.759		15	14.887
3	1217	16	15.015		17	15.143		18	15.271
1	1217	19	15.449						
3	2433		10.0001			20.0208			410.0001
1	2433		420.0208						
3	2497	1	0.184		2	0.083		19	0.184
2	2516	1	45.0		20	70.0			
1	2536	1	0.50						
3	2556	1	0.9		2	0.7		20	0.9
3	2576	1	0.796		2	0.840		3	0.871
3	2576	4	0.866		5	0.865		6	0.872
3	2576	7	0.876		8	0.878		9	0.880
3	2576	10	0.874		11	0.854		12	0.832
3	2576	13	0.818		14	0.814		15	0.807
3	2576	16	0.784		17	0.760		18	0.742
2	2576	19	0.709		20	0.685			
3	2596	1	1.285		2	1.210		3	1.133
3	2596	4	1.130		5	1.125		6	1.121
3	2596	7	1.118		8	1.115		9	1.112
3	2596	10	1.109		11	1.107		12	1.103
3	2596	13	1.101		14	1.100		15	1.098
3	2596	16	1.096		17	1.094		18	1.093
2	2596	19	1.125		20	1.155			
1	2616		12.907						
3	2680		15.512			35.513			55.514
3	2680		75.515			95.516			115.517
3	2680		135.518			155.519			175.521
3	2680		195.522			215.523			235.524
3	2680		255.526			275.527			295.528
3	2680		315.529			335.530			355.531

3	2680	375.532	395.534	425.535	00000510
3	2680	445.536	465.537	485.538	00000520
3	2680	505.539	525.540	545.541	00000530
2	2680	565.542	575.543		00000540
1	2744	10.036			00000550
11	2808	10.036			00000560
21	33 40 50 57				00000570
1.6	1.44 1.34 1.26 1.20 1.15 1.12 1.11 1.11 1.13 1.18 1.22 1.29 1.34				00000580
1.41	1.58 1.79 2.07 2.42				00000590
2.5	3.5 4.6 5.7 6.9 7.9 8.9 10.0 10.9 12.0 12.8 13.7 14.6 15.5				00000600
16.2	16.9 17.6 18.2 18.7 19.1 19.5 19.7 19.9 20.0 20.0 20.0 19.9 19.8				00000610
19.6	19.3 19.0 18.6 18.2 17.7 17.1 16.4 15.7 15.0 14.1 13.2 12.4 11.4				00000620
10.4	9.4 8.4 7.4 6.3 5.3 4.2 3.2 2.2				00000630
21	1 2 58				00000640
3	2433	10.0001	20.0208	420.0001	00000650
1	2433	430.0208			00000660
3	2680	15.543	45.545	65.546	00000670
3	2680	85.547	105.548	125.549	00000680
3	2680	145.550	165.551	185.553	00000690
3	2680	205.554	225.555	245.556	00000700
3	2680	265.557	285.558	305.559	00000710
3	2680	325.560	345.562	365.563	00000720
3	2680	385.564	405.565	425.566	00000730
3	2680	445.567	475.569	495.570	00000740
3	2680	515.571	535.572	555.573	00000750
21	2680	575.574	585.575		00000760
21	34 41 51 58				00000770
21	1 3 64				00000780
2	2433	10.0001	20.0208		00000790
3	2680	15.575	35.576	55.577	00000800
3	2680	65.578	85.579	105.580	00000810
3	2680	125.581	145.582	165.583	00000820
3	2680	185.584	205.585	215.586	00000830
3	2680	225.587	245.588	265.589	00000840
3	2680	285.590	305.591	325.592	00000850
3	2680	345.593	365.594	385.595	00000860
3	2680	395.596	405.597	425.598	00000870
3	2680	445.599	465.600	485.601	00000880
3	2680	495.602	505.603	525.604	00000890
3	2680	545.605	565.606	585.607	00000900
31	2680	605.608	625.609	645.610	00000910
11	58 64				00000920
21	1 4 25				00000930
3	2433	10.0208	20.0001	30.0208	00000940
3	2680	15.611	35.612	55.613	00000950
3	2680	75.614	95.615	115.616	00000960
3	2680	135.617	155.618	175.619	00000970
3	2680	185.620	195.621	215.622	00000980
21	2680	235.623	255.624		00000990
11	1 1				00001000

SAMPLE PROBLEM OUTPUT LISTING

ATR NOM HOT ELEMENT TAPERED CHANNEL NO 20-SMALL AT TOP

5/07/65

INTEGER ARRAY

1 57 20 4 1 51 4 3 1 4 204

FLOATING POINT SINGLE VALUE ARRAY

4.5000E 01	-0.	2.5100E-01	2.5100E-01	3.0000E-02	1.5000E-C2	4.0000E-02	2.0000E-02
E.	0.	1.3000E 02	1.0000E 02	1.0000E 02	4.5000E C1	4.5000E 01	5.0000E-C1
5.0000E-01	7.0000E-01	7.0000E-01	1.0000E 00	9.0200E 04	1.2000E C3	1.2000E 03	1.0000E C0
5.0000E-03							

FLOATING POINT ARRAY DATA

30	1	1	1	3.0150E 00	2	1	3.1730E 00	3	1	3.3010E 00	00000100
30	1	4	1	3.4290E 00	5	1	3.5570E 00	6	1	3.6850E 00	00000110
30	1	7	1	3.8130E 00	8	1	3.9410E 00	9	1	4.0690E 00	00000120
30	1	10	1	4.1970E 00	11	1	4.3250E 00	12	1	4.4530E 00	00000130
30	1	13	1	4.5810E 00	14	1	4.7090E 00	15	1	4.8370E 00	00000140
30	1	16	1	4.9650E 00	17	1	5.0930E 00	18	1	5.2210E 00	00000150
10	1	19	1	5.3490E 00	-0	-0	-0.	-0	-0	-0.	00000160
30	1217	1	1	3.0950E 00	2	1	3.2230E 00	3	1	3.3510E 00	00000170
30	1217	4	1	3.4790E 00	5	1	3.6070E 00	6	1	3.7350E 00	00000180
30	1217	7	1	3.8630E 00	8	1	3.9910E 00	9	1	4.1190E 00	00000190
30	1217	10	1	4.2470E 00	11	1	4.3750E 00	12	1	4.5030E 00	00000200
30	1217	13	1	4.6310E 00	14	1	4.7590E 00	15	1	4.8870E 00	00000210
30	1217	16	1	5.0150E 00	17	1	5.1430E 00	18	1	5.2710E 00	00000220
10	1217	19	1	5.4490E 00	-0	-0	-0.	-0	-0	-0.	00000230
30	2433	-0	1	1.0000E-04	-0	2	2.0800E-C2	-0	41	1.0000E-04	00000240
10	2433	-0	42	2.0800E-02	-0	-0	-0.	-0	-0	-0.	00000250
30	2497	1	-0	1.8400E-01	2	-0	8.3000E-C2	19	-0	1.8400E-01	00000260
20	2516	1	-0	4.5000E 01	20	-0	7.0000E C1	-0	-0	-0.	00000270
10	2536	1	-0	5.0000E-01	-0	-0	-0.	-0	-0	-0.	00000280
30	2556	1	-0	9.0000E-01	2	-0	7.0000E-01	20	-0	9.0000E-01	00000290

30	2576	1	-0	7.9600E-01	2	-0	8.4000E-01	3	-0	8.7100E-01	00000300
30	2576	4	-0	8.6600E-01	5	-0	8.6500E-01	6	-0	8.7200E-01	00000310
30	2576	7	-0	8.7600E-01	8	-0	8.7800E-01	9	-0	8.8000E-01	00000320
30	2576	10	-0	8.7400E-01	11	-0	8.5400E-01	12	-0	8.3200E-01	00000330
30	2576	13	-0	8.1800E-01	14	-0	8.1400E-01	15	-0	8.0700E-01	00000340
30	2576	16	-0	7.8400E-01	17	-0	7.6000E-01	18	-0	7.4200E-01	00000350
20	2576	19	-0	7.0900E-01	20	-0	6.8500E-01	-0	-0	-0.	00000360
30	2596	1	-0	1.2850E 00	2	-0	1.2100E 00	3	-0	1.1330E 00	00000370
30	2596	4	-0	1.1300E 00	5	-0	1.1250E 00	6	-0	1.1210E 00	00000380
30	2596	7	-0	1.1180E 00	8	-0	1.1150E 00	9	-0	1.1120E 00	00000390
30	2596	10	-0	1.1090E 00	11	-0	1.1070E 00	12	-0	1.1030E 00	00000400
30	2596	13	-0	1.1010E 00	14	-0	1.1000E 00	15	-0	1.0980E 00	00000410
30	2596	15	-0	1.0960E 00	17	-0	1.0940E 00	18	-0	1.0930E 00	00000420
20	2596	19	-0	1.1250E 00	20	-0	1.1550E 00	-0	-0	-0.	00000430
10	2616	-0	1	2.9070E 00	-0	-0	-0.	-0	-0	-0.	00000440
30	2680	-0	1	5.5120E 00	-0	3	5.5130E 00	-0	5	5.5140E 00	00000450
30	2680	-0	7	5.5150E 00	-0	9	5.5160E 00	-0	11	5.5170E 00	00000460
30	2680	-0	13	5.5180E 00	-0	15	5.5190E 00	-0	17	5.5210E 00	00000470
30	2680	-0	19	5.5220E 00	-0	21	5.5230E 00	-0	23	5.5240E 00	00000480
30	2680	-0	25	5.5260E 00	-0	27	5.5270E 00	-0	29	5.5280E 00	00000490
30	2680	-0	31	5.5290E 00	-0	33	5.5300E 00	-0	35	5.5310E 00	00000500
30	2680	-0	37	5.5320E 00	-0	39	5.5340E 00	-0	42	5.5350E 00	00000510
30	2680	-0	44	5.5360E 00	-0	46	5.5370E 00	-0	48	5.5380E 00	00000520
30	2680	-0	50	5.5390E 00	-0	52	5.5400E 00	-0	54	5.5410E 00	00000530
20	2680	-0	56	5.5420E 00	-0	57	5.5430E 00	-0	-0	-0.	00000540
10	2744	-0	1	3.6000E-02	-0	-0	-0.	-0	-0	-0.	00000550
11	2808	-0	1	3.6000E-02	-0	-0	-0.	-0	-0	-0.	00000560

HORIZONTAL PEAKING

1.60	1.44	1.34	1.26	1.20	1.15	1.12	1.11	1.11	1.13	1.18	1.22	1.29	1.34
1.41	1.58	1.79	2.07	2.42									

VERTICAL PEAKING

2.50	3.50	4.60	5.70	6.90	7.90	8.90	10.00	11.90	12.00	12.80	13.70	14.60	15.50
16.20	16.90	17.60	18.20	18.70	19.10	19.50	19.70	19.90	20.00	20.00	20.00	19.90	19.80
19.60	19.30	19.00	18.50	18.20	17.70	17.10	16.40	15.70	15.00	14.10	13.20	12.40	11.40
10.40	9.40	8.40	7.40	6.30	5.30	4.20	3.20	2.20					

INTEGER ARRAY

2 58 20 4 1 51 4 3 1 4 204

FLOATING POINT ARRAY DATA

30	2433	-0	1	1.0000E-04	-0	2	2.0800E-02	-0	42	1.0000E-04	00000650
10	2433	-0	43	2.0800E-02	-0	-0	-0.	-0	-0	-0.	00000660
30	2680	-0	1	5.5430E 00	-0	4	5.5450E 00	-0	6	5.5460E 00	00000670
30	2680	-0	8	5.5470E 00	-0	10	5.5480E 00	-0	12	5.5490E 00	00000680
30	2680	-0	14	5.5500E 00	-0	16	5.5510E 00	-0	18	5.5530E 00	00000690
30	2680	-0	20	5.5540E 00	-0	22	5.5550E 00	-0	24	5.5560E 00	00000700
30	2680	-0	26	5.5570E 00	-0	28	5.5580E 00	-0	30	5.5590E 00	00000710
30	2680	-0	32	5.5600E 00	-0	34	5.5620E 00	-0	36	5.5630E 00	00000720
30	2680	-0	38	5.5640E 00	-0	40	5.5650E 00	-0	42	5.5660E 00	00000730
30	2680	-0	45	5.5670E 00	-0	47	5.5690E 00	-0	49	5.5700E 00	00000740
30	2680	-0	51	5.5710E 00	-0	53	5.5720E 00	-0	55	5.5730E 00	00000750
21	2680	-0	57	5.5740E 00	-0	58	5.5750E 00	-0	-0	-0.	00000760

INTEGER ARRAY

3 64 20 4 1 51 4 3 1 4 204

FLOATING POINT ARRAY DATA

20	2433	-0	1	1.0000E-04	-0	2	2.0800E-02	-0	-0	-0.	00000790
30	2680	-0	1	5.5750E 00	-0	3	5.5760E 00	-0	5	5.5770E 00	00000800
30	2680	-0	6	5.5780E 00	-0	8	5.5790E 00	-0	10	5.5800E 00	00000810
30	2680	-0	12	5.5810E 00	-0	14	5.5820E 00	-0	16	5.5830E 00	00000820
30	2680	-0	18	5.5840E 00	-0	20	5.5850E 00	-0	21	5.5860E 00	00000830
30	2680	-0	22	5.5870E 00	-0	24	5.5880E 00	-0	26	5.5890E 00	00000840
30	2680	-0	28	5.5900E 00	-0	30	5.5910E 00	-0	32	5.5920E 00	00000850
30	2680	-0	34	5.5930E 00	-0	36	5.5940E 00	-0	38	5.5950E 00	00000860

30	2680	-0	39	5.596CE 0C	-0	40	5.5970E C0	-0	42	5.5980E 00	00000870
30	2680	-0	44	5.5990E 0C	-0	46	5.6000E 00	-0	48	5.6010E 00	00000880
30	2680	-0	49	5.6020E 0C	-0	50	5.6030E 00	-0	52	5.6040E 00	00000890
30	2680	-0	54	5.6050E 0C	-0	56	5.6060E C0	-0	58	5.6070E 00	00000900
31	2680	-0	60	5.6080E 0C	-0	62	5.6090E 00	-0	64	5.6100E 00	00000910

INTEGER ARRAY

4 25 20 4 1 51 4 3 1 4 204

FLOATING POINT ARRAY DATA

30	2433	-0	1	2.0800E-02	-0	2	1.0000E-04	-0	3	2.0800E-02	00000940
30	2680	-0	1	5.6110E 0C	-0	3	5.6120E 00	-0	5	5.6130E 00	00000950
30	2680	-0	7	5.6140E 0C	-0	9	5.6150E 00	-0	11	5.6160E 00	00000960
30	2680	-0	13	5.6170E 0C	-0	15	5.6180E 00	-0	17	5.6190E 00	00000970
30	2680	-0	18	5.6200E 0C	-0	19	5.6210E C0	-0	21	5.6220E 00	00000980
21	2680	-0	23	5.6230E 0C	-0	25	5.6240E C0	-0	-0	-0.	00000990

FLOFEC= 101.44871 LBS./SEC. AVEPL= 97.44627

FLOFEC= 101.35770 LBS./SEC. AVEPL= 100.16156

ATR NOM HOT ELEMENT TAPERED CHANNEL NO 2C-SMALL AT TOP

5/07/65

	V E L FT./SEC.	T O T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.·FT ²	Q / A BTU/HR.·FT ²	W I N D O W
MESH POINT- 1								
Δx= 0.00010 FT.								
CHANNEL								
1	48.627 52.899	23.548 27.866	130.000					
2	49.463	24.364	130.000	130.000	130.000			
3	49.462	24.364	130.000	130.000	130.000			
4	49.462	24.364	130.000	130.000	130.000			
5	49.462	24.363	130.000	130.000	130.000			
6	49.462	24.363	130.000	130.000	130.000			
7	49.462	24.363	130.000	130.000	130.000			
8	49.461	24.363	130.000	130.000	130.000			
9	49.461	24.363	130.000	130.000	130.000			
10	49.461	24.363	130.000	130.000	130.000			
11	49.462	24.363	130.000	130.000	130.000			
12	49.462	24.363	130.000	130.000	130.000			
13	49.462	24.363	130.000	130.000	130.000			
14	49.462	24.363	130.000	130.000	130.000			
15	49.462	24.364	130.000	130.000	130.000			
16	49.462	24.364	130.000	130.000	130.000			
17	49.463	24.364	130.000	130.000	130.000			
18	49.463	24.365	130.000	130.000	130.000	0.	0.	
19	49.463	24.365	130.000	130.000	130.000	0.	0.	
20	55.597 48.627	30.783 23.548	130.000					

ATR NOM HOT ELEMENT TAPERED CHANNEL NO 20-SMALL AT TOP

5/07/65

	V E L FT./SEC.	T O T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.·FT ²	Q / A BTU/HR.·FT ²	W I N D O W
MESH POINT- 5								
DX= 0.02080 FT.								
CHANNEL								
1	48.590 52.899	25.569 29.328	130.050		151.472 151.427			
2	49.464	26.280	130.141		149.242 149.240			
3	49.464	26.279	130.129		147.906 147.904			
4	49.463	26.279	130.120		146.837 146.836			
5	49.463	26.278	130.114		146.036 146.035			
6	49.463	26.278	130.109		145.368 145.367			
7	49.463	26.278	130.105		144.967 144.967			
8	49.463	26.278	130.103		144.833 144.833			
9	49.463	26.278	130.103		144.833 144.833			
10	49.463	26.278	130.104		145.100 145.101			
11	49.463	26.278	130.107		145.767 145.768			
12	49.463	26.278	130.111		146.302 146.303			
13	49.463	26.278	130.116		147.236 147.237			
14	49.463	26.278	130.122		147.905 147.906			
15	49.463	26.279	130.127		148.840 148.843			
16	49.464	26.279	130.130		151.109 151.112			
17	49.464	26.279	130.150		153.912 153.916			
18	49.465	26.280	130.179		157.647 157.652	3.2682E 05	3.2661E 05	
19	49.465	26.280	130.200		161.176 160.058	3.6854E 05	3.9537E 05	
20	53.877 48.590	32.450 25.569	130.123					

ATR NCM HOT ELEMENT TAPERED CHANNEL NO 20-SMALL AT TOP

5/07/65

	V E L FT./SEC.	T O T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.·FT ²	Q / A BTU/HR.·FT ²	W I N D O W
MESH POINT- 9								
DX= 0.02080 FT.								
CHANNEL								
1	48.553 52.902	27.587 30.791	130.294					
2	49.471	28.197	130.816	158.535	158.575			
3	49.470	28.196	130.746	155.820	155.807			
4	49.469	28.196	130.699	154.027	154.018			
5	49.469	28.195	130.661	152.596	152.590			
6	49.468	28.195	130.631	151.521	151.516			
7	49.468	28.195	130.610	150.628	150.624			
8	49.468	28.195	130.599	150.090	150.088			
9	49.468	28.195	130.597	149.910	149.909			
10	49.468	28.195	130.602	149.910	149.911			
11	49.468	28.195	130.621	150.268	150.271			
12	49.468	28.195	130.644	151.157	151.161			
13	49.468	28.195	130.674	151.876	151.881			
14	49.469	28.195	130.707	153.122	153.127			
15	49.469	28.196	130.739	154.020	154.026			
16	49.470	28.196	130.804	155.278	155.290			
17	49.471	28.197	130.905	158.304	158.322			
18	49.473	28.198	131.038	162.052	162.075			
19	49.473	28.198	131.183	167.033	167.057	4.2983E C5	4.2865E 05	
20	52.263	33.570	130.736	172.025	170.874	4.8800E C5	5.1563E 05	
	48.553	27.587						

ATR NOM HOT ELEMENT TAPERED CHANNEL NC 2C-SMALL AT TOP

5/07/65

	V E L FT./SEC.	T C T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.*FT2	Q / A BTU/HR.*FT2	W I N D O W
MESH POINT- 13								
DX= 0.02080 FT.								
CHANNEL								
1	48.516 52.905	29.602 32.255	130.604		165.665 165.816			
2	49.480	30.114	131.672	162.518	162.454			
3	49.479	30.113	131.531	160.264	160.247			
4	49.477	30.112	131.434	158.467	158.453			
5	49.476	30.112	131.356	157.115	157.104			
6	49.475	30.111	131.295	155.992	155.985			
7	49.475	30.111	131.252	155.317	155.313			
8	49.475	30.111	131.230	155.088	155.087			
9	49.475	30.111	131.226	155.085	155.091			
10	49.475	30.111	131.235	155.535	155.546			
11	49.475	30.111	131.274	156.652	156.660			
12	49.475	30.111	131.322	157.558	157.569			
13	49.475	30.111	131.383	159.118	159.130			
14	49.476	30.112	131.450	160.251	160.263			
15	49.477	30.112	131.517	161.835	161.858			
16	49.478	30.113	131.645	165.624	165.660			
17	49.480	30.114	131.858	170.325	170.371			
18	49.482	30.115	132.125	176.558	176.608	5.3296E 05	5.3057E 05	
19	49.484	30.116	132.433	183.175	182.163	6.0949E 05	6.3386E 05	
20	50.744	35.359	131.504					
	48.516	29.602						

ATR NOM. HOT ELEMENT TAPERED CHANNEL NO 2C-SMALL AT TOP

5/07/65

	VE L FT./SEC.	T O T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.*FT2	Q / A BTU/HR.*FT2	W I N D O W
MESH POINT- 17								
DX= 0.02080 FT.								
CHANNEL								
1	48.460 52.909	31.602 33.718	130.985					
2	49.491	32.029	132.717	173.473	173.745			
3	49.489	32.028	132.491	169.871	169.832			
4	49.487	32.028	132.333	167.114	167.087			
5	49.485	32.027	132.206	164.917	164.855			
				163.263	163.245			
6	49.484	32.026	132.107					
7	49.483	32.026	132.037	161.890	161.878			
8	49.483	32.026	132.001	161.063	161.057			
9	49.483	32.026	131.992	160.782	160.780			
10	49.483	32.026	132.010	160.783	160.786			
				161.334	161.345			
11	49.483	32.026	132.074					
12	49.483	32.026	132.151	162.691	162.704			
13	49.484	32.026	132.250	163.802	163.820			
14	49.485	32.027	132.359	165.705	165.724			
15	49.486	32.027	132.468	167.094	167.112			
				169.034	169.071			
16	49.488	32.028	132.683					
17	49.491	32.029	133.023	173.654	173.711			
18	49.495	32.031	133.464	175.390	179.462			
19	49.497	32.032	133.967	186.981	187.061	5.4549E C5	6.4167E-05	
20	48.622	36.159	132.436	195.803	195.379	7.4732E C5	7.5748E-05	
	48.460	31.602						

ATR NOM HOT ELEMENT TAPERED CHANNEL NO 2C-SMALL AT TOP

5/07/65

	VEL FT./SEC.	T C T P L PSI	BULK DEG. F.	T WALL DEG. F.	T WALL DEG. F.	C / A BTU/HR.*FT2	Q / A BTU/HR.*FT2	W I N D O W
MESH POINT- 21								
DX= 0.02080 FT.								
CHANNEL								
1	48.423	33.610						
	52.912	35.181	131.433					
2	49.503	33.943	133.942	180.129	180.549			
3	49.501	33.942	133.619	176.251	176.167			
4	49.498	33.941	133.389	173.063	173.025			
5	49.495	33.941	133.205	170.524	170.492			
				168.608	168.583			
6	49.494	33.940	133.061					
7	49.493	33.940	132.958	167.021	167.003			
8	49.492	33.940	132.907	166.063	166.054			
9	49.492	33.940	132.894	165.736	165.734			
10	49.492	33.940	132.920	165.738	165.743			
				166.375	166.351			
11	49.493	33.940	133.012					
12	49.493	33.940	133.125	167.940	167.960			
13	49.494	33.940	133.269	169.230	169.254			
14	49.495	33.941	133.427	171.425	171.452			
15	49.497	33.941	133.589	173.034	173.061			
				175.283	175.336			
16	49.499	33.942	133.895					
17	49.503	33.943	134.392	180.609	180.650			
18	49.509	33.945	135.032	187.229	187.331			
19	49.513	33.946	135.781	195.975	196.091	7.3967E C5	7.3411E 05	
20	47.307	37.278	133.510	206.629	206.704	8.6238E C5	8.6058E C5	
	48.423	33.610						

ATR NOM HOT ELEMENT TAPERED CHANNEL NO 2C-SMALL AT TOP

5/07/65

	V E L FT./SEC.	T C T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.*FT2	Q / A BTU/HR.*FT2	W I N D O W
MESH POINT- 25								
DX= 0.02080 FT.								
CHANNEL								
1	48.367 52.919	35.604 36.644	131.943	186.822	187.407			
2	49.517	35.855	135.331	182.708	182.637			
3	49.514	35.854	134.899	179.085	179.037			
4	49.510	35.854	134.588	176.205	176.163			
5	49.507	35.853	134.338	174.027	173.994			
6	49.506	35.853	134.144	172.224	172.200			
7	49.504	35.852	134.005	171.135	171.123			
8	49.503	35.852	133.935	170.761	170.758			
9	49.503	35.852	133.918	170.764	170.770			
10	49.503	35.852	133.953	171.488	171.510			
11	49.504	35.852	134.078	173.262	173.288			
12	49.504	35.852	134.230	174.731	174.764			
13	49.506	35.853	134.425	177.215	177.254			
14	49.508	35.853	134.640	179.051	179.086			
15	49.510	35.853	134.853	181.605	181.679			
16	49.513	35.854	135.277	187.642	187.750			
17	49.518	35.855	135.945	195.144	195.280			
18	49.525	35.856	136.813	205.044	205.201	8.3386E C5	8.2632E C5	
19	49.531	35.857	137.847	218.001	219.078	9.8336E C5	9.5753E C5	
20	45.459	37.924	134.733					
	48.367	35.604						

ATR NCM HOT ELEMENT TAPERED CHANNEL NO 2C-SMALL AT TOP

5/07/65

	V E L FT./SEC.	T O T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.·FT ²	Q / A BTU/HR.·FT ²	W I N D O W
MESH POINT- 29								
DX= 0.02080 FT.								
CHANNEL								
1	48.331 52.925	37.605 38.106	132.519					
2	49.533	37.764	136.891	194.154	194.914			
3	49.530	37.764	136.339	189.775	189.686			
4	49.525	37.763	135.936	185.688	185.622			
5	49.521	37.763	135.613	182.429	182.376			
				179.966	179.924			
6	49.518	37.763	135.362	177.928	177.898			
7	49.517	37.763	135.182	176.695	176.680			
8	49.516	37.762	135.092	176.271	176.267			
9	49.516	37.762	135.069	176.275	176.283			
10	49.516	37.762	135.115	177.094	177.121			
11	49.516	37.762	135.276	179.095	179.128			
12	49.517	37.763	135.471	180.755	180.801			
13	49.519	37.763	135.725	183.565	183.611			
14	49.521	37.763	136.003	185.635	185.685			
15	49.524	37.763	136.284	188.535	188.625			
16	49.527	37.764	136.829	195.335	195.472			
17	49.534	37.764	137.695	203.795	203.968			
18	49.543	37.765	138.815	214.940	215.140	9.3735E 05	9.2774E 05	
19	49.551	37.766	140.186	230.126	232.043	1.1132E 06	1.0672E 06	
20	44.309	38.836	136.086					
	48.331	37.605						

ATR NGM HOT ELEMENT TAPERED CHANNEL NO 20-SMALL AT TOP

5/07/65

MESH POINT- 33

DX= 0.02080 FT.

CHANNEL

	VEL FT./SEC.	T O T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.·FT ²	Q / A BTU/HR.·FT ²	W I N D O W
1	48.294 52.931	39.604 39.568	133.157		200.339 201.258			•
2	49.551	39.671	138.614		195.868 195.759			•
3	49.546	39.671	137.931		191.384 191.302			•
4	49.540	39.671	137.428		187.806 187.740			•
5	49.536	39.671	137.024		185.095 185.046			•
6	49.533	39.671	136.709		182.861 182.823			•
7	49.531	39.671	136.484		181.506 181.487			•
8	49.529	39.671	136.371		181.037 181.033			•
9	49.529	39.671	136.343		181.042 181.052			•
10	49.529	39.671	136.400		181.942 181.976			•
11	49.530	39.671	136.602		184.135 184.176			•
12	49.531	39.671	136.848		185.966 186.019			•
13	49.533	39.671	137.163		189.041 189.098			•
14	49.536	39.671	137.511		191.324 191.380			•
15	49.539	39.671	137.858		194.505 194.620			•
16	49.544	39.671	138.545		201.955 202.126			•
17	49.552	39.671	139.626		211.184 211.378			•
18	49.563	39.671	141.030		223.240 223.459	1.0219E 06	1.0113E 06	•
19	49.573	39.671	142.783		240.393 243.319	1.2236E 06	1.1534E 06	•
20	43.217	39.680	137.569					•
	48.294	39.604						

ATR NOM HOT ELEMENT TAPERED CHANNEL NO 2C-SMALL AT TOP

5/07/65

	V E L FT./SEC.	T C T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.*FT2	Q / A BTU/HR.*FT2	W I N D G W
MESH POINT- 37								
DX= 0.02080 FT.								
CHANNEL								
1	48.257 53.489	41.600 41.432	133.955	207.317	208.643			•
2	49.570	41.575	140.498	203.036	202.914			•
3	49.565	41.575	139.576	198.111	198.013			•
4	49.557	41.575	139.062	194.158	194.078			•
5	49.552	41.576	138.568	191.163	191.100			•
6	49.548	41.576	138.184	188.685	188.644			•
7	49.546	41.576	137.911	187.190	187.167			•
8	49.544	41.576	137.773	186.670	186.664			•
9	49.544	41.576	137.738	186.676	186.687			•
10	49.544	41.576	137.307	187.672	187.713			•
11	49.545	41.576	138.054	190.091	190.141			•
12	49.546	41.576	138.355	192.120	192.183			•
13	49.549	41.576	138.739	195.512	195.581			•
14	49.553	41.576	139.163	198.040	198.108			•
15	49.556	41.575	139.587	201.550	201.676			•
16	49.562	41.575	140.425	209.682	209.863			•
17	49.571	41.574	141.743	219.738	219.961			•
18	49.585	41.574	143.456	232.931	233.199	1.1254E 06	1.1125E 06	•
19	49.601	41.574	145.637	251.496	254.567	1.3450E 06	1.2713E 06	•
20	43.715	41.379	139.170					•
	48.257	41.600						

ATR NCM HOT ELEMENT TAPERED CHANNEL NO 2C-SMALL AT TOP

5/07/65

	VEL FT./SEC.	TOT PL PSI	T BULK DEG. F.	T WALL DEG. F.	T WALL DEG. F.	C / A BTU/HR. * FT.2	C / A BTU/HR. * FT.2	W I N D O W
MESH POINT- 41								
DX= 0.00010 FT.								
CHANNEL								
1	47.623 54.562	42.711 43.325	134.606					
2	49.236	42.773	142.530	211.076	213.074			
3	49.229	42.773	141.562	207.925	207.789			
4	49.220	42.774	140.828	202.743	202.639			
5	49.213	42.775	140.239	198.592	198.507			
				195.435	195.364			
6	49.209	42.775	139.780					
7	49.206	42.775	139.453	192.810	192.756			
8	49.204	42.776	139.288	191.210	191.183			
9	49.204	42.776	139.246	190.654	190.647			
10	49.204	42.776	139.329	190.660	190.674			
				191.722	191.771			
11	49.205	42.776	139.624	194.294	194.353			
12	49.206	42.775	139.983	196.448	196.516			
13	49.209	42.775	140.442	200.015	200.088			
14	49.214	42.775	140.949	202.665	202.741			
15	49.218	42.774	141.457	206.365	206.506			
16	49.225	42.773	142.457					
17	49.238	42.774	144.032	214.948	215.162			
18	49.258	42.774	146.080	225.590	225.856			
19	49.278	42.774	148.718	239.535	239.866	1.1832E 06	1.1675E 06	
20	48.159	45.136	140.826	255.995	256.005	1.3741E 06	1.3740E 06	
	47.623	42.711						

ATR NOM HOT ELEMENT TAPERED CHANNEL NO 2C-SMALL AT TOP

5/07/65

	V E L FT./SEC.	T O T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.*FT2	Q / A BTU/HR.*FT2	W I N D O W
MESH POINT- 45								
DX= 0.02080 FT.								
CHANNEL								
1	47.587 54.569	44.658 44.664	135.200					
2	49.257	44.645	144.156	216.806	218.969			
3	49.249	44.646	143.076	213.527	213.377			
4	49.237	44.646	142.246	208.004	207.887			
5	49.227	44.647	141.580	203.574	203.478			
				200.205	200.133			
6	49.223	44.648	141.061					
7	49.219	44.649	140.691	197.426	197.371			
8	49.217	44.649	140.505	195.736	195.708			
9	49.217	44.649	140.458	195.148	195.141			
10	49.217	44.649	140.552	195.155	195.169			
				196.276	196.327			
11	49.218	44.649	140.384					
12	49.219	44.649	141.291	198.998	199.058			
13	49.223	44.648	141.310	201.282	201.358			
14	49.228	44.647	142.384	205.088	205.169			
15	49.234	44.647	142.958	207.922	208.004			
				211.870	212.028			
16	49.243	44.646	144.090					
17	49.259	44.645	145.871	221.018	221.257			
18	49.281	44.643	148.187	232.355	232.658			
19	49.304	44.641	151.163	247.262	247.657	1.2662E C6	1.2473E C6	
20	47.052	45.975	142.046	265.631	266.494	1.4796E C6	1.4589E C6	
	47.587	44.658						

ATR NOM HOT ELEMENT TAPERED CHANNEL NO 2C-SMALL AT TOP

5/07/65

	VEL FT./SEC.	T C T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.·FT ²	O / A BTU/HR.·FT ²	W I N D O W
MESH PCINT- 49								
DX= C.C2080 FT.								
CHANNEL								
1	47.550 54.577	46.601 46.405	136.038		222.912 225.304			
2	49.286	46.516	146.448	219.640	219.469			
3	49.277	46.518	145.214	213.752	213.617			
4	49.263	46.520	144.248	209.022	208.912			
5	49.252	46.522	143.473	205.426	205.339			
6	49.245	46.523	142.869	202.454	202.391			
7	49.240	46.523	142.439	200.647	200.615			
8	49.238	46.524	142.222	200.017	200.009			
9	49.237	46.524	142.167	200.025	200.041			
10	49.238	46.524	142.277	201.225	201.282			
11	49.239	46.523	142.663	204.125	204.195			
12	49.241	46.523	143.137	206.571	206.658			
13	49.246	46.523	143.740	210.627	210.721			
14	49.253	46.521	144.408	213.659	213.754			
15	49.260	46.520	145.077	217.880	218.064			
16	49.271	46.519	146.393	227.625	227.904			
17	49.289	46.516	148.466	239.761	240.137			
18	49.315	46.512	151.162	255.821	256.337	1.3530E C6	1.3282E C6	
19	49.341	46.507	154.620	276.135	277.754	1.5867E C6	1.5479E C6	
20	45.998	46.759	143.759					
	47.550	46.601						

ATR NOM HOT ELEMENT TAPERED CHANNEL NC 2C-SMALL AT TOP

5/C7/65

	V E L FT./SEC.	T O T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.*FT2	Q / A BTU/HR.*FT2	W I N D O W
MESH POINT- 53								
DX= 0.02080 FT.								
CHANNEL								
1	47.270 54.641	48.380 47.587	136.932		229.106 231.859			•
2	49.063	48.209	148.889	226.105	225.915			•
3	49.053	48.212	147.492	219.837	219.683			•
4	49.037	48.216	146.382	214.791	214.664			•
5	49.025	48.219	145.490	210.950	210.850			•
6	49.017	48.220	144.796	207.777	207.705			•
7	49.012	48.222	144.302	205.847	205.811			•
8	49.009	48.222	144.052	205.172	205.163			•
9	49.008	48.223	143.989	205.181	205.199			•
10	49.009	48.222	144.116	206.463	206.528			•
11	49.010	48.222	144.560	209.554	209.633			•
12	49.012	48.222	145.104	212.165	212.269			•
13	49.018	48.220	145.798	216.491	216.599			•
14	49.026	48.218	146.565	219.732	219.840			•
15	49.034	48.217	147.335	224.242	224.453			•
16	49.046	48.214	148.849	234.666	235.013			•
17	49.067	48.209	151.233	247.766	248.241			•
18	49.097	48.202	154.334	265.045	265.648	1.4389E 06	1.4102E 06	•
19	49.127	48.194	158.309	286.506	288.073	1.6842E 06	1.6466E 06	•
20	45.799	47.596	145.568					•
	47.270	48.380						

ATR NOM HOT ELEMENT TAPERED CHANNEL NO 2C-SMALL AT TOP

5/07/65

	VEL FT./SEC.	T C T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.*FT2	C / A BTU/HR.*FT2	W I N D O W
MESH POINT- 57								
DX= 0.02080 FT.								
CHANNEL								
1	47.216 55.139	50.289 49.600	137.876					.
2	49.096	50.C54	151.473	234.018	237.284			.
3	49.085	50.C58	149.910	231.659	231.410			.
4	49.067	50.C63	148.646	224.986	224.809			.
5	49.053	50.C68	147.632	219.676	219.531			.
				215.631	215.517			.
6	49.044	50.C70	146.842					.
7	49.038	50.C72	146.279	212.292	212.209			.
8	49.034	50.C73	145.995	210.258	210.216			.
9	49.034	50.C73	145.923	209.544	209.533			.
10	49.034	50.C73	146.067	209.554	209.575			.
				210.904	210.979			.
11	49.036	50.C73	146.572					.
12	49.038	50.C72	147.192	214.150	214.241			.
13	49.045	50.C70	147.982	216.909	217.024			.
14	49.054	50.C67	148.855	221.448	221.572			.
15	49.063	50.C65	149.733	224.866	224.990			.
				229.675	229.946			.
16	49.077	50.C60	151.457					.
17	49.101	50.C53	154.170	240.774	241.202			.
18	49.134	50.C43	157.699	254.677	255.225			.
19	49.168	50.C33	162.213	272.817	273.460	1.5102E C6	1.4793E C6	.
20	46.635	49.E58	147.430	294.438	295.335	1.7583E C6	1.7367E C6	.
	47.216	50.289						.

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ATR NOM HOT ELEMENT TAPERED CHANNEL NC 2C-SMALL AT TOP

5/07/65

	VEL FT./SEC.	T C T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.*FT2	C / A BTU/HR.*FT2	W I N D O W
MESH POINT- 58								
DX= 0.00010 FT.								
CHANNEL								
1	45.548 55.975	49.264 50.518	138.11		233.996 238.076			
2	48.215	49.490	152.135		233.333 233.080			
3	48.199	49.490	150.528		226.612 226.459			
4	48.038	49.405	149.225		221.298 221.153			
5	48.014	49.403	148.175		217.194 217.079			
6	48.000	49.402	147.365		213.804 213.722			
7	47.988	49.401	146.788		211.740 211.658			
8	47.983	49.401	146.491		211.015 211.004			
9	47.982	49.400	146.417		211.025 211.047			
10	47.982	49.401	146.568		212.395 212.475			
11	47.985	49.401	147.087		215.698 215.750			
12	47.989	49.401	147.728		218.502 218.617			
13	48.000	49.402	148.540		223.105 223.234			
14	48.017	49.404	149.440		226.591 226.722			
15	48.032	49.405	150.348		231.436 231.679			
16	48.187	49.491	152.124		242.602 243.036			
17	48.221	49.490	154.921		256.706 257.261			
18	48.263	49.489	158.555		275.055 275.691	1.5100E C6	1.4797E C6	
19	48.315	49.487	163.210		288.145 279.481	1.6436E C6	1.8516E C6	
20	58.325	57.580	147.892					
	45.543	49.264						

ATR NOM HOT ELEMENT TAPERED CHANNEL NO 2C-SMALL AT TOP

5/07/65

	V E L FT./SEC.	T O T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	C / A BTU/HR.*FT2	Q / A BTU/HR.*FT2	W I N D O W
MESH POINT- 196								
DX= 0.02080 FT.								
CHANNEL								
1	39.505 52.866	100.530 99.561	173.993					
2	45.861	101.291	238.516	221.406	241.545			
3	45.877	101.306	236.930	258.514	258.144			
4	45.732	101.242	230.664	253.857	252.420			
5	45.610	101.275	225.255	246.986	245.754			
6	45.531	101.294	221.024	241.329	240.372			
7	45.471	101.309	218.029	236.973	236.303			
8	45.440	101.316	216.476	234.184	233.839			
9	45.435	101.317	216.099	232.980	232.896			
10	45.441	101.316	216.948	233.071	233.260			
11	45.455	101.312	219.552	234.834	235.416			
12	45.477	101.307	222.908	238.359	239.117			
13	45.533	101.294	227.111	242.498	243.452			
14	45.622	101.272	231.786	247.742	248.808			
15	45.707	101.250	236.938	253.134	254.317			
16	45.822	101.325	246.241	260.613	262.768			
17	46.026	101.272	260.681	273.178	277.163			
18	46.325	101.227	278.785	291.754	296.152			
19	46.445	101.157	290.398	310.520	313.375	5.1903E 05	3.8199E 05	
20	57.941	101.303	191.733	295.529	259.700	9.1944E 04	9.6143E 05	
	39.505	100.530						

ATR NOM HOT ELEMENT TAPERED CHANNEL NO 2C-SMALL AT TOP

5/07/65

	V E L FT./SEC.	T G T P L PSI	T B U L K DEG. F.	T W A L L DEG. F.	T W A L L DEG. F.	Q / A BTU/HR.*FT2	Q / A BTU/HR.*FT2	W I N D G
MESH POINT- 200								
OX= 0.02080 FT.								
CHANNEL								
	39.461	102.319						
1	52.873	100.940	174.501					
				216.475	236.789			
2	45.867	102.726	238.931					
				254.513	254.205			
3	45.888	102.741	237.622					
				250.308	248.855			
4	45.743	102.680	231.352					
				243.623	242.372			
5	45.620	102.716	225.909					
				238.086	237.114			
6	45.542	102.737	221.650					
				233.834	233.152			
7	45.481	102.752	218.635					
				231.103	230.751			
8	45.450	102.760	217.070					
				229.913	229.828			
9	45.445	102.761	216.691					
				230.006	230.200			
10	45.451	102.760	217.550					
				231.727	232.318			
11	45.465	102.756	220.156					
				235.131	235.902			
12	45.487	102.751	223.545					
				239.195	240.164			
13	45.544	102.737	227.774					
				244.277	245.361			
14	45.633	102.713	232.481					
				249.592	250.801			
15	45.719	102.689	237.692					
				256.970	259.165			
16	45.834	102.761	247.057					
				269.795	273.246			
17	46.040	102.704	261.598					
				287.366	291.815			
18	46.340	102.658	279.748					
				305.304	308.076	4.1852E 05	2.8547E 05	
19	46.453	102.585	290.921					
				289.431	253.072	2.4799E 04	8.4782E 05	
20	56.925	101.453	192.155					
	39.461	102.319						

ATR NOM HOT ELEMENT TAPERED CHANNEL NO 2C-SMALL AT TOP

5/C7/65

	VEL FT./SEC.	TCTPL PSI	TBULK DEG. F.	TWALL DEG. F.	TWALL DEG. F.	C/A BTU/HR.·FT2	J/A BTU/HR.·FT2	WINDOW
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MESH POINT- 204

DX= 0.02080 FT.

CHANNEL

	39.432	100.617						
1	52.873	100.476	174.501					
2	45.867	100.099	238.931	174.501	238.931			
3	45.888	100.111	237.622	238.931	237.622			
4	45.743	100.070	231.352	237.622	231.352			
5	45.620	100.123	225.909	231.352	225.909			
				225.909	221.650			
6	45.542	100.155	221.650					
7	45.481	100.177	218.635	221.650	218.635			
8	45.450	100.189	217.070	218.635	217.070			
9	45.445	100.191	216.691	217.070	216.691			
10	45.451	100.189	217.550	216.691	217.550			
				217.550	220.166			
11	45.465	100.183	220.166					
12	45.487	100.175	223.545	220.166	223.545			
13	45.544	100.154	227.774	223.545	227.774			
14	45.633	100.117	232.481	227.774	232.481			
15	45.719	100.082	237.692	232.481	237.692			
				237.692	247.067			
16	45.834	100.139	247.067					
17	46.040	100.055	261.598	247.067	261.598			
18	46.340	99.974	279.748	261.598	279.748			
19	46.453	99.888	290.921	279.748	290.921	0.	0.	
20	56.263	99.771	192.155	290.921	192.155	0.	0.	
	39.432	100.617						

ELAPSED TIME 001846

END-OF-DATA ENCOUNTERED ON SYSTEM INPUT FILE.

K. DICKEY ATR

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