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COMPUTER PROGRAM GRADE FOR DESIGN AND ANALYSIS OF GRADED-POROSITY HEAT-PIPE WICKS

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INTRODUCTION

The purpose of the computer program GRADE is to numerically solve the differential equations that describe heat pipes with graded-porosity fibrous wicks. Such wicks have an axial variation in porosity so that, at the maximum heat-transfer rate, the porosity is just low enough for the wick to support the local liquid-flow pressure drop plus any hydrostatic head. Thus, the highest possible permeability is obtained along the wick. For comparison of graded- to uniform-porosity wicks, GRADE can also compute the performance of the latter. In fact, the user can have GRADE calculate the porosity for a given fiber diameter, or both the porosity and fiber diameter, that gives the highest heat-transfer capacity for a uniform-porosity wick.

In the graded-porosity case, the user specifies an initial porosity* at the condenser end and either a final porosity or maximum liquid stress** at the evaporator end. GRADE then calculates the optimum porosity variation along the wick and the maximum heat-transfer rate. A summary of GRADE's capabilities follow:

- Calculation of optimum porosity variation and corresponding maximum heat-transfer rate.
- Calculation of maximum heat-transfer rate at other than the wick's design condition.
- Both earth - gravity and zero-gravity computations.
- Heat pipes having multiple sections each having different tilts.
- Multiple heat input and output zones.

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*If the user wishes, he can have GRADE compute the initial porosity as the highest for which the wick's condenser end will self-prime in a gravitational field.

**We define stress as the local vapor-liquid pressure difference.

- Calculation of the amount of liquid contained in the wick.
- Calculation of the performance of uniform-porosity wicks with a specified constant porosity.
- Calculation of optimum uniform-porosity wicks.

The mathematical model for flow through a wick is based on the TRW Report No. 21160-6005-RU-00, "Capillary Flow through Partially Saturated Wicks", however that analysis has been corrected and modified in light of recent theoretical and experimental research. A brief discussion of the mathematical basis for GRADE follows.

CAPILLARY PRESSURE

The model of capillary pressure generated by a fibrous wick includes hysteresis, that is, the capillary pressure generated for filling being significantly lower than that for emptying. The expression for the capillary pressure P generated by a wick of porosity ϕ and of diameter δ is given by

$$P = 3.247RH \frac{(1-\phi)}{\phi} \frac{\sigma}{\delta} . \qquad (1)$$

Here, σ is the surface tension and H is an empirical constant equal to unity if the wick is filling and 1.955 if emptying. The empirical constant R is the ratio of the maximum stress of a full region to the larger stress necessary to half empty the region. Its value is approximately 0.6 .

Eq. (1) is derived by first calculating the component of force perpendicular to a vapor-liquid interface exerted by surface tension acting on a single fiber that penetrates the interface at an arbitrary orientation. The force components of all fibers penetrating a given area are then summed with proper account taken of the statistical distribution of their orientations, and the sum is equated to the product of the capillary pressure and the liquid area.

Eq. (1) can be solved for ϕ , which results in

$$\phi = \frac{3.247RH\sigma/\delta}{P + 3.247RH\sigma/\delta} \qquad (2)$$

PERMEABILITY

The permeability K is the proportionality factor in Darcy's law, which relates the superficial mass flux $\dot{M}$ to the pressure gradient $\frac{dP}{dx}$ and the kinematic viscosity υ :

$$\dot{M} = \frac{K}{\upsilon} \frac{dP}{dx} .$$

The expression we use for the permeability in terms of the porosity ϕ and the fiber diameter δ is

$$K = \frac{3}{8} D \delta^2 \frac{\phi}{1-\phi} \left\{ \frac{4\phi}{4(1-\phi)-(1-\phi)^2-2\ln(1-\phi)-3} - \frac{8}{\ln(1-\phi) + \frac{1-(1-\phi)^2}{1+(1-\phi)^2}} \right\}^{-1} . \quad (3)$$

The empirical constant D is introduced to obtain close agreement between theory and experiment.

This expression is derived by first calculating the drag on an arbitrarly orientated fiber segment in the presence of neighboring fibers. The drags on all such segments contained in a cylindrical region whose axis is aligned with the flow direction are summed with account taken of the statistical distribution of their orientations. The total drag is then equated with the difference in pressure forces at each end of the cylinder.

OPTIMUM UNIFORM WICK

With the use of Eq. (1) for the capillary pressure and Eq. (3) for the permeability, we can optimize the capacity of a uniform-porosity wick with respect to its fiber diameter and porosity. The results for operation in a gravitational field are

- The optimum porosity is 0.79 and the optimum fiber diameter is such that Eq. (1) gives twice the hydrostatic contribution to the stress at the evaporator end.
- If the fiber diameter is fixed, the optimum porosity is given by Eq. (2) with P equal to twice the hydrostatic contribution to the stress at the evaporator end.

MATHEMATICAL PROBLEM STATEMENT

In this formulation, we neglect vapor-flow pressure drop. Three first-order differential equations govern the stress P (at the top of the wick if in a gravitational field), the mass flow rate $\dot{m}$, and the cumulative mass M of liquid in the wick:

$$\frac{dP}{dx} = \frac{\upsilon}{KA}\dot{m}(x) + \rho g \frac{dh}{dx} , \tag{4}$$

$$\frac{d\dot{m}}{dx} = -\frac{1}{\lambda}\dot{Q}(x) , \tag{5}$$

$$\frac{dM}{dx} = \rho A\, \phi(x) , \tag{6}$$

where υ, ρ, g, λ, A, $\frac{dh}{dx}$, and $\dot{Q}(x)$ are, respectively, the kinematic viscosity, density, gravitational acceleration, latent heat, wick area, heat-pipe slope, and heat input per unit length. The permeability K is given by Eq. (3), and for the optimum graded-porosity wick, the porosity $\phi(x)$ is set just low enough to generate the required capillary pressure. In particular, $\phi(x)$ is taken as the lowest of:

(1) The porosity required to sustain the stress P, which is calculated from Eq. (2) with the hysteresis constant $H = 1.955$.

(2) The initial porosity ϕ_o, which, if not specified, is calculated from Eq. (2) with $P = \rho g h_w$ (h_w is the wick height) and $H = 1$.

(3) The local self-priming porosity, which is calculated from Eq. (2) with $H = 1$ and $P = \rho g[h(x) + h_w]$.

In zero gravity, priming is not a factor, and the porosity $\phi(x)$ is the lower of Items (1) and (2) above. In non-zero gravity, if the user does not require the wick to self-prime along its entire length at the operating elevation, then the self-priming porosity given by Item (3) is not considered. For this case, in actual operation the wick must first be

primed by lowering the heat pipe to a more nearly level position prior to its operation. The advantage of not requiring self-priming is that higher maximum heat-transfer rates can be achieved.

The boundary conditions for the differential equations are

$$P(o) = \begin{cases} \rho g h_w & \text{if } g \neq o \ , \\ 4\sigma/D_{VS} & \text{if } g = o \ , \end{cases} \tag{7}$$

where D_{VS} is the hydraulic diameter of the vapor space,

$$\dot{m}(o) = M(o) = o \ , \tag{8}$$

$$\phi(o) = \phi_o \ , \tag{9}$$

and

$$P(L) = P_f \ . \tag{10}$$

If the final porosity $\phi(L) = \phi_f$ is specified rather than P_f, then P_f is calculated from Eq. (1) with $H = 1.955$.

The differential equations (4) - (6) are integrated repeatedly with the Runge-Kutta routine. Each time, the total heat-transfer rate is adjusted until Eq. (10) is satisfied, or, for a pre-specified porosity distributions, until the stress just matches the wick's critical stress anywhere in the interval $0 \leq x \leq L$.

INPUT

The input is in Fortran NAMELIST form. The required parameters are defined and discussed below. An input form is given in Table 1.

Headings

After writing on the first card or line the NAMELIST identifier $GRDATA, the user then inputs two lines of descriptive information by writing on one card or line HD1 = 60H followed by up to 60 characters of title and on the next card or line HD2 = 60H followed by another 60 characters. GRADE will print these two lines at the beginning of the output.

TABLE 1

HD1 = 60H _____

HD2 = 60H _____

LIQ = _____

TKELVN = _____

RHOL = _____ }

ST = _____ }

VISL = _____ } INPUT ONLY IF LIQ = 0.0

HFG = _____ }

GEE = _____

AW = _____

HW = _____

DIAF = _____

PHIO = _____ }

PHIF = _____ } HOMOGENEOUS WICK? SET PHIF = PF = 0.0
AND PHIO = WICK POROSITY. (IF ONE SETS PHIO = 0.0 OR
PHIO = DIAF = 0.0, GRADE PROVIDES OPTIMUM VALUES FOR
THESE.)

PF = _____ }

DIAVS = _____

QDΦT = _____

NQ = _____

XQ = _____

FQ = _____

NELE = _____

XELEV = _____

ELEV = _____

DX = _____

NCASE = _____

LASTPHT = _____

ISLFRRM = _____

074-4

$END

Fluid Properties

GRADE automatically computes the required fluid properties for one of several fluids, which the user specifies by selecting a value of LIQ from the following list:

	Fluid	Temperature Range
LIQ = 1	Water	(32F < T < 400F)
LIQ = 2	Ammonia	(-108F < T < 190F)
LIQ = 3	Methyl Alcohol	(-140F < T < 380F)
LIQ = 4	FREON-21	(-55F < T < 305F)
LIQ = 5	Ethane	(-135F < T < 80F)
LIQ = 6	Methane	(-280F < T < 120F)
LIQ = 7	Nitrogen	(-340F < T < 250F)

The properties are for a temperature TKELVN that the user inputs in degrees Kelvin. All other fluid properties are automatically computed for that temperature. If another fluid is used, set LIQ = 0 . Then, values must be specified for the following quantities:

Quantity	Symbol	Units
Liquid density	RHOL	Kg/cu. m
Surface tension	ST	Newtons/m
Liquid viscosity	VISL	Newton-sec/sq. m
Latent heat	HFG	Joules/Kg

Caution must be used with fluids other than ammonia at ambient temperatures. Since GRADE was specifically written for ammonia heat pipes, the vapor-flow pressure drop was neglected. For fluids with a relatively low vapor density, GRADE must be modified to include vapor-flow pressure drop.

Geometrical Parameters

The following quantities specify the cross-sectional geometry:

Quantity	Symbol	Units
Wick area	AW	sq. cm
Wick height from tube bottom	HW	cm
Fiber diameter	DIAF	cm
Initial porosity	PHIO	dimensionless
Final porosity	PHIF	dimensionless
Vapor-space hydraulic diameter	DIAVS	cm
Final stress	PF	cm liquid

For non-zero-gravity calculations, if the user sets PHIO = 0.0 , GRADE calculates a value just low enough for the wick to self prime at the condenser end. If the user chooses to specify the final stress, instead of a final porosity, he sets PHIF = 0.0 and PF to a non-zero value. Otherwise, PF is set to zero.

To calculate the performance of a homogeneous wick, both PHIF and PF are set to zero, and PHIO is set equal to the desired constant porosity of the wick. If PHIO is set to zero, GRADE calculates an optimum value that gives the highest capacity for the operating condition. If, in addition, the fiber diameter DIAF is set to zero, GRADE will supply optimum values for both DIAF and PHIO .

Heat Input

The user specifies the heat-input distribution by specifying the fraction of the total heat-transfer rate for up to ten segments of the heat pipe. Heat transfer is assumed to be constant along the given segment. Values for the following parameters are required:

NQ - the number of segments, which must not exceed ten, into which the heat pipe is divided.

XQ(I) - the length of the I^{th} segment in cm. The segments must be numbered consecutively along the heat pipe beginning at the condenser end.

FQ(I) - the fraction of the total heat-transfer rate entering the I^{th} segment. If the I^{th} segment is adiabatic, FQ(I) is negative.

QDΦT - A nominal heat-transfer rate in watts, which is the user's best guess at the maximum. A close guess reduces the number of iterations to the final answer.

Elevations

The user specifies the heat-pipe orientation in a gravitational field by inputing values for elevations of points along the heat pipe where the slope changes. Between points, GRADE assumes a linear variation of elevation. Values of the following parameters are required (except for zero gravity):

NELEV - the total number of points along the heat pipe, which must not exceed 10.

XELEV(I) - the distance along the heat pipe in cm to the I^{th} point. Both ends of the heat pipe must be input, therefore the first point must be at zero distance [XELEV(1) = 0.0], and the last at the total heat-pipe length [XELEV(NELEV) = L].

ELEV(I) - the elevation in cm of the I^{th} point relative to a horizontal refernece plane.

GEE - gravitational acceleration in standard gravities.

Program Control

The following quantities relate to the mechanics of the program and user options:

DX - integration step size, in cm.

ISLFPRM - equals 1 if the user requires the wick to self-prime at the specified elevations and zero load.

- equals 0 if the user does not require the wick to self prime.

NCASE - equals 1 if another case follows.

- equals 0 if another case does not follow.

LASTPHI - equals 1 if the porosity distribution of the last case is to be used.

- equals 0 if it is not to be used.

$END - ends NAMELIST input.

If another case is to follow (NCASE = 1), then another NAMELIST input follows that is exactly like the first except only those quantities that are to be different in the new case are included. Up to ten cases can be run. The NAMELIST input for the sample calculations are included in Appendix A.

OUTPUT

GRADE first prints the headings that the user has input. The input variables and computed thermodynamic properties are printed next. The final iterated solution follows, which consists of the maximum heat-transfer rate, the total amount of liquid in the wick, and a tabulation of distance along the heat pipe, stress, static head, porosity and critical stress. The static head is that part of the stress due to gravity. The critical stress is the maximum the wick can sustain without failing.

SAMPLE PROBLEM

To demonstrate GRADE, a typical heat pipe was analyzed. It has a .356-cm x 1.128-cm (.140-in x .444-in) slab wick with a fiber diameter of .01016 cm (.004 in). The heat pipe is 180-cm long with single condenser,

adiabatic and evaporator sections of 60 cm. Performance was studied for ammonia at 294°K (70°F).

For the first run (output in Appendix A) the evaporator end was elevated 2 cm. A final stress of 7 cm is specified, which is slightly above the pumping ability of a .0178-cm (.007-in) pore. (We have previously judged that such a pore corresponds to the critical stress at which grooves lose communication with the wick. By setting PHIO=0. we let GRADE calculate the initial porosity that is just low enough to prime the condenser end of the wick. We require in the first run that the entire wick has a no-load self-priming capability at the 2-cm elevation (ISLFPRM = 1). GRADE computed a maximum heat-transfer rate of 81.3 watts (3843 watt-in). The stress and porosity distrubtion are shown in Fig. 1. Until the break in the stress curve at 120 cm, the reduction in porosity is due to the self-priming requirement.

For the second run, the same porosity variation was studied in zero gravity. The calculated maximum heat-transfer rate is 141 watts (6661 watts-in). Notice that in zero gravity, the initial stress has the low value of the vapor-space capillary pressure, whereas in earth gravity the initial stress is set by the hydrostatic head at the top of the wick of 1.128 cm.

For the third run, the self-priming requirement of the first run was dropped (ISLFPRM = 0). This increased the maximum heat-transfer rate to 115 watts (5452 watt-in). The wick porosity remains constant at its initial value until at 62 cm the stress reaches the capillary-pressure limit of the wick for emptying.

In the fourth run, the wick designed in the third run is studied in zero gravity. The maximum heat transfer rate is 200 watts (9439 watt-in).

In the fifth run, we study a homogeneous wick with a porosity of .683, which is the same final value as the graded-porosity wicks. Thus the homogeneous and graded-porosity wicks have the same elevation at which the heat-transfer capacity goes to zero. The calculated capacity for the homogeneous wick at a 2-cm elevation is 30 watts (1409 watt-in).

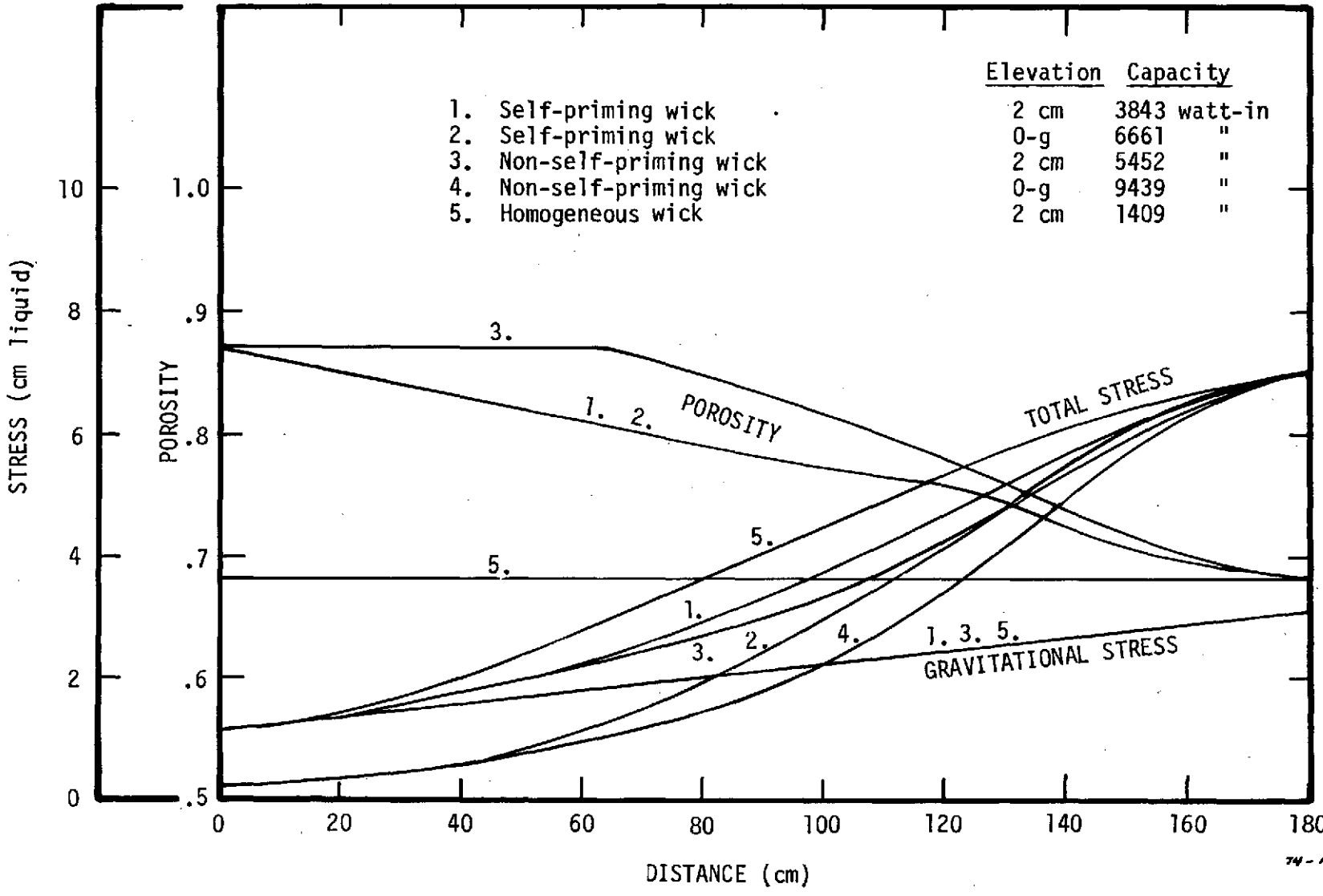

FIGURE 1. Porosity and Stress Distribution for the Sample Problem

APPENDIX A

SAMPLE PROBLEM INPUT AND OUTPUT

NAMELIST INPUT

```
$GRDATA
HD1=60HGRADE SAMPLE PROBLEM
HD2=60HSELF-PRIMING WICK   2-CM ELEVATION
LIQ=2
TKELVN=294.
GEE=1.0
AW=0.401
HW=1.128
DIAF=0.01016
PHI0=0.0
PHIF=0.0
PF=7.0
DIAVS=0.470
QDOT=100.
NO=3
FQ=-1.0,0.0,1.0
XQ=60.,60.,60.
NELEV=2
XELEV=0.0,180.
ELEV=0.0,2.0
DX=2.
LASTPHI=0
ISLFPRM=1
NCASE=1
$END
$GRDATA
HD2=60HSELF-PRIMING WICK   ZERO GRAVITY
GEE=0.0
LASTPHI=1
$END
$GRDATA
HD2=60HNON-SELF-PRIMING WICK   2-CM ELEVATION
GEE=1.0
LASTPHI=0
ISLFPRM=0
$END
$GRDATA
HD2=60HNON-SELF-PRIMING WICK   ZERO GRAVITY
GEE=0.0
LASTPHI=1
$END
$GRDATA
```

```
HD2=6)HHOMOGENEOUS WICK   2-CM ELEVATION
GEE=1.0
LASTPHI=0
PF=0.0
PHI0=.6835
NCASE=0
ISLFPRM=0
$END
```

GRADE SAMPLE PROBLEM
SELF-PRIMING WICK 2-CM ELEVATION

CASE NO. 1

INPUT VARIABLES AND FLUID PROPERTIES:

LIQUID NUMBER.....	LIQ =	2	
TEMPERATURE.....	TKELVN =	2.94000E+02	DEGREES KELVIN
LIQUID DENSITY.....	RHOL =	6.09435E+02	KG/CU. M
SURFACE TENSION.....	ST =	2.09409E-02	NEWTONS/M
LIQUID VISCOSITY.....	VISL =	1.37340E-04	NEWTON-SEC/SQ. M
LATENT HEAT.....	HFG =	1.18576E+06	JOULES/KG
GRAVITATIONAL ACCELERATION....	GEE =	1.00000E+00	STANDARD GRAVITIES
WICK AREA.....	AW =	4.81000E-01	SQ. CM
WICK HEIGHT.....	HW =	1.12800E+00	CM
WICK FIBER DIAMETER.....	DIAF =	1.01600E-02	CM
INITIAL POROSITY.....	PHIO =	0.	
FINAL POROSITY.....	PHIF =	0.	
FINAL STRESS.....	PF =	7.00000E+00	CM LIQ.
VAPOR-SPACE DIAMETER.....	DIAVS =	4.70000E-01	CM
NOMINAL HEAT-TRANSFER RATE....	QDOT =	1.00000E+02	WATTS
NO. HEAT-INPUT SECTIONS.....	NQ =	3	
SECTION NUMBER 1			
SECTION LENGTH.....	XQ =	6.00000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	-1.00000E+00	
SECTION NUMBER 2			
SECTION LENGTH.....	XQ =	6.00000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	0.	
SECTION NUMBER 3			
SECTION LENGTH.....	XQ =	6.00000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	1.00000E+00	
NO. ELEVATION POINTS.....	NELEV =	2	
ELEVATION POINT NO. 1			
DISTANCE TO POINT.....	XELEV =	0.	CM
ELEVATION OF POINT.....	ELEV =	0.	CM

```
ELEVATION POINT NO.   2
     DISTANCE TO POINT.........    XELEV =  1.800000E+02  CM
     ELEVATION OF POINT........     ELEV =  2.000000E+00  CM

INTEGRATION STEP SIZE..........       DX =  2.000000E+00  CM

ANOTHER CASE (0=NO, 1=YES).....    NCASE =  1
USE LAST POROSITY DISTN........  LASTPHI =  0
REQUIRE SELF PRIME.............  ISLFPRM =  1
```

FINAL SOLUTION

THE MAXIMUM HEAT-TRANSFER RATE IS 8.14453E+01 WATTS

THE TOTAL LIQUID IN WICK IS 3.43306E+01 GRAMS

DISTANCE (CM)	STRESS (CM LIQ.)	STATIC HEAD (CM LIQ.)	POROSITY	CRIT. STRESS (CM LIQ.)
0.	1.1280E+00	1.1280E+00	8.7265E-01	2.2052E+00
2.0000E+00	1.1505E+00	1.1502E+00	8.7046E-01	2.2487E+00
4.0000E+00	1.1737E+00	1.1724E+00	8.6829E-01	2.2921E+00
6.0000E+00	1.1975E+00	1.1947E+00	8.6613E-01	2.3356E+00
8.0000E+00	1.2220E+00	1.2169E+00	8.6398E-01	2.3790E+00
1.0000E+01	1.2473E+00	1.2391E+00	8.6184E-01	2.4225E+00
1.2000E+01	1.2734E+00	1.2613E+00	8.5971E-01	2.4659E+00
1.4000E+01	1.3004E+00	1.2836E+00	8.5759E-01	2.5094E+00
1.6000E+01	1.3282E+00	1.3058E+00	8.5548E-01	2.5528E+00
1.8000E+01	1.3570E+00	1.3280E+00	8.5338E-01	2.5962E+00
2.0000E+01	1.3868E+00	1.3502E+00	8.5129E-01	2.6397E+00
2.2000E+01	1.4176E+00	1.3724E+00	8.4921E-01	2.6831E+00
2.4000E+01	1.4496E+00	1.3947E+00	8.4714E-01	2.7266E+00
2.6000E+01	1.4827E+00	1.4169E+00	8.4509E-01	2.7700E+00
2.8000E+01	1.5170E+00	1.4391E+00	8.4304E-01	2.8135E+00
3.0000E+01	1.5525E+00	1.4613E+00	8.4100E-01	2.8569E+00
3.2000E+01	1.5894E+00	1.4836E+00	8.3897E-01	2.9004E+00
3.4000E+01	1.6277E+00	1.5058E+00	8.3695E-01	2.9438E+00
3.6000E+01	1.6674E+00	1.5280E+00	8.3494E-01	2.9872E+00
3.8000E+01	1.7086E+00	1.5502E+00	8.3294E-01	3.0307E+00
4.0000E+01	1.7514E+00	1.5724E+00	8.3095E-01	3.0741E+00
4.2000E+01	1.7958E+00	1.5947E+00	8.2897E-01	3.1176E+00
4.4000E+01	1.8419E+00	1.6169E+00	8.2700E-01	3.1610E+00
4.6000E+01	1.8898E+00	1.6391E+00	8.2504E-01	3.2045E+00
4.8000E+01	1.9395E+00	1.6613E+00	8.2309E-01	3.2479E+00
5.0000E+01	1.9912E+00	1.6836E+00	8.2114E-01	3.2914E+00
5.2000E+01	2.0448E+00	1.7058E+00	8.1921E-01	3.3348E+00
5.4000E+01	2.1004E+00	1.7280E+00	8.1729E-01	3.3782E+00
5.6000E+01	2.1582E+00	1.7502E+00	8.1537E-01	3.4217E+00
5.8000E+01	2.2181E+00	1.7724E+00	8.1346E-01	3.4651E+00

6.0000E+01	2.2804E+00	1.7947E+00	8.1156E-01	3.5086E+00
6.2000E+01	2.3441E+00	1.8169E+00	8.0968E-01	3.5520E+00
6.4000E+01	2.4087E+00	1.8391E+00	8.0780E-01	3.5955E+00
6.6000E+01	2.4744E+00	1.8613E+00	8.0592E-01	3.6389E+00
6.8000E+01	2.5411E+00	1.8836E+00	8.0406E-01	3.6824E+00
7.0000E+01	2.6088E+00	1.9058E+00	8.0221E-01	3.7258E+00
7.2000E+01	2.6776E+00	1.9280E+00	8.0036E-01	3.7692E+00
7.4000E+01	2.7474E+00	1.9502E+00	7.9852E-01	3.8127E+00
7.6000E+01	2.8183E+00	1.9724E+00	7.9669E-01	3.8561E+00
7.8000E+01	2.8903E+00	1.9947E+00	7.9487E-01	3.8996E+00
8.0000E+01	2.9634E+00	2.0169E+00	7.9306E-01	3.9430E+00
8.2000E+01	3.0376E+00	2.0391E+00	7.9126E-01	3.9865E+00
8.4000E+01	3.1130E+00	2.0613E+00	7.8946E-01	4.0299E+00
8.6000E+01	3.1895E+00	2.0836E+00	7.8767E-01	4.0734E+00
8.8000E+01	3.2672E+00	2.1058E+00	7.8589E-01	4.1168E+00
9.0000E+01	3.3461E+00	2.1280E+00	7.8412E-01	4.1602E+00
9.2000E+01	3.4262E+00	2.1502E+00	7.8236E-01	4.2037E+00
9.4000E+01	3.5075E+00	2.1724E+00	7.8060E-01	4.2471E+00
9.6000E+01	3.5900E+00	2.1947E+00	7.7885E-01	4.2906E+00
9.8000E+01	3.6738E+00	2.2169E+00	7.7711E-01	4.3340E+00
1.0000E+02	3.7589E+00	2.2391E+00	7.7538E-01	4.3775E+00
1.0200E+02	3.8452E+00	2.2613E+00	7.7366E-01	4.4209E+00
1.0400E+02	3.9328E+00	2.2836E+00	7.7194E-01	4.4644E+00
1.0600E+02	4.0218E+00	2.3058E+00	7.7023E-01	4.5078E+00
1.0800E+02	4.1121E+00	2.3280E+00	7.6853E-01	4.5512E+00
1.1000E+02	4.2037E+00	2.3502E+00	7.6683E-01	4.5947E+00
1.1200E+02	4.2967E+00	2.3724E+00	7.6515E-01	4.6381E+00
1.1400E+02	4.3911E+00	2.3947E+00	7.6347E-01	4.6816E+00
1.1600E+02	4.4868E+00	2.4169E+00	7.6180E-01	4.7250E+00
1.1800E+02	4.5840E+00	2.4391E+00	7.6013E-01	4.7685E+00
1.2000E+02	4.6827E+00	2.4613E+00	7.5847E-01	4.8119E+00
1.2200E+02	4.7829E+00	2.4836E+00	7.5682E-01	4.8554E+00
1.2400E+02	4.8845E+00	2.5058E+00	7.5518E-01	4.8988E+00
1.2600E+02	4.9877E+00	2.5280E+00	7.5224E-01	4.9423E+00
1.2800E+02	5.0924E+00	2.5502E+00	7.4862E-01	5.0742E+00
1.3000E+02	5.1717E+00	2.5724E+00	7.4502E-01	5.1717E+00
1.3200E+02	5.2691E+00	2.5947E+00	7.4146E-01	5.2691E+00
1.3400E+02	5.3664E+00	2.6169E+00	7.3794E-01	5.3664E+00
1.3600E+02	5.4633E+00	2.6391E+00	7.3446E-01	5.4633E+00
1.3800E+02	5.5597E+00	2.6613E+00	7.3103E-01	5.5597E+00
1.4000E+02	5.6553E+00	2.6836E+00	7.2767E-01	5.6553E+00
1.4200E+02	5.7500E+00	2.7058E+00	7.2436E-01	5.7500E+00

1.4400E+02	5.8435E+00	2.7280E+00	7.2113E-01	5.8435E+00
1.4600E+02	5.9355E+00	2.7502E+00	7.1798E-01	5.9355E+00
1.4800E+02	6.0258E+00	2.7724E+00	7.1491E-01	6.0258E+00
1.5000E+02	6.1141E+00	2.7947E+00	7.1194E-01	6.1141E+00
1.5200E+02	6.2001E+00	2.8169E+00	7.0907E-01	6.2001E+00
1.5400E+02	6.2836E+00	2.8391E+00	7.0630E-01	6.2836E+00
1.5600E+02	6.3642E+00	2.8613E+00	7.0365E-01	6.3642E+00
1.5800E+02	6.4416E+00	2.8836E+00	7.0112E-01	6.4416E+00
1.6000E+02	6.5157E+00	2.9058E+00	6.9872E-01	6.5157E+00
1.6200E+02	6.5860E+00	2.9280E+00	6.9646E-01	6.5860E+00
1.6400E+02	6.6522E+00	2.9502E+00	6.9434E-01	6.6522E+00
1.6600E+02	6.7141E+00	2.9724E+00	6.9237E-01	6.7141E+00
1.6800E+02	6.7715E+00	2.9947E+00	6.9055E-01	6.7715E+00
1.7000E+02	6.8240E+00	3.0169E+00	6.8890E-01	6.8240E+00
1.7200E+02	6.8714E+00	3.0391E+00	6.8741E-01	6.8714E+00
1.7400E+02	6.9135E+00	3.0613E+00	6.8610E-01	6.9135E+00
1.7600E+02	6.9501E+00	3.0836E+00	6.8496E-01	6.9501E+00
1.7800E+02	6.9811E+00	3.1058E+00	6.8400E-01	6.9811E+00
1.8000E+02	7.0062E+00	3.1280E+00	6.8322E-01	7.0062E+00

GRADE SAMPLE PROBLEM
SELF-PRIMING WICK ZERO GRAVITY

CASE NO. 2

INPUT VARIABLES AND FLUID PROPERTIES:

LIQUID NUMBER.....	LIQ =	2	
TEMPERATURE.....	TKELVN =	2.94000E+02	DEGREES KELVIN
LIQUID DENSITY.....	RHOL =	6.09435E+02	KG/CU. M
SURFACE TENSION.....	ST =	2.03409E-02	NEWTONS/M
LIQUID VISCOSITY.....	VISL =	1.37840E-04	NEWTON-SEC/SQ. M
LATENT HEAT.....	HFG =	1.18576E+06	JOULES/KG
GRAVITATIONAL ACCELERATION....	GEE =	0.	STANDARD GRAVITIES
WICK AREA.....	AW =	4.01000E-01	SQ. CM
WICK HEIGHT.....	HW =	1.12800E+00	CM
WICK FIBER DIAMETER.....	DIAF =	1.01600E-02	CM
INITIAL POROSITY.....	PHIO =	0.	
FINAL POROSITY.....	PHIF =	0.	
FINAL STRESS.....	PF =	7.00000E+00	CM LIQ.
VAPOR-SPACE DIAMETER.....	DIAVS =	4.70000E-01	CM
NOMINAL HEAT-TRANSFER RATE....	QDOT =	1.00000E+02	WATTS
NO. HEAT-INPUT SECTIONS.....	NQ =	3	
SECTION NUMBER 1			
SECTION LENGTH.....	XQ =	6.00000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	-1.00000E+00	
SECTION NUMBER 2			
SECTION LENGTH.....	XQ =	6.00000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	0.	
SECTION NUMBER 3			
SECTION LENGTH.....	XQ =	6.03000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	1.00000E+00	
NO. ELEVATION POINTS.....	NELEV =	2	
ELEVATION POINT NO. 1			
DISTANCE TO POINT.....	XELEV =	0.	CM
ELEVATION OF POINT.....	ELEV =	0.	CM

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ELEVATION POINT NO.   2
     DISTANCE TO POINT.........     XELEV =  1.80000E+02  CM
     ELEVATION OF POINT........      ELEV =  2.00000E+00  CM

INTEGRATION STEP SIZE..........        DX =  2.00000E+00  CM

ANOTHER CASE (0=NO, 1=YES).....     NCASE =  1
USE LAST POROSITY DISTN........   LASTPHI =  1
REQUIRE SELF PRIME.............   ISLFPRM =  1
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FINAL SOLUTION

THE MAXIMUM HEAT-TRANSFER RATE IS 1.39551E+02 WATTS

THE TOTAL LIQUID IN WICK IS 3.43306E+01 GRAMS

DISTANCE (CM)	STRESS (CM LIQ.)	STATIC HEAD (CM LIQ.)	POROSITY	CRIT. STRESS (CM LIQ.)
0.	2.9840E-01	0.	8.7265E-01	2.2052E+00
2.0000E+00	2.9892E-01	0.	8.7046E-01	2.2487E+00
4.0000E+00	3.0051E-01	0.	8.6829E-01	2.2921E+00
6.0000E+00	3.0325E-01	0.	8.6613E-01	2.3356E+00
8.0000E+00	3.0722E-01	0.	8.6398E-01	2.3790E+00
1.0000E+01	3.1248E-01	0.	8.6184E-01	2.4225E+00
1.2000E+01	3.1912E-01	0.	8.5971E-01	2.4659E+00
1.4000E+01	3.2721E-01	0.	8.5759E-01	2.5094E+00
1.6000E+01	3.3685E-01	0.	8.5548E-01	2.5528E+00
1.8000E+01	3.4810E-01	0.	8.5338E-01	2.5962E+00
2.0000E+01	3.6106E-01	0.	8.5129E-01	2.6397E+00
2.2000E+01	3.7582E-01	0.	8.4921E-01	2.6831E+00
2.4000E+01	3.9246E-01	0.	8.4714E-01	2.7266E+00
2.6000E+01	4.1108E-01	0.	8.4509E-01	2.7700E+00
2.8000E+01	4.3178E-01	0.	8.4304E-01	2.8135E+00
3.0000E+01	4.5464E-01	0.	8.4100E-01	2.8569E+00
3.2000E+01	4.7977E-01	0.	8.3897E-01	2.9004E+00
3.4000E+01	5.0727E-01	0.	8.3695E-01	2.9438E+00
3.6000E+01	5.3724E-01	0.	8.3494E-01	2.9872E+00
3.8000E+01	5.6979E-01	0.	8.3294E-01	3.0307E+00
4.0000E+01	6.0503E-01	0.	8.3095E-01	3.0741E+00
4.2000E+01	6.4307E-01	0.	8.2897E-01	3.1176E+00
4.4000E+01	6.8401E-01	0.	8.2700E-01	3.1610E+00
4.6000E+01	7.2798E-01	0.	8.2504E-01	3.2045E+00
4.8000E+01	7.7509E-01	0.	8.2309E-01	3.2479E+00
5.0000E+01	8.2547E-01	0.	8.2114E-01	3.2914E+00
5.2000E+01	8.7922E-01	0.	8.1921E-01	3.3348E+00
5.4000E+01	9.3649E-01	0.	8.1729E-01	3.3782E+00
5.6000E+01	9.9740E-01	0.	8.1537E-01	3.4217E+00
5.8000E+01	1.0621E+00	0.	8.1346E-01	3.4651E+00

6.0000E+01	1.1306E+00	0.	8.1156E-01	3.5036E+00
6.2000E+01	1.2017E+00	0.	8.0968E-01	3.5520E+00
6.4000E+01	1.2744E+00	0.	8.0780E-01	3.5955E+00
6.6000E+01	1.3488E+00	0.	8.0592E-01	3.6389E+00
6.8000E+01	1.4250E+00	0.	8.0406E-01	3.6824E+00
7.0000E+01	1.5029E+00	0.	8.0221E-01	3.7258E+00
7.2000E+01	1.5827E+00	0.	8.0036E-01	3.7692E+00
7.4000E+01	1.6643E+00	0.	7.9852E-01	3.8127E+00
7.6000E+01	1.7477E+00	0.	7.9669E-01	3.8561E+00
7.8000E+01	1.8330E+00	0.	7.9487E-01	3.8996E+00
8.0000E+01	1.9202E+00	0.	7.9306E-01	3.9430E+00
8.2000E+01	2.0093E+00	0.	7.9126E-01	3.9865E+00
8.4000E+01	2.1004E+00	0.	7.8946E-01	4.0299E+00
8.6000E+01	2.1934E+00	0.	7.8767E-01	4.0734E+00
8.8000E+01	2.2885E+00	0.	7.8589E-01	4.1168E+00
9.0000E+01	2.3855E+00	0.	7.8412E-01	4.1602E+00
9.2000E+01	2.4847E+00	0.	7.8236E-01	4.2037E+00
9.4000E+01	2.5859E+00	0.	7.8060E-01	4.2471E+00
9.6000E+01	2.6893E+00	0.	7.7885E-01	4.2906E+00
9.8000E+01	2.7947E+00	0.	7.7711E-01	4.3340E+00
1.0000E+02	2.9024E+00	0.	7.7538E-01	4.3775E+00
1.0200E+02	3.0122E+00	0.	7.7366E-01	4.4209E+00
1.0400E+02	3.1243E+00	0.	7.7194E-01	4.4644E+00
1.0600E+02	3.2386E+00	0.	7.7023E-01	4.5078E+00
1.0800E+02	3.3552E+00	0.	7.6853E-01	4.5512E+00
1.1000E+02	3.4742E+00	0.	7.6683E-01	4.5947E+00
1.1200E+02	3.5954E+00	0.	7.6515E-01	4.6381E+00
1.1400E+02	3.7191E+00	0.	7.6347E-01	4.6816E+00
1.1600E+02	3.8451E+00	0.	7.6180E-01	4.7250E+00
1.1800E+02	3.9735E+00	0.	7.6013E-01	4.7685E+00
1.2000E+02	4.1045E+00	0.	7.5847E-01	4.8119E+00
1.2200E+02	4.2364E+00	0.	7.5682E-01	4.8554E+00
1.2400E+02	4.3662E+00	0.	7.5518E-01	4.8988E+00
1.2600E+02	4.4948E+00	0.	7.5224E-01	4.9770E+00
1.2800E+02	4.6234E+00	0.	7.4862E-01	5.0742E+00
1.3000E+02	4.7523E+00	0.	7.4502E-01	5.1717E+00
1.3200E+02	4.8812E+00	0.	7.4146E-01	5.2691E+00
1.3400E+02	5.0097E+00	0.	7.3794E-01	5.3664E+00
1.3600E+02	5.1377E+00	0.	7.3446E-01	5.4633E+00
1.3800E+02	5.2648E+00	0.	7.3103E-01	5.5597E+00
1.4000E+02	5.3906E+00	0.	7.2767E-01	5.6553E+00
1.4200E+02	5.5147E+00	0.	7.2436E-01	5.7500E+00

1.4400E+02	5.6368E+00	0.	7.2113E-01	5.8435E+00
1.4600E+02	5.7564E+00	0.	7.1798E-01	5.9355E+00
1.4800E+02	5.8730E+00	0.	7.1491E-01	6.0258E+00
1.5000E+02	5.9862E+00	0.	7.1194E-01	6.1141E+00
1.5200E+02	6.0955E+00	0.	7.0907E-01	6.2001E+00
1.5400E+02	6.2004E+00	0.	7.0630E-01	6.2836E+00
1.5600E+02	6.3005E+00	0.	7.0365E-01	6.3642E+00
1.5800E+02	6.3951E+00	0.	7.0112E-01	6.4416E+00
1.6000E+02	6.4839E+00	0.	6.9872E-01	6.5157E+00
1.6200E+02	6.5662E+00	0.	6.9646E-01	6.5860E+00
1.6400E+02	6.6416E+00	0.	6.9434E-01	6.6522E+00
1.6600E+02	6.7097E+00	0.	6.9237E-01	6.7141E+00
1.6800E+02	6.7698E+00	0.	6.9055E-01	6.7715E+00
1.7000E+02	6.8217E+00	0.	6.8890E-01	6.8240E+00
1.7200E+02	6.8649E+00	0.	6.8741E-01	6.8714E+00
1.7400E+02	6.8989E+00	0.	6.8610E-01	6.9135E+00
1.7600E+02	6.9236E+00	0.	6.8496E-01	6.9501E+00
1.7800E+02	6.9385E+00	0.	6.8400E-01	6.9811E+00
1.8000E+02	6.9436E+00	0.	6.8322E-01	7.0062E+00

GRADE SAMPLE PROBLEM
NON-SELF-PRIMING WICK 2-CM ELEVATION

CASE NO. 3

INPUT VARIABLES AND FLUID PROPERTIES:

LIQUID NUMBER.....	LIQ =	2	
TEMPERATURE.....	TKELVN =	2.94000E+02	DEGREES KELVIN
LIQUID DENSITY.....	RHOL =	6.03435E+02	KG/CU. M
SURFACE TENSION.....	ST =	2.09409E-02	NEWTONS/M
LIQUID VISCOSITY.....	VISL =	1.37840E-04	NEWTON-SEC/SQ. M
LATENT HEAT.....	HFG =	1.18576E+06	JOULES/KG
GRAVITATIONAL ACCELERATION....	GEE =	1.00000E+00	STANDARD GRAVITIES
WICK AREA.....	AW =	4.01000E-01	SQ. CM
WICK HEIGHT.....	HW =	1.12800E+00	CM
WICK FIBER DIAMETER.....	DIAF =	1.01600E-02	CM
INITIAL POROSITY.....	PHIO =	0.	
FINAL POROSITY.....	PHIF =	0.	
FINAL STRESS.....	PF =	7.00000E+00	CM LIQ.
VAPOR-SPACE DIAMETER.....	DIAVS =	4.70000E-01	CM
NOMINAL HEAT-TRANSFER RATE....	QDOT =	1.00000E+02	WATTS
NO. HEAT-INPUT SECTIONS.....	NQ =	3	
SECTION NUMBER 1			
SECTION LENGTH.....	XQ =	6.00000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	-1.00000E+00	
SECTION NUMBER 2			
SECTION LENGTH.....	XQ =	6.00000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	0.	
SECTION NUMBER 3			
SECTION LENGTH.....	XQ =	6.00000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	1.00000E+00	
NO. ELEVATION POINTS.....	NELEV =	2	
ELEVATION POINT NO. 1			
DISTANCE TO POINT.....	XELEV =	0.	CM
ELEVATION OF POINT.....	ELEV =	0.	CM

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ELEVATION POINT NO.   2
     DISTANCE TO POINT.........     XELEV =   1.80000E+02   CM
     ELEVATION OF POINT........      ELEV =   2.00000E+00   CM

INTEGRATION STEP SIZE..........        DX =   2.00000E+00   CM

ANOTHER CASE (0=NO, 1=YES).....     NCASE =   1
USE LAST POROSITY DISTN........   LASTPHI =   0
REQUIRE SELF PRIME.............   ISLFPRM =   0
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FINAL SOLUTION

THE MAXIMUM HEAT-TRANSFER RATE IS 1.15430E+02 WATTS

THE TOTAL LIQUID IN WICK IS 3.56100E+01 GRAMS

DISTANCE (CM)	STRESS (CM LIQ.)	STATIC HEAD (CM LIQ.)	POROSITY	CRIT. STRESS (CM LIQ.)
0.	1.1280E+00	1.1280E+00	8.7265E-01	2.2052E+00
2.0000E+00	1.1506E+00	1.1502E+00	8.7265E-01	2.2052E+00
4.0000E+00	1.1741E+00	1.1724E+00	8.7265E-01	2.2052E+00
6.0000E+00	1.1984E+00	1.1947E+00	8.7265E-01	2.2052E+00
8.0000E+00	1.2236E+00	1.2169E+00	8.7265E-01	2.2052E+00
1.0000E+01	1.2495E+00	1.2391E+00	8.7265E-01	2.2052E+00
1.2000E+01	1.2763E+00	1.2613E+00	8.7265E-01	2.2052E+00
1.4000E+01	1.3040E+00	1.2836E+00	8.7265E-01	2.2052E+00
1.6000E+01	1.3324E+00	1.3058E+00	8.7265E-01	2.2052E+00
1.8000E+01	1.3617E+00	1.3280E+00	8.7265E-01	2.2052E+00
2.0000E+01	1.3919E+00	1.3502E+00	8.7265E-01	2.2052E+00
2.2000E+01	1.4228E+00	1.3724E+00	8.7265E-01	2.2052E+00
2.4000E+01	1.4547E+00	1.3947E+00	8.7265E-01	2.2052E+00
2.6000E+01	1.4873E+00	1.4169E+00	8.7265E-01	2.2052E+00
2.8000E+01	1.5208E+00	1.4391E+00	8.7265E-01	2.2052E+00
3.0000E+01	1.5551E+00	1.4613E+00	8.7265E-01	2.2052E+00
3.2000E+01	1.5902E+00	1.4836E+00	8.7265E-01	2.2052E+00
3.4000E+01	1.6262E+00	1.5058E+00	8.7265E-01	2.2052E+00
3.6000E+01	1.6630E+00	1.5280E+00	8.7265E-01	2.2052E+00
3.8000E+01	1.7006E+00	1.5502E+00	8.7265E-01	2.2052E+00
4.0000E+01	1.7391E+00	1.5724E+00	8.7265E-01	2.2052E+00
4.2000E+01	1.7784E+00	1.5947E+00	8.7265E-01	2.2052E+00
4.4000E+01	1.8185E+00	1.6169E+00	8.7265E-01	2.2052E+00
4.6000E+01	1.8595E+00	1.6391E+00	8.7265E-01	2.2052E+00
4.8000E+01	1.9013E+00	1.6613E+00	8.7265E-01	2.2052E+00
5.0000E+01	1.9439E+00	1.6836E+00	8.7265E-01	2.2052E+00
5.2000E+01	1.9874E+00	1.7058E+00	8.7265E-01	2.2052E+00
5.4000E+01	2.0317E+00	1.7280E+00	8.7265E-01	2.2052E+00
5.6000E+01	2.0768E+00	1.7502E+00	8.7265E-01	2.2052E+00
5.8000E+01	2.1228E+00	1.7724E+00	8.7265E-01	2.2052E+00

6.0000E+01	2.1696E+00	1.7947E+00	8.7265E-01	2.2052E+00
6.2000E+01	2.2167E+00	1.8169E+00	8.7207E-01	2.2167E+00
6.4000E+01	2.2645E+00	1.8391E+00	8.6967E-01	2.2645E+00
6.6000E+01	2.3132E+00	1.8613E+00	8.6724E-01	2.3132E+00
6.8000E+01	2.3629E+00	1.8836E+00	8.6477E-01	2.3629E+00
7.0000E+01	2.4137E+00	1.9058E+00	8.6227E-01	2.4137E+00
7.2000E+01	2.4656E+00	1.9280E+00	8.5972E-01	2.4656E+00
7.4000E+01	2.5187E+00	1.9502E+00	8.5713E-01	2.5187E+00
7.6000E+01	2.5729E+00	1.9724E+00	8.5450E-01	2.5729E+00
7.8000E+01	2.6284E+00	1.9947E+00	8.5183E-01	2.6284E+00
8.0000E+01	2.6852E+00	2.0169E+00	8.4911E-01	2.6852E+00
8.2000E+01	2.7433E+00	2.0391E+00	8.4635E-01	2.7433E+00
8.4000E+01	2.8029E+00	2.0613E+00	8.4353E-01	2.8029E+00
8.6000E+01	2.8640E+00	2.0836E+00	8.4067E-01	2.8640E+00
8.8000E+01	2.9266E+00	2.1058E+00	8.3775E-01	2.9266E+00
9.0000E+01	2.9909E+00	2.1280E+00	8.3477E-01	2.9909E+00
9.2000E+01	3.0570E+00	2.1502E+00	8.3174E-01	3.0570E+00
9.4000E+01	3.1248E+00	2.1724E+00	8.2864E-01	3.1248E+00
9.6000E+01	3.1946E+00	2.1947E+00	8.2548E-01	3.1946E+00
9.8000E+01	3.2664E+00	2.2169E+00	8.2226E-01	3.2664E+00
1.0000E+02	3.3404E+00	2.2391E+00	8.1896E-01	3.3404E+00
1.0200E+02	3.4166E+00	2.2613E+00	8.1559E-01	3.4166E+00
1.0400E+02	3.4952E+00	2.2836E+00	8.1215E-01	3.4952E+00
1.0600E+02	3.5763E+00	2.3058E+00	8.0862E-01	3.5763E+00
1.0800E+02	3.6602E+00	2.3280E+00	8.0501E-01	3.6602E+00
1.1000E+02	3.7468E+00	2.3502E+00	8.0131E-01	3.7468E+00
1.1200E+02	3.8366E+00	2.3724E+00	7.9752E-01	3.8366E+00
1.1400E+02	3.9295E+00	2.3947E+00	7.9362E-01	3.9295E+00
1.1600E+02	4.0259E+00	2.4169E+00	7.8962E-01	4.0259E+00
1.1800E+02	4.1260E+00	2.4391E+00	7.8552E-01	4.1260E+00
1.2000E+02	4.2301E+00	2.4613E+00	7.8129E-01	4.2301E+00
1.2200E+02	4.3374E+00	2.4836E+00	7.7698E-01	4.3374E+00
1.2400E+02	4.4461E+00	2.5058E+00	7.7266E-01	4.4461E+00
1.2600E+02	4.5561E+00	2.5280E+00	7.6834E-01	4.5561E+00
1.2800E+02	4.6672E+00	2.5502E+00	7.6402E-01	4.6672E+00
1.3000E+02	4.7793E+00	2.5724E+00	7.5971E-01	4.7793E+00
1.3200E+02	4.8923E+00	2.5947E+00	7.5543E-01	4.8923E+00
1.3400E+02	5.0058E+00	2.6169E+00	7.5116E-01	5.0058E+00
1.3600E+02	5.1197E+00	2.6391E+00	7.4693E-01	5.1197E+00
1.3800E+02	5.2339E+00	2.6613E+00	7.4274E-01	5.2339E+00
1.4000E+02	5.3479E+00	2.6836E+00	7.3863E-01	5.3479E+00
1.4200E+02	5.4615E+00	2.7058E+00	7.3452E-01	5.4615E+00

1.4400E+02	5.5744E+00	2.7230E+00	7.3052E-01	5.5744E+00
1.4600E+02	5.6862E+00	2.7502E+00	7.2659E-01	5.6862E+00
1.4800E+02	5.7966E+00	2.7724E+00	7.2275E-01	5.7966E+00
1.5000E+02	5.9052E+00	2.7947E+00	7.1902E-01	5.9052E+00
1.5200E+02	6.0115E+00	2.8169E+00	7.1540E-01	6.0115E+00
1.5400E+02	6.1150E+00	2.8391E+00	7.1191E-01	6.1150E+00
1.5600E+02	6.2154E+00	2.8613E+00	7.0856E-01	6.2154E+00
1.5800E+02	6.3122E+00	2.8836E+00	7.0536E-01	6.3122E+00
1.6000E+02	6.4048E+00	2.9058E+00	7.0232E-01	6.4048E+00
1.6200E+02	6.4928E+00	2.9280E+00	6.9946E-01	6.4928E+00
1.6400E+02	6.5756E+00	2.9502E+00	6.9679E-01	6.5756E+00
1.6600E+02	6.6528E+00	2.9724E+00	6.9432E-01	6.6528E+00
1.6800E+02	6.7239E+00	2.9947E+00	6.9206E-01	6.7238E+00
1.7000E+02	6.7884E+00	3.0169E+00	6.9002E-01	6.7884E+00
1.7200E+02	6.8459E+00	3.0391E+00	6.8821E-01	6.8459E+00
1.7400E+02	6.8961E+00	3.0613E+00	6.8664E-01	6.8961E+00
1.7600E+02	6.9387E+00	3.0836E+00	6.8532E-01	6.9387E+00
1.7800E+02	6.9732E+00	3.1058E+00	6.8424E-01	6.9732E+00
1.8000E+02	6.9996E+00	3.1280E+00	6.8343E-01	6.9996E+00

GRADE SAMPLE PROBLEM
NON-SELF-PRIMING WICK ZERO GRAVITY

CASE NO. 4

INPUT VARIABLES AND FLUID PROPERTIES:

LIQUID NUMBER.....	LIQ =	2	
TEMPERATURE.....	TKELVN =	2.94000E+02	DEGREES KELVIN
LIQUID DENSITY.....	RHOL =	6.09435E+02	KG/CU. M
SURFACE TENSION.....	ST =	2.09409E-02	NEWTONS/M
LIQUID VISCOSITY.....	VISL =	1.37840E-04	NEWTON-SEC/SQ. M
LATENT HEAT.....	HFG =	1.18576E+06	JOULES/KG
GRAVITATIONAL ACCELERATION....	GEE =	0.	STANDARD GRAVITIES
WICK AREA.....	AW =	4.01000E-01	SQ. CM
WICK HEIGHT.....	HW =	1.12800E+00	CM
WICK FIBER DIAMETER.....	DIAF =	1.01600E-02	CM
INITIAL POROSITY.....	PHIO =	0.	
FINAL POROSITY.....	PHIF =	0.	
FINAL STRESS.....	PF =	7.00000E+00	CM LIQ.
VAPOR-SPACE DIAMETER.....	DIAVS =	4.70000E-01	CM
NOMINAL HEAT-TRANSFER RATE....	QDOT =	1.00000E+02	WATTS
NO. HEAT-INPUT SECTIONS.....	NQ =	3	
SECTION NUMBER 1			
SECTION LENGTH.....	XQ =	6.00000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	-1.00000E+00	
SECTION NUMBER 2			
SECTION LENGTH.....	XQ =	6.00000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	0.	
SECTION NUMBER 3			
SECTION LENGTH.....	XQ =	6.00000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	1.00000E+00	
NO. ELEVATION POINTS.....	NELEV =	2	
ELEVATION POINT NO. 1			
DISTANCE TO POINT.....	XELEV =	0.	CM
ELEVATION OF POINT.....	ELEV =	0.	CM

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ELEVATION POINT NO.   2
     DISTANCE TO POINT.........     XELEV =  1.800000E+02  CM
     ELEVATION OF POINT........      ELEV =  2.000000E+00  CM

INTEGRATION STEP SIZE..........        DX =  2.000000E+00  CM

ANOTHER CASE (0=NO, 1=YES).....     NCASE =  1
USE LAST POROSITY DISTN........   LASTPHI =  1
REQUIRE SELF PRIME.............   ISLFPRM =  0
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FINAL SOLUTION

THE MAXIMUM HEAT-TRANSFER RATE IS 2.00000E+02 WATTS

THE TOTAL LIQUID IN WICK IS 3.56100E+01 GRAMS

DISTANCE (CM)	STRESS (CM LIQ.)	STATIC HEAD (CM LIQ.)	POROSITY	CRIT. STRESS (CM LIQ.)
0.	2.9840E-01	0.	8.7265E-01	2.2052E+00
2.0000E+00	2.9912E-01	0.	8.7265E-01	2.2052E+00
4.0000E+00	3.0129E-01	0.	8.7265E-01	2.2052E+00
6.0000E+00	3.0490E-01	0.	8.7265E-01	2.2052E+00
8.0000E+00	3.0995E-01	0.	8.7265E-01	2.2052E+00
1.0000E+01	3.1645E-01	0.	8.7265E-01	2.2052E+00
1.2000E+01	3.2439E-01	0.	8.7265E-01	2.2052E+00
1.4000E+01	3.3377E-01	0.	8.7265E-01	2.2052E+00
1.6000E+01	3.4459E-01	0.	8.7265E-01	2.2052E+00
1.8000E+01	3.5686E-01	0.	8.7265E-01	2.2052E+00
2.0000E+01	3.7053E-01	0.	8.7265E-01	2.2052E+00
2.2000E+01	3.8573E-01	0.	8.7265E-01	2.2052E+00
2.4000E+01	4.0233E-01	0.	8.7265E-01	2.2052E+00
2.6000E+01	4.2039E-01	0.	8.7265E-01	2.2052E+00
2.8000E+01	4.3987E-01	0.	8.7265E-01	2.2052E+00
3.0000E+01	4.6080E-01	0.	8.7265E-01	2.2052E+00
3.2000E+01	4.8317E-01	0.	8.7265E-01	2.2052E+00
3.4000E+01	5.0699E-01	0.	8.7265E-01	2.2052E+00
3.6000E+01	5.3225E-01	0.	8.7265E-01	2.2052E+00
3.8000E+01	5.5895E-01	0.	8.7265E-01	2.2052E+00
4.0000E+01	5.8710E-01	0.	8.7265E-01	2.2052E+00
4.2000E+01	6.1669E-01	0.	8.7265E-01	2.2052E+00
4.4000E+01	6.4773E-01	0.	8.7265E-01	2.2052E+00
4.6000E+01	6.8021E-01	0.	8.7265E-01	2.2052E+00
4.8000E+01	7.1413E-01	0.	8.7265E-01	2.2052E+00
5.0000E+01	7.4950E-01	0.	8.7265E-01	2.2052E+00
5.2000E+01	7.8631E-01	0.	8.7265E-01	2.2052E+00
5.4000E+01	8.2456E-01	0.	8.7265E-01	2.2052E+00
5.6000E+01	8.6425E-01	0.	8.7265E-01	2.2052E+00
5.8000E+01	9.0539E-01	0.	8.7265E-01	2.2052E+00

6.0000E+01	9.4798E-01	0.	8.7265E-01	2.2052E+00
6.2000E+01	9.9124E-01	0.	8.7207E-01	2.2167E+00
6.4000E+01	1.0355E+00	0.	8.6967E-01	2.2645E+00
6.6000E+01	1.0815E+00	0.	8.6724E-01	2.3132E+00
6.8000E+01	1.1292E+00	0.	8.6477E-01	2.3629E+00
7.0000E+01	1.1787E+00	0.	8.6227E-01	2.4137E+00
7.2000E+01	1.2301E+00	0.	8.5972E-01	2.4656E+00
7.4000E+01	1.2835E+00	0.	8.5713E-01	2.5187E+00
7.6000E+01	1.3390E+00	0.	8.5450E-01	2.5729E+00
7.8000E+01	1.3966E+00	0.	8.5183E-01	2.6284E+00
8.0000E+01	1.4565E+00	0.	8.4911E-01	2.6852E+00
8.2000E+01	1.5187E+00	0.	8.4635E-01	2.7433E+00
8.4000E+01	1.5835E+00	0.	8.4353E-01	2.8029E+00
8.6000E+01	1.6508E+00	0.	8.4067E-01	2.8640E+00
8.8000E+01	1.7209E+00	0.	8.3775E-01	2.9266E+00
9.0000E+01	1.7938E+00	0.	8.3477E-01	2.9909E+00
9.2000E+01	1.8697E+00	0.	8.3174E-01	3.0570E+00
9.4000E+01	1.9488E+00	0.	8.2864E-01	3.1248E+00
9.6000E+01	2.0312E+00	0.	8.2548E-01	3.1946E+00
9.8000E+01	2.1171E+00	0.	8.2226E-01	3.2664E+00
1.0000E+02	2.2067E+00	0.	8.1896E-01	3.3404E+00
1.0200E+02	2.3003E+00	0.	8.1559E-01	3.4166E+00
1.0400E+02	2.3980E+00	0.	8.1215E-01	3.4952E+00
1.0600E+02	2.5001E+00	0.	8.0862E-01	3.5763E+00
1.0800E+02	2.6068E+00	0.	8.0501E-01	3.6602E+00
1.1000E+02	2.7185E+00	0.	8.0131E-01	3.7469E+00
1.1200E+02	2.8355E+00	0.	7.9752E-01	3.8366E+00
1.1400E+02	2.9580E+00	0.	7.9362E-01	3.9295E+00
1.1600E+02	3.0866E+00	0.	7.8962E-01	4.0259E+00
1.1800E+02	3.2215E+00	0.	7.8552E-01	4.1260E+00
1.2000E+02	3.3634E+00	0.	7.8129E-01	4.2301E+00
1.2200E+02	3.5128E+00	0.	7.7693E-01	4.3384E+00
1.2400E+02	3.6697E+00	0.	7.7246E-01	4.4511E+00
1.2600E+02	3.8347E+00	0.	7.6784E-01	4.5681E+00
1.2800E+02	3.9968E+00	0.	7.6402E-01	4.6872E+00
1.3000E+02	4.1225E+00	0.	7.5971E-01	4.7793E+00
1.3200E+02	4.2796E+00	0.	7.5543E-01	4.8923E+00
1.3400E+02	4.4379E+00	0.	7.5116E-01	5.0059E+00
1.3600E+02	4.5968E+00	0.	7.4693E-01	5.1197E+00
1.3800E+02	4.7560E+00	0.	7.4274E-01	5.2339E+00
1.4000E+02	4.9150E+00	0.	7.3860E-01	5.3479E+00
1.4200E+02	5.0734E+00	0.	7.3452E-01	5.4615E+00

1.4400E+02	5.2305E+00	0.	7.3052E-01	5.5744E+00
1.4600E+02	5.3857E+00	0.	7.2659E-01	5.6862E+00
1.4800E+02	5.5385E+00	0.	7.2275E-01	5.7966E+00
1.5000E+02	5.6880E+00	0.	7.1902E-01	5.9052E+00
1.5200E+02	5.8337E+00	0.	7.1540E-01	6.0115E+00
1.5400E+02	5.9746E+00	0.	7.1191E-01	6.1150E+00
1.5600E+02	6.1101E+00	0.	7.0856E-01	6.2154E+00
1.5800E+02	6.2392E+00	0.	7.0536E-01	6.3122E+00
1.6000E+02	6.3611E+00	0.	7.0232E-01	6.4048E+00
1.6200E+02	6.4750E+00	0.	6.9946E-01	6.4928E+00
1.6400E+02	6.5800E+00	0.	6.9679E-01	6.5756E+00
1.6600E+02	6.6752E+00	0.	6.9432E-01	6.6528E+00
1.6800E+02	6.7598E+00	0.	6.9206E-01	6.7238E+00
1.7000E+02	6.8331E+00	0.	6.9002E-01	6.7884E+00
1.7200E+02	6.8943E+00	0.	6.8821E-01	6.8459E+00
1.7400E+02	6.9428E+00	0.	6.8664E-01	6.8961E+00
1.7600E+02	6.9780E+00	0.	6.8532E-01	6.9387E+00
1.7800E+02	6.9993E+00	0.	6.8424E-01	6.9732E+00
1.8000E+02	7.0065E+00	0.	6.8343E-01	6.9996E+00

GRADE SAMPLE PROBLEM
HOMOGENEOUS WICK 2-CM ELEVATION

CASE NO. 5

INPUT VARIABLES AND FLUID PROPERTIES:

LIQUID NUMBER.....	LIQ =	2	
TEMPERATURE.....	TKELVN =	2.940000E+02	DEGREES KELVIN
LIQUID DENSITY.....	RHOL =	6.09435E+02	KG/CU. M
SURFACE TENSION.....	ST =	2.09409E-02	NEWTONS/M
LIQUID VISCOSITY.....	VISL =	1.37840E-04	NEWTON-SEC/SQ. M
LATENT HEAT.....	HFG =	1.13576E+06	JOULES/KG
GRAVITATIONAL ACCELERATION....	GEE =	1.000000E+00	STANDARD GRAVITIES
WICK AREA.....	AW =	4.01000E-01	SQ. CM
WICK HEIGHT.....	HW =	1.12800E+00	CM
WICK FIBER DIAMETER.....	DIAF =	1.01600E-02	CM
INITIAL POROSITY.....	PHI0 =	6.83500E-01	
FINAL POROSITY.....	PHIF =	0.	
FINAL STRESS.....	PF =	0.	CM LIQ.
VAPOR-SPACE DIAMETER.....	DIAVS =	4.70300E-01	CM
NOMINAL HEAT-TRANSFER RATE....	QDOT =	1.000000E+02	WATTS
NO. HEAT-INPUT SECTIONS.....	NQ =	3	
SECTION NUMBER 1			
SECTION LENGTH.....	XQ =	6.000000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	-1.000000E+00	
SECTION NUMBER 2			
SECTION LENGTH.....	XQ =	6.000000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	0.	
SECTION NUMBER 3			
SECTION LENGTH.....	XQ =	6.000000E+01	CM
HEAT-INPUT FRACTION.....	FQ =	1.000000E+00	
NO. ELEVATION POINTS.....	NELEV =	2	
ELEVATION POINT NO. 1			
DISTANCE TO POINT.....	XELEV =	0.	CM
ELEVATION OF POINT.....	ELEV =	0.	CM

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ELEVATION POINT NO.    2
     DISTANCE TO POINT.........     XELEV =   1.80000E+02   CM
     ELEVATION OF POINT........      ELEV =   2.00000E+00   CM

INTEGRATION STEP SIZE..........        DX =   2.00000E+00   CM

ANOTHER CASE (0=NO, 1=YES).....     NCASE =   0
USE LAST POROSITY DISTN........   LASTPHI =   0
REQUIRE SELF PRIME.............   ISLFPRM =   0
```

FINAL SOLUTION

THE MAXIMUM HEAT-TRANSFER RATE IS 2.98828E+01 WATTS

THE TOTAL LIQUID IN WICK IS 3.00665E+01 GRAMS

DISTANCE (CM)	STRESS (CM LIQ.)	STATIC HEAD (CM LIQ.)	POROSITY	CRIT. STRESS (CM LIQ.)
0.	1.1280E+00	1.1280E+00	6.8350E-01	6.9972E+00
2.0000E+00	1.1513E+00	1.1502E+00	6.8350E-01	6.9972E+00
4.0000E+00	1.1768E+00	1.1724E+00	6.8350E-01	6.9972E+00
6.0000E+00	1.2044E+00	1.1947E+00	6.8350E-01	6.9972E+00
8.0000E+00	1.2342E+00	1.2169E+00	6.8350E-01	6.9972E+00
1.0000E+01	1.2661E+00	1.2391E+00	6.8350E-01	6.9972E+00
1.2000E+01	1.3002E+00	1.2613E+00	6.8350E-01	6.9972E+00
1.4000E+01	1.3365E+00	1.2836E+00	6.8350E-01	6.9972E+00
1.6000E+01	1.3749E+00	1.3058E+00	6.8350E-01	6.9972E+00
1.8000E+01	1.4154E+00	1.3280E+00	6.8350E-01	6.9972E+00
2.0000E+01	1.4582E+00	1.3502E+00	6.8350E-01	6.9972E+00
2.2000E+01	1.5031E+00	1.3724E+00	6.8350E-01	6.9972E+00
2.4000E+01	1.5501E+00	1.3947E+00	6.8350E-01	6.9972E+00
2.6000E+01	1.5993E+00	1.4169E+00	6.8350E-01	6.9972E+00
2.8000E+01	1.6507E+00	1.4391E+00	6.8350E-01	6.9972E+00
3.0000E+01	1.7042E+00	1.4613E+00	6.8350E-01	6.9972E+00
3.2000E+01	1.7599E+00	1.4836E+00	6.8350E-01	6.9972E+00
3.4000E+01	1.8177E+00	1.5058E+00	6.8350E-01	6.9972E+00
3.6000E+01	1.8778E+00	1.5280E+00	6.8350E-01	6.9972E+00
3.8000E+01	1.9399E+00	1.5502E+00	6.8350E-01	6.9972E+00
4.0000E+01	2.0042E+00	1.5724E+00	6.8350E-01	6.9972E+00
4.2000E+01	2.0707E+00	1.5947E+00	6.8350E-01	6.9972E+00
4.4000E+01	2.1394E+00	1.6169E+00	6.8350E-01	6.9972E+00
4.6000E+01	2.2102E+00	1.6391E+00	6.8350E-01	6.9972E+00
4.8000E+01	2.2831E+00	1.6613E+00	6.8350E-01	6.9972E+00
5.0000E+01	2.3582E+00	1.6836E+00	6.8350E-01	6.9972E+00
5.2000E+01	2.4355E+00	1.7058E+00	6.8350E-01	6.9972E+00
5.4000E+01	2.5149E+00	1.7280E+00	6.8350E-01	6.9972E+00
5.6000E+01	2.5965E+00	1.7502E+00	6.8350E-01	6.9972E+00
5.8000E+01	2.6803E+00	1.7724E+00	6.8350E-01	6.9972E+00

6.0000E+01	2.7662E+00	1.7947E+00	6.8350E-01	6.9972E+00
6.2000E+01	2.8523E+00	1.8169E+00	6.8350E-01	6.9972E+00
6.4000E+01	2.9395E+00	1.8391E+00	6.8350E-01	6.9972E+00
6.6000E+01	3.0261E+00	1.8613E+00	6.8350E-01	6.9972E+00
6.8000E+01	3.1127E+00	1.8836E+00	6.8350E-01	6.9972E+00
7.0000E+01	3.1994E+00	1.9058E+00	6.8350E-01	6.9972E+00
7.2000E+01	3.2860E+00	1.9280E+00	6.8350E-01	6.9972E+00
7.4000E+01	3.3726E+00	1.9502E+00	6.8350E-01	6.9972E+00
7.6000E+01	3.4592E+00	1.9724E+00	6.8350E-01	6.9972E+00
7.8000E+01	3.5459E+00	1.9947E+00	6.8350E-01	6.9972E+00
8.0000E+01	3.6325E+00	2.0169E+00	6.8350E-01	6.9972E+00
8.2000E+01	3.7191E+00	2.0391E+00	6.8350E-01	6.9972E+00
8.4000E+01	3.8058E+00	2.0613E+00	6.8350E-01	6.9972E+00
8.6000E+01	3.8924E+00	2.0836E+00	6.8350E-01	6.9972E+00
8.8000E+01	3.9790E+00	2.1058E+00	6.8350E-01	6.9972E+00
9.0000E+01	4.0657E+00	2.1280E+00	6.8350E-01	6.9972E+00
9.2000E+01	4.1523E+00	2.1502E+00	6.8350E-01	6.9972E+00
9.4000E+01	4.2389E+00	2.1724E+00	6.8350E-01	6.9972E+00
9.6000E+01	4.3256E+00	2.1947E+00	6.8350E-01	6.9972E+00
9.8000E+01	4.4122E+00	2.2169E+00	6.8350E-01	6.9972E+00
1.0000E+02	4.4988E+00	2.2391E+00	6.8350E-01	6.9972E+00
1.0200E+02	4.5855E+00	2.2613E+00	6.8350E-01	6.9972E+00
1.0400E+02	4.6721E+00	2.2836E+00	6.8350E-01	6.9972E+00
1.0600E+02	4.7587E+00	2.3058E+00	6.8350E-01	6.9972E+00
1.0800E+02	4.8453E+00	2.3280E+00	6.8350E-01	6.9972E+00
1.1000E+02	4.9320E+00	2.3502E+00	6.8350E-01	6.9972E+00
1.1200E+02	5.0186E+00	2.3724E+00	6.8350E-01	6.9972E+00
1.1400E+02	5.1052E+00	2.3947E+00	6.8350E-01	6.9972E+00
1.1600E+02	5.1919E+00	2.4169E+00	6.8350E-01	6.9972E+00
1.1800E+02	5.2785E+00	2.4391E+00	6.8350E-01	6.9972E+00
1.2000E+02	5.3651E+00	2.4613E+00	6.8350E-01	6.9972E+00
1.2200E+02	5.4518E+00	2.4836E+00	6.8350E-01	6.9972E+00
1.2400E+02	5.5384E+00	2.5058E+00	6.8350E-01	6.9972E+00
1.2600E+02	5.6250E+00	2.5280E+00	6.8350E-01	6.9972E+00
1.2800E+02	5.6958E+00	2.5502E+00	6.8350E-01	6.9972E+00
1.3000E+02	5.7731E+00	2.5724E+00	6.8350E-01	6.9972E+00
1.3200E+02	5.8482E+00	2.5947E+00	6.8350E-01	6.9972E+00
1.3400E+02	5.9212E+00	2.6169E+00	6.8350E-01	6.9972E+00
1.3600E+02	5.9920E+00	2.6391E+00	6.8350E-01	6.9972E+00
1.3800E+02	6.0606E+00	2.6613E+00	6.8350E-01	6.9972E+00
1.4000E+02	6.1271E+00	2.6836E+00	6.8350E-01	6.9972E+00
1.4200E+02	6.1914E+00	2.7058E+00	6.8350E-01	6.9972E+00

1.4400E+02	6.2556E+00	2.7280E+00	6.8350E-01	6.9972E+00
1.4600E+02	6.3136E+00	2.7502E+00	6.8350E-01	6.9972E+00
1.4800E+02	6.3714E+00	2.7724E+00	6.8350E-01	6.9972E+00
1.5000E+02	6.4271E+00	2.7947E+00	6.8350E-01	6.9972E+00
1.5200E+02	6.4806E+00	2.8169E+00	6.8350E-01	6.9972E+00
1.5400E+02	6.5320E+00	2.8391E+00	6.8350E-01	6.9972E+00
1.5600E+02	6.5812E+00	2.8613E+00	6.8350E-01	6.9972E+00
1.5800E+02	6.6283E+00	2.8836E+00	6.8350E-01	6.9972E+00
1.6000E+02	6.6732E+00	2.9058E+00	6.8350E-01	6.9972E+00
1.6200E+02	6.7159E+00	2.9280E+00	6.8350E-01	6.9972E+00
1.6400E+02	6.7565E+00	2.9502E+00	6.8350E-01	6.9972E+00
1.6600E+02	6.7949E+00	2.9724E+00	6.8350E-01	6.9972E+00
1.6800E+02	6.8311E+00	2.9947E+00	6.8350E-01	6.9972E+00
1.7000E+02	6.8652E+00	3.0169E+00	6.8350E-01	6.9972E+00
1.7200E+02	6.8972E+00	3.0391E+00	6.8350E-01	6.9972E+00
1.7400E+02	6.9269E+00	3.0613E+00	6.8350E-01	6.9972E+00
1.7600E+02	6.9546E+00	3.0836E+00	6.8350E-01	6.9972E+00
1.7800E+02	6.9800E+00	3.1058E+00	6.8350E-01	6.9972E+00
1.8000E+02	7.0033E+00	3.1280E+00	6.8350E-01	6.9972E+00

APPENDIX B

PROGRAM LISTING

```
RUNX COMPILER (VER.2.3M)                    08/23/74. 15.31.43.

                PROGRAM MAIN(INPUT=201,TAPE5=INPUT,OUTPUT,TAPE6=OUTPUT)
000004          COMMON /PARAM/ PHI,PHI0,DPHI,PBF0,PBVS,PND,GEE,G,NI,NIP1,HW,
000004         1               NQ,FQ(10),NELEV,XELEV(10),ZELEV(10),ELEV(10),
000004         2               ELEVB(10),D,H,FNUB,AW,AB,XTOT,DX,DZ,QDTB,QDOT,
000004         3               DIAF,A(7,1000),XQ(10),ZQ(10),PBS,PHIF,PF,
000004         4               NCASE,LASTPHI,SAVPHI(1000),ISLFPRM,IFAIL
000004          COMMON /CPROPS/ XMW,SHRV,HFG,PV,RHOL,RHOV,VISL,VISV,XKL,ST,TF
      C
000004          DO 500 K=1,10
000006          CALL INPT
000007          II=1
000010          QDTB=1.
000012          DQDTB=.5
000014          CALL INGRTN(PBF)
000016          DO 404 I=1,40
000020          IF(IFAIL .EQ. 1) GO TO 303
000022          IF(PBF-PBF0) 101,202,303
      C
000025    101   IF(II.EQ.1) DQDTB=2.*DQDTB
000031          IF(II.EQ.2) DQDTB=.5*DQDTB
000035          QDTB=QDTB+DQDTB
000037          CALL INGRTN(PBF)
000041          IF(PBF.GT.PBF0) II=2
000045          GO TO 395
      C
000046    303   IF(II.EQ.2) DQDTB=.5*DQDTB
000052          QDTB=QDTB-DQDTB
000054          IFSAV=IFAIL
000056          CALL INGRTN(PBF)
000060          IF(IFSAV-IFAIL .EQ. 1) II=2
000064          IF(IFSAV .EQ. 1) GO TO 305
000066          IF(PBF.LT.PBF0) II=2
000072    305   CONTINUE
      C
000072    395   TEST=ABS(PBF-PBF0)/PBF0
000075          IF(TEST .LT. 0.001) GO TO 202
000100          IF(DQDTB .LT. 0.001*QDTB) GO TO 202
```

```
0 00104      404 CONTINUE
0 00105      202 CONTINUE
0 00106          CALL WRT
0 00107          IF(NCASE.EQ.0) GO TO 501
0 00110      500 CONTINUE
0 00112      501 CONTINUE
0 00112          STOP
0 00114          END
```

```
RUNX COMPILER (VER.2.3M)                    08/23/74. 15.31.43.

            SUBROUTINE DERIV(YP,Y)
000005      COMMON /PARAM/ PHI,PHIO,DPHI,PBFO,PBVS,PND,GEE,G,NI,NIP1,HW,
000005     1               NQ,FQ(10),NELEV,XELEV(10),ZELEV(10),ELEV(10),
000005     2               ELEVB(10),D,H,FNUB,AW,AB,XTOT,DX,DZ,QDTB,QDOT,
000005     3               DIAF,A(7,1000),XQ(10),ZQ(10),PBS,PHIF,PF,
000005     4               NCASE,LASTPHI,SAVPHI(1000),ISLFPRM,IFAIL
000005      COMMON /CPROPS/ XMW,SHRV,HFG,PV,RHOL,RHOV,VISL,VISV,XKL,ST,TF
      C
000005      DIMENSION YP(4),Y(4)
      C
000005      YP(1)=1.
000007      PB=Y(2)
000011      N=NELEV-1
000013      DO 101 I=1,N
000015      Z=Y(1)
000016      IF(Z.GE.ZELEV(I) .AND. Z.LE.ZELEV(I+1)) IMK=I
000031  101 CONTINUE
000034      DELEV=(ELEVB(IMK+1)-ELEVB(IMK))/(ZELEV(IMK+1)-ZELEV(IMK))
000041      HB=ELEVB(IMK)+(ELEVB(IMK+1)-ELEVB(IMK))*(Z-ZELEV(IMK))/
000041     1              (ZELEV(IMK+1)-ZELEV(IMK))+1.
      C
000055      PHISPO=PHIO
000057      IF(PHIO .EQ. 0.0) PHISPO=(PBS/H)/(1.+PBS/H)
000066      PHISP=(PBS/H)/(HB+PBS/H)
000074      IF(GEE .EQ. 0.) PHISP=1.
000077      IF(ISLFPRM .EQ. 0) PHISP=1.
000102      PHI=PBS/(PB+PBS)
000105      IF(PHI .LT. 0.1) PHI=0.1
000110      IF(PHI .GT. PHISP) PHI=PHISP
000113      IF(PHI.GT.PHISPO) PHI=PHISPO
000116      IF(PHIF .EQ. 0. .AND. PF .EQ. 0.) PHI=PHIO
000125      IF(LASTPHI .EQ. 0) GO TO 105
000126      IZ=INT((Z+1.01*DZ)/DZ)
000132      PHI=SAVPHI(NIP1)
000134      IF(IZ .EQ. NIP1) GO TO 105
000136      PHI=SAVPHI(IZ)+(SAVPHI(IZ+1)-SAVPHI(IZ))*(Z-(IZ-1)*DZ)/DZ
000150  105 CONTINUE
```

```
      C
000150        PERM=(3./8.)*D*(PHI/(1-PHI))/
000150       1         (4.*PHI/(4.*(1.-PHI)-(1.-PHI)**2-2.*ALOG(1.-PHI)-3.) -
000150       2          8./(ALOG(1.-PHI)+(1.-(1.-PHI)**2)/(1.+(1.-PHI)**2)))
      C
000205        YP(2)=FNUB*Y(3)/(PERM*A3)+DELEV*GEE
000213        DIST=0.
000214        DO 112 I=1,NQ
000216        DIST=DIST+ZQ(I)
000221        IMK=I
000223        IF(Z.LT.DIST) GO TO 113
000226    112 CONTINUE
000231    113 YP(3)=-QDT3*FQ(IMK)/ZQ(IMK)
000235        YP(4)=PHI
000237        IF(PB .GT. 1.0001*PBS*(1.-PHI)/PHI) IFAIL=1
000246        RETURN
000247        END
```

```
                SUBROUTINE INGRTN(PBF)
000003          COMMON /PARAM/ PHI,PHI3,DPHI,PBF0,PBVS,PN0,GEE,G,NI,NIP1,HW,
000003         1               NQ,FQ(10),NELEV,XELEV(10),ZELEV(10),ELEV(10),
000003         2               ELEV3(10),D,H,FNUB,AW,AB,XTOT,DX,DZ,QDT3,QDOT,
000003         3               DIAF,A(7,1000),XQ(10),ZQ(10),PBS,PHIF,PF,
000003         4               NCASE,LASTPHI,SAVPHI(1000),ISLPRM,IFAIL
000003          DIMENSION Y(4),YP(4)
000003          COMMON /CPROPS/ XMW,SHRV,HFG,PV,RHOL,RHOV,VISL,VISV,XKL,ST,TF
000003          A(1,1)=0.
000004          A(2,1)=1.
000006          IF(GEE.EQ.0.) A(2,1)=PBVS
000011          A(3,1)=0.
000012          A(4,1)=0.
000013          A(5,1)=PHI0
000015          IF(PHI0 .EQ. 0.) A(5,1)=(PBS/H)/(1.+PBS/H)
000024          IF(LASTPHI .EQ. 1) A(5,1)=SAVPHI(1)
000030          Y(1)=A(1,1)
000032          Y(2)=A(2,1)
000034          Y(3)=A(3,1)
000036          Y(4)=A(4,1)
000040          IFAIL=0
000041          CALL DERIV(YP,Y)
000044          NIP1=NI+1
000046          DO 120 I=2,NIP1
000050          CALL RUNGE(Y,YP,DZ)
000054          DO 110 J=1,4
000056          A(J,I)=Y(J)
000062          A(5,I)=PHI
000065      110 CONTINUE
000067      120 CONTINUE
000072          PBF=A(2,NIP1)
000075          RETURN
000076          END
```

```
RUNX COMPILER (VER.2.3M)                    08/23/74. 15.31.43.

          SUBROUTINE INPT
000002    COMMON /PARAM/ PHI,PHI0,DPHI,PSFC,PRVS,PND,GEE,G,NI,NIP1,HW,
000002   1               NQ,FQ(10),NELEV,XELEV(10),ZELEV(10),ELEV(10),
000002   2               ELEV0(10),D,H,FNUE,AW,AB,XTOT,DX,DZ,QDOT,QDOT,
000002   3               DIAF,A(7,1000),XQ(10),ZQ(10),PBS,PHIF,PF,
000002   4               NCASE,LASTPHI,SAVPHI(1000),ISLFPRM,IFAIL
000002    COMMON /CPROPS/ XMW,SHRV,HFG,PV,RHOL,RHOV,VISL,VISV,XKL,ST,TF
000002    DIMENSION HD1(6),HD2(6)
000002    DATA HD1/6*1H /,HD2/6*1H /
000002    DATA H/1.955/,D/2.63/,R/.69/,G/9.80/
      C
000002    NAMELIST /GRDATA/ LIQ,TKELVN,RHOL,ST,VISL,HFG,GEE,AW,HW,DIAF,
000002   1                  PHIC,PHIF,DIAVS,QDOT,NQ,FQ,NELEV,XELEV,ELEV,
000002   2                  DX,HD1,HD2,XQ,NCASE,LASTPHI,PF,ISLFPRM
      C
000002    READ(5,GRDATA)
000005    TRANK=1.80*TKELVN
000007    CALL PROPS(LIQ,TRANK)
000011    IF(LIQ.EQ.0) GO TO 10
000012    ST=4.448*3.281*ST
000014    RHOL=.4536*3.281**3*RHOL
000017    VISL=4.448*3.281**2*3600.*VISL
000023    HFG=(1055.*2.205)*HFG
000026 10 CONTINUE
000026    WRITE(6,900) HD1,HD2
000036    WRITE(6,901)
000042    WRITE(6,902) LIQ
000050    WRITE(6,904) TKELVN
000056    WRITE(6,906) RHOL
000064    WRITE(6,908) ST
000072    WRITE(6,910) VISL
000100    WRITE(6,912) HFG
000106    WRITE(6,914) GEE
000114    WRITE(6,916) AW
000122    WRITE(6,918) HW
000130    WRITE(6,920) DIAF
000136    WRITE(6,922) PHIC
```

```
000144          WRITE(6,924) PHIF
000152          WRITE(6,925) PF
000160          WRITE(6,926) DIAVS
000166          WRITE(6,928) QDOT
000174          WRITE(6,930) NQ
000202          DO 5 I=1,NQ
000204          WRITE(6,932) I,XQ(I),FQ(I)
000216        5 CONTINUE
000221          WRITE(6,934) NELEV
000227          DO 6 I=1,NELEV
000231          WRITE(6,936) I,XELEV(I),ELEV(I)
000243        6 CONTINUE
000246          WRITE(6,938) DX
000254          WRITE(6,940) NCASE
000262          WRITE(6,942) LASTPHI
000270          WRITE(6,944) ISLPRM
000276      900 FORMAT(1H1,4X,6A10,/5X,6A10)
000276      901 FORMAT(//5X,38H INPUT VARIABLES AND FLUID PROPERTIES://)
000276         1          5X,37H INPUT VARIABLES AND FLUID PROPERTIES*//)
000276      902 FORMAT( 10X,42HLIQUID NUMBER.................      LIQ = ,I2)
000276      904 FORMAT( 10X,42HTEMPERATURE....................   TKELVN = ,
000276         1          E12.5,16H  DEGREES KELVIN)
000276      906 FORMAT( 10X,42HLIQUID DENSITY.................     RHOL = ,
000276         1          E12.5,16H  KG/CU. M      )
000276      908 FORMAT( 10X,42HSURFACE TENSION................      ST = ,
000276         1          E12.5,16H  NEWTONS/M     )
000276      910 FORMAT( 10X,42HLIQUID VISCOSITY...............     VISL = ,
000276         1          E12.5,18H  NEWTON-SEC/SQ. M)
000276      912 FORMAT( 10X,42HLATENT HEAT....................      HFG = ,
000276         1          E12.5,16H  JOULES/KG     )
000276      914 FORMAT(/10X,42HGRAVITATIONAL ACCELERATION....      GEE = ,
000276         1          E12.5,20H  STANDARD GRAVITIES)
000276      916 FORMAT(/10X,42HWICK AREA......................       AW = ,
000276         1          E12.5,16H  SQ. CM        )
000276      918 FORMAT( 10X,42HWICK HEIGHT....................       HW = ,
000276         1          E12.5,16H  CM            )
000276      920 FORMAT( 10X,42HWICK FIBER DIAMETER............     DIAF = ,
000276         1          E12.5,16H  CM            )
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RUNX COMPILER (VER.2.3M)                    03/23/74. 15.31.43.          INPT

000276      922 FORMAT( 10X,42HINITIAL POROSITY.............      PHI0 = ,
000276         1        E12.5)
000276      924 FORMAT( 10X,42HFINAL POROSITY...............      PHIF = ,
000276         1        E12.5)
000276      925 FORMAT(/10X,42HFINAL STRESS.................       PF = ,
000276         1        E12.5,16H  GM LIQ.       )
000276      926 FORMAT(/10X,42HVAPOR-SPACE DIAMETER.........     DIAVS = ,
000276         1        E12.5,16H  CM            )
000276      928 FORMAT(/10X,42HNOMINAL HEAT-TRANSFER RATE....     QDOT = ,
000276         1        E12.5,16H  WATTS         )
000276      930 FORMAT( 10X,42HNO. HEAT-INPUT SECTIONS.......       NQ = ,
000276         1        I2)
000276      932 FORMAT( 10X,16HSECTION NUMBER  ,I2/
000276         1        15X,37HSECTION LENGTH...........       XQ = ,
000276         2        E12.5,10H  CM      /
000276         3        15X,37HHEAT-INPUT FRACTION......       FQ = ,
000276         4        E12.5)
000276      934 FORMAT(/10X,42HNO. ELEVATION POINTS.........    NELEV = ,
000276         1        I2)
000276      936 FORMAT(10X,21HELEVATION POINT NO.  ,I2/
000276         1        15X,37HDISTANCE TO POINT........    XELEV = ,
000276         2        E12.5,10H  CM      /
000276         3        15X,37HELEVATION OF POINT.......     ELEV = ,
000276         4        E12.5,10H  CM      )
000276      938 FORMAT(/10X,42HINTEGRATION STEP SIZE.........       DX = ,
000276         1        E12.5,16H  CM            )
000276      940 FORMAT(/10X,42HANOTHER CASE (0=NO, 1=YES)....    NCASE = ,
000276         1        I2)
000276      942 FORMAT( 10X,42HUSE LAST POROSITY DISTN.......  LASTPHI = ,
000276         1        I2)
000276      944 FORMAT( 10X,42HREQUIRE SELF PRIME............  ISLFPM = ,
000276         1        I2)
      C
000276           PND=RHOL*G*(HW/100.)
000302           IF(DIAF .EQ. 0.0) GO TO 11
000303           PDS=3.246*R*H*ST/((DIAF/100.)*PND)
000311        11 IF(GEE.NE.0.) GO TO 12
000312           PBVS=(4.*ST/(DIAVS/100.))/PND)
```

```
000317      12 CONTINUE
000317         XTOT=0.
000320         DO 16 I=1,NQ
000322         XTOT=XTOT+XQ(I)
000325      16 CONTINUE
000330         AB=AW/HW**2
000333         DO 18 I=1,NELEV
000335         ZELEV(I)=XELEV(I)/XTOT
000340         ELEVB(I)=ELEV(I)/HW
000343      18 CONTINUE
000346         DO 20 I=1, NQ
000350         ZQ(I)=XQ(I)/XTOT
000353      20 CONTINUE
000356         NI=XTOT/DX
000361         DZ=DX/XTOT
000363         IF(PHI0 .NE. 0.0) GO TO 50
000364         IF(PHIF .NE. 0.0) GO TO 50
000365         IF(PF .NE. 0.0) GO TO 50
           C
           C     OPTIMUM-HOMOGENEOUS-WICK CALCULATIONS
           C
000366         IF(DIAF .NE. 0.0) GO TO 30
000367         PHI0 = 0.79
000371         PBS=2.*(ELEVB(NELEV)+1.)*PHI0/(1.-PHI0)
000400         DIAF=100.*3.246*R*H*ST/(PBS*PND)
000405         WRITE(6,950) DIAF,PHI0
000415         GO TO 50
000416      30 PHI0=PBS/(2.*(ELEVB(NELEV)+1.)+PBS)
000423         WRITE(6,952) PHI0
000431     950 FORMAT(///10X,40H OPTIMUM HOMOGENEOUS WICK:  FIBER DIA. =,
000431        1       E12.5,16H CM,  POROSITY =,E12.5)
000431     952 FORMAT(///10X,47H OPTIMUM-POROSITY HOMOGENEOUS WICK:  POROSITY =,
000431        1       E12.5)
000431      50 CONTINUE
           C
000431         FNUB=(VISL/RHOL)*(QDOT/HFG)*(XTOT/100.)/
000431        1     (PND*(DIAF/100.)**2*(HW/100.)**2)
           C
```

```
C     CALCULATION OF FINAL STRESS  PBF0
C
C     1.  PF  SPECIFIED IN GRADED-POROSITY DESIGN:
C
000446      IF(LASTPHI.EQ.0 .AND. PF.GT.0.0) PBF0=PF/HW
C
C     2.  PHIF  SPECIFIED IN GRADED-POROSITY DESIGN:
C
000460      IF(LASTPHI.EQ.0 .AND. PHIF.GT.0.0) PBF0=PBS*(1.-PHIF)/PHIF
C
C     3.  PBF0  SET BY  PHIF  OF LAST CASE:
C
000473      IF(LASTPHI.EQ.1)  PBF0=PBS*(1.-SAVPHI(NIP1))/SAVPHI(NIP1)
C
C     4.  HOMOGENEOUS WICK  -  PBF0  SET BY PHI0:
C
000501      IF(LASTPHI.EQ.0 .AND. PHIF+PF.EQ.0) PBF0=PBS*(1.-PHI0)/PHI0
C
000514   22 CONTINUE
000514      RETURN
000515      END
```

```
      SUBROUTINE PROPS(L,T)
C
CC       THIS ROUTINE COMPUTES FLUID PROPERTIES FROM DATA FITS
C
000005      COMMON /CPROPS/ XMW,SHRV,HFG,PV,RHOL,RHOV,VISL,VISV,XKL,ST,TF
000005      DIMENSION A11(7), A21(7),
000005     1   A31(7), A32(7), A33(7), A34(7), A35(7),
000005     2   A41(7), A42(7), A43(7), A44(7), A45(7),
000005     3   A51(7), A52(7), A53(7), A54(7), A55(7),
000005     4   A61(7), A62(7), A63(7), A64(7), A65(7),
000005     5   A71(7), A72(7), A73(7), A74(7), A75(7),
000005     6   A81(7), A82(7), A83(7), A84(7), A85(7),
000005     7   A91(7), A92(7), A93(7), A94(7), A95(7),
000005     8   A101(7), A102(7), A103(7), A104(7), A105(7),
000005     9   A111(7), A112(7), A113(7), A114(7), A115(7)
C
CC         WATER (32F<T<400F)
C
000005      DATA   A11(1),       A21(1)/
000005     *        491.7,       18.016/
000005      DATA   A31(1),       A32(1),       A33(1),       A34(1),       A35(1)/
000005     *    1.3555636,-4.957576E-5,            0.,           0.,           0./
000005      DATA   A41(1),       A42(1),       A43(1),       A44(1),       A45(1)/
000005     *    1209.5508,-5.705515E-2,-4.454588E-4,           0.,           0./
000005      DATA   A51(1),       A52(1),       A53(1),       A54(1),       A55(1)/
000005     *    14.199322,  -6.5267262,  -.81013069,           0.,           0./
000005      DATA   A61(1),       A62(1),       A63(1),       A64(1),       A65(1)/
000005     *    58.481766, 2.586296E-2,-3.547212E-5,           0.,           0./
000005      DATA   A71(1),       A72(1),       A73(1),       A74(1),       A75(1)/
000005     *    7.4432132,  -6.0175647,  -.79940982,           0.,           0./
000005      DATA   A81(1),       A82(1),       A83(1),       A84(1),       A85(1)/
000005     *    52.825735,  -.26276093, 5.033270E-4,-4.411823E-7, 1.469628E-10/
000005      DATA   A91(1),       A92(1),       A93(1),       A94(1),       A95(1)/
000005     *   -10.66488,    1.1041087,           0.,           0.,           0./
000005      DATA  A101(1),      A102(1),      A103(1),      A104(1),      A105(1)/
000005     *   -1.0535655,5.3522992E-3,-8.446050E-6,2.5152327E-9,           0./
000005      DATA  A111(1),      A112(1),      A113(1),      A114(1),      A115(1)/
```

```
000005      * -3.437350E-3, 9.717223E-5,-2.230757E-7,2.117195E-10,-7.53081E-14/
            C
            C          AMMONIA (-107.9F<T<190F)
            C
000005       DATA    A11(2),       A21(2)/
000005      *         351.8,       17.032/
000005       DATA    A31(2),       A32(2),       A33(2),       A34(2),       A35(2)/
000005      *          1.31,          0.,           0.,           0.,           0./
000005       DATA    A41(2),       A42(2),       A43(2),       A44(2),       A45(2)/
000005      *  1.093251E+3,-2.482955E+0, 4.976430E-3,-4.474967E-6,           0./
000005       DATA    A51(2),       A52(2),       A53(2),       A54(2),       A55(2)/
000005      *  1.392374E+1,-4.921740E+0, 2.065018E-1,-7.579597E-2,           0./
000005       DATA    A61(2),       A62(2),       A63(2),       A64(2),       A65(2)/
000005      *  7.043766E+1,-1.172405E-1, 1.931707E-4,-1.649313E-7,           0./
000005       DATA    A71(2),       A72(2),       A73(2),       A74(2),       A75(2)/
000005      *  1.266986E+1,-1.113379E+1, 2.993128E+0,-4.689769E-1,           0./
000005       DATA    A81(2),       A82(2),       A83(2),       A84(2),       A85(2)/
000005      *  3.537046E+1,-2.496424E-1, 6.623156E-4,-7.941805E-7,3.552154E-10/
000005       DATA    A91(2),       A92(2),       A93(2),       A94(2),       A95(2)/
000005      * -3.370396E+3, 1.966694E+3,-4.728715E+2, 5.054066E+1,-2.024369E+0/
000005       DATA   A101(2),      A102(2),      A103(2),      A104(2),      A105(2)/
000005      * -4.160186E-1, 3.944710E-3,-6.537242E-6, 3.089435E-9,           0./
000005       DATA   A111(2),      A112(2),      A113(2),      A114(2),      A115(2)/
000005      *  6.426501E-3,-7.604641E-6,-7.699759E-9,8.623533E-12,           0./
            C
            C          METHYL ALCOHOL (-140F<T<380F)
            C
000005       DATA    A11(3),       A21(3)/
000005      *         322.7,       32.042/
000005       DATA    A31(3),       A32(3),       A33(3),       A34(3),       A35(3)/
000005      *          1.203,          0.,           0.,           0.,           0./
000005       DATA    A41(3),       A42(3),       A43(3),       A44(3),       A45(3)/
000005      *  3.790546E+2,-2.478105E+0, 6.416629E-3,-7.004195E-6, 2.214439E-9/
000005       DATA    A51(3),       A52(3),       A53(3),       A54(3),       A55(3)/
000005      *  1.505411E+1,-9.240630E+0, 3.366136E+0,-1.969200E+0, 3.389658E-1/
000005       DATA    A61(3),       A62(3),       A63(3),       A64(3),       A65(3)/
000005      *  1.307883E+1, 2.932836E-1,-8.417872E-4, 9.761262E-7,-4.305028E-10/
000005       DATA    A71(3),       A72(3),       A73(3),       A74(3),       A75(3)/
```

```
000005          *  1.593164E+1,-2.109098E+1, 1.144326E+1,-4.278643E+0, 5.809908E-1/
000005           DATA   A81(3),      A82(3),      A83(3),      A84(3),      A85(3)/
000005          *  2.285363E+1,-1.153169E-1, 2.303795E-4,-2.155127E-7, 7.551726E-11/
000005           DATA   A91(3),      A92(3),      A93(3),      A94(3),      A95(3)/
000005          *  1.922596E+2,-1.286769E+2, 3.113344E+1,-3.318410E+0, 1.325051E-1/
000005           DATA  A101(3),     A102(3),     A103(3),     A104(3),     A105(3)/
000005          *  3.944433E-2, 2.097417E-4,-6.310697E-7,7.394364E-10,-3.196966E-13/
000005           DATA  A111(3),     A112(3),     A113(3),     A114(3),     A115(3)/
000005          *  5.790525E-3,-1.464494E-5, 1.205620E-8,3.516629E-12,-8.678029E-15/
C
C           FREON-21 (-55F<T<305F)
C
000005           DATA   A11(4),      A21(4)/
000005          *         248.7,      102.93/
000005           DATA   A31(4),      A32(4),      A33(4),      A34(4),      A35(4)/
000005          *         1.175,         0.,          0.,          0.,          0./
000005           DATA   A41(4),      A42(4),      A43(4),      A44(4),      A45(4)/
000005          *  8.637825E+1, 4.636558E-1,-1.631685E-3, 2.056697E-6,-1.018948E-9/
000005           DATA   A51(4),      A52(4),      A53(4),      A54(4),      A55(4)/
000005          *  5.270732E+0, 1.573176E+1,-1.607959E+1, 5.259243E+0,-6.209501E-1/
000005           DATA   A61(4),      A62(4),      A63(4),      A64(4),      A65(4)/
000005          *  1.332756E+2,-3.261757E-1, 1.111655E-3,-1.611728E-6,8.906674E-10/
000005           DATA   A71(4),      A72(4),      A73(4),      A74(4),      A75(4)/
000005          *  3.534322E+1,-1.662575E+2, 1.252581E+2,-4.265882E+1, 5.375463E+0/
000005           DATA   A81(4),      A82(4),      A83(4),      A84(4),      A85(4)/
000005          * -3.347479E+0, 8.530116E-2,-2.757866E-4, 3.643724E-7,-1.759387E-10/
000005           DATA   A91(4),      A92(4),      A93(4),      A94(4),      A95(4)/
000005          * -1.838588E+3, 1.199366E+3,-2.944711E+2, 3.215076E+1,-1.315728E+0/
000005           DATA  A101(4),     A102(4),     A103(4),     A104(4),     A105(4)/
000005          *  4.750199E-1,-2.433548E-3, 5.713512E-6,-6.391302E-9, 2.653405E-12/
000005           DATA  A111(4),     A112(4),     A113(4),     A114(4),     A115(4)/
000005          * -5.248971E-3, 4.984869E-5,-1.133747E-7,9.235658E-11,-2.259591E-14/
C
C           ETHANE (-135F<T<89F)
C
000005           DATA   A11(5),      A21(5)/
000005          *         181.6,       30.07/
000005           DATA   A31(5),      A32(5),      A33(5),      A34(5),      A35(5)/
```

```
000005      *         1.18,          0.,          0.,          0.,          0./
000005       DATA   A41(5),       A42(5),      A43(5),      A44(5),      A45(5)/
000005      * -4.278934E+3, 4.573254E+1,-1.719481E-1, 2.840439E-4,-1.756889E-7/
000005       DATA   A51(5),       A52(5),      A53(5),      A54(5),      A55(5)/
000005      *  4.513520E+1,-5.303273E+1, 3.388505E+1,-9.165778E+0, 9.154704E-1/
000005       DATA   A61(5),       A62(5),      A63(5),      A64(5),      A65(5)/
000005      * -3.433014E+2, 3.301041E+0,-1.478827E-2, 2.451166E-5,-1.518682E-8/
000005       DATA   A71(5),       A72(5),      A73(5),      A74(5),      A75(5)/
000005      *  9.831080E+1,-1.463731E+2, 8.422928E+1,-2.191841E+1, 2.129803E+0/
000005       DATA   A81(5),       A82(5),      A83(5),      A84(5),      A85(5)/
000005      * -1.723943E+1, 1.931920E-1,-7.953422E-4, 1.385103E-6,-8.90506E-10/
000005       DATA   A91(5),       A92(5),      A93(5),      A94(5),      A95(5)/
000005      *  2.999855E+4,-2.017435E+4, 5.085813E+3,-5.697099E+2, 2.392870E+1/
000005       DATA  A101(5),      A102(5),     A103(5),     A104(5),     A105(5)/
000005      * -1.142860E+0, 1.317096E-2,-5.072525E-5, 8.390294E-8,-5.11860E-11/
000005       DATA  A111(5),      A112(5),     A113(5),     A114(5),     A115(5)/
000005      *  1.123709E-2,-8.339622E-5, 2.759121E-7,-4.39343E-10,2.651468E-13/
            C
            C          METHANE (-280F<T<-120F)
            C
000005       DATA   A11(6),       A21(6)/
000005      *         163.2,        16.04/
000005       DATA   A31(6),       A32(6),      A33(6),      A34(6),      A35(6)/
000005      *         1.32,          0.,          0.,          0.,          0./
000005       DATA   A41(6),       A42(6),      A43(6),      A44(6),      A45(6)/
000005      * -1.124091E+3, 2.425142E+1,-1.589307E-1, 4.547110E-4,-4.908714E-7/
000005       DATA   A51(6),       A52(6),      A53(6),      A54(6),      A55(6)/
000005      *  1.365684E+0, 8.557617E+0,-3.746570E+0, 5.803347E-1,-3.257158E-2/
000005       DATA   A61(6),       A62(6),      A63(6),      A64(6),      A65(6)/
000005      *  1.469951E+1, 3.814831E-1,-3.223542E-3, 1.076420E-5,-1.353123E-8/
000005       DATA   A71(6),       A72(6),      A73(6),      A74(6),      A75(6)/
000005      *  6.381082E+1,-5.495063E+1, 1.837493E+1,-2.799348E+0, 1.587595E-1/
000005       DATA   A81(6),       A82(6),      A83(6),      A84(6),      A85(6)/
000005      * -3.526486E+0, 2.024132E-1,-1.540820E-3, 4.719715E-6,-5.211675E-9/
000005       DATA   A91(6),       A92(6),      A93(6),      A94(6),      A95(6)/
000005      *  3.119631E+3,-6.766529E+3, 1.880522E+3,-2.321585E+2, 1.074400E+1/
000005       DATA  A101(6),      A102(6),     A103(6),     A104(6),     A105(6)/
000005      *  3.486478E-1,-1.720359E-3, 3.699297E-7, 1.840747E-8,-3.733285E-11/
```

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RUNX COMPILER (VER.2.3M)                    08/23/74. 15.31.43.          PROPS

000005          DATA  A111(6),     A112(6),     A113(6),     A114(6),     A115(6)/
000005         *  5.412797E-3,-5.463947E-5, 2.856240E-7,-7.81700E-10,5.146495E-13/
      C
      C           NITROGEN (-340F<T<-250F)
      C
000005          DATA   A11(7),       A21(7)/
000005         *         113.9,       28.016/
000005          DATA   A31(7),       A32(7),       A33(7),       A34(7),       A35(7)/
000005         *         1.40,          0.,           0.,           0.,           0./
000005          DATA   A41(7),       A42(7),       A43(7),       A44(7),       A45(7)/
000005         *  7.648974E+1,-2.305556E-1, 5.317599E-3,-2.340715E-5,           0./
000005          DATA   A51(7),       A52(7),       A53(7),       A54(7),       A55(7)/
000005         *  3.217173E+1,-1.431239E+1, 3.064764E+0,-3.133777E-1, 1.176449E-2/
000005          DATA   A61(7),       A62(7),       A63(7),       A64(7),       A65(7)/
000005         *  7.298718E+1,-3.323232E-1, 2.281469E-3,-7.479632E-6,           0./
000005          DATA   A71(7),       A72(7),       A73(7),       A74(7),       A75(7)/
000005         *  2.102802E+1,-7.503727E+0, 9.613273E-1,-4.861116E-2,           0./
000005          DATA   A81(7),       A82(7),       A83(7),       A84(7),       A85(7)/
000005         * -1.130709E+1, 3.580937E-1,-3.680943E-3, 1.687014E-5,-2.509266E-8/
000005          DATA   A91(7),       A92(7),       A93(7),       A94(7),       A95(7)/
000005         *  1.718670E+4,-1.371991E+4, 4.133845E+3,-5.453515E+2, 2.716624E+1/
000005          DATA  A101(7),      A102(7),      A103(7),      A104(7),      A105(7)/
000005         *  1.179000E-1,-7.932424E-5,-1.401515E-6,           0.,           0./
000005          DATA  A111(7),      A112(7),      A113(7),      A114(7),      A115(7)/
000005         *  1.636031E-3,-3.768939E-6,-4.379371E-8,1.270396E-10,           0./
      C
000005          IF (L.EQ.0) GO TO 20
      C
000006          T2 = T*T
000007          T3 = T2*T
000011          T4 = T2*T2
000013          TR = 1000.0/T
000015          TR2 = TR*TR
000017          TR3 = TR2*TR
000021          TR4 = TR2*TR2
000023          ALT=ALOG(T)
000027          ALT2=ALT*ALT
000031          ALT3=ALT2*ALT
```

```
000033          ALT4=ALT2*ALT2
                C
                C        FLUID PROPERTIES
                C
000035          TF = A11(L)
000037          XMW=A21(L)
000041          SHRV = A31(L)+A32(L)*T+A33(L)*T2+A34(L)*T3+A35(L)*T4
000053          HFG = A41(L)+A42(L)*T+A43(L)*T2+A44(L)*T3+A45(L)*T4
000065          PV = EXP(A51(L)+A52(L)*TR+A53(L)*TR2+A54(L)*TR3+A55(L)*TR4)
000103          RHOL = A61(L)+A62(L)*T+A63(L)*T2+A64(L)*T3+A65(L)*T4
000115          RHOV = EXP(A71(L)+A72(L)*TR+A73(L)*TR2+A74(L)*TR3+A75(L)*TR4)
000133          VISL = EXP(A81(L)+A82(L)*T+A83(L)*T2+A84(L)*T3+A85(L)*T4)
000151          VISV = EXP(A91(L)+A92(L)*ALT+A93(L)*ALT2+A94(L)*ALT3+A95(L)*ALT4)
000167          XKL = A101(L)+A102(L)*T+A103(L)*T2+A104(L)*T3+A105(L)*T4
000201          ST = A111(L)+A112(L)*T+A113(L)*T2+A114(L)*T3+A115(L)*T4
000213          VISV = VISV/4.1697504E3
000215          VISL=VISL/4.1697504E8
000217          RETURN
                C
000220       20 CONTINUE
000220          RETURN
000221          END
```

```
                      SUBROUTINE RUNGE(Y,YP,DZ)
000006                COMMON /PARAM/ PHI,PHI0,DPHI,PBFG,PBVS,PND,GEE,G,NI,NIP1,HW,
000006               1               NQ,FQ(10),NELEV,XELEV(10),ZELEV(10),ELEV(10),
000006               2               ELEVB(10),D,H,FNUB,AW,AB,XTOT,DX,DD,QDTB,QDOT,
000006               3               DIAF,A(7,1000),XQ(10),ZQ(10),PBS,PHIF,PF,
000006               4               NCASE,LASTPHI,SAVPHI(1000),ISLFPRM,IFAIL
000006                DIMENSION Y(4),YP(4),YP1(4),YP2(4),YP3(4),YP4(4),YD(4)
000006                COMMON /CPROPS/ XMW,SHRV,HFG,PV,RHOL,RHOV,VISL,VISV,XKL,ST,TF
000006                DO 1 I=1,4
000010                YP1(I)=YP(I)
000013               1 YD(I)=Y(I)+YP1(I)*DZ/2.
000022                CALL DERIV(YP2,YD)
000026                DO 2 I=1,4
000030               2 YD(I)=Y(I)+YP2(I)*DZ/2.
000037                CALL DERIV(YP3,YD)
000043                DO 3 I=1,4
000045               3 YD(I)=Y(I)+YP3(I)*DZ
000053                CALL DERIV(YP4,YD)
000057                DO 4 I=1,4
000061               4 Y(I)=Y(I)+(YP1(I)+2.*YP2(I)+2.*YP3(I)+YP4(I))*(DZ/6.)
000076                CALL DERIV(YP,Y)
000102                RETURN
000103                END
```

```
000002          SUBROUTINE WRT
000002          COMMON /PARAM/ PHI,PHIO,DPHI,PBFO,PBVS,PND,GEE,G,NI,NIP1,HW,
000002         1               NQ,FQ(10),NELEV,XELEV(10),ZELEV(10),ELEV(10),
000002         2               ELEV3(10),D,H,FNUS,AW,AB,XTOT,DX,DZ,QDTB,QDOT,
000002         3               DIAF,A(7,1000),XQ(10),ZQ(10),PBS,PHIF,PF,
000002         4               NCASE,LASTPHI,SAVPHI(1000),ISLFPRM,IFAIL
000002          COMMON /CPROPS/ XMW,SHRV,HFG,PV,RHOL,RHOV,VISL,VISV,XKL,ST,TF
000002          IMK=1
000003          GMASS=A(4,NIP1)*(AW/10000.)*RHOL*(XTOT/100.)*1000.
000014          DO 50 J=1,NIP1
000016          A(1,J)=XTOT*A(1,J)
000022          A(2,J)=100.*PND*A(2,J)/(RHOL*G)
000030          IF(A(1,J).GE.XELEV(IMK)) IMK=IMK+1
000037          A(6,J)=ELEV(IMK-1)+(A(1,J)-XELEV(IMK-1))*(ELEV(IMK)-ELEV(IMK-1))
000037         1       /(XELEV(IMK)-XELEV(IMK-1))+HW
000055          IF(GEE .EQ. 0.0) A(6,J)=0.
000060          SAVPHI(J)=A(5,J)
000063          A(7,J)=(100.*PND/(RHOL*G))*PBS*(1.-A(5,J))/A(5,J)
000075       50 CONTINUE
000100          QDT=QDTB*QDOT
000102          WRITE(6,960)
000106          WRITE(6,962) QDT,GMASS
000116          DO 90 J=1,NIP1
000120          WRITE(6,966) A(1,J),A(2,J),A(6,J),A(5,J),A(7,J)
000144       90 CONTINUE
000147      960 FORMAT(1H1,4X,15HFINAL SOLUTION //)
000147      962 FORMAT(10X,35HTHE MAXIMUM HEAT-TRANSFER RATE IS  ,
000147         1       E12.5,7H  WATTS//
000147         2       10X,29HTHE TOTAL LIQUID IN WICK IS  ,
000147         3       E12.5,7H  GRAMS///
000147         4    15X,8HDISTANCE,3X,6HSTRESS,7X,11HSTATIC HEAD,6X,8HPOROSITY,
000147         5    5X,12HCRIT. STRESS/17X,4H(CM),9X,9H(CM LIQ.),6X,9H(CM LIQ.),
000147         6    22X,9H(CM LIQ.)//)
000147      966 FORMAT(10X,5E15.4)
000147          RETURN
000150          END
```