OAK RIDGE NATIONAL LABORATORY

operated by

UNION CARBIDE CORPORATION

for the

U. S. ATOMIC ENERGY COMMISSION

ORNL – TM – 2412, Part VI

DESIGN CONSIDERATIONS OF REACTOR CONTAINMENT SPRAY SYSTEMS – PART VI.

THE HEATING OF SPRAY DROPS IN AIR-STEAM ATMOSPHERES

L. F. Parsly

NOTICE This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report.

ORNL-TM-2412
Part VI

Contract No. W-7405-eng-26

REACTOR DIVISION

DESIGN CONSIDERATIONS OF REACTOR CONTAINMENT SPRAY SYSTEMS – PART VI. THE HEATING OF SPRAY DROPS IN AIR-STEAM ATMOSPHERES

L. F. Parsly

JANUARY 1970

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
operated by
UNION CARBIDE CORPORATION
for the
U. S. ATOMIC ENERGY COMMISSION

FOREWORD

The Spray and Absorption Technology Program is coordinated by Oak Ridge National Laboratory for the AEC. The program involves research on all aspects of containment spray systems proposed for use as an engineered safety feature in pressurized water reactor containment buildings and investigations of certain aspects of the pool-pressure-suppression containment concept as applied to boiling water reactors. A document (ORNL-4360, *Spray and Pool Absorption Technology Program*) has recently been issued.

This present document describes a numerical procedure which has been developed to calculate the time for a cold water drop to approach the temperature of the air-steam atmosphere which will exist in the containment building when the sprays are turned on.

This is the sixth report in a series designed to present program information pertinent to actual plant design considerations. Additional reports in this series include:

T. H. Row, L. F. Parsly, and H. E. Zittel, *Design Considerations of Reactor Containment Spray Systems – Part I,* USAEC Report ORNL-TM-2412, April 1969.

C. Stuart Patterson and William T. Humphries, *Design Considerations of Reactor Containment Spray Systems – Part II. Removal of Iodine and Methyl Iodide from Air by Liquid Solutions,* USAEC Report ORNL-TM-2412, Part II, August 1969.

J. C. Griess and A. L. Bacarella, *Design Considerations of Reactor Containment Spray Systems – Part III. The Corrosion of Materials in Spray Solutions,* USAEC Report ORNL-TM-2412, Part III.

L. F. Parsly, *Design Considerations of Reactor Containment Spray Systems – Part IV. Calculation of Iodine-Water Partition Coefficients,* USAEC Report ORNL-TM-2412, Part IV.

J. C. Griess, T. H. Row, and C. D. Watson, *Design Considerations of Reactor Containment Spray Systems – Part V. Protective Coatings Tests,* USAEC Report ORNL-TM-2412, Part V.

Thomas H. Row
Technical Coordinator
Spray and Absorption Technology Program

CONTENTS

DESIGN CONSIDERATIONS OF REACTOR CONTAINMENT SPRAY SYSTEMS – PART VI. THE HEATING OF SPRAY DROPS IN AIR-STEAM ATMOSPHERES

L. F. Parsly

ABSTRACT

In a loss-of-coolant accident, cold water sprays are frequently used to reduce the containment pressure. It has generally been assumed that the drops would attain thermal equilibrium with the air-steam mixture in the containment atmosphere, but this has not been verified by calculations. A numerical procedure has been developed to calculate the time for a cold water drop to approach the temperature of the atmosphere. Calculations have been made for typical drop sizes (500, 1000, 1500, 2000, 3000, and 4000 μ diameter) under hypothetical accident conditions. The results of the calculations confirm the assumption that the drops will essentially come to thermal equilibrium with the atmosphere in full-size reactor containment buildings.

INTRODUCTION

Spray systems are being proposed for the containment buildings of many power reactors being built today. In the unlikely event of a loss-of-coolant accident these are to serve the twofold purpose of removing heat from the containment atmosphere and knocking down airborne fission products.

From reviewing safety analysis reports on reactors, it became apparent that no one had undertaken to calculate the rate at which cold water drops sprayed into an air-steam atmosphere approach the temperature of the atmosphere. It is well known that heat transfer by condensation is sharply reduced in the presence of noncondensable gases, and we felt that backup calculations should be made which would either confirm or deny the assumption that thermal equilibrium is attained. It seemed to us that it should be possible, although difficult, to solve the problem.

The unique feature of the problem is that the major heat input comes from condensation of steam on the drop surface, although forced convection also plays a role. Since we could not see any way to handle the condensation problem analytically, we decided to solve the problem numerically.

ASSUMPTIONS

In order to solve the problem fairly readily, we had to make several simplifying assumptions. These are as follows:

1. The drops are assumed to be falling at their terminal velocity. Actually they start a lot faster and slow down as they fall.
2. The boundary layer on the drops is assumed to be fully developed. In reality there is no boundary layer when a drop is born, and therefore momentarily the heat and mass transfer are much higher.
3. The drop is assumed to act as a rigid body, so that the only heat transport mechanism inside the drop is conduction. Any internal circulation would speed up heat transfer inside the drop.

4. It is assumed that average values of the physical properties can be used.
5. The effect of condensation on the drop diameter is ignored. Actually a drop will grow a maximum of about 6% in diameter. (This is based on approximately 20% increase in mass due to condensation, which assumes a 100°C temperature rise.)
6. The temperature of the containment building atmosphere is presumed to remain constant during a drop's lifetime.

ANALYTICAL MODEL

The physical system with which we are dealing can be idealized to a rigid sphere (the spray drop) initially at some uniform temperature, exposed to surroundings at a different temperature (the containment atmosphere) and with surface heat transfer resistance (convective heat transfer through a gas boundary layer) and a surface heat source (latent heat released by condensation of steam). This is described mathematically by the classical partial differential equation of heat conduction with appropriate initial and boundary conditions. The equation, using dimensionless variables, is:

$$\frac{1}{\rho^2}\frac{\partial}{\partial \rho}\left(\rho^2 \frac{\partial \tau}{\partial \rho}\right)=\frac{\partial \tau}{\partial \theta} . \tag{1}$$

The dimensionless variables are:

$\tau = (T_\infty - T)/(T_\infty - T_0)$, dimensionless temperature,

$\theta = \alpha t/r_0^2$, dimensionless time,

$\rho = r/r_0$, dimensionless radius.

Because the vapor pressure of water enters into the boundary condition involving steam flux to the drop (the driving force for mass transfer is the partial pressure of water vapor in the atmosphere less the pressure in equilibrium with the drop surface), the boundary conditions cannot be made dimensionless.

For conversion to a finite difference problem, the drop was divided into ten regions – a central sphere and nine annuli. Differencing was carried out as suggested by Crank.[1] That is, the following finite difference approximations to the partial derivatives were used:

for $i > 1$,

$$\frac{1}{\rho^2}\frac{\partial}{\partial \rho}\left(\rho^2 \frac{\partial \tau}{\partial \rho}\right)=\frac{1}{(i-1)\delta\rho^2}\left[i\tau_{i+1,j} - 2(i-1)\tau_{i,j} + (i-2)\tau_{i-1,j}\right] ; \tag{2}$$

for $i = 1$,

$$\frac{1}{\rho^2}\frac{\partial}{\partial \rho}\left(\rho^2 \frac{\partial \tau}{\partial \rho}\right)=\frac{6}{\delta\rho^2}(\tau_{2,j} - \tau_{1,j}); \tag{3}$$

$$\frac{\partial \tau}{\partial \theta} = \frac{\tau_{i,j+1} - \tau_{i,j}}{\delta\theta} . \tag{4}$$

Here i refers to position step number and j to time step number; 1 refers to the center of the sphere.

---

[1] J. Crank, *The Mathematics of Diffusion*, pp. 186–99, Oxford Univ. Press, 1956.

The boundary condition was dealt with by writing a heat balance over the outermost annulus. The set of equations used for computation is:

for $i = 1$ (center of drop),

$$\tau_{1,j+1} = \tau_{2,j}; \tag{5}$$

for $2 \leqslant i \leqslant 10$,

$$\tau_{i,j+1} = \tau_{i,j} + \frac{\delta\theta}{2}\left[\left(\frac{i}{i-1}\right)(\tau_{i+1,j}) - 2\tau_{(i,j)} + \left(\frac{i-2}{i-1}\right)(\tau_{i+1,j})\right]; \tag{6}$$

for $i = 11$ (surface of drop),

$$\tau_{11,j+1} = \tau_{11,j} - \frac{9\,\delta\theta}{\delta\rho}(\tau_{11,j} - \tau_{10,j}) - \frac{100\,\delta\theta}{9}\,\frac{r_0 l_v k_g (P_\infty - P_s)}{k(T_\infty - T_0)} - \frac{100\,\delta\theta}{9}\,\frac{h r_0}{k}\,\tau_{11,j}\ . \tag{7}$$

In this last equation, the second term on the right accounts for conduction of heat into the drop, the third for condensation on the drop, and the last for forced convection heat transfer to the drop surface.

The terminal velocity was calculated from an equation recommended by Lapple:[2]

$$U_t = \frac{0.153 g^{0.714} D_p^{1.142} (\rho_p - \rho_a)^{0.714}}{(\rho_a^{0.286} \mu^{0.428})}\ ,\quad 2 \leqslant N_{\mathrm{Re}} \leqslant 1000\ . \tag{8}$$

The mass transfer coefficient k_g was calculated by the equation recommended by Ranz and Marshall:[3]

$$\frac{k_g P_{BM} M_m R T r_0}{D_v P} = 1 + 0.3 N_{\mathrm{Re}}^{1/2} N_{\mathrm{Sc}}^{1/3}\ . \tag{9}$$

The problem was programmed in FORTRAN IV and run on the IBM system 360 model 91 computer at ORNL. The time step ($\delta\theta$) was taken as $1/600$, so that $\delta\theta/\delta\rho^2$ would be $1/6$. Provision was made for 5400 time steps, with each case to be terminated sooner if the mean drop temperature became less than 0.0001 (note that with the conversion to a dimensionless temperature, the drop temperature is 1.0 throughout initially and eventually becomes 0). The program is fixed to give a printout of the results every 30 time steps.

RESULTS

The results of the calculation are summarized in Table 1, plotted in Fig. 1, and given in complete form in Tables 3–16. We have also included in Table 1 the time reported by Brown[4] for the case of no surface resistance. The table shows that heatup is appreciably slower with surface resistance and that it takes much longer to heat up large drops than small ones.

---

[2] C. E. Lapple, *Fluid and Particle Mechanics,* p. 284, University of Delaware, 1951.

[3] W. E. Ranz and W. R. Marshall, Jr., "Evaporation from Drops," *Chem. Eng. Progr.* **48,** 141–46, 173–80 (1952).

[4] G. Brown, "Heat Transmission by Condensation of Steam on a Spray of Water Drops," *ASME, Proc. Gen. Disc. Heat Transfer,* pp. 49–52 (1951).

Table 1. Summary of Results – Atmosphere Temperature 130°C, Initial Drop Temperature 30°C

Drop Diameter (μ)	Time(sec) to Attain θ for Dimensionless Temperature of –		
	θ = 0.5	θ = 0.1	θ = 0.01
Heat Transfer to Drop by Condensation and Convection (Present Calculations)			
500	0.055	0.146	0.265
1000	0.155	0.45	0.86
1500	0.31	0.95	1.83
2000	0.52	1.64	3.3
3000	1.04	3.5	7.0
4000	1.75	6.2	12.2
Drop Surface at T_∞ (Calculations of Brown[a])			
500	0.013	0.09	
1000	0.03	0.3	
1500	0.13	0.7	
2000	0.20	1.15	
3000	0.45	2.5	
4000	0.74	4.2	

[a]G. Brown, "Heat Transmission by Condensation of Steam on a Spray of Water Drops," *ASME, Proc. Gen. Disc. Heat Transfer*, pp. 49–52 (1951).

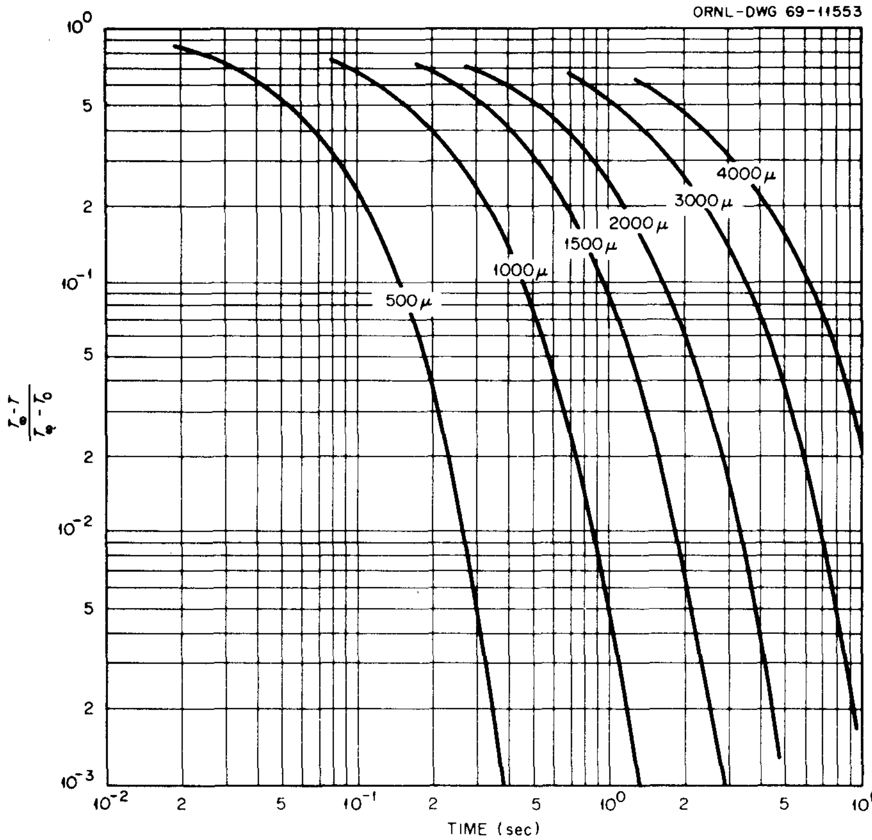

Fig. 1. Calculated Time to Heat Falling Drops Including Condensation and Convection.

Table 2 gives the calculated residence time for drops in the NSPP and in a large containment building under accident conditions. This shows that drops 1000 μ and smaller will closely approach temperature equilibrium even in the NSPP. Larger drops may not attain equilibrium in the NSPP but should certainly do so in a large containment building. The results of the calculation appear to be consistent with the observation in the NSPP that the solution temperature does not quite attain the vessel atmosphere temperature.

Table 2. Approximate Residence Times for Drops of Various Sizes in an Air-Steam Atmosphere at 120°C

Diameter (μ)	Residence Time(sec)	
	NSPP, H = 15 ft	Large PWR, H = 120 ft
500	3.0	23
1000	1.4	10.5
1500	0.9	8.2
2000	0.4	7.4
3000	0.3	6.0
4000	0.2	4.19

CONCLUSIONS

The above calculations justify the conclusion that water introduced into a full-size containment building as sprays will attain temperature equilibrium with the building atmosphere. On the other hand, coarse sprays will not come completely to equilibrium in pilot-plant equipment where residence time is appreciably less. Observations of spray solution temperatures in the Nuclear Safety Pilot Plant confirm this.

NOMENCLATURE

D_v	Diffusion coefficient for water vapor in air, cm^2/sec
D_p	Drop diameter, cm
g	Acceleration of gravity
h	Outside film heat transfer coefficient, cal/(sec) (cm^2) (°C)
k	Thermal conductivity, cal/(sec) (cm^2) (°C)
k_g	Mass transfer coefficient, g-moles/(sec) (cm^2) (atm)
l_v	Heat of vaporization, cal/g-mole
M_m	Mean molecular weight in gas film
P_∞	Partial pressure of water vapor in containment building, atm
P_s	Vapor pressure of water at surface of drop (pressure in equilibrium), atm
P_{BM}	Mean partial pressure of inert in film, atm
r_0	Radius of drop, cm
r	Radius, cm
R	Gas constant
T_∞	Temperature of atmosphere, °K
T_0	Initial drop temperature, °K
T	Temperature, °K

t	Time, sec
U_t	Terminal velocity, cm/sec
α	Thermal diffusivity, cm^2/sec
δ	Difference operator
μ	Viscosity of atmosphere, poises
ρ	Dimensionless radius, r/r_0
ρ_p	Drop density, g/cm^3
τ	Dimensionless temperature, $(T_\infty - T)/(T_\infty - T_0)$
θ	Dimensionless time, $\alpha t/r_0^2$
N_{Re}	Reynolds number, $D_p U_t \rho_a/\mu$
N_{Sc}	Schmidt number, $\mu/(\rho_a D_v)$

Table 3.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.0500 CM
ATMOSPHERE TEMPERATURE = 130.0 DEG C INITIAL DROP TEMPERATURE = 30.0 DEG C

	FRACTION OF RADIUS												
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9958	0.9949	0.9917	0.9848	0.9715	0.9478	0.9084	0.8475	0.7602	0.6442	0.5016	0.841121	0.019427
0.1000	0.9071	0.9022	0.8875	0.8619	0.8243	0.7734	0.7081	0.6281	0.5340	0.4278	0.3126	0.643805	0.038854
0.1500	0.7396	0.7336	0.7158	0.6862	0.6449	0.5923	0.5290	0.4563	0.3757	0.2894	0.2003	0.477091	0.058281
0.2000	0.5675	0.5621	0.5460	0.5197	0.4835	0.4385	0.3856	0.3264	0.2625	0.1960	0.1291	0.345603	0.077708
0.2500	0.4204	0.4160	0.4030	0.3817	0.3528	0.3172	0.2760	0.2304	0.1820	0.1326	0.0837	0.246196	0.097135
0.3000	0.3042	0.3008	0.2909	0.2746	0.2527	0.2258	0.1949	0.1611	0.1256	0.0897	0.0548	0.173315	0.116562
0.3500	0.2166	0.2141	0.2067	0.1947	0.1786	0.1589	0.1364	0.1119	0.0865	0.0609	0.0363	0.121030	0.135989
0.4000	0.1525	0.1507	0.1453	0.1367	0.1251	0.1109	0.0949	0.0775	0.0595	0.0415	0.0243	0.084067	0.155416
0.4500	0.1065	0.1052	0.1014	0.0953	0.0870	0.0771	0.0657	0.0535	0.0409	0.0283	0.0164	0.058184	0.174843
0.5000	0.0740	0.0731	0.0704	0.0661	0.0603	0.0533	0.0454	0.0369	0.0281	0.0194	0.0111	0.040174	0.194270
0.5500	0.0512	0.0506	0.0487	0.0457	0.0417	0.0368	0.0313	0.0254	0.0193	0.0133	0.0076	0.027694	0.213697
0.6000	0.0354	0.0349	0.0336	0.0316	0.0288	0.0254	0.0216	0.0175	0.0133	0.0091	0.0052	0.019070	0.233125
0.6500	0.0244	0.0241	0.0232	0.0217	0.0198	0.0175	0.0148	0.0120	0.0091	0.0062	0.0035	0.013122	0.252552
0.7000	0.0168	0.0166	0.0160	0.0150	0.0136	0.0120	0.0102	0.0083	0.0063	0.0043	0.0024	0.009025	0.271979
0.7500	0.0116	0.0114	0.0110	0.0103	0.0094	0.0083	0.0070	0.0057	0.0043	0.0029	0.0017	0.006204	0.291406
0.8000	0.0079	0.0078	0.0076	0.0071	0.0064	0.0057	0.0048	0.0039	0.0030	0.0020	0.0011	0.004264	0.310833
0.8500	0.0055	0.0054	0.0052	0.0049	0.0044	0.0039	0.0033	0.0027	0.0020	0.0014	0.0008	0.002930	0.330260
0.9000	0.0038	0.0037	0.0036	0.0033	0.0030	0.0027	0.0023	0.0018	0.0014	0.0010	0.0005	0.002013	0.349687
0.9500	0.0026	0.0025	0.0025	0.0023	0.0021	0.0018	0.0016	0.0013	0.0010	0.0007	0.0004	0.001383	0.369114
1.0000	0.0018	0.0018	0.0017	0.0016	0.0014	0.0013	0.0011	0.0009	0.0007	0.0004	0.0003	0.000950	0.388541
1.0500	0.0012	0.0012	0.0012	0.0011	0.0010	0.0009	0.0007	0.0006	0.0005	0.0003	0.0002	0.000652	0.407968
1.1000	0.0008	0.0008	0.0008	0.0007	0.0007	0.0006	0.0005	0.0004	0.0003	0.0002	0.0001	0.000448	0.427395
1.1500	0.0006	0.0006	0.0005	0.0005	0.0005	0.0004	0.0003	0.0003	0.0002	0.0001	0.0001	0.000307	0.446822
1.2000	0.0004	0.0004	0.0004	0.0004	0.0003	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.000211	0.466249
1.2500	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.000144	0.485676
1.3000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.000099	0.505103

Table 4.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.1000 CM
ATMOSPHERE TEMPERATURE = 130.0 DEG C INITIAL DROP TEMPERATURE = 30.0 DEG C

	FRACTION OF RADIUS												
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9929	0.9914	0.9861	0.9748	0.9533	0.9156	0.8542	0.7618	0.6336	0.4704	0.2802	0.756403	0.077708
0.1000	0.8574	0.8504	0.8293	0.7932	0.7410	0.6719	0.5860	0.4846	0.3707	0.2493	0.1269	0.510671	0.155416
0.1500	0.6343	0.6270	0.6053	0.5695	0.5206	0.4599	0.3893	0.3115	0.2296	0.1473	0.0686	0.339010	0.233124
0.2000	0.4379	0.4323	0.4155	0.3883	0.3518	0.3073	0.2568	0.2025	0.1467	0.0920	0.0407	0.223662	0.310833
0.2500	0.2938	0.2899	0.2781	0.2592	0.2338	0.2033	0.1689	0.1323	0.0950	0.0589	0.0253	0.147073	0.388541
0.3000	0.1947	0.1920	0.1841	0.1713	0.1543	0.1338	0.1109	0.0865	0.0619	0.0380	0.0160	0.096509	0.466249
0.3500	0.1283	0.1265	0.1212	0.1127	0.1014	0.0878	0.0727	0.0566	0.0404	0.0247	0.0103	0.063241	0.543957
0.4000	0.0842	0.0830	0.0796	0.0740	0.0665	0.0576	0.0476	0.0370	0.0264	0.0161	0.0066	0.041404	0.621665
0.4500	0.0552	0.0544	0.0522	0.0485	0.0436	0.0377	0.0311	0.0242	0.0172	0.0105	0.0043	0.027091	0.699373
0.5000	0.0362	0.0356	0.0341	0.0317	0.0285	0.0247	0.0204	0.0158	0.0113	0.0068	0.0028	0.017719	0.777081
0.5500	0.0237	0.0233	0.0223	0.0208	0.0187	0.0161	0.0133	0.0103	0.0074	0.0045	0.0018	0.011586	0.854789
0.6000	0.0155	0.0153	0.0146	0.0136	0.0122	0.0106	0.0087	0.0068	0.0048	0.0029	0.0012	0.007575	0.932498
0.6500	0.0101	0.0100	0.0096	0.0089	0.0080	0.0069	0.0057	0.0044	0.0031	0.0019	0.0008	0.004951	1.010205
0.7000	0.0066	0.0065	0.0062	0.0058	0.0052	0.0045	0.0037	0.0029	0.0021	0.0012	0.0005	0.003236	1.087914
0.7500	0.0043	0.0043	0.0041	0.0038	0.0034	0.0029	0.0024	0.0019	0.0013	0.0008	0.0003	0.002115	1.165622
0.8000	0.0028	0.0028	0.0027	0.0025	0.0022	0.0019	0.0016	0.0012	0.0009	0.0005	0.0002	0.001382	1.243330
0.8500	0.0018	0.0018	0.0017	0.0016	0.0015	0.0013	0.0010	0.0008	0.0006	0.0003	0.0001	0.000903	1.321038
0.9000	0.0012	0.0012	0.0011	0.0011	0.0010	0.0008	0.0007	0.0005	0.0004	0.0002	0.0001	0.000590	1.398746
0.9500	0.0008	0.0008	0.0007	0.0007	0.0006	0.0005	0.0004	0.0003	0.0002	0.0001	0.0001	0.000385	1.476454
1.0000	0.0005	0.0005	0.0005	0.0005	0.0004	0.0004	0.0003	0.0002	0.0002	0.0001	0.0000	0.000251	1.554163
1.0500	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.000164	1.631869
1.1000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.000107	1.709578
1.1500	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.000069	1.787286

Table 5.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.1500 CM
ATMOSPHERE TEMPERATURE = 130.0 DEG C INITIAL DROP TEMPERATURE = 30.0 DEG C

	FRACTION OF RADIUS												
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9911	0.9832	0.9827	0.9688	0.9427	0.8975	0.8248	0.7175	0.5718	0.3916	0.1897	0.714513	0.174843
0.1000	0.8326	0.8247	0.8011	0.7608	0.7034	0.6284	0.5367	0.4309	0.3150	0.1953	0.0791	0.461678	0.349687
0.1500	0.5921	0.5846	0.5622	0.5255	0.4759	0.4149	0.3451	0.2694	0.1912	0.1145	0.0431	0.298114	0.524530
0.2000	0.3953	0.3899	0.3736	0.3474	0.3123	0.2700	0.2224	0.1718	0.1206	0.0712	0.0258	0.192468	0.699373
0.2500	0.2583	0.2546	0.2437	0.2261	0.2028	0.1747	0.1434	0.1104	0.0771	0.0452	0.0160	0.124161	0.874217
0.3000	0.1674	0.1650	0.1578	0.1463	0.1311	0.1128	0.0924	0.0710	0.0495	0.0289	0.0101	0.080031	1.049060
0.3500	0.1081	0.1066	0.1019	0.0945	0.0846	0.0727	0.0596	0.0457	0.0318	0.0185	0.0064	0.051554	1.223904
0.4000	0.0697	0.0687	0.0657	0.0609	0.0545	0.0469	0.0384	0.0294	0.0204	0.0119	0.0041	0.033196	1.398746
0.4500	0.0449	0.0443	0.0423	0.0392	0.0351	0.0302	0.0247	0.0189	0.0131	0.0076	0.0026	0.021370	1.573590
0.5000	0.0289	0.0285	0.0273	0.0253	0.0226	0.0194	0.0159	0.0122	0.0085	0.0049	0.0017	0.013754	1.748433
0.5500	0.0186	0.0184	0.0176	0.0163	0.0145	0.0125	0.0102	0.0078	0.0054	0.0032	0.0011	0.008851	1.923277
0.6000	0.0120	0.0118	0.0113	0.0105	0.0094	0.0080	0.0066	0.0050	0.0035	0.0020	0.0007	0.005695	2.098120
0.6500	0.0077	0.0076	0.0073	0.0067	0.0060	0.0052	0.0042	0.0032	0.0023	0.0013	0.0004	0.003664	2.272964
0.7000	0.0050	0.0049	0.0047	0.0043	0.0039	0.0033	0.0027	0.0021	0.0014	0.0008	0.0003	0.002357	2.447807
0.7500	0.0032	0.0031	0.0030	0.0028	0.0025	0.0021	0.0018	0.0013	0.0009	0.0005	0.0002	0.001516	2.622651
0.8000	0.0021	0.0020	0.0019	0.0018	0.0016	0.0014	0.0011	0.0009	0.0006	0.0003	0.0001	0.000975	2.797494
0.8500	0.0013	0.0013	0.0012	0.0012	0.0010	0.0009	0.0007	0.0006	0.0004	0.0002	0.0001	0.000627	2.972338
0.9000	0.0009	0.0008	0.0008	0.0007	0.0007	0.0006	0.0005	0.0004	0.0002	0.0001	0.0000	0.000403	3.147181
0.9500	0.0005	0.0005	0.0005	0.0005	0.0004	0.0004	0.0003	0.0002	0.0002	0.0001	0.0000	0.000259	3.322024
1.0000	0.0004	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.000166	3.496868
1.0500	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.0000	0.000107	3.671709
1.1000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.000068	3.846553

Table 6.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.22[illegible] CM
ATMOSPHERE TEMPERATURE = 130.0 DEG C INITIAL DROP TEMPERATURE = 30.0 DEG C

	FRACTION OF RADIUS											
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9896	0.9874	0.9800	0.9641	0.9345	0.8837	0.8032	0.6860	0.5301	0.3420	0.1380	0.685863	0.310833
0.1000	0.8153	0.8069	0.7818	0.7392	0.6790	0.6011	0.5072	0.4002	0.2851	0.1684	0.0575	0.433706	0.621665
0.1500	0.5665	0.5589	0.5364	0.4997	0.4502	0.3898	0.3211	0.2474	0.1721	0.0990	0.0318	0.276426	0.932498
0.2000	0.3715	0.3663	0.3505	0.3250	0.2910	0.2503	0.2046	0.1564	0.1079	0.0614	0.0191	0.176507	1.243331
0.2500	0.2395	0.2360	0.2256	0.2089	0.1867	0.1601	0.1306	0.0995	0.0684	0.0387	0.0119	0.112702	1.554164
0.3000	0.1534	0.1512	0.1445	0.1337	0.1194	0.1023	0.0833	0.0634	0.0435	0.0246	0.0074	0.071934	1.864996
0.3500	0.0981	0.0956	0.0923	0.0854	0.0762	0.0653	0.0532	0.0404	0.0277	0.0156	0.0047	0.045898	2.175829
0.4000	0.0626	0.0617	0.0589	0.0545	0.0487	0.0417	0.0339	0.0258	0.0177	0.0100	0.0030	0.029278	2.486662
0.4500	0.0400	0.0394	0.0376	0.0348	0.0310	0.0266	0.0216	0.0164	0.0113	0.0063	0.0019	0.018673	2.797495
0.5000	0.0255	0.0251	0.0240	0.0222	0.0198	0.0170	0.0138	0.0105	0.0072	0.0040	0.0012	0.011908	3.108328
0.5500	0.0163	0.0160	0.0153	0.0142	0.0126	0.0108	0.0088	0.0067	0.0046	0.0026	0.0008	0.007593	3.419160
0.6000	0.0104	0.0102	0.0098	0.0090	0.0081	0.0069	0.0056	0.0043	0.0029	0.0016	0.0005	0.004841	3.729993
0.6500	0.0066	0.0065	0.0062	0.0058	0.0051	0.0044	0.0036	0.0027	0.0019	0.0010	0.0003	0.003087	4.040826
0.7000	0.0042	0.0042	0.0040	0.0037	0.0033	0.0028	0.0023	0.0017	0.0012	0.0007	0.0002	0.001968	4.351659
0.7500	0.0027	0.0026	0.0025	0.0023	0.0021	0.0018	0.0015	0.0011	0.0008	0.0004	0.0001	0.001254	4.662492
0.8000	0.0017	0.0017	0.0016	0.0015	0.0013	0.0011	0.0009	0.0007	0.0005	0.0003	0.0001	0.000799	4.973325
0.8500	0.0011	0.0011	0.0010	0.0010	0.0008	0.0007	0.0006	0.0004	0.0003	0.0002	0.0001	0.000509	5.284158
0.9000	0.0007	0.0007	0.0007	0.0006	0.0005	0.0005	0.0004	0.0003	0.0002	0.0001	0.0000	0.000324	5.594991
0.9500	0.0004	0.0004	0.0004	0.0004	0.0003	0.0003	0.0002	0.0002	0.0001	0.0001	0.0000	0.000207	5.905824
1.0000	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0000	0.0000	0.000131	6.216657
1.0500	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.000083	6.527484

Table 7.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.3000 CM
ATMOSPHERE TEMPERATURE = 130.0 DEG C INITIAL DROP TEMPERATURE = 30.0 DEG C

	FRACTION OF RADIUS												
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9872	0.9846	0.9756	0.9568	0.9222	0.8638	0.7732	0.6446	0.4787	0.2860	0.0865	0.649628	0.699373
0.1000	0.7925	0.7836	0.7569	0.7121	0.6492	0.5690	0.4737	0.3669	0.2541	0.1420	0.0378	0.402970	1.398746
0.1500	0.5368	0.5292	0.5068	0.4704	0.4215	0.3623	0.2956	0.2245	0.1527	0.0839	0.0214	0.253516	2.098119
0.2000	0.3458	0.3406	0.3254	0.3009	0.2684	0.2294	0.1861	0.1406	0.0951	0.0518	0.0129	0.159973	2.797493
0.2500	0.2197	0.2164	0.2066	0.1908	0.1699	0.1450	0.1174	0.0885	0.0597	0.0325	0.0080	0.100993	3.496866
0.3000	0.1390	0.1369	0.1307	0.1206	0.1074	0.0916	0.0741	0.0558	0.0376	0.0204	0.0050	0.063753	4.196239
0.3500	0.0878	0.0865	0.0825	0.0762	0.0678	0.0578	0.0468	0.0352	0.0237	0.0129	0.0031	0.040239	4.895612
0.4000	0.0554	0.0546	0.0521	0.0481	0.0428	0.0365	0.0295	0.0222	0.0150	0.0081	0.0020	0.025395	5.594986
0.4500	0.0350	0.0345	0.0329	0.0304	0.0270	0.0230	0.0186	0.0140	0.0094	0.0051	0.0012	0.016025	6.294359
0.5000	0.0221	0.0218	0.0208	0.0192	0.0171	0.0145	0.0118	0.0088	0.0060	0.0032	0.0008	0.010112	6.993733
0.5500	0.0139	0.0137	0.0131	0.0121	0.0108	0.0092	0.0074	0.0056	0.0038	0.0020	0.0005	0.006380	7.693106
0.6000	0.0088	0.0087	0.0083	0.0076	0.0068	0.0058	0.0047	0.0035	0.0024	0.0013	0.0003	0.004025	8.392479
0.6500	0.0055	0.0055	0.0052	0.0048	0.0043	0.0037	0.0030	0.0022	0.0015	0.0008	0.0002	0.002539	9.091853
0.7000	0.0035	0.0034	0.0033	0.0030	0.0027	0.0023	0.0019	0.0014	0.0009	0.0005	0.0001	0.001602	9.791222
0.7500	0.0022	0.0022	0.0021	0.0019	0.0017	0.0015	0.0012	0.0009	0.0006	0.0003	0.0001	0.001010	10.490601
0.8000	0.0014	0.0014	0.0013	0.0012	0.0011	0.0009	0.0007	0.0006	0.0004	0.0002	0.0000	0.000637	11.189970
0.8500	0.0009	0.0009	0.0008	0.0008	0.0007	0.0006	0.0005	0.0004	0.0002	0.0001	0.0000	0.000402	11.889339
0.9000	0.0006	0.0005	0.0005	0.0005	0.0004	0.0004	0.0003	0.0002	0.0001	0.0001	0.0000	0.000253	12.588718
0.9500	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.000159	13.288088
1.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.000100	13.987467
1.0500	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.000063	14.686828

Table 8.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.4000 CM
ATMOSPHERE TEMPERATURE = 130.0 DEG C INITIAL DROP TEMPERATURE = 30.0 DEG C

	FRACTION OF RADIUS												
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9854	0.9824	0.9724	0.9515	0.9135	0.8503	0.7537	0.6193	0.4496	0.2571	0.0631	0.628317	1.243331
0.1000	0.7783	0.7692	0.7417	0.6958	0.6318	0.5508	0.4553	0.3493	0.2383	0.1291	0.0287	0.386476	2.486661
0.1500	0.5201	0.5126	0.4903	0.4542	0.4059	0.3476	0.2821	0.2127	0.1429	0.0764	0.0164	0.241499	3.729993
0.2000	0.3319	0.3269	0.3120	0.2881	0.2564	0.2185	0.1765	0.1324	0.0886	0.0471	0.0099	0.151407	4.973325
0.2500	0.2093	0.2061	0.1966	0.1814	0.1612	0.1372	0.1107	0.0829	0.0554	0.0294	0.0061	0.094984	6.216657
0.3000	0.1315	0.1295	0.1235	0.1139	0.1012	0.0861	0.0694	0.0520	0.0347	0.0184	0.0038	0.059589	7.459987
0.3500	0.0826	0.0813	0.0775	0.0715	0.0635	0.0540	0.0435	0.0326	0.0217	0.0115	0.0024	0.037381	8.703318
0.4000	0.0518	0.0510	0.0486	0.0449	0.0399	0.0339	0.0273	0.0204	0.0136	0.0072	0.0015	0.023448	9.946645
0.4500	0.0325	0.0320	0.0305	0.0281	0.0250	0.0213	0.0171	0.0128	0.0086	0.0045	0.0009	0.014707	11.189980
0.5000	0.0204	0.0201	0.0191	0.0177	0.0157	0.0133	0.0107	0.0080	0.0054	0.0028	0.0006	0.009225	12.433313
0.5500	0.0128	0.0126	0.0120	0.0111	0.0098	0.0084	0.0067	0.0050	0.0034	0.0018	0.0004	0.005785	13.676639
0.6000	0.0080	0.0079	0.0075	0.0069	0.0062	0.0052	0.0042	0.0032	0.0021	0.0011	0.0002	0.003628	14.919972
0.6500	0.0050	0.0050	0.0047	0.0044	0.0039	0.0033	0.0027	0.0020	0.0013	0.0007	0.0001	0.002275	16.163300
0.7000	0.0032	0.0031	0.0030	0.0027	0.0024	0.0021	0.0017	0.0012	0.0008	0.0004	0.0001	0.001426	17.406631
0.7500	0.0020	0.0019	0.0019	0.0017	0.0015	0.0013	0.0010	0.0008	0.0005	0.0003	0.0001	0.000894	18.649963
0.8000	0.0012	0.0012	0.0012	0.0011	0.0010	0.0008	0.0007	0.0005	0.0003	0.0002	0.0000	0.000560	19.893295
0.8500	0.0008	0.0008	0.0007	0.0007	0.0006	0.0005	0.0004	0.0003	0.0002	0.0001	0.0000	0.000351	21.136612
0.9000	0.0005	0.0005	0.0005	0.0004	0.0004	0.0003	0.0003	0.0002	0.0001	0.0001	0.0000	0.000220	22.379959
0.9500	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0001	0.0001	0.0000	0.0000	0.000137	23.623291
1.0000	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	-0.0001	0.0000	0.0000	0.0000	0.000086	24.866623

Table 9.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.0500 CM
ATMOSPHERE TEMPERATURE = 130.0 DEG C INITIAL DROP TEMPERATURE = 80.0 DEG C

	FRACTION OF RADIUS												
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9953	0.9948	0.9916	0.9847	0.9713	0.9475	0.9081	0.8473	0.7604	0.6456	0.5052	0.841242	0.018968
0.1000	0.9071	0.9023	0.8877	0.8624	0.8252	0.7750	0.7109	0.6326	0.5410	0.4381	0.3274	0.648515	0.037935
0.1500	0.7424	0.7366	0.7193	0.6904	0.6503	0.5993	0.5381	0.4680	0.3907	0.3083	0.2234	0.488454	0.056903
0.2000	0.5757	0.5705	0.5551	0.5297	0.4950	0.4517	0.4011	0.3444	0.2833	0.2197	0.1556	0.362884	0.075870
0.2500	0.4345	0.4303	0.4178	0.3974	0.3697	0.3356	0.2959	0.2520	0.2053	0.1573	0.1094	0.267087	0.094838
0.3000	0.3229	0.3196	0.3100	0.2943	0.2730	0.2469	0.2167	0.1836	0.1485	0.1127	0.0774	0.195264	0.113805
0.3500	0.2376	0.2351	0.2279	0.2160	0.2000	0.1804	0.1579	0.1332	0.1072	0.0808	0.0549	0.142060	0.132773
0.4000	0.1736	0.1718	0.1664	0.1576	0.1457	0.1312	0.1146	0.0964	0.0773	0.0580	0.0391	0.102985	0.151740
0.4500	0.1263	0.1250	0.1210	0.1145	0.1058	0.0951	0.0829	0.0696	0.0557	0.0416	0.0279	0.074466	0.170708
0.5000	0.0915	0.0906	0.0876	0.0829	0.0765	0.0688	0.0599	0.0502	0.0401	0.0298	0.0199	0.053744	0.189675
0.5500	0.0662	0.0655	0.0633	0.0599	0.0553	0.0496	0.0432	0.0361	0.0288	0.0214	0.0142	0.038736	0.208643
0.6000	0.0478	0.0472	0.0457	0.0432	0.0399	0.0358	0.0311	0.0260	0.0207	0.0154	0.0102	0.027892	0.227610
0.6500	0.0344	0.0340	0.0329	0.0311	0.0287	0.0257	0.0224	0.0187	0.0149	0.0110	0.0073	0.020070	0.246578
0.7000	0.0248	0.0245	0.0237	0.0224	0.0207	0.0185	0.0161	0.0135	0.0107	0.0079	0.0052	0.014434	0.265545
0.7500	0.0178	0.0176	0.0171	0.0161	0.0149	0.0133	0.0116	0.0097	0.0077	0.0057	0.0038	0.010377	0.284513
0.8000	0.0128	0.0127	0.0123	0.0116	0.0107	0.0096	0.0083	0.0069	0.0055	0.0041	0.0027	0.007458	0.303480
0.8500	0.0092	0.0091	0.0088	0.0083	0.0077	0.0069	0.0060	0.0050	0.0040	0.0029	0.0019	0.005359	0.322448
0.9000	0.0066	0.0066	0.0063	0.0060	0.0055	0.0049	0.0043	0.0036	0.0028	0.0021	0.0014	0.003850	0.341415
0.9500	0.0048	0.0047	0.0046	0.0043	0.0040	0.0036	0.0031	0.0026	0.0020	0.0015	0.0010	0.002765	0.360383
1.0000	0.0034	0.0034	0.0033	0.0031	0.0028	0.0026	0.0022	0.0018	0.0015	0.0011	0.0007	0.001986	0.379350
1.0500	0.0025	0.0024	0.0023	0.0022	0.0020	0.0018	0.0016	0.0013	0.0011	0.0008	0.0005	0.001426	0.398318
1.1000	0.0018	0.0017	0.0017	0.0016	0.0015	0.0013	0.0011	0.0010	0.0008	0.0006	0.0004	0.001024	0.417285
1.1500	0.0013	0.0013	0.0012	0.0011	0.0011	0.0009	0.0008	0.0007	0.0005	0.0004	0.0003	0.000735	0.436253
1.2000	0.0009	0.0009	0.0009	0.0008	0.0008	0.0007	0.0006	0.0005	0.0004	0.0003	0.0002	0.000527	0.455221
1.2500	0.0007	0.0006	0.0006	0.0006	0.0005	0.0005	0.0004	0.0004	0.0003	0.0002	0.0001	0.000378	0.474188
1.3000	0.0005	0.0005	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003	0.0002	0.0001	0.0001	0.000271	0.493155
1.3500	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.000194	0.512123
1.4000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.000139	0.531090
1.4500	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.000099	0.550058

Table 10.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.1000 CM
ATMOSPHERE TEMPERATURE = 130.0 DEG C INITIAL DROP TEMPERATURE = 80.0 DEG C

	FRACTION OF RADIUS												
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9929	0.9913	0.9861	0.9748	0.9534	0.9160	0.8553	0.7645	0.6392	0.4809	0.2980	0.759956	0.075870
0.1000	0.8594	0.8526	0.8320	0.7968	0.7461	0.6791	0.5961	0.4982	0.3887	0.2720	0.1542	0.523728	0.151740
0.1500	0.6431	0.6361	0.6151	0.5805	0.5333	0.4746	0.4063	0.3308	0.2511	0.1704	0.0925	0.357147	0.227610
0.2000	0.4530	0.4475	0.4312	0.4047	0.3690	0.3254	0.2758	0.2220	0.1664	0.1113	0.0590	0.242429	0.303480
0.2500	0.3116	0.3077	0.2960	0.2772	0.2519	0.2213	0.1867	0.1495	0.1114	0.0739	0.0385	0.164098	0.379350
0.3000	0.2122	0.2095	0.2014	0.1884	0.1710	0.1499	0.1262	0.1008	0.0748	0.0494	0.0255	0.110868	0.455220
0.3500	0.1438	0.1420	0.1364	0.1275	0.1156	0.1013	0.0852	0.0679	0.0503	0.0331	0.0170	0.074809	0.531090
0.4000	0.0972	0.0959	0.0922	0.0862	0.0781	0.0684	0.0574	0.0458	0.0339	0.0222	0.0114	0.050435	0.606960
0.4500	0.0656	0.0648	0.0622	0.0581	0.0527	0.0461	0.0387	0.0308	0.0228	0.0149	0.0076	0.033983	0.682830
0.5000	0.0442	0.0437	0.0419	0.0392	0.0355	0.0311	0.0261	0.0207	0.0153	0.0100	0.0051	0.022888	0.758700
0.5500	0.0298	0.0294	0.0283	0.0264	0.0239	0.0209	0.0176	0.0140	0.0103	0.0068	0.0034	0.015412	0.834570
0.6000	0.0201	0.0198	0.0190	0.0178	0.0161	0.0141	0.0118	0.0094	0.0069	0.0045	0.0023	0.010375	0.910440
0.6500	0.0135	0.0133	0.0128	0.0120	0.0108	0.0095	0.0080	0.0063	0.0047	0.0031	0.0015	0.006983	0.986310
0.7000	0.0091	0.0090	0.0086	0.0081	0.0073	0.0064	0.0054	0.0043	0.0031	0.0021	0.0010	0.004700	1.062180
0.7500	0.0061	0.0060	0.0058	0.0054	0.0049	0.0043	0.0036	0.0029	0.0021	0.0014	0.0007	0.003163	1.138050
0.8000	0.0041	0.0041	0.0039	0.0036	0.0033	0.0029	0.0024	0.0019	0.0014	0.0009	0.0005	0.002128	1.213920
0.8500	0.0028	0.0027	0.0026	0.0025	0.0022	0.0019	0.0016	0.0013	0.0010	0.0006	0.0003	0.001432	1.289790
0.9000	0.0019	0.0018	0.0018	0.0017	0.0015	0.0013	0.0011	0.0009	0.0006	0.0004	0.0002	0.000963	1.365660
0.9500	0.0013	0.0012	0.0012	0.0011	0.0010	0.0009	0.0007	0.0006	0.0004	0.0003	0.0001	0.000647	1.441530
1.0000	0.0008	0.0008	0.0008	0.0007	0.0007	0.0006	0.0005	0.0004	0.0003	0.0002	0.0001	0.000435	1.517401
1.0500	0.0006	0.0006	0.0005	0.0005	0.0005	0.0004	0.0003	0.0003	0.0002	0.0001	0.0001	0.000292	1.593269
1.1000	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003	0.0002	0.0002	0.0001	0.0001	0.0000	0.000196	1.669139
1.1500	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0000	0.000131	1.745009
1.2000	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.000088	1.820880

Table 11.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.1500 CM
ATMOSPHERE TEMPERATURE = 130.0 DEG C INITIAL DROP TEMPERATURE = 80.0 DEG C

	FRACTION OF RADIUS												
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9911	0.9892	0.9827	0.9689	0.9431	0.8985	0.8272	0.7223	0.5810	0.4073	0.2139	0.720296	0.170708
0.1000	0.8357	0.8281	0.8051	0.7660	0.7103	0.6377	0.5490	0.4465	0.3343	0.2178	0.1039	0.476237	0.341415
0.1500	0.6025	0.5952	0.5734	0.5378	0.4894	0.4299	0.3616	0.2871	0.2098	0.1333	0.0611	0.314828	0.512123
0.2000	0.4102	0.4048	0.3888	0.3628	0.3281	0.2860	0.2386	0.1878	0.1360	0.0854	0.0384	0.208005	0.682830
0.2500	0.2739	0.2702	0.2592	0.2415	0.2178	0.1894	0.1574	0.1235	0.0890	0.0556	0.0247	0.137304	0.853538
0.3000	0.1815	0.1790	0.1717	0.1598	0.1441	0.1251	0.1038	0.0813	0.0585	0.0364	0.0160	0.090562	1.024245
0.3500	0.1200	0.1183	0.1134	0.1056	0.0951	0.0825	0.0685	0.0536	0.0385	0.0239	0.0105	0.059697	1.194953
0.4000	0.0791	0.0781	0.0748	0.0696	0.0627	0.0544	0.0451	0.0353	0.0253	0.0157	0.0069	0.039335	1.365661
0.4500	0.0522	0.0515	0.0493	0.0459	0.0413	0.0358	0.0297	0.0232	0.0167	0.0103	0.0045	0.025911	1.536368
0.5000	0.0344	0.0339	0.0325	0.0302	0.0272	0.0236	0.0196	0.0153	0.0110	0.0068	0.0030	0.017065	1.707076
0.5500	0.0227	0.0223	0.0214	0.0199	0.0179	0.0156	0.0129	0.0101	0.0072	0.0045	0.0019	0.011237	1.877784
0.6000	0.0149	0.0147	0.0141	0.0131	0.0118	0.0102	0.0085	0.0066	0.0048	0.0029	0.0013	0.007399	2.048491
0.6500	0.0098	0.0097	0.0093	0.0086	0.0078	0.0067	0.0056	0.0044	0.0031	0.0019	0.0008	0.004871	2.219199
0.7000	0.0065	0.0064	0.0061	0.0057	0.0051	0.0044	0.0037	0.0029	0.0021	0.0013	0.0006	0.003207	2.389907
0.7500	0.0043	0.0042	0.0040	0.0037	0.0034	0.0029	0.0024	0.0019	0.0014	0.0008	0.0004	0.002111	2.560615
0.8000	0.0028	0.0028	0.0026	0.0025	0.0022	0.0019	0.0016	0.0012	0.0009	0.0006	0.0002	0.001389	2.731322
0.8500	0.0018	0.0018	0.0017	0.0016	0.0015	0.0013	0.0010	0.0008	0.0006	0.0004	0.0002	0.000914	2.902030
0.9000	0.0012	0.0012	0.0011	0.0011	0.0010	0.0008	0.0007	0.0005	0.0004	0.0002	0.0001	0.000601	3.072738
0.9500	0.0008	0.0008	0.0008	0.0007	0.0006	0.0005	0.0005	0.0004	0.0003	0.0002	0.0001	0.000395	3.243445
1.0000	0.0005	0.0005	0.0005	0.0005	0.0004	0.0004	0.0003	0.0002	0.0002	0.0001	0.0000	0.000260	3.414153
1.0500	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0001	0.0001	0.0000	0.000170	3.584859
1.1000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.0000	0.000111	3.755567
1.1500	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.000073	3.926274

Table 12.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.2000 CM
ATMOSPHERE TEMPERATURE = 130.0 DEG C INITIAL DROP TEMPERATURE = 80.0 DEG C

	FRACTION OF RADIUS												
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9896	0.9875	0.9801	0.9644	0.9352	0.8854	0.8068	0.6928	0.5421	0.3[illegible]09	0.1649	0.693445	0.303480
0.1000	0.8193	0.8112	0.7868	0.7455	0.6870	0.6115	0.5202	0.4161	0.3036	0.1888	0.0786	0.448244	0.606960
0.1500	0.5775	0.5700	0.5480	0.5121	0.4635	0.4041	0.3364	0.2633	0.1881	0.1145	0.0461	0.291477	0.910441
0.2000	0.3856	0.3803	0.3646	0.3392	0.3053	0.2645	0.2186	0.1699	0.1205	0.0727	0.0288	0.189762	1.213921
0.2500	0.2532	0.2497	0.2392	0.2222	0.1996	0.1725	0.1423	0.1102	0.0779	0.0469	0.0184	0.123523	1.517402
0.3000	0.1654	0.1630	0.1561	0.1450	0.1301	0.1124	0.0926	0.0716	0.0506	0.0303	0.0118	0.080375	1.820882
0.3500	0.1077	0.1062	0.1017	0.0944	0.0847	0.0731	0.0602	0.0466	0.0329	0.0197	0.0076	0.052281	2.124362
0.4000	0.0701	0.0691	0.0662	0.0614	0.0551	0.0476	0.0392	0.0303	0.0213	0.0128	0.0049	0.033999	2.427842
0.4500	0.0456	0.0450	0.0431	0.0400	0.0359	0.0309	0.0255	0.0197	0.0139	0.0083	0.0032	0.022105	2.731323
0.5000	0.0297	0.0292	0.0280	0.0260	0.0233	0.0201	0.0166	0.0128	0.0090	0.0054	0.0021	0.014371	3.034803
0.5500	0.0193	0.0190	0.0182	0.0169	0.0152	0.0131	0.0108	0.0083	0.0059	0.0035	0.0013	0.009342	3.338284
0.6000	0.0125	0.0124	0.0118	0.0110	0.0099	0.0085	0.0070	0.0054	0.0038	0.0023	0.0009	0.006072	3.641764
0.6500	0.0082	0.0080	0.0077	0.0071	0.0064	0.0055	0.0045	0.0035	0.0025	0.0015	0.0006	0.003946	3.945245
0.7000	0.0053	0.0052	0.0050	0.0046	0.0042	0.0036	0.0030	0.0023	0.0016	0.0010	0.0004	0.002565	4.248725
0.7500	0.0034	0.0034	0.0032	0.0030	0.0027	0.0023	0.0019	0.0015	0.0010	0.0006	0.0002	0.001666	4.552206
0.8000	0.0022	0.0022	0.0021	0.0020	0.0018	0.0015	0.0012	0.0010	0.0007	0.0004	0.0002	0.001082	4.855685
0.8500	0.0015	0.0014	0.0014	0.0013	0.0011	0.0010	0.0008	0.0006	0.0004	0.0003	0.0001	0.000703	5.159166
0.9000	0.0009	0.0009	0.0009	0.0008	0.0007	0.0006	0.0005	0.0004	0.0003	0.0002	0.0001	0.000456	5.462646
0.9500	0.0006	0.0006	0.0006	0.0005	0.0005	0.0004	0.0003	0.0003	0.0002	0.0001	0.0000	0.000296	5.766128
1.0000	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003	0.0002	0.0002	0.0001	0.0001	0.0000	0.000192	6.069608
1.0500	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.0000	0.000124	6.373083
1.1000	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.000080	6.676565

Table 13.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.3000 CM
ATMOSPHERE TEMPERATURE = 130.0 DEG C INITIAL DROP TEMPERATURE = 80.0 DEG C

	FRACTION OF RADIUS											
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9873	0.9847	0.9759	0.9574	0.9236	0.8666	0.7784	0.6537	0.4931	0.3063	0.1119	0.658881	0.682830
0.1000	0.7975	0.7888	0.7628	0.7192	0.6579	0.5796	0.4862	0.3813	0.2698	0.1583	0.0535	0.416077	1.365660
0.1500	0.5474	0.5399	0.5178	0.4818	0.4335	0.3748	0.3084	0.2374	0.1652	0.0954	0.0314	0.265806	2.048491
0.2000	0.3578	0.3527	0.3374	0.3129	0.2802	0.2409	0.1971	0.1509	0.1044	0.0599	0.0195	0.170238	2.731320
0.2500	0.2307	0.2273	0.2174	0.2013	0.1800	0.1546	0.1262	0.0964	0.0666	0.0381	0.0123	0.109074	3.414151
0.3000	0.1481	0.1460	0.1395	0.1292	0.1155	0.0991	0.0809	0.0617	0.0426	0.0244	0.0078	0.069879	4.096981
0.3500	0.0950	0.0936	0.0895	0.0828	0.0740	0.0635	0.0518	0.0395	0.0273	0.0156	0.0050	0.044763	4.779811
0.4000	0.0609	0.0600	0.0573	0.0531	0.0474	0.0407	0.0332	0.0253	0.0175	0.0100	0.0032	0.028670	5.462642
0.4500	0.0390	0.0384	0.0367	0.0340	0.0304	0.0260	0.0212	0.0162	0.0112	0.0064	0.0020	0.018362	6.145473
0.5000	0.0250	0.0246	0.0235	0.0218	0.0195	0.0167	0.0136	0.0104	0.0072	0.0041	0.0013	0.011758	6.828303
0.5500	0.0160	0.0158	0.0151	0.0139	0.0125	0.0107	0.0087	0.0066	0.0046	0.0026	0.0008	0.007529	7.511133
0.6000	0.0102	0.0101	0.0096	0.0089	0.0080	0.0068	0.0056	0.0043	0.0029	0.0017	0.0005	0.004821	8.193963
0.6500	0.0066	0.0065	0.0062	0.0057	0.0051	0.0044	0.0036	0.0027	0.0019	0.0011	0.0003	0.003087	8.876794
0.7000	0.0042	0.0041	0.0040	0.0037	0.0033	0.0028	0.0023	0.0017	0.0012	0.0007	0.0002	0.001976	9.559620
0.7500	0.0027	0.0026	0.0025	0.0023	0.0021	0.0018	0.0015	0.0011	0.0008	0.0004	0.0001	0.001265	10.242455
0.8000	0.0017	0.0017	0.0016	0.0015	0.0013	0.0011	0.0009	0.0007	0.0005	0.0003	0.0001	0.000809	10.925282
0.8500	0.0011	0.0011	0.0010	0.0010	0.0009	0.0007	0.0006	0.0005	0.0003	0.0002	0.0001	0.000517	11.608109
0.9000	0.0007	0.0007	0.0007	0.0006	0.0005	0.0005	0.0004	0.0003	0.0002	0.0001	0.0000	0.000331	12.290945
0.9500	0.0005	0.0004	0.0004	0.0004	0.0004	0.0003	0.0002	0.0002	0.0001	0.0001	0.0000	0.000211	12.973772
1.0000	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0001	0.0001	0.0000	0.0000	0.000135	13.656608
1.0500	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.000086	14.339425

Table 14.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.4000 CM
ATMOSPHERE TEMPERATURE = 130.0 DEG C INITIAL DROP TEMPERATURE = 80.0 DEG C

	FRACTION OF RADIUS											
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9855	0.9826	0.9728	0.9523	0.9153	0.8537	0.7598	0.6292	0.4641	0.2761	0.0849	0.637815	1.213921
0.1000	0.7836	0.7747	0.7478	0.7030	0.6403	0.5608	0.4668	0.3620	0.2517	0.1425	0.0411	0.398079	2.427841
0.1500	0.5298	0.5224	0.5003	0.4645	0.4166	0.3585	0.2931	0.2235	0.1531	0.0856	0.0242	0.251882	3.641764
0.2000	0.3423	0.3373	0.3224	0.2983	0.2664	0.2282	0.1856	0.1408	0.0961	0.0534	0.0149	0.159854	4.855685
0.2500	0.2185	0.2153	0.2056	0.1901	0.1696	0.1450	0.1178	0.0893	0.0608	0.0337	0.0094	0.101509	6.069608
0.3000	0.1390	0.1369	0.1308	0.1209	0.1078	0.0921	0.0748	0.0566	0.0385	0.0214	0.0059	0.064461	7.283528
0.3500	0.0883	0.0870	0.0831	0.0768	0.0685	0.0585	0.0475	0.0360	0.0245	0.0136	0.0037	0.040932	8.497450
0.4000	0.0561	0.0553	0.0528	0.0488	0.0435	0.0372	0.0302	0.0228	0.0155	0.0086	0.0024	0.025990	9.711367
0.4500	0.0356	0.0351	0.0335	0.0310	0.0276	0.0236	0.0191	0.0145	0.0099	0.0055	0.0015	0.016501	10.925291
0.5000	0.0226	0.0223	0.0213	0.0197	0.0175	0.0150	0.0122	0.0092	0.0063	0.0035	0.0010	0.010476	12.139215
0.5500	0.0144	0.0141	0.0135	0.0125	0.0111	0.0095	0.0077	0.0058	0.0040	0.0022	0.0006	0.006650	13.353131
0.6000	0.0091	0.0090	0.0086	0.0079	0.0071	0.0060	0.0049	0.0037	0.0025	0.0014	0.0004	0.004221	14.567056
0.6500	0.0058	0.0057	0.0054	0.0050	0.0045	0.0038	0.0031	0.0024	0.0016	0.0009	0.0002	0.002679	15.780980
0.7000	0.0037	0.0036	0.0035	0.0032	0.0028	0.0024	0.0020	0.0015	0.0010	0.0006	0.0002	0.001700	16.994888
0.7500	0.0023	0.0023	0.0022	0.0020	0.0018	0.0015	0.0013	0.0009	0.0006	0.0004	0.0001	0.001079	18.208817
0.8000	0.0015	0.0015	0.0014	0.0013	0.0011	0.0010	0.0008	0.0006	0.0004	0.0002	0.0001	0.000684	19.422729
0.8500	0.0009	0.0009	0.0009	0.0008	0.0007	0.0006	0.0005	0.0004	0.0003	0.0001	0.0000	0.000434	20.636658
0.9000	0.0006	0.0006	0.0006	0.0005	0.0005	0.0004	0.0003	0.0002	0.0002	0.0001	0.0000	0.000275	21.850571
0.9500	0.0004	0.0004	0.0004	0.0003	0.0003	0.0002	0.0002	0.0002	0.0001	0.0001	0.0000	0.000174	23.064499
1.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.0000	0.000110	24.278427
1.0500	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.000069	25.492325

Table 15.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.1000 CM
ATMOSPHERE TEMPERATURE = 100.0 DEG C INITIAL DROP TEMPERATURE = 30.0 DEG C

	FRACTION OF RADIUS												
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9944	0.9932	0.9890	0.9800	0.9629	0.9326	0.8832	0.8082	0.7031	0.5674	0.4065	0.802768	0.077708
0.1000	0.8845	0.8788	0.8613	0.8313	0.7876	0.7293	0.6560	0.5682	0.4676	0.3576	0.2428	0.588573	0.155416
0.1500	0.6949	0.6885	0.6693	0.6377	0.5940	0.5391	0.4742	0.4012	0.3223	0.2403	0.1583	0.424499	0.233124
0.2000	0.5163	0.5109	0.4950	0.4689	0.4336	0.3900	0.3396	0.2841	0.2254	0.1656	0.1070	0.303592	0.310833
0.2500	0.3743	0.3703	0.3581	0.3384	0.3118	0.2792	0.2419	0.2011	0.1584	0.1154	0.0735	0.215986	0.388541
0.3000	0.2682	0.2652	0.2563	0.2419	0.2224	0.1987	0.1716	0.1422	0.1115	0.0807	0.0510	0.153118	0.466249
0.3500	0.1910	0.1888	0.1824	0.1719	0.1579	0.1409	0.1214	0.1004	0.0785	0.0566	0.0355	0.108282	0.543957
0.4000	0.1354	0.1339	0.1293	0.1218	0.1118	0.0996	0.0858	0.0708	0.0552	0.0397	0.0248	0.076443	0.621665
0.4500	0.0958	0.0947	0.0914	0.0861	0.0790	0.0703	0.0605	0.0499	0.0389	0.0279	0.0173	0.053899	0.699373
0.5000	0.0676	0.0668	0.0645	0.0607	0.0557	0.0496	0.0426	0.0351	0.0273	0.0196	0.0121	0.037972	0.777081
0.5500	0.0477	0.0471	0.0455	0.0428	0.0393	0.0349	0.0300	0.0247	0.0192	0.0138	0.0085	0.026735	0.854789
0.6000	0.0336	0.0332	0.0320	0.0302	0.0276	0.0246	0.0211	0.0174	0.0135	0.0097	0.0060	0.018815	0.932498
0.6500	0.0236	0.0234	0.0226	0.0212	0.0195	0.0173	0.0149	0.0122	0.0095	0.0068	0.0042	0.013237	1.010205
0.7000	0.0166	0.0164	0.0159	0.0149	0.0137	0.0122	0.0105	0.0086	0.0067	0.0048	0.0029	0.009311	1.087914
0.7500	0.0117	0.0116	0.0112	0.0105	0.0096	0.0086	0.0074	0.0060	0.0047	0.0034	0.0021	0.006548	1.165622
0.8000	0.0082	0.0081	0.0079	0.0074	0.0068	0.0060	0.0052	0.0043	0.0033	0.0024	0.0015	0.004605	1.243330
0.8500	0.0058	0.0057	0.0055	0.0052	0.0048	0.0042	0.0036	0.0030	0.0023	0.0017	0.0010	0.003238	1.321038
0.9000	0.0041	0.0040	0.0039	0.0037	0.0033	0.0030	0.0026	0.0021	0.0016	0.0012	0.0007	0.002277	1.398746
0.9500	0.0029	0.0028	0.0027	0.0026	0.0024	0.0021	0.0018	0.0015	0.0011	0.0008	0.0005	0.001601	1.476454
1.0000	0.0020	0.0020	0.0019	0.0018	0.0017	0.0015	0.0013	0.0010	0.0008	0.0006	0.0004	0.001125	1.554163
1.0500	0.0014	0.0014	0.0013	0.0013	0.0012	0.0010	0.0009	0.0007	0.0006	0.0004	0.0002	0.000791	1.631869
1.1000	0.0010	0.0010	0.0009	0.0009	0.0008	0.0007	0.0006	0.0005	0.0004	0.0003	0.0002	0.000556	1.709578
1.1500	0.0007	0.0007	0.0007	0.0006	0.0006	0.0005	0.0004	0.0004	0.0003	0.0002	0.0001	0.000391	1.787286
1.2000	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0003	0.0003	0.0002	0.0001	0.0001	0.000275	1.864994
1.2500	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.000193	1.942703
1.3000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.000136	2.020410
1.3500	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.000095	2.098119

Table 16.

CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH AN AIR-STEAM ATMOSPHERE

DROP DIAMETER = 0.1000 CM
ATMOSPHERE TEMPERATURE = 100.0 DEG C INITIAL DROP TEMPERATURE = 50.0 DEG C

	FRACTION OF RADIUS												
THETA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	MEAN TEMP	TIME, SEC
0.0500	0.9944	0.9932	0.9891	0.9801	0.9631	0.9332	0.8841	0.8099	0.7061	0.5723	0.4139	0.804738	0.077109
0.1000	0.8857	0.8800	0.8627	0.8331	0.7900	0.7326	0.6603	0.5739	0.4749	0.3668	0.2540	0.594042	0.154218
0.1500	0.6987	0.6924	0.6736	0.6424	0.5994	0.5453	0.4815	0.4096	0.3319	0.2510	0.1701	0.432533	0.231327
0.2000	0.5229	0.5176	0.5019	0.4762	0.4414	0.3984	0.3486	0.2937	0.2356	0.1762	0.1178	0.312871	0.308436
0.2500	0.3828	0.3787	0.3667	0.3472	0.3208	0.2885	0.2513	0.2107	0.1681	0.1250	0.0828	0.225428	0.385546
0.3000	0.2774	0.2744	0.2655	0.2511	0.2317	0.2079	0.1807	0.1511	0.1202	0.0889	0.0586	0.162002	0.462655
0.3500	0.2000	0.1978	0.1914	0.1808	0.1667	0.1494	0.1297	0.1083	0.0859	0.0634	0.0416	0.116211	0.539764
0.4000	0.1438	0.1422	0.1375	0.1299	0.1197	0.1072	0.0930	0.0775	0.0614	0.0452	0.0296	0.083255	0.616872
0.4500	0.1031	0.1020	0.0986	0.0931	0.0858	0.0768	0.0665	0.0554	0.0439	0.0323	0.0210	0.059590	0.693982
0.5000	0.0739	0.0731	0.0706	0.0667	0.0614	0.0550	0.0476	0.0396	0.0313	0.0230	0.0150	0.042624	0.771091
0.5500	0.0529	0.0523	0.0506	0.0477	0.0439	0.0393	0.0340	0.0283	0.0224	0.0164	0.0107	0.030473	0.848200
0.6000	0.0378	0.0374	0.0362	0.0341	0.0314	0.0281	0.0243	0.0202	0.0160	0.0117	0.0076	0.021779	0.925309
0.6500	0.0270	0.0267	0.0258	0.0244	0.0225	0.0201	0.0174	0.0145	0.0114	0.0084	0.0054	0.015562	1.002418
0.7000	0.0193	0.0191	0.0185	0.0174	0.0160	0.0144	0.0124	0.0103	0.0082	0.0060	0.0039	0.011117	1.079527
0.7500	0.0138	0.0137	0.0132	0.0125	0.0115	0.0103	0.0089	0.0074	0.0058	0.0043	0.0028	0.007941	1.156636
0.8000	0.0099	0.0098	0.0094	0.0089	0.0082	0.0073	0.0063	0.0053	0.0042	0.0031	0.0020	0.005672	1.233746
0.8500	0.0070	0.0070	0.0067	0.0064	0.0058	0.0052	0.0045	0.0038	0.0030	0.0022	0.0014	0.004051	1.310855
0.9000	0.0050	0.0050	0.0048	0.0045	0.0042	0.0037	0.0032	0.0027	0.0021	0.0016	0.0010	0.002893	1.387963
0.9500	0.0036	0.0036	0.0034	0.0032	0.0030	0.0027	0.0023	0.0019	0.0015	0.0011	0.0007	0.002066	1.465073
1.0000	0.0026	0.0025	0.0025	0.0023	0.0021	0.0019	0.0016	0.0014	0.0011	0.0008	0.0005	0.001475	1.542182
1.0500	0.0018	0.0018	0.0018	0.0017	0.0015	0.0014	0.0012	0.0010	0.0008	0.0006	0.0004	0.001053	1.619289
1.1000	0.0013	0.0013	0.0013	0.0012	0.0011	0.0010	0.0008	0.0007	0.0006	0.0004	0.0003	0.000752	1.696399
1.1500	0.0009	0.0009	0.0009	0.0008	0.0008	0.0007	0.0006	0.0005	0.0004	0.0003	0.0002	0.000537	1.773508
1.2000	0.0007	0.0007	0.0006	0.0006	0.0006	0.0005	0.0004	0.0004	0.0003	0.0002	0.0001	0.000383	1.850617
1.2500	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0003	0.0003	0.0002	0.0001	0.0001	0.000274	1.927728
1.3000	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.000195	2.004835
1.3500	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.000139	2.081944
1.4000	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.000099	2.159054

APPENDIX

This section contains a listing of the computer program. The program is written in FORTRAN IV level H for the IBM 360. The program consists of the main program and the following subroutines:

VPRPRS – Calculation of Vapor Pressure of Water
ATMRHØ – Calculation of Atmosphere Density
VISMIX – Calculation of Viscosity of Air-Steam Mixture
DIFF – Calculation of the Diffusivity of Steam in Air
TERMV – Calculation of Terminal Velocity of Water Drops in Air-Steam Mixture
KG – Calculation of Mass Transfer Coefficient of Steam Through Air Film
HTCØEF – Calculation of Forced-Convection Heat Transfer Coefficient

```
C THIS PROGRAM IS WRITTEN TO CALCULATE THE HEATING RATE OF WATER DROPS
C FALLING THROUGH AN AIR-STEAM MIXTURE
      DIMENSION TBAR(90,20), TATM(20), TZERO(20), T(11,5401), TIME(90,
     120), D(20) , THETA(90,20)
      REAL*4 KSUBG
      DO 4 K = 1,20
    1 READ(50,2,END = 3) TATM(K), TZERO(K), D(K)
    2 FORMAT(3F10.2)
C INITIALIZE T
      DO 5 I = 1,11
      DO 5 J = 1,5401
    5 T(I,J) = 1.
C CALCULATE INITIAL PROPERTIES AND DROP TERMINAL VELOCITY
      TINF = TATM(K) + 273.16
      TDROP = TZERO(K) + 273.16
      CALL VPRPRS (TINF, PINF)
      CALL ATMRHO( TINF, PINF, RHOATM)
      CALL VISMIX(TINF,PINF,ETAMIX,PTOTAL,FRSTM,FRAIR)
      CALL DIFF (TINF, PTOTAL, DSUBV)
      CALL TERMV (TZERO(K), D(K),RHOATM,ETAMIX,VTER,REYNO, RHOLIQ)
      CALL HTCOEF (VTER,ETAMIX,D(K),RHOATM,FRSTM,FRAIR,H)
C CARRY OUT FINITE DIFFERENCE CALCULATION OF TIME-DEPENDENT TEMPERATURE DISTRI-
C BUTION IN THE DROP
      WRITE(51,6) D(K),TATM(K),TZERO(K)
    6 FORMAT(1H1,'CALCULATION OF EQUILIBRATION OF A COLD WATER DROP WITH
     1 AN AIR-STEAM ATMOSPHERE'//' DROP DIAMETER = ',F6.4, ' CM'/' ATMOS
     2PHERE TEMPERATURE = ',F5.1,' DEG C'0' INITIAL DRCP TEMPERATURE = '
     3,F5.1,' DEG C'C//41X,'FRACTION OF RADIUS'/2X
     4' THETA  0.0      0.1      0.2      0.3      0.4      0.5      0.6
     50.7      0.8      0.9      1.0  MEAN TEMP  TIME, SEC')
      JA = 0
      JB = 0
      DO 7 J = 1,5400
      JA = JA + 1
      T(1,J+1) = T(2,J)
      DO 8 I = 2,10
      P = FLOAT(I)
    8 T(I,J+1) = T(I,J) + 0.1666667*((P/(P-1.))*T(I+1,J)- 2.*T(I,J) +
     1 ((P-2.)/(P-1.))*T(I - 1,J))
      CALL VPRPRS (TDROP, PDROP)
      CALL KG (DSUBV, D(K),VTER,ETAMIX,PTOTAL,PINF,PDROP,RHOATM,KSUBG)
C FOR CALCULATION WE ASSUME THE LATENT HEAT OF VAPORIZATION IS 10,000 CAL/MOL
      CONDEN = 1.E7*KSUBG*(PINF - PDROP)*D(K)/(3.202*(TINF - TZERO(K)))
      CONVEC = H*D(K)*T(11,J)/3.202E-3
C DENOMINATOR IS CONDUCTIVITY OF LIQUID WATER TIMES 2
      T(11,J+1) = T(11,J) - 0.15*(T(11,J) - T(10,J)) - 0.01851852*(CONDE
     1N + CONVEC)
      TDROP = TINF -  T(11,J+1)*(TATM(K)  - TZERO(K))
      IF(JA.NE.30) GO TO 7
      JB = JA/30
      SUM = 0.
      DO 10 I = 1,10
   10 SUM = SUM + 0.0005*(I**3 - (I - 1)**3)*(T(I,J) + T(I-1,J))
      TBAR(JB,K) = SUM
      THETA(JB,K) = FLOAT(J)/600.
      ALPHA = 1.601E-3/(1.*RHOLIQ)
      TIME(JB,K) = (D(K)**2)*THETA(JB,K)/(4.*ALPHA)
      WRITE(51,11) THETA(JB,K),(T(I,J),I=1,11),TBAR(JB,K), TIME(JB,K)
      JA = 0
      IF(TBAR(JB,K).LT.1.E-4) GO TO 4
    7 CONTINUE
    4 CONTINUE
   11 FORMAT (F8.4,11F8.4,2F10.6)
    3 STOP
      END
```

```
      SUBROUTINE VPRPRS(ABST,P)
C     THIS CALCULATES THE VAPOR PRESSURE OF THE ATMOSPHERE AND THE DROPS
      X = 647.27 - ABST
      TOP = 3.2437814 + (5.86826E-3)*X + (1.1702379E-8)*(X**3)
      DENOM = 1. + (2.1878462E-3)*X
      PHI1X = TOP /DENOM
      PHI2X = (2.302585*X*PHI1X)/ABST
      PHIP = EXP(PHI2X)
      P = 218.167/PHIP
      RETURN
      END
```

```
      SUBROUTINE ATMRHO(ABST, P, RHOATM)
      RHOAIR = 0.001185
      TAU = 1./ABST
      TAUSQ = TAU**2
      G1TAU = 82.546*TAU - (1.6246E5)*TAUSQ
      G2TAU = 0.21828 -(1.2697E5)*TAUSQ
      G3TAU = 3.635E-4 - (6.768E64)*(TAU**24)
      BZERO = 1.89 - 2641.6*TAU*(10.**(80870.*TAUSQ))
      B = BZERO + (BZERO**2)*(G1TAU*TAU*P) +(BZERO**4)*G2TAU*((TAU*P)
     1**3) +(BZERO**13)*G3TAU*((TAU*P)**12)
      V = (4.55504*ABST)/P + B
      RHOSTM = 1./V
      RHOATM = RHOAIR + RHOSTM
      RETURN
      END
```

```
      SUBROUTINE VISMIX(ABST,P,ETAMIX,PTOTAL,FRSTM, FRAIR)
      TAU = 1./ABST
      DENOM = 1. + 680.1*TAU
      TOP = (1.851E-5)*(ABST**0.5)
      ETA0 = TOP/DENOM
      F1OFP = P*(1.E-4)*(0.03103 -P * 3.65E-5)
      ETA = ETA0 + F1OFP
      PAIR = 1.*ABST/298.16
      PTOTAL = P + PAIR
      ETAAIR = (1.709E-4)*((ABST/273.16)**0.768)
      FRAIR = PAIR/PTOTAL
      FRSTE M = P/PTOTAL
      TOP = FRSTE M*ETA*SQRT(18.) + FRAIR*ETAAIR*SQRT(29.)
      DENOM = FRSTE M*SQRT(18.) + FRAIR*SQRT(29.)
      ETAMIX = TOP/DENOM
      RETURN
      END
```

```
      SUBROUTINE DIFF (ABST,PTOTAL,DSUBV)
C THIS CALCULATES THE DIFFUSIVITY OF STEAM IN AIR
      EPS1K = 97.0
      EPS2K = 363.
      EPS12K = SQRT(EPS1K*EPS2K)
      COLINT = 0.3674 + 0.3478*(EPS12K/ABST)
      RAIR = 3.617
      RW = 2.655
      RWAIR = 0.5*(RAIR + RW)
      FOFM = SQRT(1./18. + 1./29.)
      B = (10.7 - 2.46*FOFM)*1.E-4
      PFUNT = ABST**1.5
      TOP = B*PFUNT*FOFM
      DENOM = PTOTAL*(RWAIR**2)*COLINT
      DSUBV = TOP/DENOM
      RETURN
      END
```

```
      SUBROUTINE TERMV(TLIQ,D,RHOATM,ETAMIX,VTER,REYNO, RHOLIQ)
C THIS CALCULATES THE TERMINAL VELOCITY OF THE DROP
      XPGC = 980.**0.714
      XPDP = D**1.142
      VLIQ = 1.0018 + .0002615*(TLIQ - 20.) + (3.219E-6)*((TLIQ - 20.)**
     12)
      RHOLIQ = 1./VLIQ
      DELRHO = RHOLIQ - RHOATM
      XPRHOA = RHOATM**0.286
      XPDRHO = DELRHO**0.714
      XPETA = ETAMIX**0.428
      VTER = 0.153*XPGC*XPDP*XPDRHO/(XPRHOA*XPETA)
      REYNO = (D*VTER*RHOATM)/ETAMIX
      IF(REYNO.LT.1000.) GO TO 100
      VTER = 1.74*(SQRT((980.*D*DELRHO)/RHOATM))
      REYNO = (D*VTER*RHOATM)/ETAMIX
  100 RETURN
      END
```

```
SUBROUTINE KG(DSUBV,D,VTER,ETAMIX,PTOTAL,PINF,PDROP,RHOATM,KSUBG)
REAL*4 KSUBG
REYNO = D*VTER*RHOATM/ETAMIX
SMITNO = ETAMIX/(RHOATM*DSUBV)
Y = 2.0 + 0.6*SQRT(REYNO)*(SMITNO**0.3333)
PBM = PTOTAL - 0.5*(PINF + PDROP)
AVMW = (PBM/PTOTAL)*29. + ((PTOTAL - PBM)/PTOTAL)*18.
KSUBG = Y*RHOATM*DSUBV/(D*AVMW*PBM)
RETURN
END
```

```
      SUBROUTINE HTCOEF(VTER,ETAMIX,D    ,RHOATM,FRSTM,FRAIR,H)
C CALCULATES OUTSIDE FILM HEAT TRANSFER COEFFICIENT
      REYNO = D    *VTER*RHOATM/ETAMIX
      PRNO = 0.76
      ANUNO = 2.0 + 0.6*(SQRT(REYNO))*(PRNO**0.3)
      COND = ((7.56E-4)*FRAIR*(29.**.333) +(6.57E-4)*FRSTM*(18.**.333))/
     1 (FRSTM*(18.**.333) + FRAIR*(29.**.333))
      H = ANUNO*COND/D
      RETURN
      END
```

INTERNAL DISTRIBUTION

1. R. D. Ackley
2. R. E. Adams
3. T. D. Anderson
4. A. L. Bacarella
5. J. E. Baker
6. C. J. Barton
7. S. E. Beall
8. C. G. Bell
9. M. Bender
10. R. L. Bennett
11. C. R. Benson
12. R. F. Benson
13. R. G. Berggren
14. D. S. Billington
15. F. T. Binford
16. J. P. Blakely
17. R. E. Blanco
18. C. M. Blood
19. A. L. Boch
20. E. G. Bohlman
21. G. E. Boyd
22. R. B. Briggs
23. R. H. Bryan
24. J. R. Buchanan
25. C. A. Burchsted
26. T. J. Burnett
27. D. A. Canonico
28. D. W. Cardwell
29. T. E. Cole
30. Z. Combs
31. J. A. Conlin

32–33. Wm. B. Cottrell

34. K. E. Cowser
35. E. N. Cramer
36. G. E. Creek
37. D. J. Crouse
38. F. L. Culler, Jr.
39. R. J. Davis
40. W. DeLaguna
41. H. J. deNordwall
42. W. K. Ergen
43. D. E. Ferguson
44. W. F. Ferguson
45. H. F. E. Feuerstein
46. M. H. Fontana
47. A. P. Fraas
48. S. H. Freid
49. J. H Frye, Jr.
50. A. B. Fuller
51. W. R. Gall
52. J. S. Gill
53. D. L. Gray
54. B. L. Greenstreet
55. J. C. Griess
56. W. R. Grimes
57. R. C. Gwaltney
58. R. P. Hammond
59. P. N. Haubenreich
60. F. A. Heddleson
61. R. E. Helms
62. W. H. Hinds
63. J. M. Holmes
64. D. G. Jacobs
65. W. H. Jordan
66. S. I. Kaplan
67. P. R. Kasten
68. G. W. Keilholtz
69. J. O. Kolb
70. L. F. Kooistra
71. R. E. Lampton
72. J. A. Lane
73. C. G. Lawson
74. T. F. Lomenick
75. R. A. Lorenz
76. M. I. Lundin
77. R. N. Lyon
78. H. G. MacPherson
79. R. E. MacPherson
80. A. P. Malinauskas
81. W. J. Martin
82. H. C. McCurdy
83. H. A. McLain
84. J. G. Merkle
85. A. J. Miller
86. E. C. Miller
87. W. H. Montgomery
88. S. E. Moore
89. J. G. Morgan
90. F. H. Neill
91. H. G. O'Brien
92. M. F. Osborne
93. R. C. Olson
94. G. W. Parker
95. R. B. Parker

96–105. L. F. Parsly, Jr.
106. P. Patriarca
107. A. M. Perry
108. H. B. Piper
109. R. H. Rainey
110. D. M. Richardson
111. P. Rittenhouse
112. B. F. Roberts
113. G. C. Robinson
114–133. T. H. Row
134. P. Rubel
135. A. W. Savolainen
136. R. A. Schmidt
137. L. B. Shappert
138. L. J. Shersky
139. R. P. Shields
140. M. D. Silverman
141. O. Sisman
142. M. J. Skinner
143. R. Slusher
144. B. A. Soldano
145. I. Spiewak
146. L. E. Stanford
147. J. T. Stanley
148. W. G. Stockdale
149. W. C. Stoddart
150. D. B. Trauger
151. J. Truitt
152. W. C. Ulrich
153. W. E. Unger
154. C. S. Walker
155. J. L. Wantland
156. W. T. Ward
157. G. M. Watson
158. C. C. Webster
159. M. S. Wechsler
160. A. M. Weinberg
161. G. D. Whitman
162. F. J. Witt
163. F. C. Zapp
164. H. E. Zittel
165. Nuclear Safety Information Center
166–167. Central Research Library
168–169. Document Reference Section
170–179. Laboratory Records Department
180. Laboratory Records Department, ORNL R.C.
181–422. Nuclear Safety Program Distribution

EXTERNAL DISTRIBUTION

423. W. T. Humphries, Texas Gulf Sulphur Co., Aurora, N.C.
424. W. P. Kelleghan, Project Mgr., Browns Ferry Nuclear Plant, Tenn. Valley Authority, PO Box 2000, Decatur, Ala. 35601
425. C. S. Patterson, Furman University, Greenville, S.C.
426–440. Division of Technical Information Extension
441. Laboratory and University Division, AEC, ORO