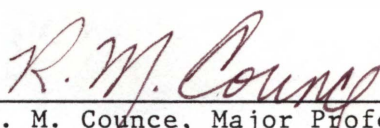


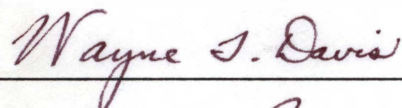
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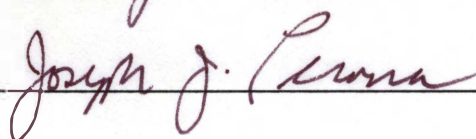
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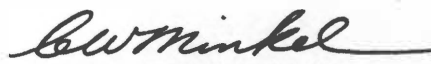
R. M. Counce, Major Professor

We have read this thesis
and recommend its acceptance:





Accepted for the Council:



The Graduate School

MATHEMATICAL MODEL FOR THE REMOVAL OF
SULFUR DIOXIDE IN A PILOT SCALE
SPRAY DRYER

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Thomas E. Pearson

March 1984

To ELLEN,

who has been patient and
understanding during this
study and who has been my
constant source of support.

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ABSTRACT

The purpose of this study was to develop a mathematical model for the absorption of SO_2 into droplets of a $\text{Ca}(\text{OH})_2$ slurry in a pilot scale spray dryer. This model is an expansion of the two film theory and uses basic spray drying expressions to predict contact times.

The developed model uses a series of resistances and a series of drying periods. The resistances are: (a) gas film, (b) liquid film, (c) solid dissolution, and (d) ash film. The drying periods are: (a) constant rate and (b) falling rate. The model also includes droplet breakup into particles between the constant and falling rate drying periods.

The results from the model indicate that as the stoichiometric ratio between SO_2 and $\text{Ca}(\text{OH})_2$ is increased, SO_2 removal efficiency increases because of the increasing number of particles being generated. The effect of reducing the temperature approach to saturation (difference between dry bulb and wet bulb temperatures) in the spray dryer increases the SO_2 removal efficiency because of the increased contact time during the falling rate drying period.

The model shows that a rigorous development for the dry scrubbing process is possible. Further research should consider product recycle effects and the competing reaction by CO_2 .

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
II. LITERATURE REVIEW	3
The Drying Process	3
The Reacting Process	5
Gas Film Resistance	7
Liquid Film Resistance	7
Ash Film Resistance	8
Solid Dissolution Resistance	9
III. DEVELOPMENT OF THE MODEL	10
Constant Rate Period Model	12
Falling Rate Period Model	15
Computer Program	18
Program Input	18
Time Calculations	21
Liquid Phase Physical Properties	30
Gas Phase Physical Properties	31
Mass Transfer Rate	35
SO ₂ Removal Rate	35
Average SO ₂ Concentration	35
Efficiency Calculations	36
Gas Phase Composition Adjustment and Conversion from Drops to Particles	36
Results Analysis	37
IV. EXPERIMENTAL DATA	38
V. CORRELATION OF DATA AND DISCUSSION OF RESULTS	40
VI. CONCLUSIONS AND RECOMMENDATIONS	51
Conclusions	51
Recommendations	51
LIST OF REFERENCES	53
APPENDIXES	56
A. DERIVATION OF THE CONSTANT RATE PERIOD MODEL	57

PAGE

B. DERIVATION OF THE FALLING RATE PERIOD MODEL	60
C. FINAL COMPUTER MODEL WITH RESULTS	64
D. VERIFICATION OF THE DRY SCRUBBING MODEL ASSUMPTIONS . . .	124
E. COMPUTER PROGRAM, RESULTS, AND PLOTS USED FOR DETERMINING THE RATIO OF POROSITY TO TORTUOSITY AS A FUNCTION OF STOICHIOMETRIC RATIO	129
F. COMPUTER PROGRAM AND RESULTS USED IN SELECTING THE FINAL COMPUTER MODEL	148
VITA	163

LIST OF TABLES

TABLE	PAGE
Computer Model Input	20
2. Critical Temperature (TEMPC) Estimates	29
3. Experimental Data Categories	39
4. FORTRAN Expressions for "B" Developed by Linear Regression	41
5. Model Selection Variables	43
6. Model Rankings	43
7. Model Ranking Scores	44
D-1. Verification of Long Contact Times for the Constant Rate Period	125
D-2. Verification of Long Contact Times for the Falling Rate Period	126
D-3. Verification That Solid Dissolution During the Constant Rate Period is Unimportant in the Liquid Film Containing the Reaction Zone	127
D-4. Verification That Solid Dissolution During the Falling Rate Period is Unimportant in the Liquid Film Containing the Reaction Zone	128
Results from Optimizing the Ratio of Porosity to Tortuosity for k_s Equalling 2.0×10^{-5} m/sec	137
E-2. Results from Optimizing the Ratio of Porosity to Tortuosity for k_s Equalling 3.0×10^{-5} m/sec	138
E-3. Results from Optimizing the Ratio of Porosity to Tortuosity for k_s Equalling 4.0×10^{-5} m/sec	139
E-4. Results from Optimizing the Ratio of Porosity to Tortuosity for k_s Equalling 5.0×10^{-5} m/sec	140
E-5. Results from Optimizing the Ratio of Porosity to Tortuosity for k_s Equalling 6.0×10^{-5} m/sec	141

TABLE	PAGE
E-6. Results from Optimizing the Ratio of Porosity to Tortuosity for k_s Equalling 7.0×10^{-5} m/sec	142
E-7. Results from Optimizing the Ratio of Porosity to Tortuosity for k_s Equalling 8.0×10^{-5} m/sec	143
F-1. Results from the Dry Scrubbing Model for k_s Equalling 2.0×10^{-5} m/sec	156
F-2. Results from the Dry Scrubbing Model for k_s Equalling 3.0×10^{-5} m/sec	157
F-3. Results from the Dry Scrubbing Model for k_s Equalling 4.0×10^{-5} m/sec	158
F-4. Results from the Dry Scrubbing Model for k_s Equalling 5.0×10^{-5} m/sec	159
F-5. Results from the Dry Scrubbing Model for k_s Equalling 6.0×10^{-5} m/sec	160
F-6. Results from the Dry Scrubbing Model for k_s Equalling 7.0×10^{-5} m/sec	161
F-7. Results from the Dry Scrubbing Model for k_s Equalling 8.0×10^{-5} m/sec	162

LIST OF FIGURES

FIGURE	PAGE
1. Classic Drying Curve for Slurries in Spray Dryers	4
2. Dry Scrubbing Model	11
3. Model for the Constant Rate Period	13
4. Model for the Falling Rate Period	16
5. Flowsheet for the Dry Scrubbing Computer Model	19
6. Comparison between Experimental and Predicted Values for the Specific Gravity of Lime Slurries	23
7. Predicted Moisture Content in the Dry Scrubbing Product	25
8. Temperature Profile During Spray Drying	26
9. Heat Balance	27
10. Calcium Hydroxide Solubility	32
11. Henry's Law Constants for SO ₂ in Water	33
12. Final Computer Model Performance	45
13. Effect of Stoichiometric Ratio on the Generation of Particles	46
14. Effect of Temperature Approach to Saturation on the Falling Rate Period Contact Time	48
15. Effect of Stoichiometric Ratio and Temperature Approach to Saturation on the Constant Rate Period SO ₂ Removal Efficiency	49
16. Effect of Stoichiometric Ratio and Temperature Approach to Saturation on the Overall SO ₂ Removal Efficiencies	50
E-1. Effect of Stoichiometric Ratio on the Ratio of Porosity to Tortuosity for k _s Equalling 2.0 x 10 ⁻⁵ m/sec	144

FIGURE

PAGE

E-2.	Effect of Stoichiometric Ratio on the Ratio of Porosity to Tortuosity for k_S Equalling 3.0×10^{-5} m/sec	144
E-3.	Effect of Stoichiometric Ratio on the Ratio of Porosity to Tortuosity for k_S Equalling 4.0×10^{-5} m/sec	145
E-4.	Effect of Stoichiometric Ratio on the Ratio of Porosity to Tortuosity for k_S Equalling 5.0×10^{-5} m/sec	145
E-5.	Effect of Stoichiometric Ratio on the Ratio of Porosity to Tortuosity for k_S Equalling 6.0×10^{-5} m/sec	146
E-6.	Effect of Stoichiometric Ratio on the Ratio of Porosity to Tortuosity for k_S Equalling 7.0×10^{-5} m/sec	146
E-7.	Effect of Stoichiometric Ratio on the Ratio of Porosity to Tortuosity for k_S Equalling 8.0×10^{-5} m/sec	147

LIST OF SYMBOLS

A	defined by Equation (B-1), gm-moles/sec
A_p	ratio of the total dispersed particle surface area to the volume of the dispersion, m^2/m^3
B	ratio of porosity to tortuosity, unitless
C	concentration, gm-moles/ m^3
d	diameter, m
D	diffusivity, m^2/sec
H	Henry's Law Constant, $atm \cdot m^3/gm\text{-mole}$
k_G	gas phase mass transfer coefficient, $gm\text{-moles}/(sec \cdot m^2 \cdot atm)$
k_L	liquid phase mass transfer coefficient, m/sec
k_S	solid dissolution mass transfer coefficient, m/sec
K	thermal conductivity, $kcal/(m \cdot hr \cdot ^\circ K)$
N	mass transfer rate, gm-moles/sec
P	pressure, atm
r	mass transfer rate to a spherical surface, $gm\text{-moles}/(sec \cdot m^2)$
R	radius, m
R	Universal Gas Law Constant, $82.057 \times 10^{-6} atm \cdot m^3/(gm\text{-moles} \cdot ^\circ K)$
Re	Reynolds number, unitless
Sc	Schmidt number, unitless
Sh	Sherwood number, unitless
t	time, sec
T	temperature, $^\circ C$

V_p	ratio of volume of dispersion to surface area of dispersion, m^3/m^2
W	amount of solids, kg/m^3
W_{cr}	critical moisture content, $kg H_2O/kg$ Solids
W_2	final moisture content, $kg H_2O/kg$ Solids
x	reaction zone depth, m
x_o	liquid film depth, m
Y	gas phase mole fraction, unitless
Z	defined by Equation (41)

Subscripts

A	SO_2
B	$Ca(OH)_2$
c	liquid core
C	Constant Rate Period
cr	critical
d	drop
E	effective
F	Falling Rate Period
G	gas phase
i	gas-liquid interface
L	liquid phase
o	initial
p	product
P	particle

s	surface or saturated
S	solid phase

Greek Letters

Δ	difference
λ	latent heat of vaporization, kcal/kg
π	constant, 3.1416
ρ	density, kg/m ³
u	terminal velocity, m/sec
μ	viscosity, kg/(m·sec)
ϵ	porosity, unitless
τ	tortuosity, unitless

CHAPTER I

INTRODUCTION

The removal of sulfur dioxide (SO_2) from combustion source off-gas is commonly referred to as flue gas desulfurization (FGD). The maintenance of federal ambient air quality standards requires many coal burning utilities to install a FGD process. A relatively new FGD process which employs the use of spray drying technology for the reaction between SO_2 and calcium hydroxide ($\text{Ca}(\text{OH})_2$) is commonly referred to as "dry scrubbing" because the process waste product is essentially dry in nature. The purpose of this research was to develop an understanding of the mechanisms involved during the dry scrubbing reaction.

Dry scrubbing couples simultaneous heat and mass transfer with chemical reaction. Spray drying technology regarding heat and mass transfer has been well established by Ranz and Marshall (1952) and Lijn (1976). The addition of chemical reaction to the existing technology and determining the rate limiting steps was the goal of this work.

This research expands the two film model described by Danckwerts (1970) to include ash and dissolution resistances. The expanded model is applied to the dry scrubbing process in this study. Expressions for estimating the contact times for the constant and falling rate drying periods were developed by Ranz and Marshall

(1952) and are used in this study. Methods for predicting gas and liquid film mass transfer coefficients by Ranz and Marshall (1952) and Jury (1967) respectively are applied. The role of fly ash alkalinity in SO_2 absorption is neglected along with the competing reaction for Ca(OH)_2 by carbon dioxide (CO_2). The model developed applies only to once through lime systems. The effect of product recycle is not considered.

CHAPTER II

LITERATURE REVIEW

Literature which describes models for the dry scrubbing process is limited. Gelter et al. (1979) only described the physical changes that occur to the atomized droplet undergoing reaction with SO_2 . Downs et al. (1980) tried to model the dry scrubbing process assuming a gas phase diffusion controlled mechanism and using a heat and mass transfer relationship. The model underpredicted the dry scrubbing process performance.

As Gelter et al. (1979) point out, the dry scrubbing process consists of both drying and reacting phenomena. Wentz and Thygeson (1979) describe the drying process as consisting of three distinct periods. They are the constant rate period, the falling rate period, and a final diffusional period. A classical drying curve is shown in Figure 1. The reacting phenomena produces calcium sulfate and calcium sulfite and is governed by a variety of resistances. These resistances are gas and liquid film, ash film, and the solid-liquid film for $\text{Ca}(\text{OH})_2$ dissolution.

The Drying Process

Wentz and Thygeson (1979) defined the constant rate period as the part of the drying process where the evaporation rate is constant and is controlled by conditions surrounding the drying material.

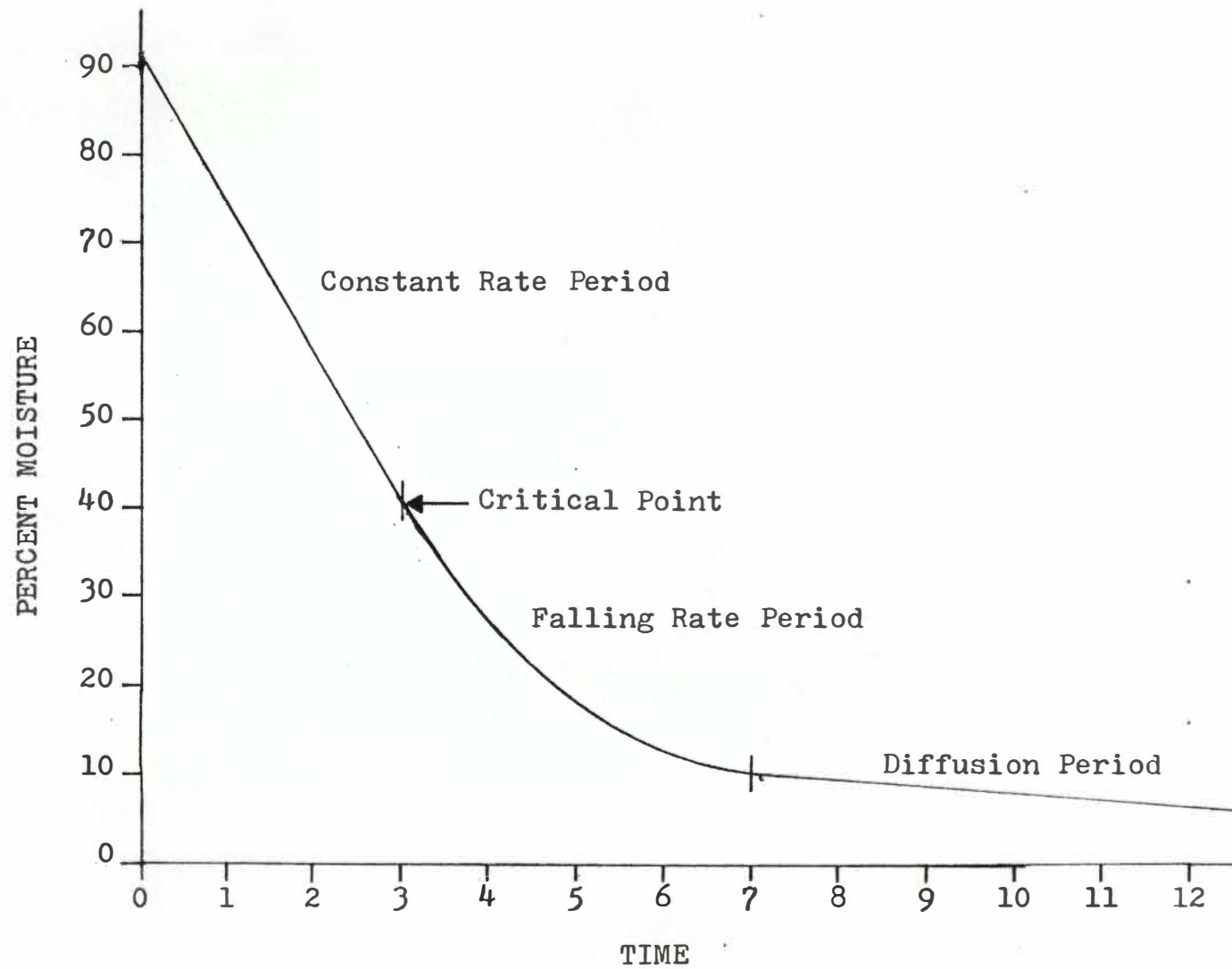


Figure 1. Classic drying curve for slurries in spray dryers.

These conditions are mass velocity, temperature, and humidity of the inlet flue gas. The falling rate period is the drying time where internal factors regulate the drying process. These factors are the particle's internal temperature and resistance to water vapor diffusion through the solid phase. The diffusional period is a state of pseudo vapor-liquid equilibrium that is maintained while the atomized particle is in contact with the flue gas. The evaporation rate during the diffusional period is greatly reduced because of the increased ash film and the reduced thermal driving force.

Ranz and Marshall (1952) studied the drying of drops and developed the following expressions for the drying times for the constant and falling rate periods:

$$t_C = \frac{\lambda \rho_o (d_{do}^2 - d_{dcr}^2)}{8K\Delta T_{Gs}} \quad (1)$$

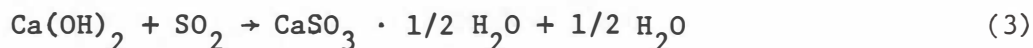
$$t_F = \frac{\lambda d_{dcr}^2 \rho_p (W_{cr} - W_2)}{12K\Delta T_{Gs}} \quad (2)$$

The critical variables (cr) contained in Equations (1) and (2) represent the point on Figure 1 where the constant rate period changes to the falling rate period.

The Reacting Process

Crystals of $\text{CaSO}_3 \cdot 1/2 \text{H}_2\text{O}$ and $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ have been identified in products from dry scrubbing facilities (Gelter et al. (1979) and

Downs et al. (1980)). These crystals suggest the following primary reactions:



During the constant rate period, Gelter et al. (1979) postulated that the liquid droplet with suspended calcium hydroxide developed into a solid matrix of unreacted core particles with the ash consisting of calcium sulfate and the core, calcium hydroxide. They concluded that the reaction between SO_2 and Ca(OH)_2 occurred at the surface of the solid core and based this conclusion on scanning electron micrograph photography of the dry scrubbing product. Downs et al. (1980) concluded however, that the aqueous ionic reaction between SO_2 and Ca(OH)_2 predominated through both the constant and falling rate drying periods. They also used scanning electron micrograph photography to reach their conclusion.

Sada et al. (1977) studied the gas absorption of CO_2 and SO_2 into slurries of Ca(OH)_2 . They stated that the SO_2 -slurry system can be modeled using the development of Ramachandran and Sharma (1969) and that the reaction of SO_2 and OH^- can be considered instantaneous. Therefore, this study uses the conditions established by Ramachandran and Sharma (1969) for modeling the dry scrubbing process and only considers an instantaneous reaction model.

Gas Film Resistance

Ranz and Marshall (1952) developed a correlation for the gas phase heat and mass transfer from evaporating drops. The equation developed for mass transfer is as follows:

$$Sh = 2.0 + 0.6 Re^{1/2} Sc^{1/3} . \quad (5)$$

Substituting for all dimensionless numbers and rearranging yields the following expression for the gas phase mass transfer coefficient:

$$k_{AG} = \frac{D_{AG}}{(RT)d_d(1 - Y_A)} \left[2.0 + 0.6 \left(\frac{\mu_G}{\rho_G D_{AG}} \right)^{1/3} \left(\frac{d_d u_d \rho_G}{\mu_G} \right)^{1/2} \right] . \quad (6)$$

Liquid Film Resistance

Calvert and Kapo (1963) describe the use of the penetration theory developed by Higbie (1935) for determining the liquid film mass transfer coefficient for drops. Calvert et al. (1972) show that for short exposure times the penetration theory works well; however, for long contact times they conclude that Jury's (1967) development for estimating liquid film mass transfer coefficients works better. Calvert et al. (1972) give conditions which determine whether a contact time should be considered long or short. The development of Jury (1967) only considered the case for stagnant drops. Calderbank and Korchinski (1956) concluded that for drops undergoing internal circulation the molecular diffusivity in the drops should be raised by a factor of 2.25.

Therefore, for short exposure times the liquid phase mass transfer coefficient may be obtained using the penetration theory as follows:

$$k_{AL} = 2.0 \left(\frac{2.25 D_{AL}}{\pi t} \right)^{1/2} \quad (7)$$

and for long exposure times using the development by Jury (1967):

$$k_{AL} = \frac{22.5 D_{AL}}{d_d} \quad (8)$$

If:

$$\left(\frac{D_{AL} t}{R_d^2} \right)^{1/2} > 0.22 \quad (9)$$

then the contact time is considered long and Equation (8) applies.

Ash Film Resistance

Levenspiel (1972) developed the rate equation for mass transfer through a nonreactive ash layer. The development is from an analogous expression to Fick's Law except that the diffusion coefficient is replaced with an effective diffusivity (D_E). Sherwood et al. (1975) state that the effective diffusion coefficient may be defined as follows:

$$D_E = \frac{\varepsilon}{\tau} D_{AG} \quad (10)$$

where D_{AG} is the ordinary binary gas phase diffusion coefficient, ε

is the ash film porosity or the fraction of free cross sectional area, and τ is the "tortuosity factor" for the ash. Substituting Equation (10) into the mass transfer rate expression (Equation (15), Chapter 12) developed by Levenspiel (1972) yields:

$$-r_A = \frac{R_e B D_{AG} (P_{As} - P_{Af})}{R_p (R_p - R_c)(RT)} \quad (11)$$

where B is the ratio of porosity to tortuosity.

Solid Dissolution Resistance

Ramachandran and Sharma (1969) developed expressions for the absorption with fast reaction in a slurry containing sparingly soluble fine particles. Two cases were addressed in the paper where the solid dissolution in the liquid film was either unimportant or important. A test condition for either case was given along with an expanded two film model rate equation for absorption with an instantaneous reaction. Their basic rate equation for solid dissolution is given below:

$$-r_A = k_S A_P (C_s - C_B) \quad (12)$$

where k_S ranged from 2.0 to 8.0×10^{-5} m/sec. A_P is calculated from the following expression:

$$A_P = \frac{6W}{\rho_S d_S} \quad (13)$$

CHAPTER III

DEVELOPMENT OF THE MODEL

The overall model for SO_2 removal in a spray dryer is based on the SO_2 removed in (1) the constant rate period and (2) the falling rate period. The diffusional rate period is considered to be of negligible importance in the model. An illustration of the assumed physical changes which occur during the constant and falling rate periods is shown in Figure 2. The initially atomized drop absorbs SO_2 and produces $\text{CaSO}_3 \cdot 1/2 \text{H}_2\text{O}$ in the liquid phase and decreases in size because of water evaporation. This process continues throughout the constant rate period. At the beginning of the falling rate period the drop containing both Ca(OH)_2 and $\text{CaSO}_3 \cdot 1/2 \text{H}_2\text{O}$ breaks up into smaller drops which form an ash layer and a liquid core. The ash layer forms because the slurry density increases to a point that restricts water diffusion to the particle surface to a rate less than the evaporation rate. During the falling rate period SO_2 must diffuse through the ash layer and penetrate the liquid film where conversion to $\text{CaSO}_3 \cdot 1/2 \text{H}_2\text{O}$ takes place. During both drying periods only reaction (3) is assumed to take place primarily because of its lower heat of formation. Experimental values of Davis (1983) of the mass mean diameter for the dry scrubbing product for stoichiometric ratios ranging from 0.7 to 1.7 were relatively constant, averaging 7.8 μm . This finding was the basis for the drop breakup in the model because

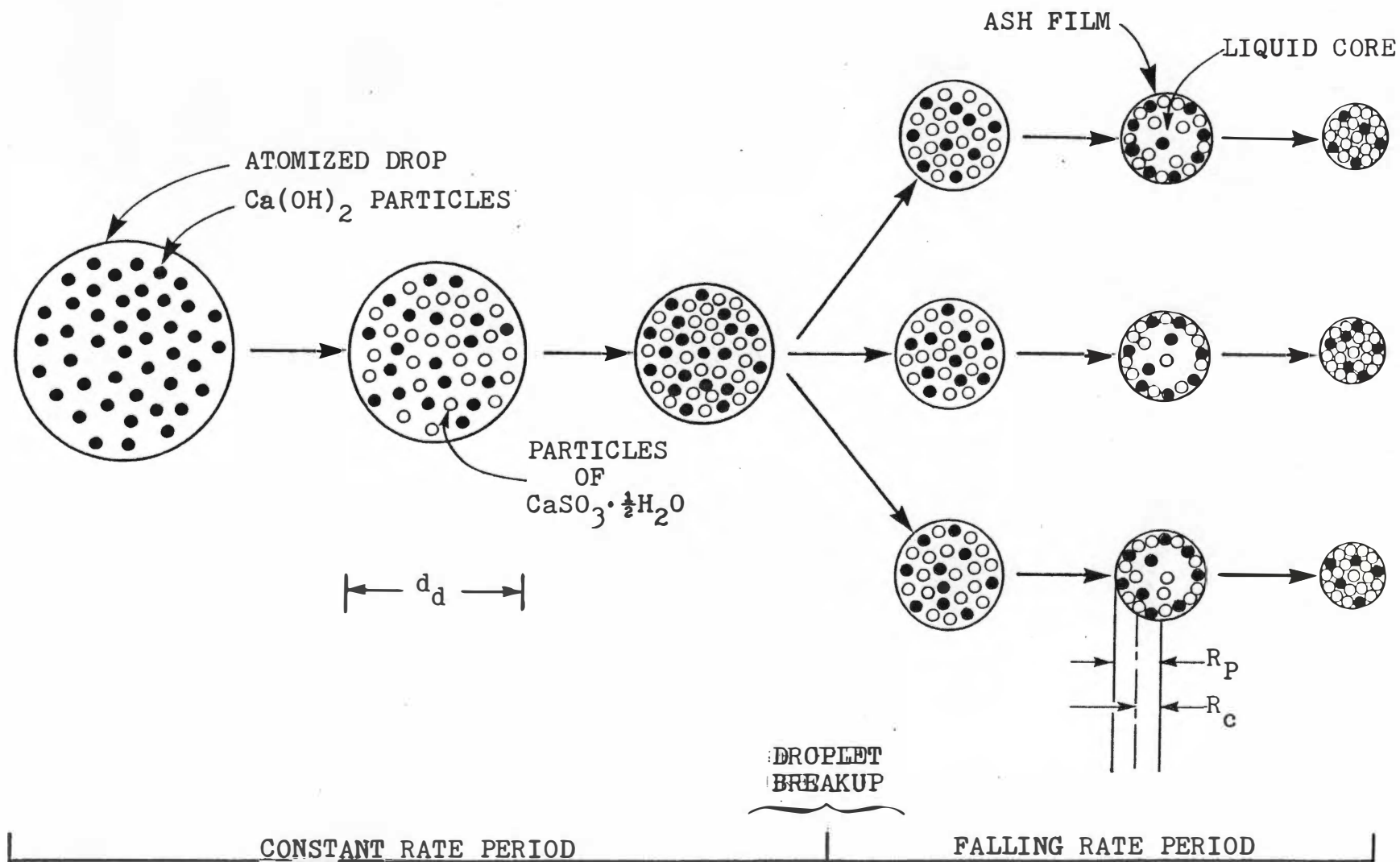


Figure 2. Dry scrubbing model.

evaporation alone would not reduce the drops to the size measured experimentally.

Constant Rate Period Model

The model for the constant rate period is based on film theory for an instantaneous liquid phase reaction of the form shown below:



The form shown above is similar to reaction (3) neglecting H_2O with all coefficients equalling one. Figure 3 illustrates the constant rate model. Sulfur dioxide diffuses through the gas film and is absorbed into the liquid phase. The absorbed SO_2 then diffuses into the liquid and simultaneously reacts with $Ca(OH)_2$. At the point of the reaction zone the concentration of SO_2 and $Ca(OH)_2$ become zero. Further into the liquid phase the concentration of $Ca(OH)_2$ increases until it reaches the bulk concentration. The dissolution of $Ca(OH)_2$ into the bulk liquid occurs at the solid $Ca(OH)_2$ liquid interface. The equations which describe this situation are given by Levenspiel (1972) and Ramachandran and Sharma (1969). The equations are as follows:

$$-r_A = k_{AG} (P_A - P_{Ai}) \quad (15)$$

$$-r_A = k_{AL} (C_{Ai} - 0) \frac{x_o}{x} \quad (16)$$

$$-r_A = k_{BL} (C_B - 0) \frac{x_o}{x_o - x} \quad (17)$$

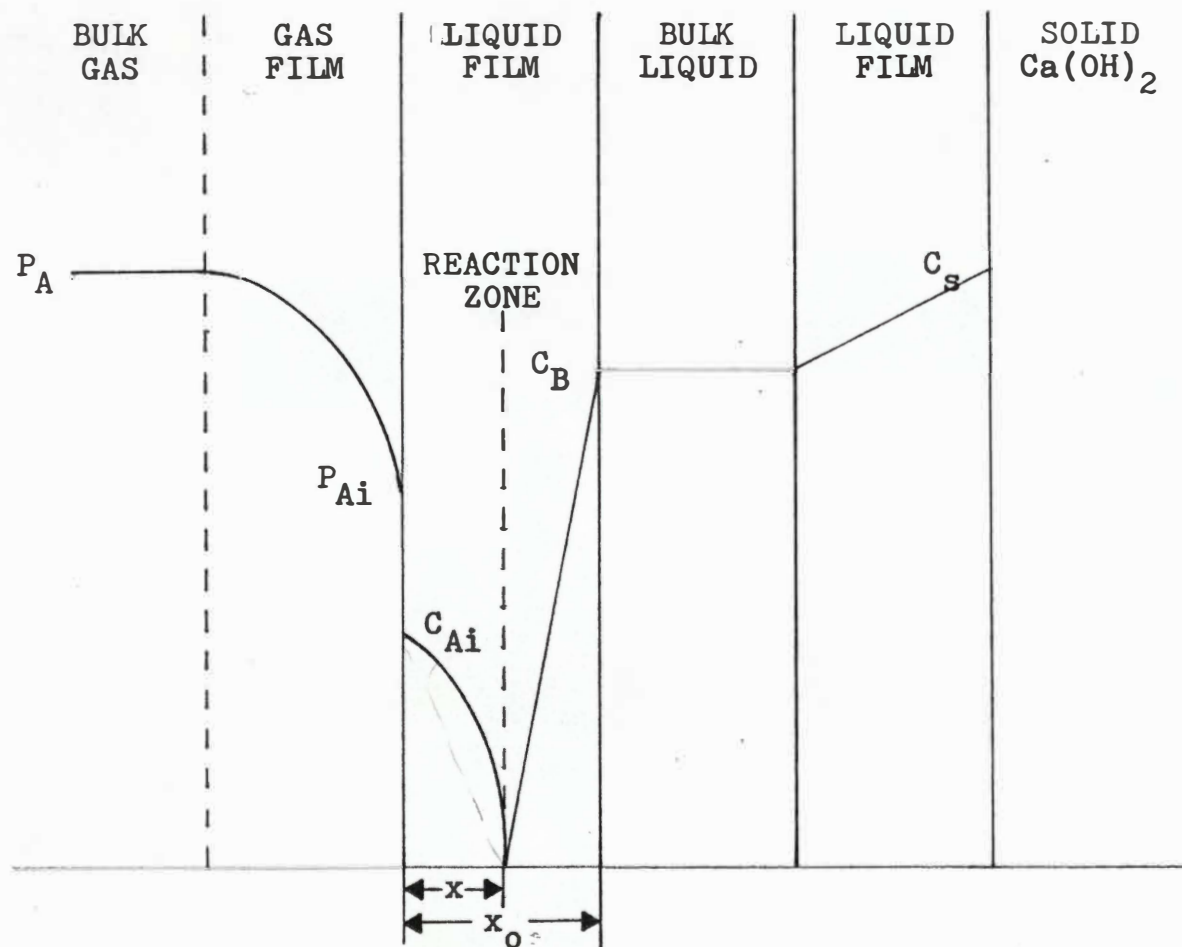


Figure 3. Model for the constant rate period.

$$-r_A = k_S A_P V_P (C_s - C_B) \quad (18)$$

$$P_{Ai} = H_A C_{Ai} \quad (19)$$

$$\frac{k_{AL}}{k_{BL}} = \frac{D_{AL}/x_o}{D_{BL}/x_o} = \frac{D_{AL}}{D_{BL}} \quad (20)$$

The solution to these equations is given in Appendix A. The result is:

$$-r_A = \frac{\frac{P_A}{H_A} + \frac{D_{BL}}{D_{AL}} C_s}{\frac{1}{k_{AG} H_A} + \frac{1}{k_{AL}} + \frac{D_{BL}}{D_{AL}} \frac{1}{k_S A_P V_P}} \quad (21)$$

which is the equation given by Ramachandran and Sharma (1969) provided that the solid dissolution in the liquid film is unimportant. The test condition for this case is as follows:

$$\frac{k_S A_P D_{AL}^2}{4 k_{AL}^2 D_{BL}} \ll 1.0 \quad (22)$$

It will be shown later that this test condition is met.

Danckwerts (1970) also discusses conditions where Equation (21) may not accurately describe the process of mass transfer. If the absorption of SO_2 is controlled by the gas film resistance the model simply becomes:

$$-r_A = k_{AG} P_A \quad (23)$$

when:

$$k_{AG} P_A < \frac{k_{AL} D_{BL} C_B}{D_{AL}} . \quad (24)$$

Falling Rate Period Model

The falling rate model is also based on film theory for an instantaneous liquid phase reaction but includes an additional resistance in the form of an ash layer. This ash layer is the cause for the reduction in the evaporation rate from the drops and therefore is included as a resistance to SO_2 mass transfer. Figure 4 illustrates the falling rate model. Sulfur dioxide diffuses through both the gas and ash film before being absorbed into the liquid core. The remainder of the model is identical to that for the constant rate period. The equations which describe the falling rate model are the same as for the constant rate period with the following equation:

$$-r_A = \frac{R_c D_E (P_{As} - P_{Al})}{R_P (R_P - R_c) (RT)} . \quad (25)$$

The solution to the equations (15) through (20) and (25) is given in Appendix B. The result is:

$$-r_A = \frac{\frac{P_A}{H_A} + \frac{D_{BL}}{D_{AL}} C_S}{\frac{R_c^2}{H_A k_{AG} R_P^2} + \frac{1}{k_{AL}} + \frac{R_c (R_P - R_c) (RT)}{H_A D_E R_P} + \frac{D_{BL}}{D_{AL}} \cdot \frac{1}{k_S A_P V_P}} \quad (26)$$

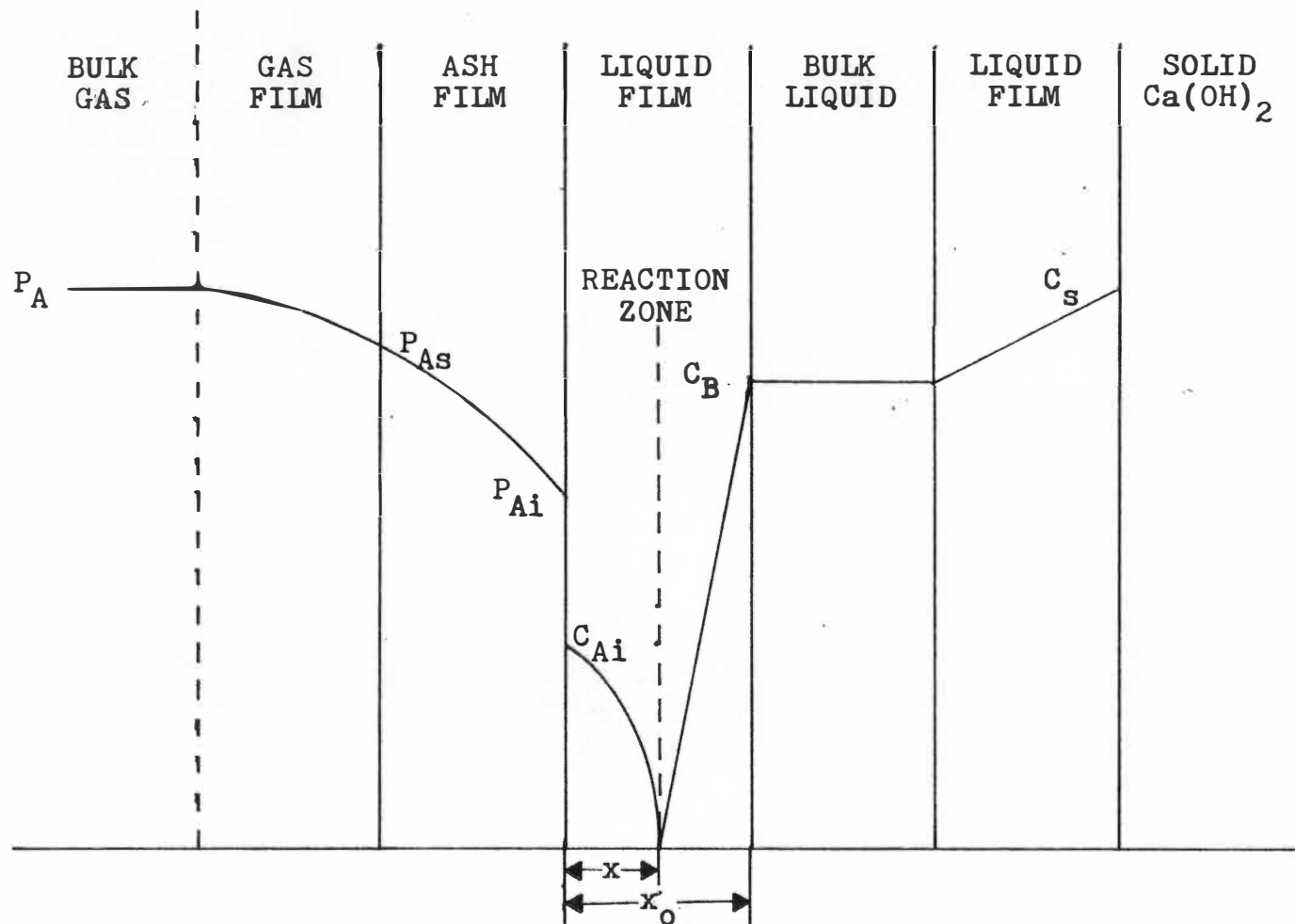


Figure 4. Model for the falling rate period.

which is also governed by Equation (21) to determine whether or not dissolution in the liquid film is important.

Similar to the situation for the constant rate period, if the absorption of SO_2 is controlled by the gas and ash film resistances the following rate expressions become limiting:

$$-r_A = k_{AG} (P_A - P_{As}) \quad (27)$$

$$-r_A = \frac{R_c D_E (P_{As} - P_{Ai})}{R_p (R_p - R_c) (RT)} \quad (28)$$

where: $P_{Ai} = 0$. Rearranging Equation (28) yields:

$$P_{As} = \frac{-r_A R_p (R_p - R_c) (RT)}{R_c D_E} \quad (29)$$

substituting (29) into (27) yields:

$$-r_A = k_{AG} P_A + \frac{k_{AG} r_A R_p (R_p - R_c) (RT)}{R_c D_E} \quad (30)$$

rearranging (30) yields:

$$-r_A \left(1.0 + \frac{k_{AG} R_p (R_p - R_c) (RT)}{R_c D_E} \right) = k_{AG} P_A \quad (31)$$

and finally:

$$-r_A = \frac{P_A}{\frac{1}{k_{AG}} + \frac{R_p (R_p - R_c) (RT)}{R_c D_E}} \quad (32)$$

if:

$$\frac{1}{k_{AG}} + \frac{R_P (R_P - R_C) (RT)}{R_C D_E} < \frac{k_{AL} D_{BL} C_B}{D_{AL}} \quad (33)$$

Computer Program

Appendix C contains the complete listing of the FORTRAN program developed for the dry scrubbing process. Figure 5 is a general flow sheet for the program and highlights only the major calculated variables. The following subsections discuss each block on Figure 5.

Program Input

The data required to run the dry scrubbing program with their units are presented in Table 1. Davis and Reed (1982) published the data used for this research. The variables in Table 1 are the same as used in the report. RUN and PAGE provide the data set counter for the program and the report page reference respectively. YN2, YCO2, YO2, YH2O, YSO2 are the flue gas feed component mole fractions of nitrogen, carbon dioxide, oxygen, water, and sulfur dioxide respectively. SO20NC is the inlet sulfur dioxide concentration and TEMP1C is the inlet flue gas temperature. SLCONC is the lime slurry concentration and SCFM1C is the inlet flue gas flowrate. GPM is the lime slurry feed rate to the spray dryer and PBAR is the barometric pressure during the test. SP1 and SP2 are the static pressures

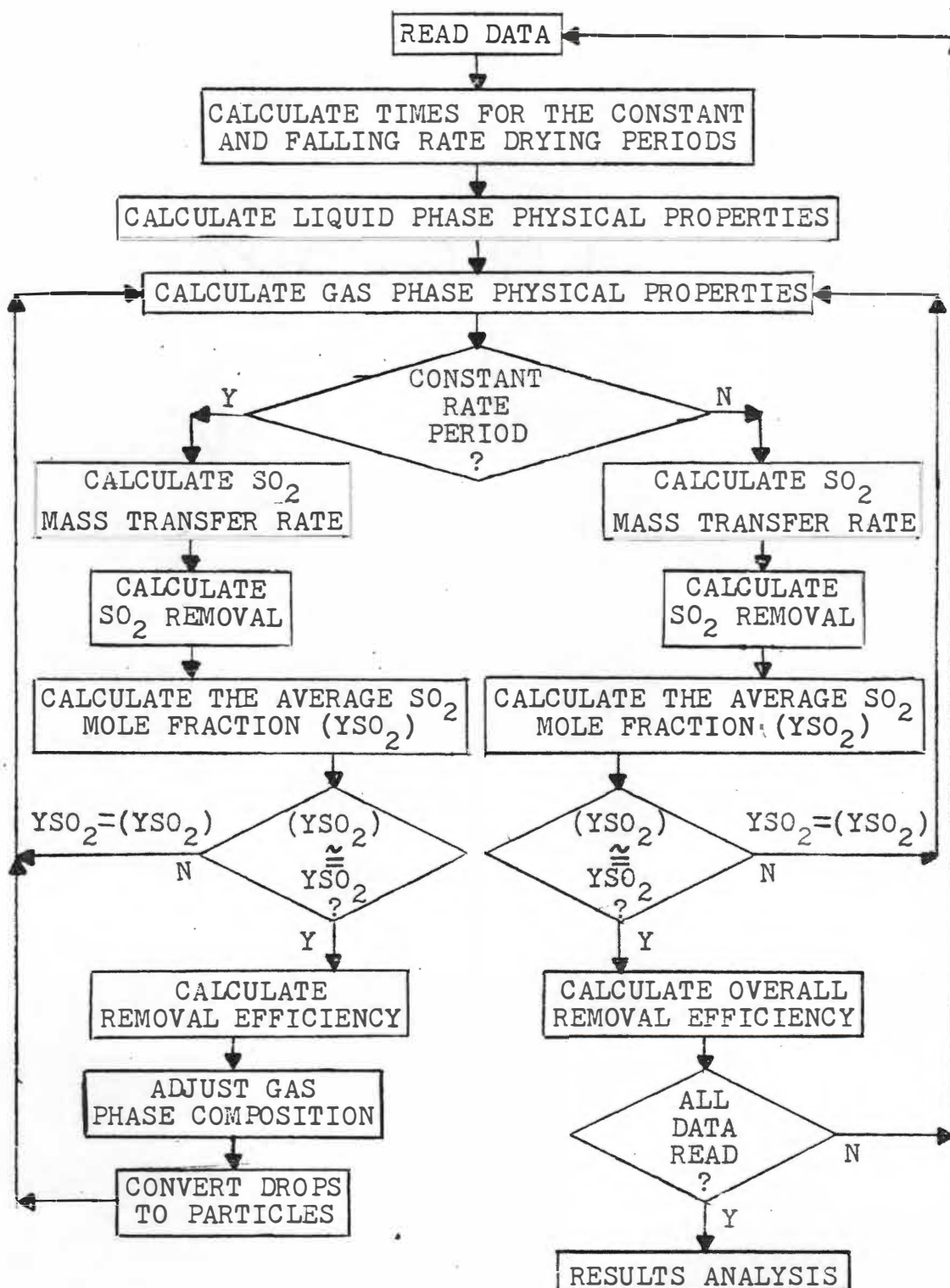


Figure 5. Flowsheet for the dry scrubbing computer model.

TABLE 1
COMPUTER MODEL INPUT

Variable	Units
RUN	unitless
PAGE	unitless
YN2	unitless
YCO2	unitless
YO2	unitless
YH2O	unitless
YSO2	unitless
S020NC	PPM
TEMP1C	°F
SLCONC	#CaO/gal
SCFM1C*	ft ³ /min
GPM	gal/min
PBAR	in. Hg
SP1	in. H ₂ O
SP2	in. H ₂ O
TSLURR	°F
TEMP2	°F
TW2	°F
DROPDI	m
PRODDN	kg/m ³
EFFSD(RUN)	%
BW2	unitless

*At 1 atm and 60°F.

measured at the inlet and outlet of the spray dryer. TSLURR is the lime slurry temperature and TEMP2 is the outlet spray dryer temperature. TW2 is the wet bulb temperature at the outlet of the spray dryer and DROPDI is the estimated drop diameter during the test. PRODDN is the spray dryer product density. EFFSD(RUN) is the experimental spray dryer efficiency and BW2 is the water vapor mole fraction exiting the spray dryer.

The experimental data of Davis and Reed (1982) did not provide all of the gas phase mole fractions. Therefore YN₂, YCO₂, and YO₂ were input as 0.75, 0.12, and 0.08 respectively and then adjusted proportionally so that when all gas phase mole fractions were summed the total equaled 1.00. The mole fractions used for nitrogen, carbon dioxide, and oxygen are considered representative of the actual flue gas composition from The University of Tennessee steam plant.

The temperature of the slurry and the density of the spray dryer product were not provided by Davis and Reed (1982). The temperature of the slurry was assumed to equal 70 degrees Fahrenheit. Simple laboratory experiments were conducted using a graduated cylinder and a scale to determine the product bulk density. A relatively constant density was found to be approximately 500 kg/m³ for product generated at stoichiometric ratios between 0.7 and 1.7. The value of 500 kg/m³ was therefore used for all runs.

Time Calculations

The method outlined by Masters (1979) for calculating evaporation times for the constant and falling rate periods is

followed by the dry scrubbing program with the following noted exception. In the calculation for the log mean temperature during the falling rate period the drops or particles increase in temperature above the wet bulb temperature. This temperature rise cannot be accurately predicted and therefore the value for the log mean temperature difference during the falling rate period was simply the average between the critical and the wet bulb temperatures of the flue gas.

The method of Masters (1979) requires that a number of variables be either known or predicted. Therefore a relationship for the slurry density as a function of the slurry concentration (SLCONC) was developed assuming ideal mixing and no calcium hydroxide dissolution. The equation developed is:

$$\text{SLDEN} = 1000.0 + 86.3795 \times \text{SLCONC} \quad (34)$$

where: $\text{SLDEN} = \text{kg/m}^3$. In a similar manner an expression for the initial moisture content of the drops was developed. The equation is:

$$\text{W1} = 6.3118/\text{SLCONC} - 0.4545 \quad (35)$$

where: $\text{W1} = \text{kg H}_2\text{O/kg Ca(OH)}_2$. Equations (34) and (35) were used to plot the predicted specific gravity versus percent solids line shown on Figure 6. The agreement with the experimental values of Davis (1983) is good. The experimental values should have converged to 1.00 at zero percent solids as the predicted values. The final moisture content of the spray dried product is also required by the method

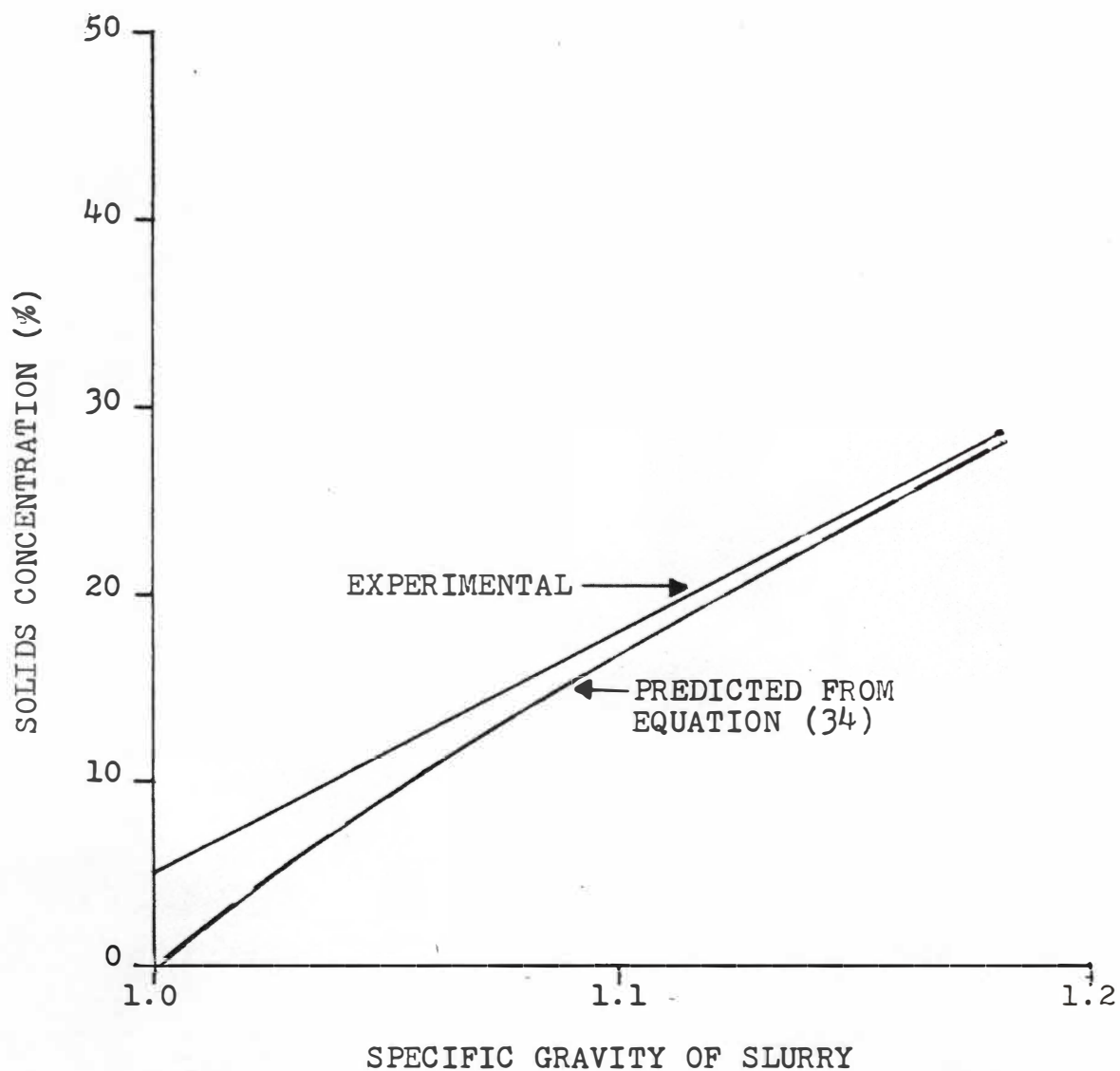


Figure 6. Comparison between experimental and predicted values for the specific gravity of lime slurries.

of Masters (1979). Final moisture content as a function of temperature approach to saturation has been investigated by Davis (1983) and Stevens (1980). The work of Davis (1983) indicated much lower moisture contents than were reported by Stevens (1980). Therefore an expression for Davis' (1983) work which predicts lower moisture contents was developed. The expression is:

$$W3 = \frac{4.4732 \times 10^4}{\text{DELTAT}^{4.3463}} \quad (36)$$

where: $W3 = \text{kg H}_2\text{O/kg TOTAL}$

$\text{DELTAT} = \text{Temperature approach to saturation (}^\circ\text{F)}$

and:

$$W2 = \frac{W3}{1.0 - W3} \quad (37)$$

where: $W2 = \text{Final moisture content, kg H}_2\text{O/kg Ca(OH)}_2$. Figure 7 illustrates the work of Stevens (1980) and the results from Equation (36).

The critical temperature as shown on Figure 8 is the temperature of the flue gas at the point where drying changes from the constant rate period to the falling rate period. This temperature cannot be measured and therefore a simplistic enthalpy and mass balance was written to predict the critical temperature. Figure 9 illustrates the heat and mass balance components. HEAT can be calculated by subtracting the heat lost by the flue gas from the sum of the heats gained by the slurry and the evaporated water. Depending on the heat

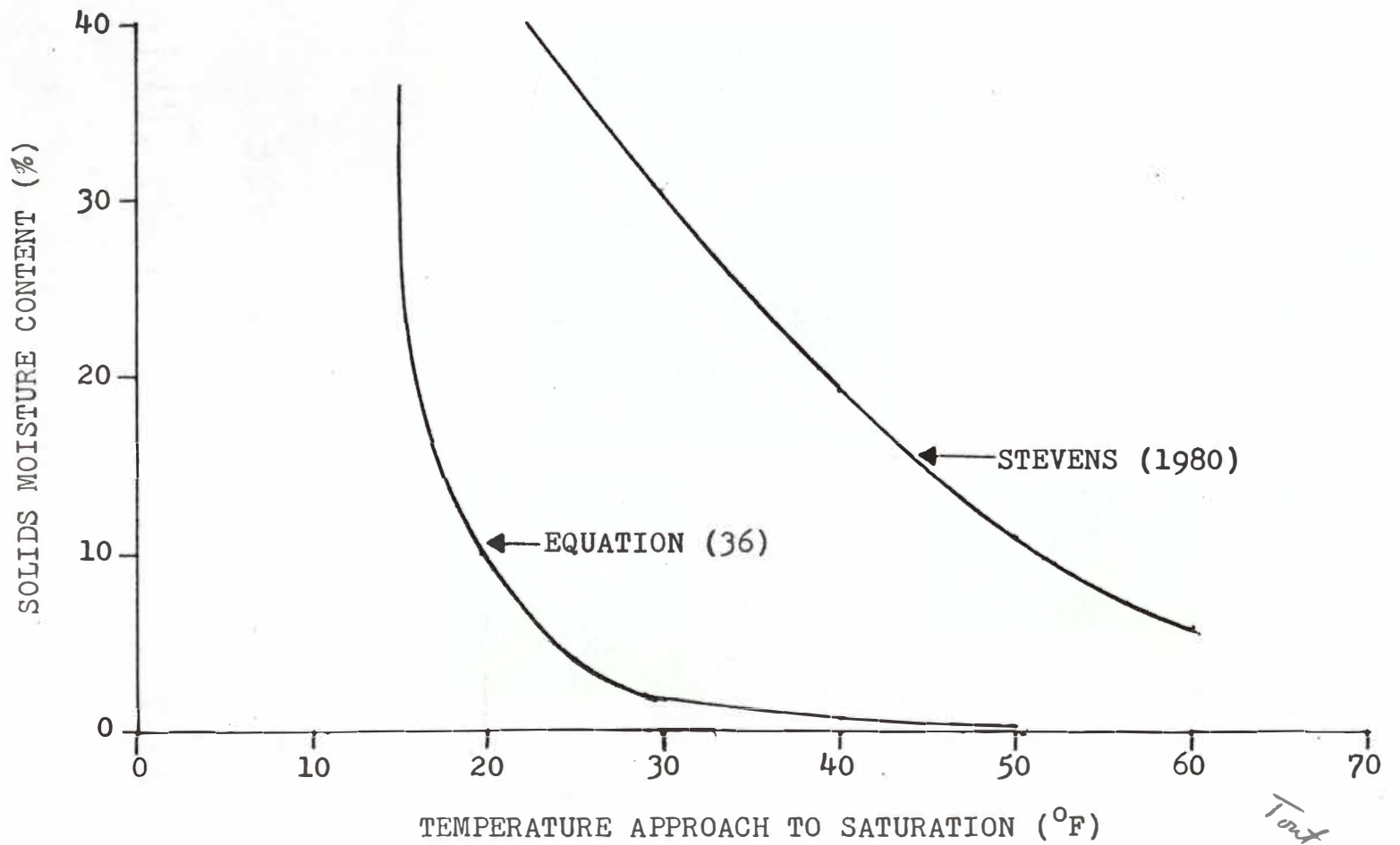


Figure 7. Predicted moisture content in the dry scrubbing product.

Test - Tub

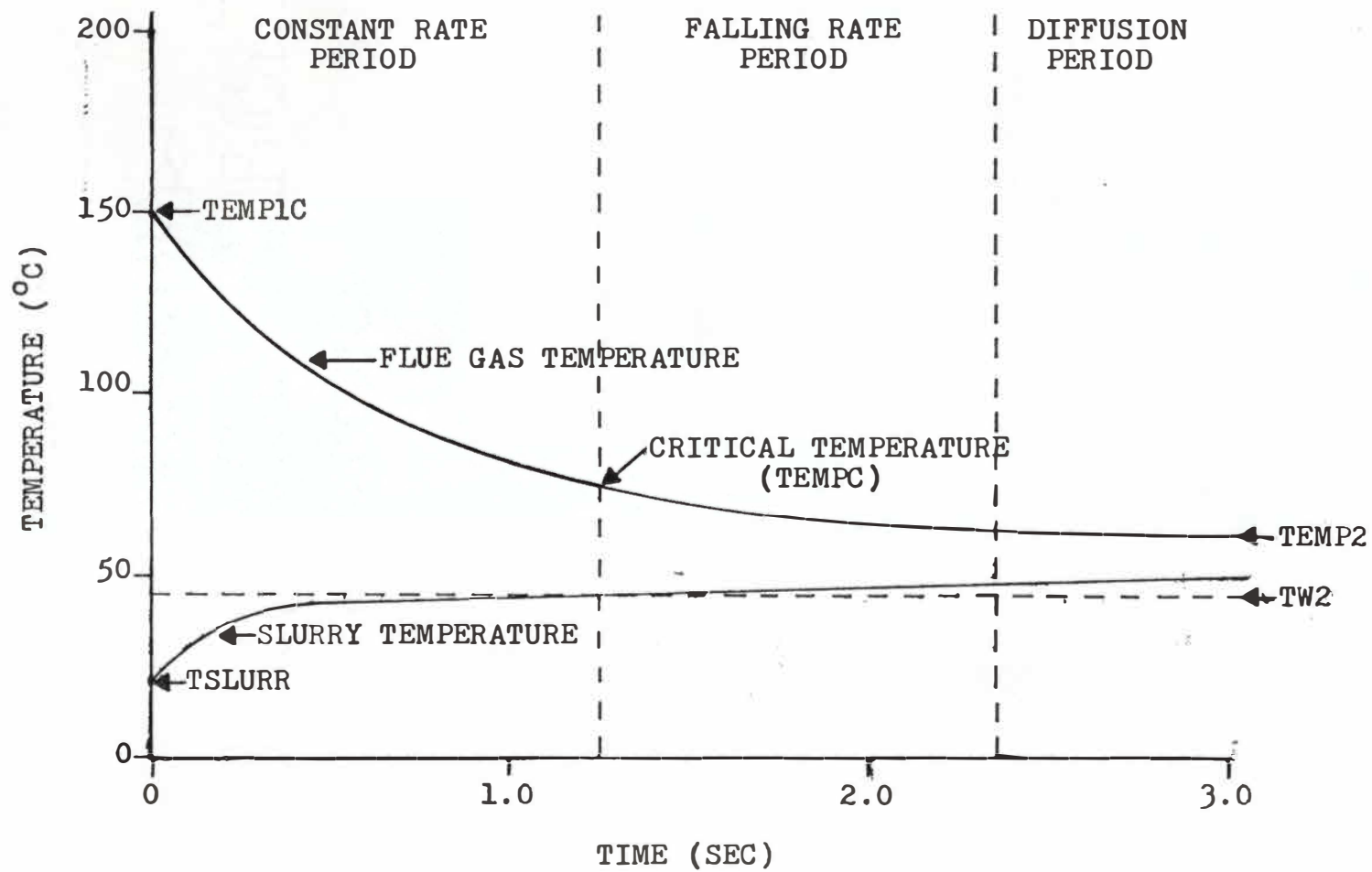
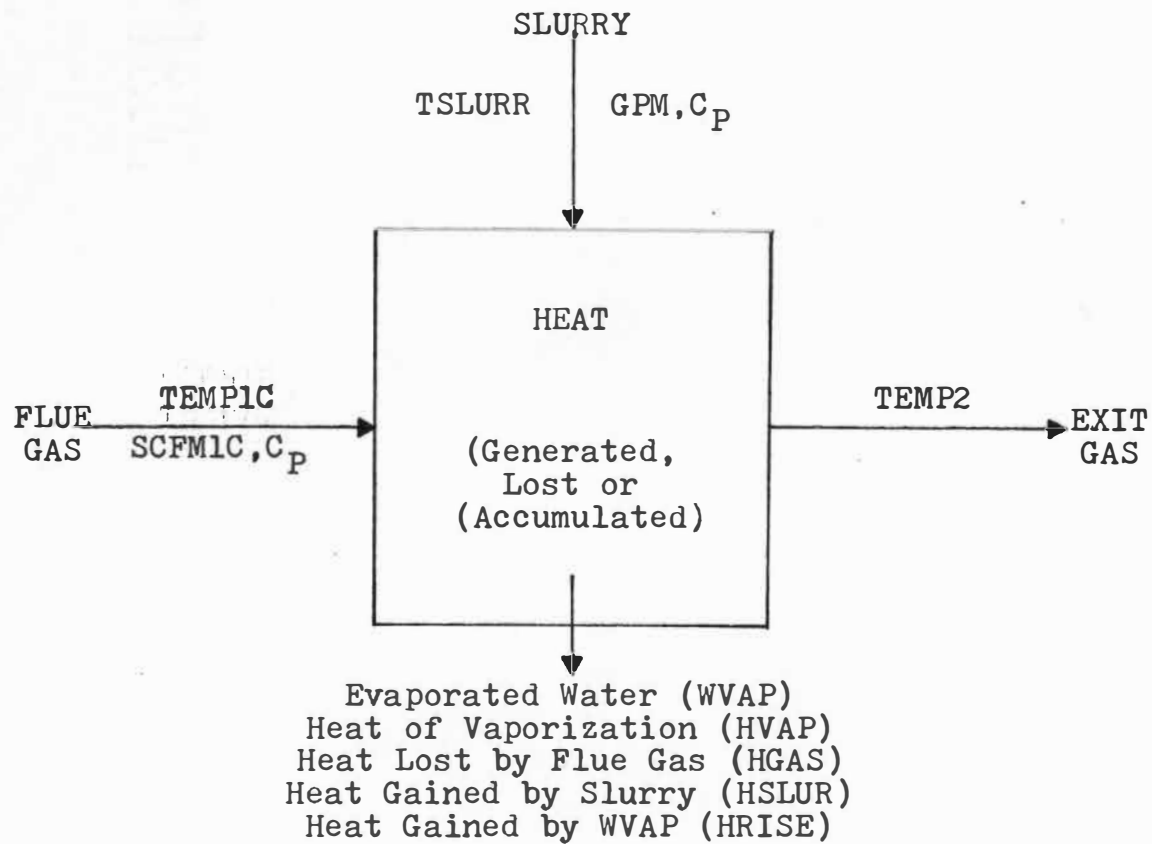


Figure 8. Temperature profile during spray drying.



$$\text{HEAT} = (\text{HVAP} * \text{WVAP}) + (\text{HRISE} * \text{WVAP}) + \text{HSLUR} - \text{HGAS}$$

Figure 9. Heat balance.

lost from the spray dryer HEAT can be either positive or negative. Then ratioing HEAT to the amount of water evaporated during the constant rate period and doing a heat balance with temperature as the variable the critical temperature can be estimated. Table 2 presents the estimated critical temperature (TEMPC) for each run. The heat capacity of the flue gas was estimated by multiplying the gas phase mole fractions with their respective mean heat capacities and then summing the products. Values for the individual mean heat capacities were obtained from Himmelblau (1982). Expressions as a function of temperature for the heat of evaporation and the specific heat for the evaporating water were developed from "Steam Tables" by Weast (1974) and are shown below:

$$\text{HVAP} = -0.3290 \cdot \text{TW2} + 608.2879 \quad (38)$$

$$\text{HRISE} = 0.2272 \cdot \text{DELTAT} \quad (39)$$

where: HVAP = kcal/kg

HRISE = kcal/kg.

The thermal conductivity of the gaseous film surrounding the drops or particles is estimated from an expression developed from values given by Reid et al. (1977). The expression developed is shown below:

$$\text{KD} = 8.64 \times 10^{-5} \times \text{TW2} - 1.196 \times 10^{-2} \quad (40)$$

where: KD = kcal/(m·hr·°K).

TABLE 2
CRITICAL TEMPERATURE (TEMPC) ESTIMATES

Run	TEMP1 ^a (°F)	TEMPC (°F)	TEMP2 ^b (°F)
1	271	178	144
2	270	172	150
3	284	164	135
4	273	167	144
5	277	177	137
6	275	182	147
7	271	147	135
8	272	151	140
9	273	161	150
10	253	176	133
11	255	179	140
12	255	162	135
13	254	150	138
14	257	147	134
15	256	164	140
16	255	159	149
17	261	189	151
18	260	174	151
19	296	183	140
20	296	148	135
21	293	162	140
22	287	157	135
23	299	171	150
24	293	152	140
25	297	161	150

^aSpray dryer inlet temperature.

^bSpray dryer outlet temperature.

All of the above expressions were written in FORTRAN along with those of Masters (1979) to predict the contact times for the constant and falling rate drying periods.

Liquid Phase Physical Properties

Values for the liquid phase diffusivities for SO_2 and Ca(OH)_2 were given by Sada et al. (1977). Temperatures for these values were determined by comparison with values for other diffusivities given by Perry and Chilton (1973). The hydrodynamic theory and the Wilke-Chang estimation method referenced by Reid et al. (1977) indicate that the liquid phase diffusivities are directly proportional to the liquid's absolute temperature and inversely proportional to the liquid's viscosity. Therefore the values for diffusivity given by Sada et al. (1977) and the expression for water viscosity as a function of temperature given by Weast (1974) were combined to create expressions as a function of temperature for SO_2 and Ca(OH)_2 diffusivities in water. The developed expressions are given below:

$$Z = \frac{1.3272(20 - T) - 0.001053 (T - 20)^2}{(T + 105)} \quad (41)$$

$$\text{DOSO}_2 = \frac{5.1735 \times 10^{-12} (T + 273)}{1.002 \times 10^Z} \quad (42)$$

$$\text{DOCA} = \frac{4.781 \times 10^{-12} (T + 273)}{1.002 \times 10^Z} \quad (43)$$

where: $\text{DOSO}_2 = \text{m}^2/\text{sec}$

$\text{DOCA} = \text{m}^2/\text{sec}.$

The liquid phase concentration of Ca(OH)_2 is estimated from an expression developed from values given by Perry and Chilton (1973). Figure 10 illustrates the data and the expression developed is given below:

$$\text{CCA} = 10.0 \times ((-0.0011 \times T) + 0.185) \quad (44)$$

where: $\text{CCA} = \text{kg/m}^3$.

Expressions for Henry's Law constants (HENRY) for SO_2 absorption in water were developed from data given by Loomis (1928). For temperatures between 10 and 30 degrees Centigrade an expression was given; however, for temperatures greater than 30 degrees an expression had to be developed. The data above 30 degrees were plotted as shown on Figure 11 and the following FORTRAN expressions were developed:

$$\text{HENRY} = ((19.265 \times T) - 92.6574) \times 10000 \quad 30 < T \leq 52 \quad (45)$$

$$\text{HENRY} = ((29.597 \times T) - 657.2676) \times 10000 \quad T > 52 \quad (46)$$

where: $\text{HENRY} = \text{atm/mole fraction}$.

Gas Phase Physical Properties

The density of the flue gas is estimated from the ideal gas law. An average molecular weight is calculated for the gas composition and then the gas law is applied to calculate the density.

The viscosity of the flue gas is estimated from methods given by Perry and Chilton (1973). Values of viscosity for each gas

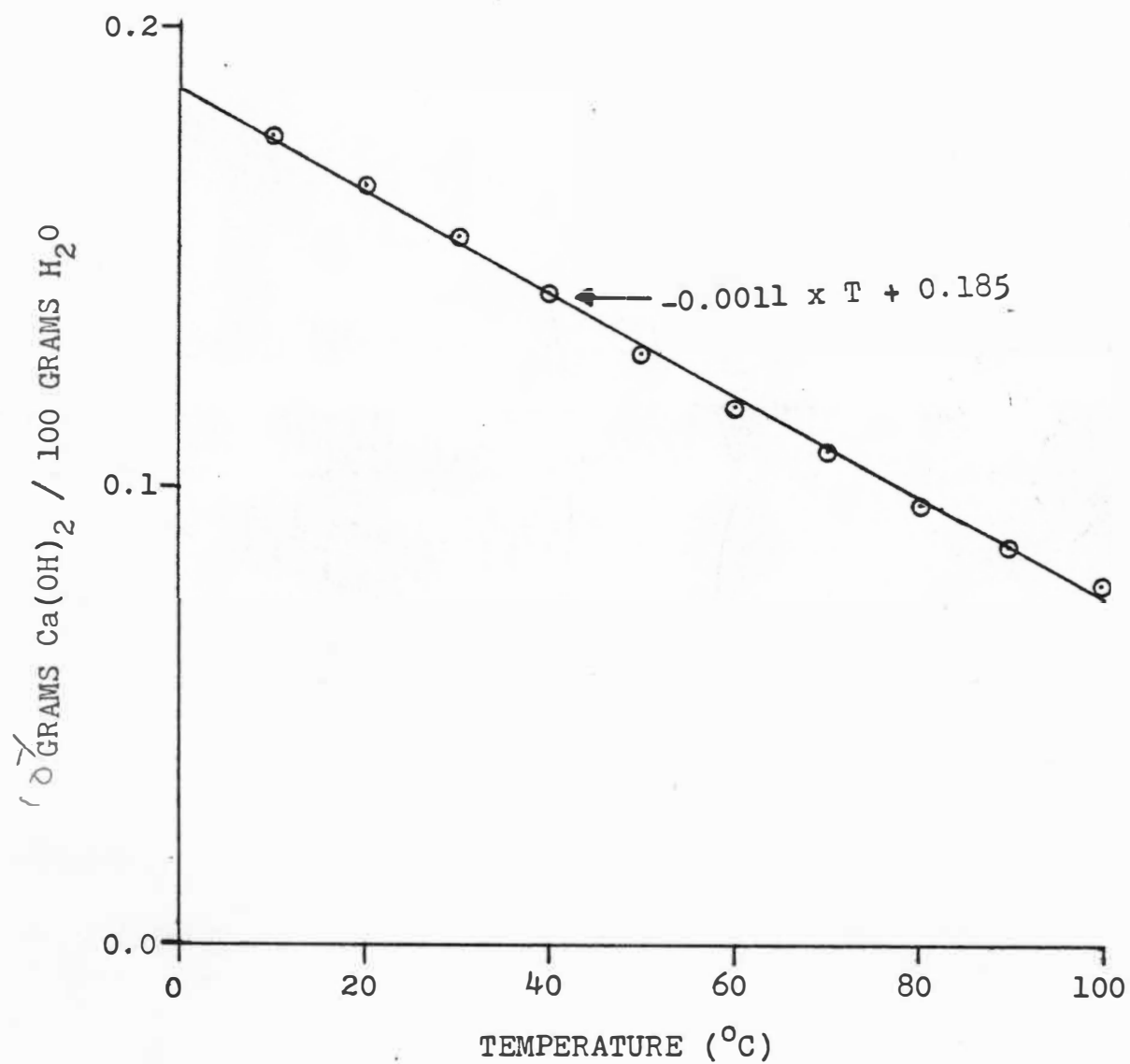


Figure 10. Calcium hydroxide solubility.

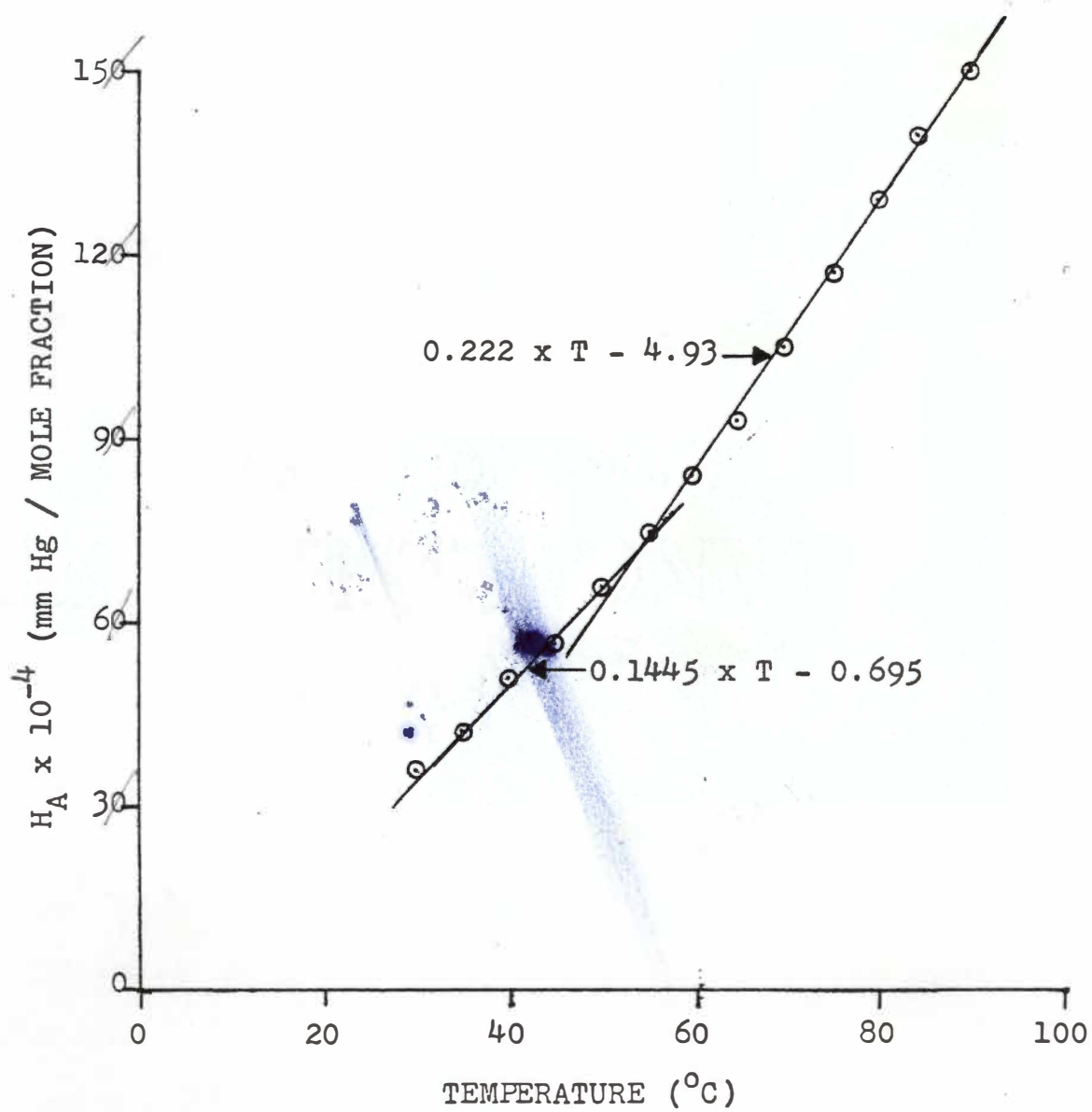


Figure 11. Henry's Law constants for SO₂ in water.

component were obtained at 100°C and then coupled with Equation (3-133) of Perry and Chilton (1973) to create expressions for gas component viscosity as a function of temperature. The viscosity of the flue gas is then calculated using Equation (3-135) from Perry and Chilton (1973).

The gas phase component diffusivities were estimated using the Wilke-Lee modification of the Hirschfelder-Bird-Spotz method shown by Treybal (1968). The temperature used in the initial estimates was 100°C and the pressure was 1 atm. According to Fuller-Schettler-Giddings as referenced by Reid (1977) the component diffusivities vary as a function of absolute temperature to the 7/4 power. Therefore the gas phase component diffusivities were ratioed by temperature to the 7/4 power. The Wilke-Lee method expresses component diffusivity as an inverse function of pressure. Therefore the calculated diffusivities were also divided by the operating pressure of the spray dryer.

The terminal velocity calculation for the drops or particles follows the method described by Crawford (1976).

The method for calculating the gas phase diffusivity of H_2O and SO_2 in the mixture of the flue gas follows Equation (2.36) given by Treybal (1968).

The water saturation pressure is estimated from a relationship given by Lijn (1976).

Mass Transfer Rate

The calculation of the mass transfer rate for the constant rate period follows Equations (21), (23), and (24) and assumes that the contact times are long and that the solid dissolution is unimportant in the liquid film containing the reaction zone. Similarly, the falling rate period mass transfer rate is calculated using Equations (26), (32), and (33). The same assumptions as for the constant rate period are made. The effect of H_2O counterdiffusion on the diffusivity of SO_2 through the gas film is checked during both periods using Equation (2.35) given by Treybal (1968). As verified in Appendix D, the contact times for both drying periods are to be considered long and the solid dissolution is unimportant in the reaction zone liquid film.

SO_2 Removal Rate

The rate of removal of SO_2 during either the constant or falling rate drying periods is the product of the respective mass transfer rate, contact time, and the total surface area of the liquid phase of the drops or within the particles.

Average SO_2 Concentration

Immediately following the calculation of the SO_2 removal rate the dry scrubbing program calculates a new SO_2 concentration. The average between the inlet and the new SO_2 concentration is compared to the SO_2 concentration used to calculate the gas phase physical properties and the mass transfer rate. If the average concentration

differs significantly from the SO_2 concentration used in the calculations, the calculations are repeated using the average SO_2 concentration as the new SO_2 concentration for physical property and mass transfer rate calculations. This procedure obtains an average mass transfer rate for both the constant and falling rate drying periods.

Efficiency Calculations

When the average SO_2 concentration is approximately equal to the SO_2 concentration used for calculating the gas phase physical properties and the mass transfer rate the dry scrubbing program calculates the SO_2 removal efficiency for the constant rate period or the entire dry scrubbing process. Efficiency is simply the difference between the inlet SO_2 flowrate and the outlet SO_2 flowrate divided by the inlet SO_2 flowrate. The outlet SO_2 flowrate can be from either the constant rate period or the falling rate period.

Gas Phase Composition Adjustment and Conversion from Drops to Particles

Following the calculation for efficiency for the constant rate period the flue gas composition is adjusted to account for the SO_2 removed and the increased water concentration. The conversion from drops to particles is based on the size of spray dryer product and the total volume available if each drop were dried to the final moisture content. In other words, each drop is theoretically dried to the final moisture content. The volume of this dried drop is calculated and divided into equal volumes with a diameter of 7.8 μm . The diameter

of 7.8 μm was found by Davis (1983) to be relatively constant for tests where the stoichiometric ratio ranged between 0.7 and 1.7. Knowing the ratio of drop volume to the dried volume, the drops per second are converted to particles per second by simple multiplication.

Results Analysis

The dry scrubbing program concludes by calculating the percent difference between the predicted and the experimental efficiencies and finds the average percent difference. A perfect model would have the predicted and experimental values falling on a straight line plot with a slope of one and an intercept of zero. Therefore a linear regression model tests the linear correlation of the predicted efficiencies with the experimental efficiencies. The regression model gives the slope and intercept of the best fit line.

CHAPTER IV

EXPERIMENTAL DATA

The experimental data used for this model falls into nine categories as shown by Table 3. This breakdown, however, puts less than three data points into each category. Therefore the data are categorized only according to the temperature approach to saturation in the remainder of this paper.

The data were obtained from a 1000 ACFM pilot scale spray dryer located at The University of Tennessee steam plant. Rotary atomization was used for the droplet formation and a fabric filter removed the fine particles before atmospheric discharge. A complete description of the system and experimental apparatus is given by Davis and Reed (1982).

The inlet SO_2 for all tests was held within a range of 1723-2183 ppm and averaged 1972 ppm. The stoichiometric ratio of lime to SO_2 was varied from 0.25 to 1.93. The actual data for this study are found on pages 53-88 of Davis and Reed (1982).

TABLE 3
EXPERIMENTAL DATA CATEGORIES

Inlet Temperature Range (°F)	Temperature Approach to Saturation (°F)
253-261	20 ± 2
253-261	25 ± 2
253-261	35 ± 3
270-284	20 ± 2
270-284	25 ± 2
270-284	35 ± 3
287-299	20 ± 2
287-299	25 ± 2
287-299	35 ± 3

CHAPTER V

CORRELATION OF DATA AND DISCUSSION OF RESULTS

Two unknowns remained after developing the rate equations for both the constant and falling rate periods. The effective diffusivity for the ash layer was completely unknown and only a range for the dissolution mass transfer coefficient was known. Therefore the dry scrubbing program was modified to choose a value for the dissolution mass transfer coefficient and iterate around the falling rate period searching for a value for the ratio of porosity to tortuosity (B) which made the predicted overall efficiency approximately equal to the experimental efficiency. The values of B were plotted as a function of stoichiometric ratio and temperature approach to saturation. There was no visible effect by the temperature approach to saturation parameter; however, there was a definite relationship to stoichiometric ratio. As the ratio was increased the effective diffusivity decreased. Appendix E contains the program for searching for B, the results, and the plots of the results. Applying linear regression to the data, expressions for B as a function of stoichiometric ratio were developed for the range of solid dissolution mass transfer coefficients. The FORTRAN expressions developed for B are given in Table 4.

The expressions in Table 4 were then put into the dry scrubbing program. The program was run for each value of the solid dissolution

TABLE 4
 FORTRAN EXPRESSIONS FOR "B" DEVELOPED BY LINEAR REGRESSION

$k_S \times 10^5$ (m/sec)	B =	R^2	Number of Points
2.0	10.**(-.4607*SR-1.087)	.7949	18
3.0	10.**(-.4602*BR-1.123)	.7866	19
4.0	10.**(-.4199*SR-1.215)	.7149	20
5.0	10.**(-.4089*SR-1.260)	.6384	22
6.0	10.**(-.3936*SR-1.313)	.5941	22
7.0	10.**(-.3308*SR-1.426)	.4397	23
8.0	10.**(-.3511*SR-1.427)	.4609	22

mass transfer coefficient (k_g) shown in Table 4 and the results are contained in Appendix F. Table 5 contains the four variables used for selecting the best model. The variables are: (1) the average percent difference between the predicted and experimental efficiencies, (2) the slope of the best fit line determined by linear regression, (3) the intercept also determined by linear regression, and (4) the R^2 value for the degree of linear correlation. The average percent difference should equal zero; the slope should equal one; the intercept should equal zero; and the R^2 value should equal one for a perfect model. Table 6 ranks each test variable according to the above stated criteria. Each value of k_g was then scored by adding its rank for each test variable. The scores are shown in Table 7. The best dry scrubbing model is that using a k_g value of 6.0×10^{-5} m/sec and its respective expression for B given in Table 4. This model was described earlier and is contained in Appendix C. Figure 12 illustrates the dry scrubbing model performance using the best value for k_g and the respective expression for B.

It has been realized that the dry scrubbing efficiency increases by increasing the stoichiometric ratio and decreasing the temperature approach to saturation. The dry scrubbing model developed here responds to an increase in stoichiometric ratio by increasing the number of particles per second generated at the beginning of the falling rate period. This increase in particles increases the amount of available surface for SO_2 absorption and consequently increases the amount of SO_2 removed. Figure 13 shows this effect and

TABLE 5
MODEL SELECTION VARIABLES

$k_s \times 10^5$ (m/sec)	Average	Slope	Intercept	R^2
2.0	15.5934	.906	3.94	.7952
3.0	15.7486	.928	2.69	.7936
4.0	15.3021	.934	3.03	.8020
5.0	15.3838	.954	2.00	.8031
6.0	15.4658	.966	1.49	.8040
7.0	15.3604	.946	3.02	.7988
8.0	15.6368	.977	1.13	.7985

TABLE 6
MODEL RANKINGS

Rank	Average	Slope	Intercept	R^2
1	4.0	8.0	8.0	6.0
2	7.0	6.0	6.0	5.0
3	5.0	5.0	5.0	4.0
4	6.0	7.0	3.0	7.0
5	2.0	4.0	7.0	8.0
6	8.0	3.0	4.0	2.0
7	3.0	2.0	2.0	3.0

TABLE 7
MODEL RANKING SCORES

$k_S \times 10^5$ (m/sec)	Score
6.0	9
5.0	11
8.0	13
7.0	15
4.0	15
3.0	24
2.0	25

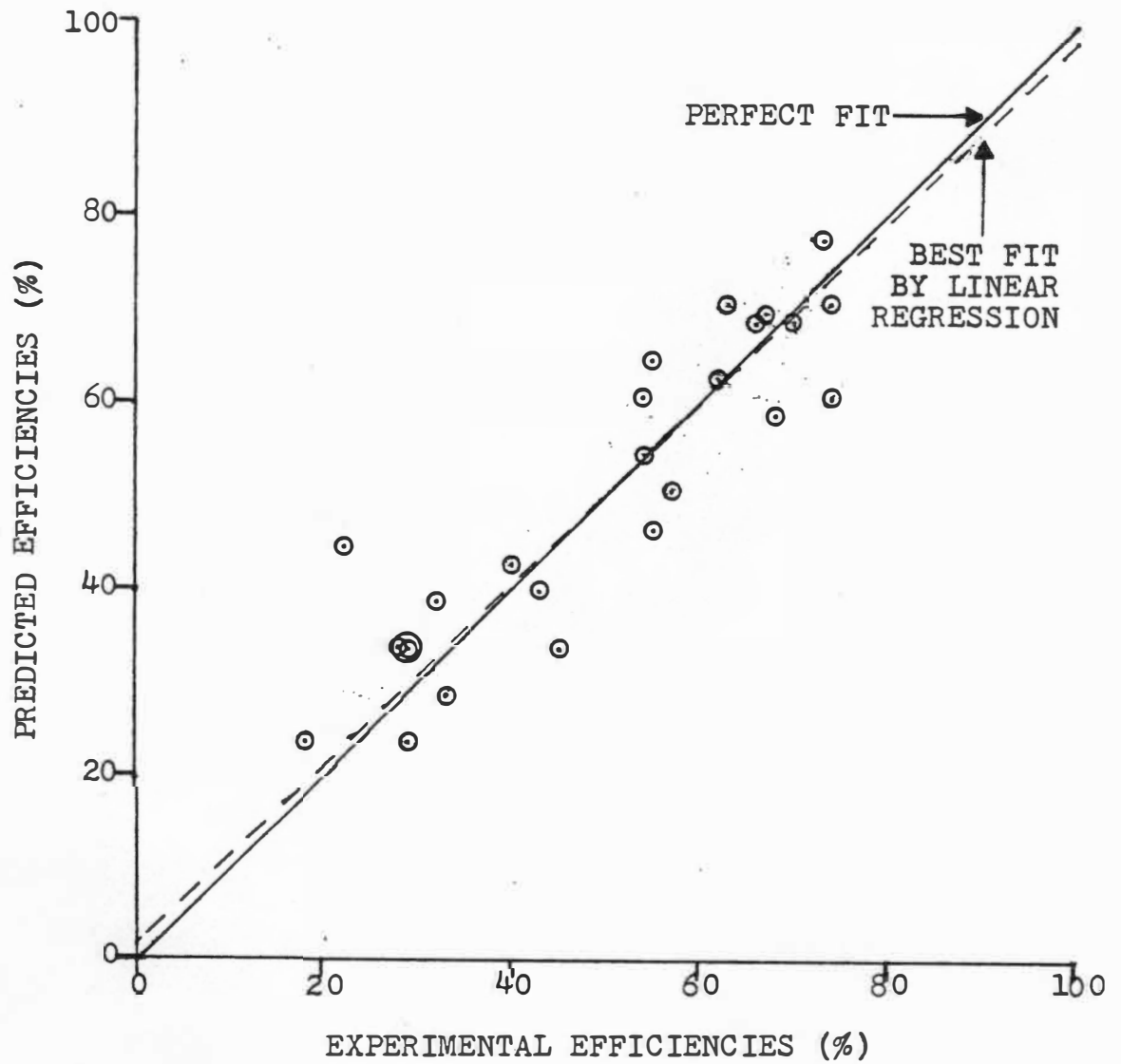


Figure 12. Final computer model performance.

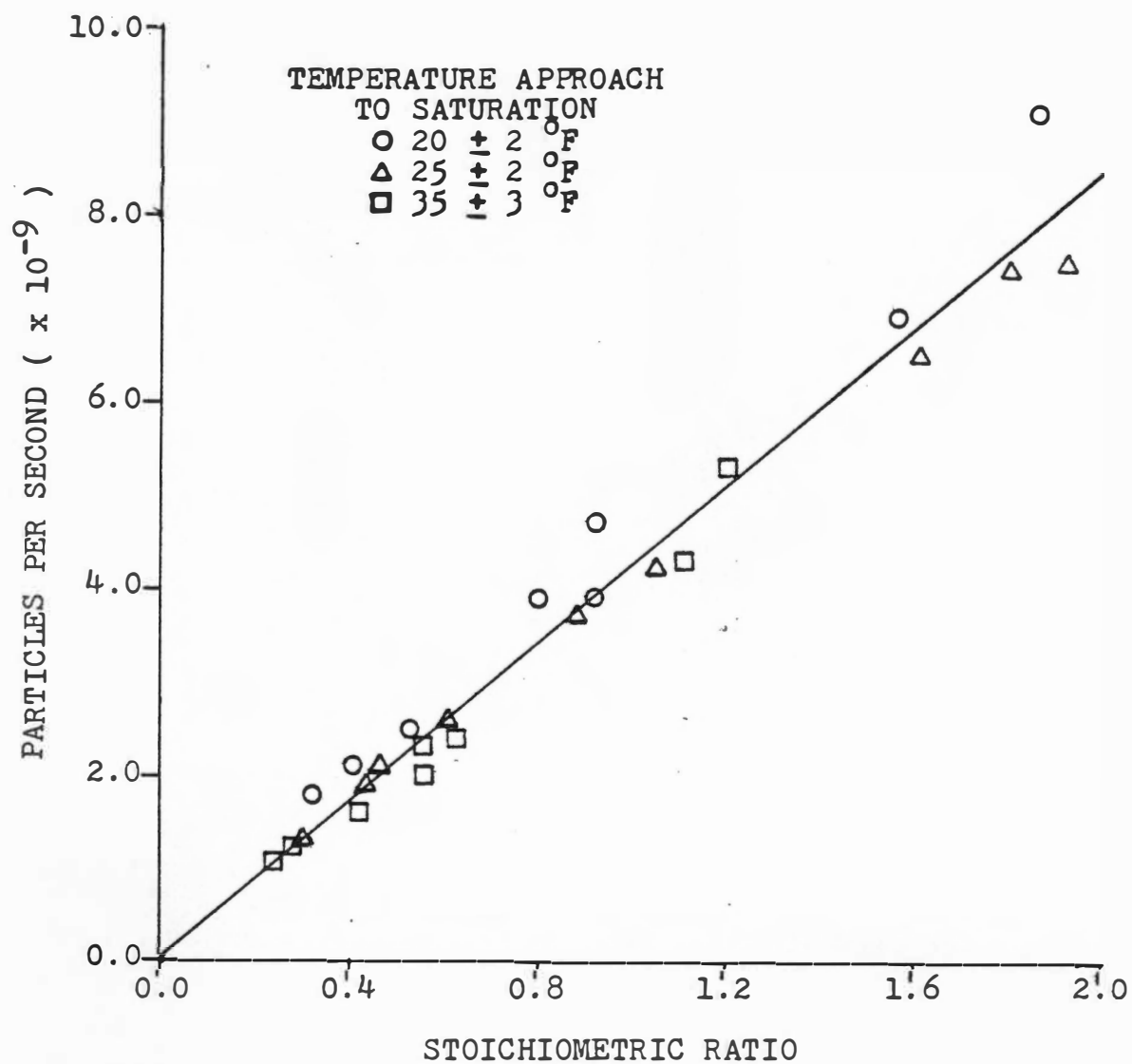


Figure 13. Effect of stoichiometric ratio on the generation of particles.

illustrates that the temperature approach to saturation does not have a visible effect on the generation of particles. The effect of reducing the temperature approach to saturation on the falling rate period contact time is illustrated by Figure 14. As the temperature approach is reduced the contact time during the falling rate period increases which directly increases the amount of SO_2 removed.

Figure 15 shows the combined effect of temperature approach to saturation and stoichiometric ratio on the efficiencies for the constant rate period. The data do not indicate an effect caused by the temperature approach variable, but clearly indicate there is an increase in efficiency with the stoichiometric ratio. Figure 16 clearly shows that as the temperature approach to saturation is decreased and as the stoichiometric ratio is increased the predicted efficiencies increase.

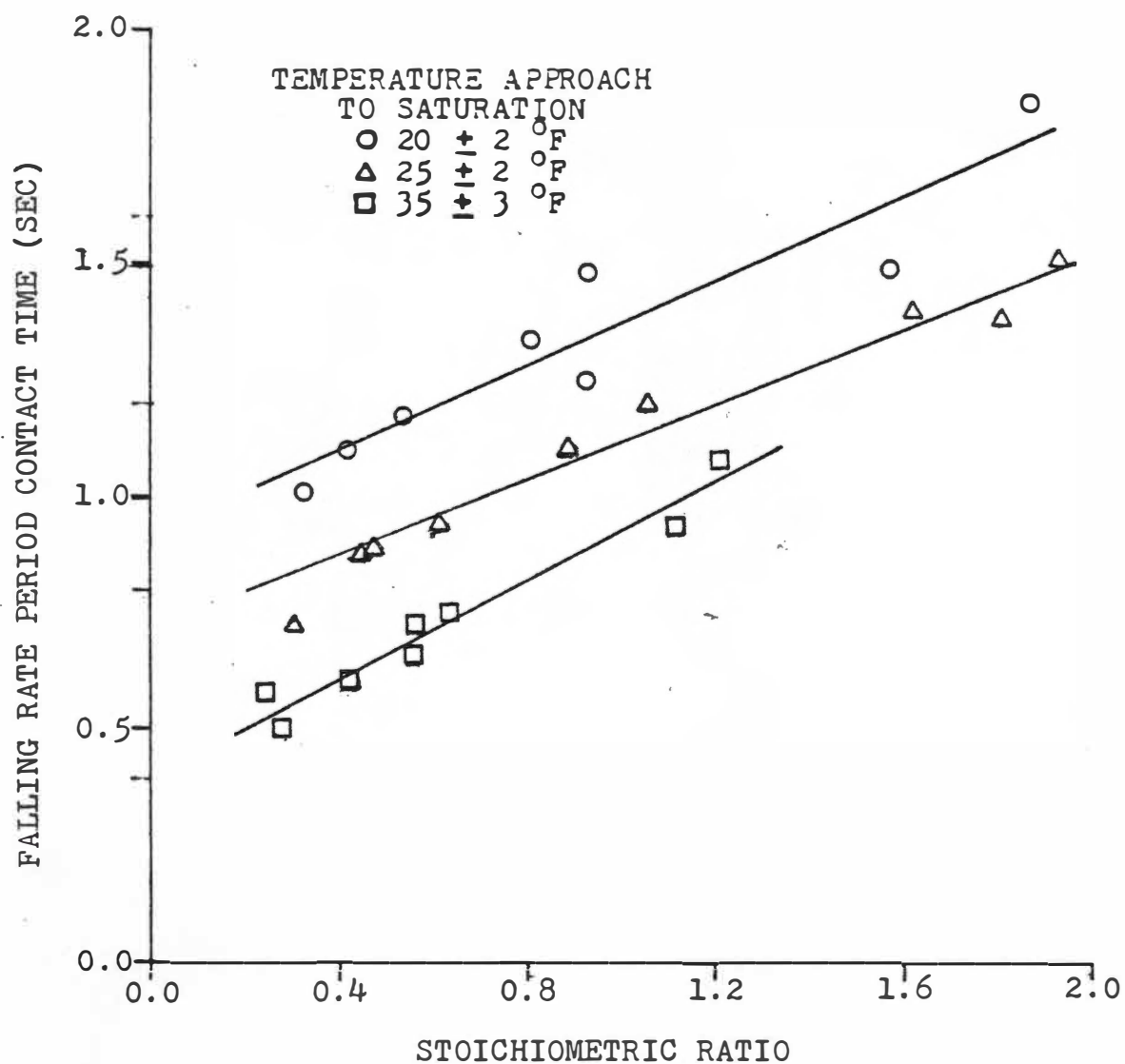


Figure 14. Effect of temperature approach to saturation on the falling rate period contact time.

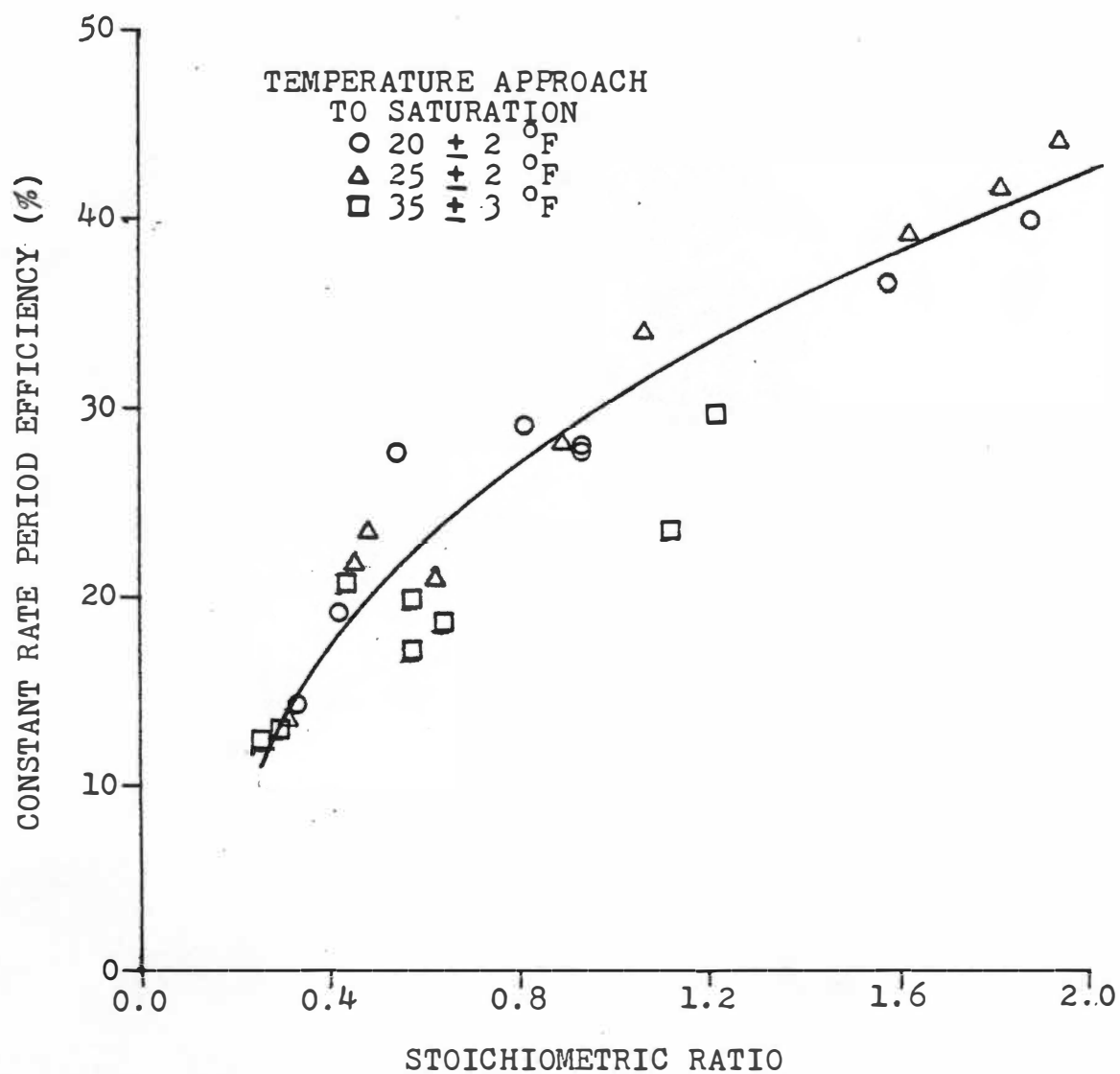


Figure 15. Effect of stoichiometric ratio and temperature approach to saturation on the constant rate period SO_2 removal efficiency.

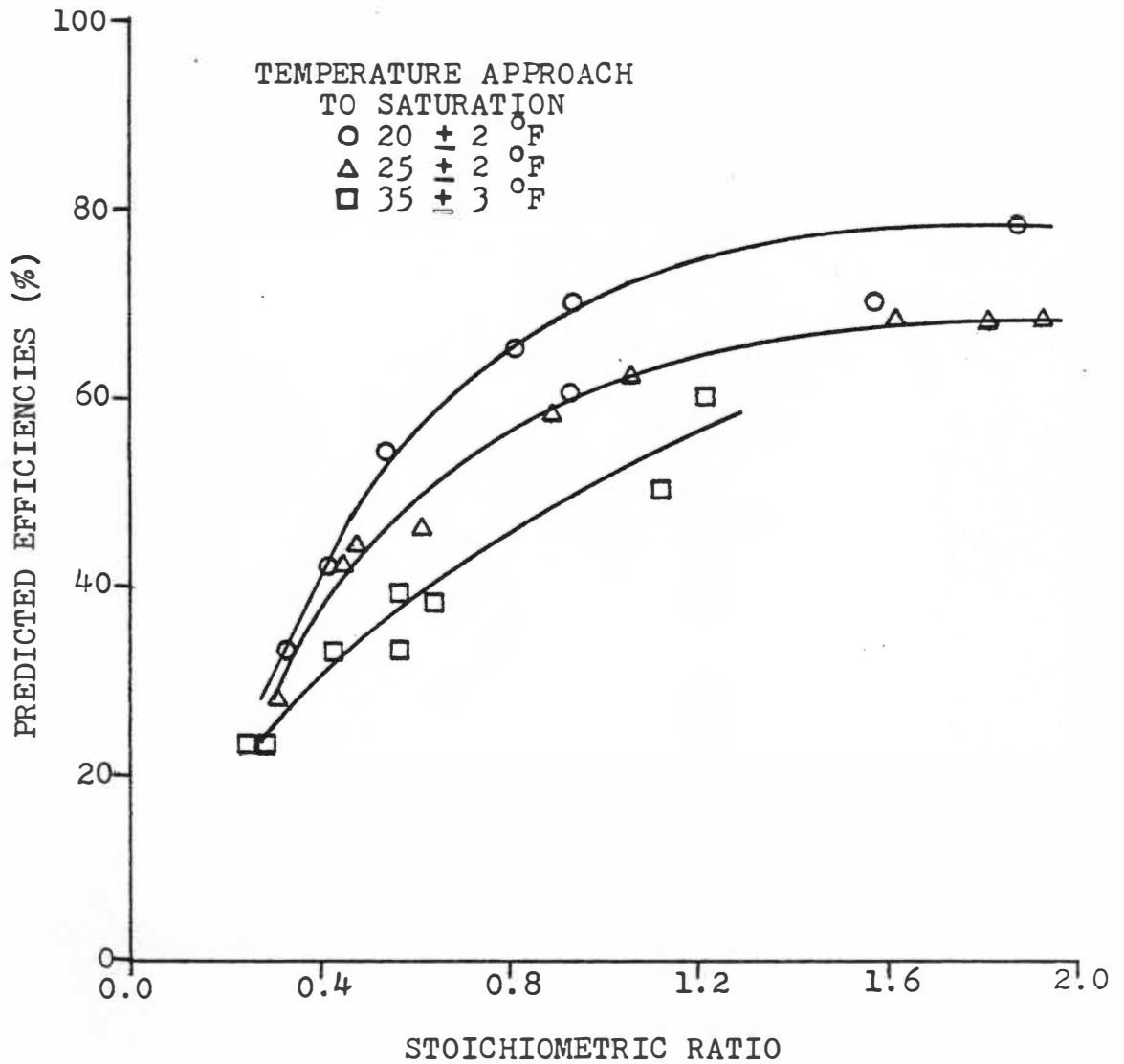


Figure 16. Effect of stoichiometric ratio and temperature approach to saturation on the overall SO₂ removal efficiencies.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following conclusions can be drawn from the results of this study:

1. The model adequately represents the experimental results over the range of variables studied.
2. The model adequately represents the effects (a) temperature approach to saturation and (b) stoichiometric ratio have on dry scrubbing efficiency.
3. The model can serve as the foundation for the development of more rigorous expressions for the dry scrubbing process.

Recommendations

The following recommendations are made:

1. A detailed sensitivity analysis of the current model should be performed. The minimum number of variables which should be considered are as follows:
 - a. product density
 - b. product diameter
 - c. temperature surrounding the drops
 - d. temperature surrounding the particles
 - e. the inlet gas composition

- f. the inlet slurry temperature
 - g. temperature of the drop
 - h. temperature of the liquid core
2. The model should be refined to account for:
- a. product recycle
 - b. fly ash alkalinity
 - c. reaction with CO_2
3. A detailed heat transfer study of the dry scrubbing system producing a model which predicts the lime feed rate as a function of:
- a. atmospheric conditions
 - b. inlet SO_2 concentration
 - c. stoichiometric ratio
 - d. inlet temperature
 - e. temperature approach to saturation
 - f. inlet flow and composition
- is recommended.
4. A coupling of the computer model listed by Davis and Reed (1982), this model, and a heat transfer model is recommended, thereby producing a totally dynamic dry scrubbing model which could be applied for scale up purposes.

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LIST OF REFERENCES

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APPENDIXES

APPENDIX A

DERIVATION OF THE CONSTANT RATE PERIOD MODEL

$$-r_A = k_{AG}(P_A - P_{Ai}) \quad (A-1)$$

$$-r_A = k_{AL}(C_{Ai} - 0) \frac{x_o}{x} \quad (A-2)$$

$$-r_A = k_{BL}(C_B - 0) \frac{x_o}{x_o - x} \quad (A-3)$$

$$-r_A = k_S(C_S - C_B)A_P V_P \quad (A-4)$$

$$P_{Ai} = H_A C_{Ai} \quad (A-5)$$

$$\frac{k_{AL}}{k_{BL}} = \frac{D_{AL}/x_o}{D_{BL}/x_o} = \frac{D_{AL}}{D_{BL}} \quad (A-6)$$

Rearranging A-4, A-1, and A-2 yields:

$$C_B = C_S + \frac{r_A}{k_S A_P V_P} \quad (A-7)$$

$$P_{Ai} = P_A + \frac{r_A}{k_{AG}} \quad (A-8)$$

$$x = \frac{-k_{AL} C_{Ai} x_o}{r_A} \quad (A-9)$$

Substituting x_o from A-6 into A-8 yields:

$$x = \frac{-C_{Ai} D_{AL}}{r_A} \quad (A-10)$$

Substituting x_o from A-6 and A-10 into A-3 yields:

$$-r_A = \frac{C_B^D D_{BL}}{\frac{D_{BL}}{k_{BL}} + \frac{C_{Ai}^D D_{AL}}{r_A}} \quad (A-11)$$

which equals:

$$\frac{-r_A^D D_{BL}}{k_{BL}} - C_{Ai}^D D_{AL} = C_B^D D_{BL} \quad (A-12)$$

Substituting A-5 into A-8 yields:

$$C_{Ai} = \frac{P_A}{H_A} + \frac{r_A}{k_{AG} H_A} \quad (A-13)$$

Combining A-12, A-13, and A-7 yields:

$$\frac{-r_A^D D_{BL}}{k_{BL}} - \frac{D_{AL} P_A}{H_A} - \frac{D_{AL} r_A}{k_{AG} H_A} = D_{BL} C_s + \frac{D_{BL} r_A}{k_{SAPV_P}} \quad (A-14)$$

By rearranging A-14 we get:

$$-r_A \left(\frac{D_{BL}}{k_{BL}} + \frac{D_{AL}}{k_{AG} H_A} + \frac{D_{BL}}{k_{SAPV_P}} \right) = \frac{D_{AL} P_A}{H_A} + D_{BL} C_s \quad (A-15)$$

Dividing through by D_{AL} , substituting A-6 and rearranging yields:

$$-r_A = \frac{\frac{P_A}{H_A} + \frac{D_{BL} C_s}{D_{AL}}}{\frac{1}{k_{AG} H_A} + \frac{1}{k_{AL}} + \frac{D_{BL}}{D_{AL} k_{SAPV_P}}} \quad (A-16)$$

APPENDIX B

DERIVATION OF THE FALLING RATE PERIOD MODEL

$$-A = -\frac{N_A}{4\pi} = k_{AG}(P_A - P_{As})R_P^2 \quad (B-1)$$

$$-A = -\frac{N_A}{4\pi} = \frac{R_P R_C D_E (P_{As} - P_{Ai})}{(R_P - R_C)(RT)} \quad (B-2)$$

$$-A = -\frac{N_A}{4\pi} = k_{AL}(C_{Ai} - 0) \frac{x_o}{x} R_C^2 \quad (B-3)$$

$$-A = -\frac{N_A}{4\pi} = k_{BL}(C_B - 0) \frac{x_o}{x_o - x} R_C^2 \quad (B-4)$$

$$-A = -\frac{N_A}{4\pi} = k_{SPA} V_P (C_s - C_B) R_C^2 \quad (B-5)$$

$$P_{Ai} = H_A C_{Ai} \quad (B-6)$$

$$\frac{k_{AL}}{k_{BL}} = \frac{D_{AL}/x_o}{D_{BL}/x_o} = \frac{D_{AL}}{D_{BL}} \quad (B-7)$$

Rearranging B-5, B-3, and B-1 yields:

$$C_B = C_s + \frac{A}{k_{SPA} V_P R_C^2} \quad (B-8)$$

$$x = -\frac{k_{AL} C_{Ai} x_o R_C^2}{A} \quad (B-9)$$

$$P_{As} = P_A - \frac{A}{R_P^2 k_{AG}} \quad (B-10)$$

Substituting x_o from B-7 into B-9 yields:

$$x = - \frac{C_{Ai} D_{AL} R_c^2}{A} \quad (B-11)$$

Substituting B-11 and x_0 from B-7 into B-4 yields:

$$-A = \frac{C_B D_{BL} R_c^2}{\frac{D_{BL}}{k_{BL}} - \frac{C_{Ai} D_{AL} R_c^2}{A}} \quad (B-12)$$

which equals:

$$-\frac{A D_{BL}}{k_{BL}} - C_{Ai} D_{AL} R_c^2 = C_B D_{BL} R_c^2 \quad (B-13)$$

Substituting B-10 into B-2 and rearranging yields:

$$-\frac{A(R_P - R_c)(RT)}{R_P R_c D_E} = P_A - \frac{A}{R_P^2 k_{AG}} - P_{Ai} \quad (B-14)$$

Substituting B-6 into B-14 and rearranging yields:

$$C_{Ai} = \frac{A(R_P - R_c)(RT)}{R_P R_c D_E H_A} - \frac{P_A}{H_A} - \frac{A}{R_P^2 k_{AG} H_A} \quad (B-15)$$

Substituting B-15 and B-8 into B-13 yields:

$$\begin{aligned} -\frac{A D_{BL}}{k_{BL}} - \frac{A D_{AL} R_c^2 (R_P - R_c)(RT)}{R_P R_c D_E H_A} - \frac{P_A D_{AL} R_c^2}{H_A} - \frac{A D_{AL} R_c^2}{R_P^2 k_{AG} H_A} \\ = C_B D_{BL} R_c^2 + \frac{A D_{BL} R_c^2}{k_{SAP}^2} \end{aligned} \quad (B-16)$$

Rearranging and simplifying yields:

$$\begin{aligned}
 & -\frac{AD_{BL}}{k_{AL}} - \frac{D_{AL} R_c (R_P - R_c) (RT)}{R_P D_{EH_A}} - \frac{D_{AL} R_c^2}{R_c^2 k_{AG_H_A}} - \frac{D_{BL}}{k_{S_P}^A V_P} \\
 & = \frac{P_A D_{AL} R_c^2}{H_A} + C_s D_{BL} R_c^2 . \quad (B-17)
 \end{aligned}$$

Dividing through by D_{AL} , substituting B-7 and rearranging yields:

$$\begin{aligned}
 -r_A = -\frac{N_A}{4\pi R_c^2} = & \frac{\frac{P_A}{H_A} + \frac{D_{BL} C_s}{D_{AL}}}{\frac{R_c^2}{R_P^2 k_{AG_H_A}} + \frac{R_c (R_P - R_c) (RT)}{R_P D_{EH_A}} + \frac{1}{k_{AL}} + \frac{D_{BL}}{D_{AL} k_{S_P}^A V_P}} . \quad (B-18)
 \end{aligned}$$

APPENDIX C

FINAL COMPUTER MODEL WITH RESULTS

```

C
C      MODEL
C
      DIMENSION EFF(29), EFFSD(29), PERDIF(29)
      REAL LMTDC, KD, LMTDF, MWAVG, NH2O, KG, NSO2, MSO2, NSO2RX,
      SMCCA, N2PS, KL, KGW, KS
      INTEGER RUN, PAGE
101  READ(5,34)RUN, PAGE
      34  FORMAT(2I3)
      IF(RUN.EQ.999)GO TO 100
      WRITE(6,35)RUN, PAGE
      35  FORMAT('1',10X,'RUN = ',I3,5X,'PAGE NO. = ',I3)
      READ(5,1)YN2,YCO2,YO2,YH2O,YSO2
      1  FORMAT(5F8.6)
      READ(5,2)SO2ONC, TEMP1C, SLCONC, SCFM1C
      2  FORMAT(F6.1,F5.1,F5.3,F5.1)
      READ(5,3)GPM,PBAR,SP1,SP2,TSLURR
      3  FORMAT(F5.3,F5.2,2F3.1,F5.1)
      READ(5,4)TEMP2,TW2,DROPDI,PRODDN
      4  FORMAT(2F5.1,E10.2,F6.1)
      READ(5,37)EFFSD(RUN),BW2
      37  FORMAT(F5.2,F8.6)
      YFIX=YH2O+YSO2
      YADJST=1.-YFIX
      YN2=(YADJST/.95)*YN2
      YCO2=(YADJST/.95)*YCO2
      YO2=(YADJST/.95)*YO2
      SLDEN=1000.+86.3795*SLCONC
      W1=6.3118/SLCONC-0.4545
      DELTAT=TEMP2-TW2

C
C      NUMBER OF DROPS ENTERING THE SYSTEM
C
      DPS=(GPM/((DROPDI)**3.))*1.204E-04
      WRITE(6,7)DPS
      7  FORMAT('0',5X,'DROPS PER SECOND = ',E14.6)

C
C      SPRAY DRYER OPERATING PRESSURE
C
      PT=(PBAR/29.921)-((SP1+SP2)/810.62)
      WRITE(6,8)PT
      8  FORMAT('0',5X,'OPERATING PRESSURE = ',F5.3,4X,'ATM')

C
C      MOLES OF GAS ENTERING THE SYSTEM
C
      GGASPS=SCFM1C*1.9545E-02
      YSO2I=YSO2
      SO2PS=GGASPS*YSO2
      SO2PSI=SO2PS
      SO2AVG=SO2PSI/2.
      N2PS=GGASPS*YN2
      CO2PS=GGASPS*YCO2
      O2PS=GGASPS*YO2
      H2OPS=GGASPS*YH2O
      WRITE(6,9)SO2PS
      9  FORMAT('0',5X,'MOLES OF SO2 PER SECOND = ',E14.6)

C
C      MOLES OF CA(OH)2 PER DROP
C
      TMCCA=SLCONC*2.137E+03

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```

CAPD=TMCCA*0.5236*(DROPDI**3.)
WRITE(6,44)CAPD
44 FORMAT('0',5X,'GM-MOLES OF CA(OH)2 PER DROP =',E14.6)
C
C
C   STIOCHIMETRIC RATIO CALCULATION
C
SR=CAPD*DPS/SO2PS
WRITE(6,107)SR
107 FORMAT('0',5X,'STOICHIOMETRIC RATIO = ',F6.4)
C
C
C   FINAL MOISTURE CONTENT APPROXIMATION
C
GWATPS=GPM*SLDEN*6.3115E-02*W1/(1.+W1)
GCOHPS=(GPM*SLDEN*6.3115E-02)-GWATPS
DTSLUR=(TW2-TSLURR)/1.8
HWAT=DTSLUR*GWATPS/1000.
HCOH=DTSLUR*(21.4/74.1)*GCOHPS/1000.
HSLUR=HWAT+HCOH
CP=((29.141*YN2)+(38.166*YCO2)+(29.526*YO2)+(33.727*YH2O))
$*2.39E-04
HGAS=CP*GGASPS*(TEMP1C-TEMP2)/1.8
HVAP=-0.3290*TW2+608.2879
HRISE=.22722*DELTAT
W3=4.4732E+04/(DELTAT**4.3463)
W2=W3/(1.-W3)
WVAP=(W1-W2)*GCOHPS/1000.
HEAT=(HVAP*WVAP)+(HRISE*WVAP)+HSLUR-HGAS
DC=DROPDI*((SLDEN/PRODDN)*((1.+W2)/(1.+W1)))**((1./3.))
WC=((SLDEN-158.3354*SLCONC)-1000.)/(1000.*
$(DC/DROPDI)**3.)/(158.3354*SLCONC)
WRITE(6,190)DELTAT
190 FORMAT('0',5X,'TEMPERATURE APPROACH TO SATURATION = ',
$F5.1,' DEG F')
AVGDEN=(SLDEN+PRODDN)/2.
KD=8.64E-05*((TW2-32.)/1.8)+273.)-1.196E-02
TSLURR=(TSLUR-32.)/1.8
TEMP1C=(TEMP1C-32.)/1.8
TEMP2=(TEMP2-32.)/1.8
TW2=(TW2-32.)/1.8
T=TW2
C
C
C   AVERAGE DENSITY CALCULATIONS
C
WCAVG=(W1+WC)/2.
WFAVG=(WC+W2)/2.
SLCC=6.3118/(WCAVG+.4545)
SLCF=6.3118/(WFAVG+.4545)
SLDC=1000.+86.3795*SLCC
SLDF=1000.+86.3795*SLCF
C
C
C   CRITICAL TEMPERATURE ESTIMATION
C
WVAPC=(W1-WC)*GCOHPS/1000.
HEATC=((W1-WC)/(W1-W2))*HEAT
C=CP*GGASPS
A=.22722*1.8*WVAPC
TEMPC=(HEATC+C*TEMP1C-HVAP*WVAPC+A*TW2-HSLUR)/(A+C)
WRITE(6,63)TEPC
63 FORMAT('0',5X,'CRITICAL TEMPERATURE =',F6.2,2X,'DEG C')
C

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C      CONSTANT RATE PERIOD CALCULATION
C
C      LMTDC=((TEMP1C-TEMPC)-(TW2-TSLURR))/
$ALOG((TEMP1C-TEMPC)/(TW2-TSLURR))
C      TC=HVAP*AVGDEN*((DROPDI)**2.-(DC)**2.)*3600./((8.*KD*LMTDC)
C
C      FALLING RATE PERIOD CALCULATION
C
C      LMTDF=(TEMPC+TEMP2)/2.-TW2
C      TF=HVAP*PRODDN*DC**2.*(WC-W2)*3600./((12.*KD*LMTDF)
C
C      RESULTS FROM TIME PERIOD CALCULATIONS
C
C      WRITE(6,5)
5      FORMAT(1,5X,'CONSTANT RATE PERIOD',5X,'FALLING RATE PERIOD')
C      WRITE(6,6)TC,TF
C      6      FORMAT(1,9X,F5.3,4X,'SEC',13X,F5.3,4X,'SEC')
C
C      CA++ DIFFUSION IN WATER - WILKE/CHANG EQN.
C
C      DOCA=4.781E-12*(T+273.)/(1.002*10.**((1.3272*(20.-T)-
$0.001053*(T-20.))**2.)/(T+105.)))
C      WRITE(6,25)DOCA
25      FORMAT(1,5X,'CA++ DIFFUSION IN WATER = ',E12.5,4X,'M2/SEC')
C
C      SO2 DIFFUSION IN WATER - WILKE/CHANG EQN.
C
C      DOSO2=5.1735E-12*(T+273.)/(1.002*10.**((1.3272*(20.-T)-
$0.001053*(T-20.))**2.)/(T+105.)))
C      WRITE(6,26)DOSO2
26      FORMAT(1,5X,'SO2 DIFFUSION IN WATER = ',E12.5,4X,'M2/SEC')
C
C      GAS PHASE PHYSICAL PROPERTY ESTIMATIONS
C
C      DENSITY OF FLUE GAS
C
C      WRITE(6,45)
45      FORMAT(1,27X,'CONSTANT RATE PERIOD VALUES')
C      AVGDIA=((DROPDI**3.)+(DC**3.))/2.**(1./3.)
C      DROPDI=AVGDIA
C      I1=0
C      I11=0
43      MWAVG=YN2*28.02+YC02*44.01+Y02*32.+YH2O*18.016+YSO2*64.06
C      FGDEN=(PT*MWAVG/(82.057*(T+273.)))*1000.
10      FORMAT(1,5X,'AVERAGE MOLECULAR WEIGHT OF FLUE GAS = ',
$F5.2,X,'GM/GM-MOLE')
11      FORMAT(1,5X,'DENSITY OF FLUE GAS = ',F6.4,X,'KG/M3')
C
C      VISCOSITY OF FLUE GAS
C
C      UN2=0.0208*((T+273.)/373.)**(3./2.)*(486.484/(T+386.484))
C      UC02=0.0178*((T+273.)/373.)**(3./2.)*(658.915/(T+558.915))
C      U02=0.0239*((T+273.)/373.)**(3./2.)*(505.3/(T+405.3))
C      UH2O=0.0124*((T+273.)/373.)**(3./2.)*(921.31/(T+821.31))
C      USO2=0.0163*((T+273.)/373.)**(3./2.)*(759.61/(T+659.61))
C      UMIK=((YN2*5.2934*UN2)+(YC02*6.6340*UC02)+(Y02*5.6569*U02)+
$(YH2O*4.2445*UH2O)+(YSO2*8.0037*USO2))/((YN2*5.2934)+
$(YC02*6.6340)+(Y02*5.6569)+(YSO2*8.0037)+(YH2O*4.2445))/1000.
12      FORMAT(1,5X,'VISCOSITY OF FLUE GAS = ',E11.4,X,'KG/M.SEC')
C

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```

C
C
      GAS PHASE COMPONENT DIFFUSIVITIES
      DH2ON2=3.535E-05*((T+273.)/373.)**(7./4.)/PT
      DH2OCO=2.505E-05*((T+273.)/373.)**(7./4.)/PT
      DH2O02=3.525E-05*((T+273.)/373.)**(7./4.)/PT
      DH2OSO=1.979E-05*((T+273.)/373.)**(7./4.)/PT
      DSO2N2=2.090E-05*((T+273.)/373.)**(7./4.)/PT
      DSO2CO=1.466E-05*((T+273.)/373.)**(7./4.)/PT
      DSO2O2=2.044E-05*((T+273.)/373.)**(7./4.)/PT
      DSO2H2=1.979E-05*((T+273.)/373.)**(7./4.)/PT

C
C
      TERMINAL VELOCITY CALCULATION

      FORCE=5.1348*SLDEN*(DROPDI)**3.
      VINFIN=((2.*UMIX)/(FGDEN*DROPDI))*((9.+(FGDEN*FORCE)/
$ (3.1416*(UMIX)**2.))**((1./2.))-3.0)
      RET=(FGDEN*DROPDI*VINFIN)/UMIX
      IF(RET.LE.10.)GO TO 13
      VINFIN=((4.8*UMIX)/(FGDEN*DROPDI))*((447.+(FGDEN*FORCE)/
$ (3.1416*(UMIX)**2.))**((1./2.))-20.4)
      RET=(FGDEN*DROPDI*VINFIN)/UMIX
      IF(RET.LE.700.)GO TO 14
      GO TO 15
14  IF(RET.GT.10.)GO TO 13
15  VINFIN=(2.4/DROPDI)*(FORCE/FGDEN)**(1./2.)
      RET=(FGDEN*DROPDI*VINFIN)/UMIX
13  CONTINUE
27  FORMAT('O',5X,'DROP TERMINAL VELOCITY = ',F7.4,X,'M/SEC')
28  FORMAT('O',5X,'DROP REYNOLDS NUMBER = ',F7.5)

C
C
      GAS PHASE MASS TRANSFER CALCULATION
      DH2OMX=(1.0-YH2O)/((YN2/DH2ON2)+(YCO2/DH2OCO)+(YO2/DH2O02)+
$ (YSO2/DH2OSO))
      PSAT=EXP(-7.2465822E+03/(T+273.))+77.641232+(5.74471242
$ E-03*(T+273.))+(-8.2470402*ALOG(T+273.)))/101325.
      YSAT=PSAT/PT
      YH2OLM=(YSAT-YH2O)/ALOG(YSAT/YH2O)
      KGW=(DH2OMX/(DROPDI*(1.-YH2OLM)))*(2.0+0.6*(UMIX/(FGDEN*DH2OMX))**
$ (1./3.))*((DROPDI*VINFIN*FGDEN)/UMIX)**(1./2.))/(82.057E-06*(T+273.
$ ))
      NH2O=KGW*(PSAT-PT*YH2O)
      DSO2MX=(1.0-YSO2)/((YN2/DSO2N2)+(YCO2/DSO2CO)+(YO2/DSO2O2)+
$ (YH2O/DSO2H2))
      IF(III.GT.0)GO TO 204

C
C
      RATE EQUATION FOR INSTANTANEOUS REACTION

      IF(T.LE.30.)HENRY=(10.**((-1285.85/(T+273.))+8.805))*133.32
      IF(T.LE.30.)GO TO 62
      IF(T.GE.52.)HENRY=((29.597*T)-657.2676)*10000.
      IF(T.GE.52.)GO TO 62
      HENRY=((19.265*T)-92.6574)*10000.
62  CONTINUE
84  FORMAT('O',5X,'HENRYS LAW CONSTANT = ',E12.5,' ATM/MOLE FRAC')
      CCA=10.0*((-0.0011*T)+0.185)
      MCCA=CCA*13.495
      XA=PT*YSO2/(HENRY/101323.2)
      HC=HENRY*(1.-XA)/5.624E+09
      KL=22.5*DSO2/DROPDI

```

```

AP=5.3476E+03*SLDC/(1.+WCAVG)
VP=DRODPI/6.
KS=6.0E-05
DO 17 I=1,200
KG=(DSO2MX/(DRODPI*(1.-YSO2)))*(2.0+0.6*(UMIX/(FGDEN*DSO2MX))**(1.
$/3.))*((DRODPI*VINFIN*FGDEN)/UMIX)**(1./2.))/(82.057E-06*(T+273.))
GG=1./(HC*KG)
DD=1./KL
EE=DOCA/(DOSO2*KS*AP*VP)
NSO2RX=((DOCA*MCCA/DOSO2)+(PT*YSO2/HC))/(GG+DD+EE)
AAA=KG*PT*YSO2
BBB=KL*DOCA*MCCA/DOSO2
IF(AAA.LT.BBB)NSO2RX=AAA
DSO2C=(NSO2RX-YSO2*(NSO2RX-NH20))/((YN2*NSO2RX/DSO2N2)+(YCO2*
NSO2RX/DSO2CO)+(YO2*NSO2RX/DSO2O2)+((YH2O*NSO2RX)+(YSO2*NH20))/
SDSO2H2))
COMPAR=ABS((DSO2MX-DSO2C)/DSO2MX)
IF(COMPAR.LT.0.05)GO TO 18
DSO2MX=DSO2C
17 CONTINUE
WRITE(6,19)COMPAR
19 FORMAT('O',5X,'DSO2MX DOES NOT CONVERGE; COMPARISON = ',F6.4)
GO TO 20
18 CONTINUE
21 FORMAT('O',5X,'DSO2MX CONVERGES AFTER ',I3,' ITERATIONS;',
$' COMPARISON = ',F6.4)
20 CONTINUE
36 FORMAT('O',5X,'GAS PHASE DIFFUSIVITY OF SO2 = ',E12.5,2X,'M2/SEC')
23 FORMAT('O',5X,'GAS PHASE MASS TRANSFER COEFFICIENT = ',E12.5,X,
$'GM-MOLES/SEC.M2.ATM')
68 FORMAT('O',5X,'SO2 MASS TRANSFER',
$' = ',E12.4,2X,'GM-MOLES/SEC.M2')
SO2RXC=NSO2RX*TC*3.1416*(DRODPI**2.)*DPS
SO2PS=SO2PSI-SO2RXC
IF(SO2PS.LT.0.0)SO2PS=0.0
SO2AVC=(SO2PSI+SO2PS)/2.
GAS=N2PS+CO2PS+O2PS+H2OPS+SO2AVC
YAVG=SO2AVC/GAS
ERROR=ABS((YSO2-YAVG)/YSO2)
IF(ERROR.LE.0.02)GO TO 200
IF(II.EQ.200)GO TO 200
YN2=N2PS/GAS
YCO2=CO2PS/GAS
YO2=O2PS/GAS
YH2O=H2OPS/GAS
YSO2=YAVG
II=II+1
GO TO 43
200 CONTINUE
WRITE(6,10)MWAVG
WRITE(6,11)FGDEN
WRITE(6,12)UMIX
WRITE(6,27)VINFIN
WRITE(6,28)RET
WRITE(6,21)I,COMPAR
WRITE(6,36)DSO2MX
WRITE(6,23)KG
WRITE(6,84)HENRY
WRITE(6,48)KL
WRITE(6,52)KS

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```

SLDEN=DEN
III=III+1
R=DAVG/2.
VPART=4.18879*(R**3.)
VAVG=VPART/2.
RC=(VAVG/4.18879)**(1./3.)
GO TO 43
204 XA=PT*YSO2/(HENRY/101323.2)
KL=22.5*DOSO2/(2.*RC)
HC=HENRY*(1.-XA)/5.624E+09
VP=RC/6.
AP=5.3476E+03*SLDF/(1.+WFAVG)
DO 85 I=1,200
KG=(DSO2MX/(DROPDI*(1.-YSO2)))*(2.0+0.6*(UMIX/(FGDEN*DSO2MX))**
(1.
$/3.))*((DROPDI*VINFIN*FGDEN)/UMIX)**(1./2.))/(82.057E-06*(T+273.))
DE=B*DSO2MX
G=(RC**2.)/(HC*KG*(R**2.))
D=RC*(R-RC)*(82.057E-06*(T+273.))/(HC*DE*R)
E=DOCA/(DOSO2*KS*AP*VP)
F=1./KL
NSO2=((DOCA*MCCA/DOSO2)+(PT*YSO2/HC))/(G+D+E+F)
AA1=1./KG
AA2=((82.057E-06*(T+273.))*(R-RC)*R)/(DE*RC)
AAB=PT*YSO2/(AA1+AA2)
BBA=KL*DOCA*MCCA/DOSO2
IF(AAB.LT.BBA)NSO2=AAB
DSO2C=(NSO2-YSO2*(NSO2-NH2O))/((YN2*NSO2/DSO2N2)+(YCO2*NSO2/
$DSO2CO)+(YO2*NSO2/DSO2O2)+((YH2O*NSO2)+(YSO2*NH2O))/DSO2H2))
COMPAR=ABS((DSO2MX-DSO2C)/DSO2MX)
IF(COMPAR.LT.0.05)GO TO 89
DSO2MX=DSO2C
85 CONTINUE
WRITE(6,19)COMPAR
GO TO 90
89 CONTINUE
90 CONTINUE
92 FORMAT('O',5X,'SO2 MASS TRANSFER = ',
$E12.5,' GM-MOLES/SEC.M2')
SO2FR=NSO2*TF*12.56637*(RC**2.)*PPS
SO2PS=SO2PSI-SO2RXC-SO2FR
IF(SO2PS.LT.0.0)SO2PS=0.0
SO2AVG=(SO2PSI-SO2RXC+SO2PS)/2.
GAS=N2PS+CO2PS+O2PS+H2OPS+SO2AVG
YAVG=SO2AVG/GAS
ERROR=ABS((YSO2-YAVG)/YSO2)
IF(ERROR.LE.0.02)GO TO 205
IF(III.EQ.200)GO TO 205
YN2=N2PS/GAS
YCO2=CO2PS/GAS
YO2=O2PS/GAS
YSO2=YAVG
YH2O=H2OPS/GAS
III=III+1
GO TO 43
205 CONTINUE
WRITE(6,10)MWAVG
WRITE(6,11)FGDEN
WRITE(6,12)UMIX
WRITE(6,27)VINFIN
WRITE(6,28)RET

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```

48 FORMAT('0',5X,'LIQUID PHASE MASS TRANSFER COEFFICIENT = ',
$E12.5,' M/SEC')
WRITE(6,68)NSO2RX
IF(11.EQ.200)WRITE(6,202)ERROR
IF(11.LT.200)WRITE(6,203)11,ERROR
202 FORMAT('0',5X,'SOLUTION DOES NOT CONVERGE;',
$' ERROR = ',F8.6)
203 FORMAT('0',5X,'SOLUTION CONVERGES AFTER',13,' ITERATIONS;',
$' ERROR = ',F8.6)
EFMTRC=(SO2RXC/SO2PSI)*100.
EFFC=EFMTRC
EFFSR=SR*100.
IF(EFFC.GE.EFFSR)EFFC=EFFSR
EFMTRC=EFFC
IF(EFMTRC.GT.100.)EFMTRC=100.
WRITE(6,32)EFMTRC
IF((EFMTRC.EQ.EFFSR).OR.(EFMTRC.EQ.100.))EFF(RUN)=EFMTRC
IF((EFMTRC.EQ.EFFSR).OR.(EFMTRC.EQ.100.))GO TO 208
32 FORMAT('0',5X,'SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD',
$' = ',F8.4,2X,'%')
C
C FALLING RATE PERIOD MODEL
C
B=10.**(-.3936*SR-1.313)
X=SO2RXC
SO2PS=SO2PSI-X
DRYTOT=N2PS+CO2PS+O2PS+SO2PS
WETTOT=DRYTOT/(1.-BW2)
H2OPS=WETTOT-DRYTOT
YH2O=BW2
YN2=N2PS/WETTOT
YCO2=CO2PS/WETTOT
YO2=O2PS/WETTOT
YSO2=SO2PS/WETTOT
YSO2I=YSO2
ACFS=WETTOT*0.7913*((TEMP2+273.)/273.)*(1./PT)
RESIDT=220./ACFS
WRITE(6,40)
40 FORMAT('1',27X,'FALLING RATE PERIOD VALUES')
C
C CONVERSION FROM DROPS PER SECOND TO PARTICLES PER SECOND
C
VSOLID=CAPD*74.10/2.2E+06
VLIQID=W2*CAPD*74.10E-06
VTOTAL=VSOLID+VLIQID
D=(VTOTAL*1.9099)**(1./3.)
PPS=DPS*((D/7.8E-06)**3.)
DX=((DC**3.)/(PPS/DPS))**(1./3.)
DAVG=((DX**3.)+(7.8E-06**3.))/2.**(1./3.)
DROPI=DAVG
WRITE(6,66)PPS
66 FORMAT('0',5X,'PARTICLES PER SECOND = ',E12.5)
RCAPD=CAPD-X/DPS
WTS=((X/DPS)*129.15+(RCAPD*74.10))/1000.
WTW=WC*WTS
WTT=WTS+WTW
DEN=WTT/(0.5236*(DC**3.))
WRITE(6,73)DEN
73 FORMAT('0',5X,'DENSITY OF PARTICLE ',
$' = ',E12.5,' KG/M3')

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WRITE(6,21)I,COMPAR
WRITE(6,36)DSO2MX
WRITE(6,23)KG
WRITE(6,53)DE
53 FORMAT('0',5X,'EFFECTIVE DIFFUSIVITY =',E12.5,2X,'M2/SEC')
WRITE(6,48)KL
WRITE(6,52)KS
52 FORMAT('0',5X,'DISSOLUTION MASS TRANSFER COEFFICIENT =',
SE12.5,' M/SEC')
WRITE(6,92)NSO2
IF(III.EQ.200)WRITE(6,202)ERROR
IF(III.LT.200)WRITE(6,203)III,ERROR
EFF(RUN)=((SO2FR+X)/SO2PSI)*100.
EFFF=EFF(RUN)
IF(EFFF.GE.EFFSR)EFFF=EFFSR
EFF(RUN)=EFFF
IF((SO2FR+X).GT.SO2PSI)EFF(RUN)=100.
208 CONTINUE
WRITE(6,890)
890 FORMAT(' ',/,37X,'RESULTS')
WRITE(6,59)EFF(RUN)
59 FORMAT(' ',/,13X,'PREDICTED SPRAY DRYER EFFICIENCY = ',
SF12.4,2X,'%')
WRITE(6,91)EFFSD(RUN)
91 FORMAT('0',12X,'EXPERIMENTAL SPRAY DRYER EFFICIENCY = ',
SF9.4,2X,'%')
GO TO 101
100 CONTINUE
402 WRITE(6,450)
450 FORMAT('1',/////,29X,'MODEL PERFORMANCE TABLE')
WRITE(6,456)
456 FORMAT(' ',30X,'EXPERIMENTAL VALUES')
WRITE(6,451)KS
451 FORMAT(' ',29X,'KS =',E12.5,' M/SEC')
WRITE(6,452)
452 FORMAT(' ',5X,'RUN',2X,'PREDICTED EFFICIENCY',2X,
S'EXPERIMENTAL EFFICIENCY',2X,'PERCENT DIFFERENCE')
TOTAL=0.0
DO 400 RUN=1,25
PERDIF(RUN)=ABS((EFFSD(RUN)-EFF(RUN))/EFFSD(RUN))*100.
TOTAL=TOTAL+PERDIF(RUN)
WRITE(6,453)RUN,EFF(RUN),EFFSD(RUN),PERDIF(RUN)
453 FORMAT(' ',6X,12,8X,F8.4,15X,F8.4,15X,F8.4)
400 CONTINUE
AVGDIF=TOTAL/25.
WRITE(6,454)AVGDIF
454 FORMAT('0',52X,'AVERAGE = ',F8.4)

C
C   LINEAR REGRESSION MODEL
C
U=0.0
V=0.0
W=0.0
X=0.0
Y=0.0
DO 401 RUN=1,25
U=U+(EFF(RUN)*EFFSD(RUN))
V=V+EFF(RUN)
W=W+EFFSD(RUN)
X=X+(EFF(RUN))*2.

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      Y=Y+(EFFSD(RUN))**2.
401  CONTINUE
      R2=(U-((V*W)/25.))**2./((X-(V**2./25.))*(Y-(W**2./25.)))
      A1=(U-(V*W/25.))/(X-(V**2./25.))
      YBAR=W/25.
      XBAR=V/25.
      A0=YBAR-(A1*XBAR)
      WRITE(6,455)A1,A0,R2
455  FORMAT('0',6X,'PREDTD = ',E10.3,' * E EFFCY + ',E10.3,9X,
$'R2 = ',F8.6)
      STOP
      END

```

RUN = 1 PAGE NO. = 53
 DROPS PER SECOND = 0.558077E+08
 OPERATING PRESSURE = 0.969 ATM
 MOLES OF SO₂ PER SECOND = 0.274652E-01
 GM-MOLES OF CA(OH)₂ PER DROP = 0.796619E-09
 STOICHIOMETRIC RATIO = 1.6187
 TEMPERATURE APPROACH TO SATURATION = 25.0 DEG F
 CRITICAL TEMPERATURE = 81.17 DEG C

 CONSTANT RATE PERIOD FALLING RATE PERIOD
 1.248 SEC 1.394 SEC

 CA++ DIFFUSION IN WATER = 0.27313E-08 M²/SEC
 SO₂ DIFFUSION IN WATER = 0.29555E-08 M²/SEC

 CONSTANT RATE PERIOD VALUES
 AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.72 GM/GM-MOLE
 DENSITY OF FLUE GAS = 1.0922 KG/M³
 VISCOSITY OF FLUE GAS = 0.1800E-04 KG/M.SEC
 DROP TERMINAL VELOCITY = 0.1796 M/SEC
 DROP REYNOLDS NUMBER = 0.82946
 DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
 GAS PHASE DIFFUSIVITY OF SO₂ = 0.15740E-04 M²/SEC
 GAS PHASE MASS TRANSFER COEFFICIENT = 0.20071E+02 GM-MOLES/SEC.M².ATM
 HENRYS LAW CONSTANT = 0.83848E+07 ATM/MOLE FRAC
 LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.87377E-03 M/SEC
 DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC
 SO₂ MASS TRANSFER = 0.8452E-02 GM-MOLES/SEC.M²
 SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.003478
 SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 38.9957 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.65441×10^{10}
 DENSITY OF PARTICLE = 0.14885×10^4 KG/M³
 AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.08 GM/GM-MOLE
 DENSITY OF FLUE GAS = 1.0686 KG/M³
 VISCOSITY OF FLUE GAS = 0.1769×10^{-4} KG/M.SEC
 DROP TERMINAL VELOCITY = 0.0053 M/SEC
 DROP REYNOLDS NUMBER = 0.00342
 DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
 GAS PHASE DIFFUSIVITY OF SO₂ = 0.15740×10^{-4} M²/SEC
 GAS PHASE MASS TRANSFER COEFFICIENT = 0.11331×10^3 GM-MOLES/SEC.M².ATM
 EFFECTIVE DIFFUSIVITY = 0.17656×10^{-6} M²/SEC
 LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.78055×10^{-2} M/SEC
 DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
 SO₂ MASS TRANSFER = 0.37965×10^{-2} GM-MOLES/SEC.M²
 SOLUTION CONVERGES AFTER 4 ITERATIONS; ERROR = 0.012534

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 67.7475 %
 EXPERIMENTAL SPRAY DRYER EFFICIENCY = 65.6000 %

RUN = 2 PAGE NO. = 53

DROPS PER SECOND = $0.459211\text{E}+08$

OPERATING PRESSURE = 0.987 ATM

MOLES OF SO₂ PER SECOND = $0.250550\text{E}-01$

GM-MOLES OF CA(OH)₂ PER DROP = $0.310094\text{E}-09$

STOICHIOMETRIC RATIO = 0.5683

TEMPERATURE APPROACH TO SATURATION = 36.0 DEG F

CRITICAL TEMPERATURE = 77.96 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.085 SEC 0.648 SEC

CA⁺⁺ DIFFUSION IN WATER = $0.25804\text{E}-08$ M²/SEC

SO₂ DIFFUSION IN WATER = $0.27922\text{E}-08$ M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.74 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.1230 KG/M³

VISCOSITY OF FLUE GAS = $0.1788\text{E}-04$ KG/M.SEC

DROP TERMINAL VELOCITY = 0.1167 M/SEC

DROP REYNOLDS NUMBER = 0.44774

DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = $0.15215\text{E}-04$ M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = $0.22983\text{E}+02$ GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = $0.78497\text{E}+07$ ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = $0.10287\text{E}-02$ M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = $0.60000\text{E}-04$ M/SEC

SO₂ MASS TRANSFER = $0.7258\text{E}-02$ GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.000532

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 16.9100 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = $0.19633\text{E}+10$
DENSITY OF PARTICLE = $0.15515\text{E}+04$ KG/M3
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.34 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.1081 KG/M3
VISCOSITY OF FLUE GAS = $0.1769\text{E}-04$ KG/M.SEC
DROP TERMINAL VELOCITY = 0.0056 M/SEC
DROP REYNOLDS NUMBER = 0.00380
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
GAS PHASE DIFFUSIVITY OF SO2 = $0.15215\text{E}-04$ M2/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = $0.10959\text{E}+03$ GM-MOLES/SEC.M2.ATM
EFFECTIVE DIFFUSIVITY = $0.44216\text{E}-06$ M2/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = $0.73050\text{E}-02$ M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = $0.60000\text{E}-04$ M/SEC
SO2 MASS TRANSFER = $0.13248\text{E}-01$ GM-MOLES/SEC.M2
SOLUTION CONVERGES AFTER 2 ITERATIONS; ERROR = 0.012317

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 32.5434 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 44.9000 %

RUN = 3 PAGE NO. = 55

DROPS PER SECOND = 0.533782E+08

OPERATING PRESSURE = 0.987 ATM

MOLES OF SO₂ PER SECOND = 0.261602E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.457325E-09

STOICHIOMETRIC RATIO = 0.9331

TEMPERATURE APPROACH TO SATURATION = 21.0 DEG F

CRITICAL TEMPERATURE = 73.09 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.205 SEC 1.241 SEC

CA++ DIFFUSION IN WATER = 0.25804E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.27922E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.81 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.1258 KG/M³

VISCOSITY OF FLUE GAS = 0.1792E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1499 M/SEC

DROP REYNOLDS NUMBER = 0.65818

DSO₂MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15215E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.20811E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.78497E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.89919E-03 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.7323E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.001612

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 27.6224 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.39434×10^{10}
DENSITY OF PARTICLE = 0.15260×10^4 KG/M³
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.27 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.1055 KG/M³
VISCOSITY OF FLUE GAS = 0.1766×10^{-4} KG/M.SEC
DROP TERMINAL VELOCITY = 0.0053 M/SEC
DROP REYNOLDS NUMBER = 0.00351
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0000
GAS PHASE DIFFUSIVITY OF SO₂ = 0.15215×10^{-4} M²/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = 0.11194×10^3 GM-MOLES/SEC.M².ATM
EFFECTIVE DIFFUSIVITY = 0.31768×10^{-6} M²/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.74692×10^{-2} M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
SO₂ MASS TRANSFER = 0.78516×10^{-2} GM-MOLES/SEC.M²
SOLUTION CONVERGES AFTER 4 ITERATIONS; ERROR = 0.009706

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 60.2697 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 73.5000 %

RUN = 4 PAGE NO. = 56

DROPS PER SECOND = 0.556762E+08

OPERATING PRESSURE = 0.964 ATM

MOLES OF SO₂ PER SECOND = 0.267230E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.508136E-09

STOICHIOMETRIC RATIO = 1.0587

TEMPERATURE APPROACH TO SATURATION = 25.0 DEG F.

CRITICAL TEMPERATURE = 74.95 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.340 SEC 1.192 SEC

CA⁺⁺ DIFFUSION IN WATER = 0.27313E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.29555E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.72 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.0866 KG/M³

VISCOSITY OF FLUE GAS = 0.1800E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1592 M/SEC

DROP REYNOLDS NUMBER = 0.69450

DSO₂MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15822E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.20854E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.83848E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.92010E-03 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.7361E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.002463

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 33.7303 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.41644×10^{10}
DENSITY OF PARTICLE = 0.15613×10^4 KG/M³
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.07 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0627 KG/M³
VISCOSITY OF FLUE GAS = 0.1768×10^{-4} KG/M.SEC
DROP TERMINAL VELOCITY = 0.0055 M/SEC
DROP REYNOLDS NUMBER = 0.00357
DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
GAS PHASE DIFFUSIVITY OF SO₂ = 0.15822×10^{-4} M²/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = 0.11395×10^3 GM-MOLES/SEC.M².ATM
EFFECTIVE DIFFUSIVITY = 0.29482×10^{-6} M²/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.78054×10^{-2} M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
SO₂ MASS TRANSFER = 0.67730×10^{-2} GM-MOLES/SEC.M²
SOLUTION CONVERGES AFTER 4 ITERATIONS; ERROR = 0.007675

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 62.4075 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 62.3000 %

RUN = 5 PAGE NO. = 57
 DROPS PER SECOND = 0.552653E+08
 OPERATING PRESSURE = 0.983 ATM
 MOLES OF SO₂ PER SECOND = 0.283191E-01
 GM-MOLES OF CA(OH)₂ PER DROP = 0.802681E-09
 STOICHIOMETRIC RATIO = 1.5664
 TEMPERATURE APPROACH TO SATURATION = 22.0 DEG F
 CRITICAL TEMPERATURE = 80.59 DEG C

 CONSTANT RATE PERIOD FALLING RATE PERIOD
 1.213 SEC 1.479 SEC

 CA++ DIFFUSION IN WATER = 0.26102E-08 M²/SEC
 SO₂ DIFFUSION IN WATER = 0.28245E-08 M²/SEC

 CONSTANT RATE PERIOD VALUES
 AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.76 GM/GM-MOLE
 DENSITY OF FLUE GAS = 1.1172 KG/M³
 VISCOSITY OF FLUE GAS = 0.1792E-04 KG/M.SEC
 DROP TERMINAL VELOCITY = 0.1806 M/SEC
 DROP REYNOLDS NUMBER = 0.85767
 DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
 GAS PHASE DIFFUSIVITY OF SO₂ = 0.15328E-04 M²/SEC
 GAS PHASE MASS TRANSFER COEFFICIENT = 0.19738E+02 GM-MOLES/SEC.M².ATM
 HENRYS LAW CONSTANT = 0.79567E+07 ATM/MOLE FRAC
 LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.83437E-03 M/SEC
 DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC
 SO₂ MASS TRANSFER = 0.8436E-02 GM-MOLES/SEC.M²
 SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.003128
 SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 36.3906 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.69402×10^{10}
DENSITY OF PARTICLE = 0.14715×10^4 KG/M³
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.23 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0973 KG/M³
VISCOSITY OF FLUE GAS = 0.1766×10^{-4} KG/M.SEC
DROP TERMINAL VELOCITY = 0.0051 M/SEC
DROP REYNOLDS NUMBER = 0.00340
DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
GAS PHASE DIFFUSIVITY OF SO₂ = 0.15328×10^{-4} M²/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = 0.11205×10^3 GM-MOLES/SEC.M².ATM
EFFECTIVE DIFFUSIVITY = 0.18027×10^{-6} M²/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.75230×10^{-2} M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
SO₂ MASS TRANSFER = 0.41419×10^{-2} GM-MOLES/SEC.M²
SOLUTION CONVERGES AFTER 5 ITERATIONS; ERROR = 0.007775

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 70.0445 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 74.2000 %

RUN = 6 PAGE NO. = 59

DROPS PER SECOND = 0.532166E+08

OPERATING PRESSURE = 0.983 ATM

MOLES OF SO₂ PER SECOND = 0.313744E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.712626E-09

STOICHIOMETRIC RATIO = 1.2087

TEMPERATURE APPROACH TO SATURATION = 32.0 DEG F

CRITICAL TEMPERATURE = 83.59 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.208 SEC 1.074 SEC

CA++ DIFFUSION IN WATER = 0.26102E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.28245E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.76 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.1172 KG/M³

VISCOSITY OF FLUE GAS = 0.1791E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1662 M/SEC

DROP REYNOLDS NUMBER = 0.75426

DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15328E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.20387E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.79567E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.87357E-03 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.8647E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.002164

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 29.4523 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = $0.52880\text{E}+10$
DENSITY OF PARTICLE = $0.14990\text{E}+04$ KG/M3
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.28 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0992 KG/M3
VISCOSITY OF FLUE GAS = $0.1768\text{E}-04$ KG/M.SEC
DROP TERMINAL VELOCITY = 0.0054 M/SEC
DROP REYNOLDS NUMBER = 0.00363
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
GAS PHASE DIFFUSIVITY OF SO2 = $0.15328\text{E}-04$ M2/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = $0.11034\text{E}+03$ GM-MOLES/SEC.M2.ATM
EFFECTIVE DIFFUSIVITY = $0.24930\text{E}-06$ M2/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = $0.74016\text{E}-02$ M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = $0.60000\text{E}-04$ M/SEC
SO2 MASS TRANSFER = $0.72416\text{E}-02$ GM-MOLES/SEC.M2
SOLUTION CONVERGES AFTER 4 ITERATIONS; ERROR = 0.007428

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 59.8079 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 53.9000 %

RUN = 7 PAGE NO. = 60
 DROPS PER SECOND = 0.586489E+08
 OPERATING PRESSURE = 0.966 ATM
 MOLES OF SO₂ PER SECOND = 0.281364E-01
 GM-MOLES OF CA(OH)₂ PER DROP = 0.260871E-09
 STOICHIOMETRIC RATIO = 0.5438
 TEMPERATURE APPROACH TO SATURATION = 20.5 DEG F
 CRITICAL TEMPERATURE = 63.74 DEG C

 CONSTANT RATE PERIOD FALLING RATE PERIOD
 1.624 SEC 1.155 SEC

 CA++ DIFFUSION IN WATER = 0.25953E-08 M²/SEC
 SO₂ DIFFUSION IN WATER = 0.28083E-08 M²/SEC

 CONSTANT RATE PERIOD VALUES
 AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.76 GM/GM-MOLE
 DENSITY OF FLUE GAS = 1.0986 KG/M³
 VISCOSITY OF FLUE GAS = 0.1790E-04 KG/M.SEC
 DROP TERMINAL VELOCITY = 0.1508 M/SEC
 DROP REYNOLDS NUMBER = 0.65881
 DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
 GAS PHASE DIFFUSIVITY OF SO₂ = 0.15579E-04 M²/SEC
 GAS PHASE MASS TRANSFER COEFFICIENT = 0.20898E+02 GM-MOLES/SEC.M².ATM
 HENRYS LAW CONSTANT = 0.79032E+07 ATM/MOLE FRAC
 LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.88758E-03 M/SEC
 DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC
 SO₂ MASS TRANSFER = 0.5079E-02 GM-MOLES/SEC.M²
 SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.001635
 SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 27.3791 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = $0.25197\text{E}+10$
DENSITY OF PARTICLE = $0.17155\text{E}+04$ KG/M3
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.25 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0796 KG/M3
VISCOSITY OF FLUE GAS = $0.1766\text{E}-04$ KG/M.SEC
DROP TERMINAL VELOCITY = 0.0059 M/SEC
DROP REYNOLDS NUMBER = 0.00382
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0000
GAS PHASE DIFFUSIVITY OF SO2 = $0.15578\text{E}-04$ M2/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = $0.11491\text{E}+03$ GM-MOLES/SEC.M2.ATM
EFFECTIVE DIFFUSIVITY = $0.46290\text{E}-06$ M2/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = $0.75316\text{E}-02$ M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = $0.60000\text{E}-04$ M/SEC
SO2 MASS TRANSFER = $0.12408\text{E}-01$ GM-MOLES/SEC.M2
SOLUTION CONVERGES AFTER 3 ITERATIONS; ERROR = 0.016595

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 54.3772 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 54.2000 %

RUN = 8 PAGE NO. = 61

DROPS PER SECOND = 0.566648E+08

OPERATING PRESSURE = 0.967 ATM

MOLES OF SO₂ PER SECOND = 0.290608E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.245589E-09

STOICHIOMETRIC RATIO = 0.4789

TEMPERATURE APPROACH TO SATURATION = 25.0 DEG F

CRITICAL TEMPERATURE = 66.38 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.550 SEC 0.883 SEC

CA⁺⁺ DIFFUSION IN WATER = 0.26102E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.28245E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.72 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.0971 KG/M³

VISCOSITY OF FLUE GAS = 0.1789E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1422 M/SEC

DROP REYNOLDS NUMBER = 0.60092

DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15586E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.21392E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.79567E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.92223E-03 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.5165E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.001182

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 23.2806 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.20484×10^{10}
DENSITY OF PARTICLE = 0.17185×10^4 KG/M³
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.23 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0791 KG/M³
VISCOSITY OF FLUE GAS = 0.1765×10^{-4} KG/M.SEC
DROP TERMINAL VELOCITY = 0.0061 M/SEC
DROP REYNOLDS NUMBER = 0.00400
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0000
GAS PHASE DIFFUSIVITY OF SO₂ = 0.15586×10^{-4} M²/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = 0.11319×10^3 GM-MOLES/SEC.M².ATM
EFFECTIVE DIFFUSIVITY = 0.49120×10^{-6} M²/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.74594×10^{-2} M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
SO₂ MASS TRANSFER = 0.14916×10^{-1} GM-MOLES/SEC.M²
SOLUTION CONVERGES AFTER 3 ITERATIONS; ERROR = 0.004648

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 44.4475 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 21.7000 %

RUN = 9 PAGE NO. = 62

DROPS PER SECOND = 0.535098E+08

OPERATING PRESSURE = 0.967 ATM

MOLES OF SO₂ PER SECOND = 0.265189E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.213560E-09

STOICHIOMETRIC RATIO = 0.4309

TEMPERATURE APPROACH TO SATURATION = 35.0 DEG F

CRITICAL TEMPERATURE = 71.47 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.480 SEC 0.590 SEC

CA++ DIFFUSION IN WATER = 0.26102E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.28245E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.73 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.0974 KG/M³

VISCOSITY OF FLUE GAS = 0.1790E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1300 M/SEC

DROP REYNOLDS NUMBER = 0.52382

DSO₂MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15586E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.22149E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.79567E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.96724E-03 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.5060E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.000829

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 20.4900 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = $0.15790\text{E}+10$
DENSITY OF PARTICLE = $0.17191\text{E}+04$ KG/M3
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.28 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0810 KG/M3
VISCOSITY OF FLUE GAS = $0.1768\text{E}-04$ KG/M.SEC
DROP TERMINAL VELOCITY = 0.0062 M/SEC
DROP REYNOLDS NUMBER = 0.00411
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
GAS PHASE DIFFUSIVITY OF SO2 = $0.15586\text{E}-04$ M2/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = $0.11219\text{E}+03$ GM-MOLES/SEC.M2.ATM
EFFECTIVE DIFFUSIVITY = $0.51301\text{E}-06$ M2/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = $0.73918\text{E}-02$ M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = $0.60000\text{E}-04$ M/SEC
SO2 MASS TRANSFER = $0.15455\text{E}-01$ GM-MOLES/SEC.M2
SOLUTION CONVERGES AFTER 2 ITERATIONS; ERROR = 0.008226

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY =	33.0931	%
EXPERIMENTAL SPRAY DRYER EFFICIENCY =	29.4000	%

RUN = 10 PAGE NO. = 68
 DROPS PER SECOND = 0.537320E+08
 OPERATING PRESSURE = 0.979 ATM
 MOLES OF SO₂ PER SECOND = 0.288142E-01
 GM-MOLES OF CA(OH)₂ PER DROP = 0.100039E-08
 STOICHIOMETRIC RATIO = 1.8655
 TEMPERATURE APPROACH TO SATURATION = 20.0 DEG F
 CRITICAL TEMPERATURE = 79.92 DEG C

 CONSTANT RATE PERIOD FALLING RATE PERIOD
 1.257 SEC 1.838 SEC

 CA++ DIFFUSION IN WATER = 0.25507E-08 M²/SEC
 SO₂ DIFFUSION IN WATER = 0.27601E-08 M²/SEC

 CONSTANT RATE PERIOD VALUES
 AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.70 GM/GM-MOLE
 DENSITY OF FLUE GAS = 1.1140 KG/M³
 VISCOSITY OF FLUE GAS = 0.1783E-04 KG/M.SEC
 DROP TERMINAL VELOCITY = 0.1967 M/SEC
 DROP REYNOLDS NUMBER = 0.97097
 DSO₂MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
 GAS PHASE DIFFUSIVITY OF SO₂ = 0.15299E-04 M²/SEC
 GAS PHASE MASS TRANSFER COEFFICIENT = 0.19325E+02 GM-MOLES/SEC.M².ATM
 HENRYS LAW CONSTANT = 0.77427E+07 ATM/MOLE FRAC
 LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.78596E-03 M/SEC
 DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC
 SO₂ MASS TRANSFER = 0.8707E-02 GM-MOLES/SEC.M²
 SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.004045
 SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 40.0293 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.90495×10^{10}
DENSITY OF PARTICLE = 0.14443×10^4 KG/M³
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.28 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0982 KG/M³
VISCOSITY OF FLUE GAS = 0.1764×10^{-4} KG/M.SEC
DROP TERMINAL VELOCITY = 0.0050 M/SEC
DROP REYNOLDS NUMBER = 0.00325
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
GAS PHASE DIFFUSIVITY OF SO₂ = 0.15299×10^{-4} M²/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = 0.11328×10^3 GM-MOLES/SEC.M².ATM
EFFECTIVE DIFFUSIVITY = 0.13721×10^{-6} M²/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.74239×10^{-2} M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
SO₂ MASS TRANSFER = 0.29059×10^{-2} GM-MOLES/SEC.M²
SOLUTION CONVERGES AFTER 6 ITERATIONS; ERROR = 0.011935

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 76.9005 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 73.1000 %

RUN = 11 PAGE NO. = 69

DROPS PER SECOND = 0.515871E+08

OPERATING PRESSURE = 0.979 ATM

MOLES OF SO₂ PER SECOND = 0.271145E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.101483E-08

STOICHIOMETRIC RATIO = 1.9308

TEMPERATURE APPROACH TO SATURATION = 27.0 DEG F

CRITICAL TEMPERATURE = 81.40 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.357 SEC 1.500 SEC

CA++ DIFFUSION IN WATER = 0.25507E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.27601E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.70 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.1139 KG/M³

VISCOSITY OF FLUE GAS = 0.1784E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1951 M/SEC

DROP REYNOLDS NUMBER = 0.95816

DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15299E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.19389E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.77427E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.78985E-03 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.8768E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.004755

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 43.9498 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = $0.75281\text{E}+10$
DENSITY OF PARTICLE = $0.14794\text{E}+04$ KG/M3
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.31 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0996 KG/M3
VISCOSITY OF FLUE GAS = $0.1766\text{E}-04$ KG/M.SEC
DROP TERMINAL VELOCITY = 0.0053 M/SEC
DROP REYNOLDS NUMBER = 0.00355
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
GAS PHASE DIFFUSIVITY OF SO2 = $0.15299\text{E}-04$ M2/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = $0.11094\text{E}+03$ GM-MOLES/SEC.M2.ATM
EFFECTIVE DIFFUSIVITY = $0.12933\text{E}-06$ M2/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = $0.72653\text{E}-02$ M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = $0.60000\text{E}-04$ M/SEC
SO2 MASS TRANSFER = $0.26609\text{E}-02$ GM-MOLES/SEC.M2
SOLUTION CONVERGES AFTER 4 ITERATIONS; ERROR = 0.010052

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 69.3837 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 67.2000 %

RUN = 12 PAGE NO. = 70
 DROPS PER SECOND = 0.529052E+08
 OPERATING PRESSURE = 0.967 ATM
 MOLES OF SO₂ PER SECOND = 0.297045E-01
 GM-MOLES OF CA(OH)₂ PER DROP = 0.523842E-09
 STOICHIOMETRIC RATIO = 0.9330
 TEMPERATURE APPROACH TO SATURATION = 20.0 DEG F
 CRITICAL TEMPERATURE = 72.24 DEG C

CONSTANT RATE PERIOD	FALLING RATE PERIOD
1.277 SEC	1.465 SEC

 CA++ DIFFUSION IN WATER = 0.26102E-08 M²/SEC
 SO₂ DIFFUSION IN WATER = 0.28245E-08 M²/SEC

 CONSTANT RATE PERIOD VALUES
 AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.59 GM/GM-MOLE
 DENSITY OF FLUE GAS = 1.0928 KG/M³
 VISCOSITY OF FLUE GAS = 0.1783E-04 KG/M.SEC
 DROP TERMINAL VELOCITY = 0.1551 M/SEC
 DROP REYNOLDS NUMBER = 0.67128
 DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
 GAS PHASE DIFFUSIVITY OF SO₂ = 0.15582E-04 M²/SEC
 GAS PHASE MASS TRANSFER COEFFICIENT = 0.21100E+02 GM-MOLES/SEC.M².ATM
 HENRYS LAW CONSTANT = 0.79567E+07 ATM/MOLE FRAC
 LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.90006E-03 M/SEC
 DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC
 SO₂ MASS TRANSFER = 0.7781E-02 GM-MOLES/SEC.M²
 SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.001749
 SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 27.7171 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = $0.46657E+10$
 DENSITY OF PARTICLE = $0.15207E+04$ KG/M3
 AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.21 GM/GM-MOLE
 DENSITY OF FLUE GAS = 1.0786 KG/M3
 VISCOSITY OF FLUE GAS = $0.1765E-04$ KG/M.SEC
 DROP TERMINAL VELOCITY = 0.0052 M/SEC
 DROP REYNOLDS NUMBER = 0.00336
 DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0000
 GAS PHASE DIFFUSIVITY OF SO2 = $0.15582E-04$ M2/SEC
 GAS PHASE MASS TRANSFER COEFFICIENT = $0.11503E+03$ GM-MOLES/SEC.M2.ATM
 EFFECTIVE DIFFUSIVITY = $0.32539E-06$ M2/SEC
 LIQUID PHASE MASS TRANSFER COEFFICIENT = $0.75969E-02$ M/SEC
 DISSOLUTION MASS TRANSFER COEFFICIENT = $0.60000E-04$ M/SEC
 SO2 MASS TRANSFER = $0.83564E-02$ GM-MOLES/SEC.M2
 SOLUTION CONVERGES AFTER 5 ITERATIONS; ERROR = 0.015454

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 69.9982 %
 EXPERIMENTAL SPRAY DRYER EFFICIENCY = 63.2000 %

RUN = 13 PAGE NO. = 71

DROPS PER SECOND = 0.546336×10^8

OPERATING PRESSURE = 0.967 ATM

MOLES OF SO₂ PER SECOND = 0.287478×10^{-1}

GM-MOLES OF CA(OH)₂ PER DROP = 0.236132×10^{-9}

STOICHIOMETRIC RATIO = 0.4488

TEMPERATURE APPROACH TO SATURATION = 25.0 DEG F

CRITICAL TEMPERATURE = 65.28 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.531 SEC 0.866 SEC

CA⁺⁺ DIFFUSION IN WATER = 0.25507×10^{-8} M²/SEC

SO₂ DIFFUSION IN WATER = 0.27601×10^{-8} M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.68 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.0996 KG/M³

VISCOSITY OF FLUE GAS = 0.1782×10^{-4} KG/M.SEC

DROP TERMINAL VELOCITY = 0.1316 M/SEC

DROP REYNOLDS NUMBER = 0.53513

DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15489×10^{-4} M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.22073×10^2 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.77427×10^7 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.94263×10^{-3} M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC

SO₂ MASS TRANSFER = 0.5428×10^{-2} GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.000985

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 21.5370 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = $0.18990\text{E}+10$
DENSITY OF PARTICLE = $0.17126\text{E}+04$ KG/M3
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.31 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0858 KG/M3
VISCOSITY OF FLUE GAS = $0.1764\text{E}-04$ KG/M.SEC
DROP TERMINAL VELOCITY = 0.0061 M/SEC
DROP REYNOLDS NUMBER = 0.00402
DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0000
GAS PHASE DIFFUSIVITY OF SO2 = $0.15489\text{E}-04$ M2/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = $0.11288\text{E}+03$ GM-MOLES/SEC.M2.ATM
EFFECTIVE DIFFUSIVITY = $0.50165\text{E}-06$ M2/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = $0.72894\text{E}-02$ M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = $0.60000\text{E}-04$ M/SEC
SO2 MASS TRANSFER = $0.15366\text{E}-01$ GM-MOLES/SEC.M2
SOLUTION CONVERGES AFTER 3 ITERATIONS; ERROR = 0.003539

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 41.5874 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 39.5000 %

RUN = 14 PAGE NO. = 72

DROPS PER SECOND = 0.531958E+08

OPERATING PRESSURE = 0.967 ATM

MOLES OF SO₂ PER SECOND = 0.299666E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.233883E-09

STOICHIOMETRIC RATIO = 0.4152

TEMPERATURE APPROACH TO SATURATION = 20.0 DEG F

CRITICAL TEMPERATURE = 63.73 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.444 SEC 1.092 SEC

CA++ DIFFUSION IN WATER = 0.25804E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.27922E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.61 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.0953 KG/M³

VISCOSITY OF FLUE GAS = 0.1781E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1323 M/SEC

DROP REYNOLDS NUMBER = 0.53729

DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15535E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.22058E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.78497E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.95135E-03 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.5391E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.000783

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 18.9311 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.20946×10
DENSITY OF PARTICLE = 0.16677×10^4 KG/M³
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.25 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0818 KG/M³
VISCOSITY OF FLUE GAS = 0.1764×10^{-4} KG/M.SEC
DROP TERMINAL VELOCITY = 0.0057 M/SEC
DROP REYNOLDS NUMBER = 0.00369
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0000
GAS PHASE DIFFUSIVITY OF SO₂ = 0.15535×10^{-4} M²/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = 0.11502×10^3 GM-MOLES/SEC.M².ATM
EFFECTIVE DIFFUSIVITY = 0.51867×10^{-6} M²/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.75100×10^{-2} M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
SO₂ MASS TRANSFER = 0.16820×10^{-1} GM-MOLES/SEC.M²
SOLUTION CONVERGES AFTER 3 ITERATIONS; ERROR = 0.010824

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 41.5182 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 37.9000 %

RUN = 15 PAGE NO. = 73
 DROPS PER SECOND = 0.517340E+08
 OPERATING PRESSURE = 0.967 ATM
 MOLES OF SO₂ PER SECOND = 0.286415E-01
 GM-MOLES OF CA(OH)₂ PER DROP = 0.493837E-09
 STOICHIOMETRIC RATIO = 0.8920
 TEMPERATURE APPROACH TO SATURATION = 27.0 DEG F
 CRITICAL TEMPERATURE = 73.60 DEG C

CONSTANT RATE PERIOD	FALLING RATE PERIOD
1.336 SEC	1.094 SEC

 CA++ DIFFUSION IN WATER = 0.25507E-08 M²/SEC
 SO₂ DIFFUSION IN WATER = 0.27601E-08 M²/SEC

 CONSTANT RATE PERIOD VALUES
 AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.69 GM/GM-MOLE
 DENSITY OF FLUE GAS = 1.1000 KG/M³
 VISCOSITY OF FLUE GAS = 0.1783E-04 KG/M.SEC
 DROP TERMINAL VELOCITY = 0.1483 M/SEC
 DROP REYNOLDS NUMBER = 0.63106
 DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
 GAS PHASE DIFFUSIVITY OF SO₂ = 0.15489E-04 M²/SEC
 GAS PHASE MASS TRANSFER COEFFICIENT = 0.21419E+02 GM-MOLES/SEC.M².ATM
 HENRYS LAW CONSTANT = 0.77427E+07 ATM/MOLE FRAC
 LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.90064E-03 M/SEC
 DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC
 SO₂ MASS TRANSFER = 0.7796E-02 GM-MOLES/SEC.M²
 SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.001772
 SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 28.1069 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = $0.36737\text{E}+10$
DENSITY OF PARTICLE = $0.15616\text{E}+04$ KG/M3
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.31 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0860 KG/M3
VISCOSITY OF FLUE GAS = $0.1765\text{E}-04$ KG/M.SEC
DROP TERMINAL VELOCITY = 0.0056 M/SEC
DROP REYNOLDS NUMBER = 0.00370
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
GAS PHASE DIFFUSIVITY OF SO2 = $0.15489\text{E}-04$ M2/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = $0.11240\text{E}+03$ GM-MOLES/SEC.M2.ATM
EFFECTIVE DIFFUSIVITY = $0.33569\text{E}-06$ M2/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = $0.72652\text{E}-02$ M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = $0.60000\text{E}-04$ M/SEC
SO2 MASS TRANSFER = $0.91411\text{E}-02$ GM-MOLES/SEC.M2
SOLUTION CONVERGES AFTER 3 ITERATIONS; ERROR = 0.019749

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 57.5484 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 68.3000 %

RUN = 16 PAGE NO. = 76
 DROPS PER SECOND = 0.374049E+08
 OPERATING PRESSURE = 0.967 ATM
 MOLES OF SO₂ PER SECOND = 0.296792E-01
 GM-MOLES OF CA(OH)₂ PER DROP = 0.201296E-09
 STOICHIOMETRIC RATIO = 0.2537
 TEMPERATURE APPROACH TO SATURATION = 35.0 DEG F
 CRITICAL TEMPERATURE = 70.69 DEG C

 CONSTANT RATE PERIOD FALLING RATE PERIOD
 1.484 SEC 0.572 SEC

 CA++ DIFFUSION IN WATER = 0.25804E-08 M²/SEC
 SO₂ DIFFUSION IN WATER = 0.27922E-08 M²/SEC

 CONSTANT RATE PERIOD VALUES
 AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.60 GM/GM-MOLE
 DENSITY OF FLUE GAS = 1.0948 KG/M³
 VISCOSITY OF FLUE GAS = 0.1780E-04 KG/M.SEC
 DROP TERMINAL VELOCITY = 0.1212 M/SEC
 DROP REYNOLDS NUMBER = 0.47022
 DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
 GAS PHASE DIFFUSIVITY OF SO₂ = 0.15536E-04 M²/SEC
 GAS PHASE MASS TRANSFER COEFFICIENT = 0.22829E+02 GM-MOLES/SEC.M².ATM
 HENRYS LAW CONSTANT = 0.78497E+07 ATM/MOLE FRAC
 LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.99616E-03 M/SEC
 DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC
 SO₂ MASS TRANSFER = 0.5265E-02 GM-MOLES/SEC.M²
 SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.000315
 SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 12.3034 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.10404×10^{10}
 DENSITY OF PARTICLE = 0.17281×10^4 KG/M³
 AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.26 GM/GM-MOLE
 DENSITY OF FLUE GAS = 1.0821 KG/M³
 VISCOSITY OF FLUE GAS = 0.1763×10^{-4} KG/M.SEC
 DROP TERMINAL VELOCITY = 0.0063 M/SEC
 DROP REYNOLDS NUMBER = 0.00416
 DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0000
 GAS PHASE DIFFUSIVITY OF SO₂ = 0.15536×10^{-4} M²/SEC
 GAS PHASE MASS TRANSFER COEFFICIENT = 0.11208×10^3 GM-MOLES/SEC.M².ATM
 EFFECTIVE DIFFUSIVITY = 0.60047×10^{-6} M²/SEC
 LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.73073×10^{-2} M/SEC
 DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
 SO₂ MASS TRANSFER = 0.22422×10^{-1} GM-MOLES/SEC.M²
 SOLUTION CONVERGES AFTER 2 ITERATIONS; ERROR = 0.004301

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 22.7440 %
 EXPERIMENTAL SPRAY DRYER EFFICIENCY = 17.5000 %

RUN = 17 PAGE NO. = 77

DROPS PER SECOND = 0.472623E+08

OPERATING PRESSURE = 0.966 ATM

MOLES OF SO₂ PER SECOND = 0.278615E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.660795E-09

STOICHIOMETRIC RATIO = 1.1209

TEMPERATURE APPROACH TO SATURATION = 35.0 DEG F

CRITICAL TEMPERATURE = 87.06 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.024 SEC 0.934 SEC

CA++ DIFFUSION IN WATER = 0.26402E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.28570E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.62 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.0902 KG/M³

VISCOSITY OF FLUE GAS = 0.1787E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1497 M/SEC

DROP REYNOLDS NUMBER = 0.62133

DSO₂MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15651E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.21793E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.80638E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.94501E-03 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.9157E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.001103

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 23.1287 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.43153×10^{10}
DENSITY OF PARTICLE = 0.14651×10^4 KG/M³
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.24 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0764 KG/M³
VISCOSITY OF FLUE GAS = 0.1769×10^{-4} KG/M.SEC
DROP TERMINAL VELOCITY = 0.0053 M/SEC
DROP REYNOLDS NUMBER = 0.00349
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
GAS PHASE DIFFUSIVITY OF SO₂ = 0.15651×10^{-4} M²/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = 0.11228×10^3 GM-MOLES/SEC.M².ATM
EFFECTIVE DIFFUSIVITY = 0.27564×10^{-6} M²/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.74768×10^{-2} M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
SO₂ MASS TRANSFER = 0.80452×10^{-2} GM-MOLES/SEC.M²
SOLUTION CONVERGES AFTER 3 ITERATIONS; ERROR = 0.011224

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 50.1642 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 57.0000 %

RUN = 18 PAGE NO. = 78

DROPS PER SECOND = 0.464245E+08

OPERATING PRESSURE = 0.966 ATM

MOLES OF SO₂ PER SECOND = 0.267999E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.371299E-09

STOICHIOMETRIC RATIO = 0.6432

TEMPERATURE APPROACH TO SATURATION = 35.0 DEG F

CRITICAL TEMPERATURE = 78.85 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.121 SEC 0.737 SEC

CA⁺⁺ DIFFUSION IN WATER = 0.26402E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.28570E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.62 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.0903 KG/M³

VISCOSITY OF FLUE GAS = 0.1787E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1242 M/SEC

DROP REYNOLDS NUMBER = 0.47579

DSO₂MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15649E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.23035E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.80638E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.10238E-02 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.7726E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.000666

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 18.5747 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.23818×10
DENSITY OF PARTICLE = 0.15429×10^4 KG/M³
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.24 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0766 KG/M³
VISCOSITY OF FLUE GAS = 0.1769×10^{-4} KG/M.SEC
DROP TERMINAL VELOCITY = 0.0056 M/SEC
DROP REYNOLDS NUMBER = 0.00367
DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
GAS PHASE DIFFUSIVITY OF SO₂ = 0.15649×10^{-4} M²/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = 0.11233×10^3 GM-MOLES/SEC.M².ATM
EFFECTIVE DIFFUSIVITY = 0.42494×10^{-6} M²/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.74767×10^{-2} M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
SO₂ MASS TRANSFER = 0.12931×10^{-1} GM-MOLES/SEC.M²
SOLUTION CONVERGES AFTER 3 ITERATIONS; ERROR = 0.002907

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 38.2529 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 32.2000 %

RUN = 19 PAGE NO. = 82

DROPS PER SECOND = 0.575318E+08

OPERATING PRESSURE = 0.965 ATM

MOLES OF SO₂ PER SECOND = 0.278643E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.878541E-09

STOICHIOMETRIC RATIO = 1.8139

TEMPERATURE APPROACH TO SATURATION = 25.0 DEG F

CRITICAL TEMPERATURE = 83.67 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.239 SEC 1.371 SEC

CA++ DIFFUSION IN WATER = 0.26102E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.28245E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.88 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.1018 KG/M³

VISCOSITY OF FLUE GAS = 0.1798E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1900 M/SEC

DROP REYNOLDS NUMBER = 0.91338

DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15606E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.19644E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.79567E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.81002E-03 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.8375E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.004136

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 41.4158 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = $0.74400\text{E}+10$
DENSITY OF PARTICLE = $0.14766\text{E}+04$ KG/M3
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.22 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0772 KG/M3
VISCOSITY OF FLUE GAS = $0.1766\text{E}-04$ KG/M.SEC
DROP TERMINAL VELOCITY = 0.0052 M/SEC
DROP REYNOLDS NUMBER = 0.00343
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
GAS PHASE DIFFUSIVITY OF SO2 = $0.15606\text{E}-04$ M2/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = $0.11312\text{E}+03$ GM-MOLES/SEC.M2.ATM
EFFECTIVE DIFFUSIVITY = $0.14666\text{E}-06$ M2/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = $0.74594\text{E}-02$ M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = $0.60000\text{E}-04$ M/SEC
SO2 MASS TRANSFER = $0.31335\text{E}-02$ GM-MOLES/SEC.M2
SOLUTION CONVERGES AFTER 4 ITERATIONS; ERROR = 0.009167

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 67.5760 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 69.6000 %

RUN = 20 PAGE NO. = 83

DROPS PER SECOND = 0.541792E+08

OPERATING PRESSURE = 0.964 ATM

MOLES OF SO₂ PER SECOND = 0.301779E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.184239E-09

STOICHIOMETRIC RATIO = 0.3308

TEMPERATURE APPROACH TO SATURATION = 19.0 DEG F

CRITICAL TEMPERATURE = 64.38 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.270 SEC 0.995 SEC

CA++ DIFFUSION IN WATER = 0.26402E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.28570E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.88 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.0981 KG/M³

VISCOSITY OF FLUE GAS = 0.1799E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1302 M/SEC

DROP REYNOLDS NUMBER = 0.52506

DSO₂MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0002

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15679E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.22123E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.80638E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.97265E-03 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.4551E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.000433

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 14.2366 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = $0.17738\text{E}+10$
DENSITY OF PARTICLE = $0.16351\text{E}+04$ KG/M3
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.18 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0721 KG/M3
VISCOSITY OF FLUE GAS = $0.1765\text{E}-04$ KG/M.SEC
DROP TERMINAL VELOCITY = 0.0055 M/SEC
DROP REYNOLDS NUMBER = 0.00351
DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0000
GAS PHASE DIFFUSIVITY OF SO2 = $0.15679\text{E}-04$ M2/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = $0.11645\text{E}+03$ GM-MOLES/SEC.M2.ATM
EFFECTIVE DIFFUSIVITY = $0.56511\text{E}-06$ M2/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = $0.77377\text{E}-02$ M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = $0.60000\text{E}-04$ M/SEC
SO2 MASS TRANSFER = $0.19748\text{E}-01$ GM-MOLES/SEC.M2
SOLUTION CONVERGES AFTER 3 ITERATIONS; ERROR = 0.005685

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 33.0768 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 29.3000 %

RUN = 21 PAGE NO. = 84

DROPS PER SECOND = 0.528728E+08

OPERATING PRESSURE = 0.966 ATM

MOLES OF SO₂ PER SECOND = 0.286282E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.333889E-09

STOICHIOMETRIC RATIO = 0.6167

TEMPERATURE APPROACH TO SATURATION = 25.0 DEG F

CRITICAL TEMPERATURE = 72.04 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.211 SEC 0.930 SEC

CA++ DIFFUSION IN WATER = 0.26102E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.28245E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.82 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.1001 KG/M³

VISCOSITY OF FLUE GAS = 0.1794E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1378 M/SEC

DROP REYNOLDS NUMBER = 0.56818

DSO₂MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15596E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.21817E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.79567E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.94498E-03 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.6548E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.000925

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 20.8155 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.25986×10^{10}
DENSITY OF PARTICLE = 0.15791×10^4 KG/M³
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.23 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0785 KG/M³
VISCOSITY OF FLUE GAS = 0.1765×10^{-4} KG/M.SEC
DROP TERMINAL VELOCITY = 0.0056 M/SEC
DROP REYNOLDS NUMBER = 0.00368
DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0000
GAS PHASE DIFFUSIVITY OF SO₂ = 0.15595×10^{-4} M²/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = 0.11317×10^3 GM-MOLES/SEC.M².ATM
EFFECTIVE DIFFUSIVITY = 0.43380×10^{-6} M²/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.74594×10^{-2} M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
SO₂ MASS TRANSFER = 0.13251×10^{-1} GM-MOLES/SEC.M²
SOLUTION CONVERGES AFTER 3 ITERATIONS; ERROR = 0.008120

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 46.3134 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 54.6000 %

RUN = 22 PAGE NO. = 85

DROPS PER SECOND = 0.568447E+08

OPERATING PRESSURE = 0.966 ATM

MOLES OF SO₂ PER SECOND = 0.282571E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.404836E-09

STOICHIOMETRIC RATIO = 0.8144

TEMPERATURE APPROACH TO SATURATION = 20.0 DEG F

CRITICAL TEMPERATURE = 69.50 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.355 SEC 1.332 SEC

CA++ DIFFUSION IN WATER = 0.26102E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.28245E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.79 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.0991 KG/M³

VISCOSITY OF FLUE GAS = 0.1793E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1564 M/SEC

DROP REYNOLDS NUMBER = 0.69017

DSO₂MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15594E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.20769E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.79567E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.88296E-03 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.6557E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.001877

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 29.0902 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.38742×10^{10}
DENSITY OF PARTICLE = 0.15763×10^4 KG/M³
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.21 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0778 KG/M³
VISCOSITY OF FLUE GAS = 0.1765×10^{-4} KG/M.SEC
DROP TERMINAL VELOCITY = 0.0054 M/SEC
DROP REYNOLDS NUMBER = 0.00348
DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0000
GAS PHASE DIFFUSIVITY OF SO₂ = 0.15593×10^{-4} M²/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = 0.11515×10^3 GM-MOLES/SEC.M².ATM
EFFECTIVE DIFFUSIVITY = 0.36257×10^{-6} M²/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.75969×10^{-2} M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
SO₂ MASS TRANSFER = 0.88091×10^{-2} GM-MOLES/SEC.M²
SOLUTION CONVERGES AFTER 4 ITERATIONS; ERROR = 0.017641

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 64.4575 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 54.8000 %

RUN = 23 PAGE NO. = 86

DROPS PER SECOND = 0.500880E+08

OPERATING PRESSURE = 0.964 ATM

MOLES OF SO₂ PER SECOND = 0.296138E-01

GM-MOLES OF CA(OH)₂ PER DROP = 0.335145E-09

STOICHIOMETRIC RATIO = 0.5669

TEMPERATURE APPROACH TO SATURATION = 35.0 DEG F

CRITICAL TEMPERATURE = 77.04 DEG C

CONSTANT RATE PERIOD FALLING RATE PERIOD

1.243 SEC 0.708 SEC

CA⁺⁺ DIFFUSION IN WATER = 0.26102E-08 M²/SEC

SO₂ DIFFUSION IN WATER = 0.28245E-08 M²/SEC

CONSTANT RATE PERIOD VALUES

AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.84 GM/GM-MOLE

DENSITY OF FLUE GAS = 1.0987 KG/M³

VISCOSITY OF FLUE GAS = 0.1795E-04 KG/M.SEC

DROP TERMINAL VELOCITY = 0.1376 M/SEC

DROP REYNOLDS NUMBER = 0.56627

DSO₂MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001

GAS PHASE DIFFUSIVITY OF SO₂ = 0.15630E-04 M²/SEC

GAS PHASE MASS TRANSFER COEFFICIENT = 0.21866E+02 GM-MOLES/SEC.M².ATM

HENRYS LAW CONSTANT = 0.79567E+07 ATM/MOLE FRAC

LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.94528E-03 M/SEC

DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC

SO₂ MASS TRANSFER = 0.6588E-02 GM-MOLES/SEC.M²

SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.000850

SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 19.6671 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.23195×10^{10}
DENSITY OF PARTICLE = 0.15978×10^4 KG/M³
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.29 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0781 KG/M³
VISCOSITY OF FLUE GAS = 0.1768×10^{-4} KG/M.SEC
DROP TERMINAL VELOCITY = 0.0058 M/SEC
DROP REYNOLDS NUMBER = 0.00381
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0001
GAS PHASE DIFFUSIVITY OF SO₂ = 0.15629×10^{-4} M²/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = 0.11244×10^3 GM-MOLES/SEC.M².ATM
EFFECTIVE DIFFUSIVITY = 0.45481×10^{-6} M²/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.73918×10^{-2} M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
SO₂ MASS TRANSFER = 0.15115×10^{-1} GM-MOLES/SEC.M²
SOLUTION CONVERGES AFTER 3 ITERATIONS; ERROR = 0.002939

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 39.1422 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 42.8000 %

RUN = 24 PAGE NO. = 87
 DROPS PER SECOND = 0.525185E+08
 OPERATING PRESSURE = 0.964 ATM
 MOLES OF SO₂ PER SECOND = 0.289429E-01
 GM-MOLES OF CA(OH)₂ PER DROP = 0.168856E-09
 STOICHIOMETRIC RATIO = 0.3064
 TEMPERATURE APPROACH TO SATURATION = 24.0 DEG F
 CRITICAL TEMPERATURE = 66.45 DEG C

 CONSTANT RATE PERIOD FALLING RATE PERIOD
 1.253 SEC 0.714 SEC

 CA++ DIFFUSION IN WATER = 0.26402E-08 M²/SEC
 SO₂ DIFFUSION IN WATER = 0.28570E-08 M²/SEC

 CONSTANT RATE PERIOD VALUES
 AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.87 GM/GM-MOLE
 DENSITY OF FLUE GAS = 1.0977 KG/M³
 VISCOSITY OF FLUE GAS = 0.1799E-04 KG/M.SEC
 DROP TERMINAL VELOCITY = 0.1226 M/SEC
 DROP REYNOLDS NUMBER = 0.47899
 DSO₂MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0002
 GAS PHASE DIFFUSIVITY OF SO₂ = 0.15677E-04 M²/SEC
 GAS PHASE MASS TRANSFER COEFFICIENT = 0.22650E+02 GM-MOLES/SEC.M².ATM
 HENRYS LAW CONSTANT = 0.80638E+07 ATM/MOLE FRAC
 LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.10042E-02 M/SEC
 DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC
 SO₂ MASS TRANSFER = 0.4496E-02 GM-MOLES/SEC.M²
 SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.000350
 SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 13.1585 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = 0.13263×10^{10}
DENSITY OF PARTICLE = 0.16627×10^4 KG/M³
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.20 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0732 KG/M³
VISCOSITY OF FLUE GAS = 0.1766×10^{-4} KG/M.SEC
DROP TERMINAL VELOCITY = 0.0059 M/SEC
DROP REYNOLDS NUMBER = 0.00383
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0000
GAS PHASE DIFFUSIVITY OF SO₂ = 0.15677×10^{-4} M²/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = 0.11388×10^3 GM-MOLES/SEC.M².ATM
EFFECTIVE DIFFUSIVITY = 0.57765×10^{-6} M²/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.75621×10^{-2} M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000×10^{-4} M/SEC
SO₂ MASS TRANSFER = 0.20018×10^{-1} GM-MOLES/SEC.M²
SOLUTION CONVERGES AFTER 2 ITERATIONS; ERROR = 0.009844

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 28.0290 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 32.7000 %

RUN = 25 PAGE NO. = 88
 DROPS PER SECOND = 0.518131E+08
 OPERATING PRESSURE = 0.965 ATM
 MOLES OF SO₂ PER SECOND = 0.293979E-01
 GM-MOLES OF CA(OH)₂ PER DROP = 0.163713E-09
 STOICHIOMETRIC RATIO = 0.2885
 TEMPERATURE APPROACH TO SATURATION = 35.0 DEG F
 CRITICAL TEMPERATURE = 71.60 DEG C

 CONSTANT RATE PERIOD FALLING RATE PERIOD
 1.280 SEC 0.493 SEC

 CA++ DIFFUSION IN WATER = 0.26102E-08 M²/SEC
 SO₂ DIFFUSION IN WATER = 0.28245E-08 M²/SEC

 CONSTANT RATE PERIOD VALUES
 AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.90 GM/GM-MOLE
 DENSITY OF FLUE GAS = 1.1022 KG/M³
 VISCOSITY OF FLUE GAS = 0.1798E-04 KG/M.SEC
 DROP TERMINAL VELOCITY = 0.1201 M/SEC
 DROP REYNOLDS NUMBER = 0.46586
 DS02MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0002
 GAS PHASE DIFFUSIVITY OF SO₂ = 0.15606E-04 M²/SEC
 GAS PHASE MASS TRANSFER COEFFICIENT = 0.22793E+02 GM-MOLES/SEC.M².ATM
 HENRYS LAW CONSTANT = 0.79567E+07 ATM/MOLE FRAC
 LIQUID PHASE MASS TRANSFER COEFFICIENT = 0.10042E-02 M/SEC
 DISSOLUTION MASS TRANSFER COEFFICIENT = 0.60000E-04 M/SEC
 SO₂ MASS TRANSFER = 0.4500E-02 GM-MOLES/SEC.M²
 SOLUTION CONVERGES AFTER 1 ITERATIONS; ERROR = 0.000339
 SPRAY DRYER EFFICIENCY FOR CONSTANT RATE PERIOD = 12.7739 %

FALLING RATE PERIOD VALUES

PARTICLES PER SECOND = $0.11721\text{E}+10$
DENSITY OF PARTICLE = $0.16882\text{E}+04$ KG/M3
AVERAGE MOLECULAR WEIGHT OF FLUE GAS = 29.28 GM/GM-MOLE
DENSITY OF FLUE GAS = 1.0795 KG/M3
VISCOSITY OF FLUE GAS = $0.1767\text{E}-04$ KG/M.SEC
DROP TERMINAL VELOCITY = 0.0061 M/SEC
DROP REYNOLDS NUMBER = 0.00404
DSO2MX CONVERGES AFTER 1 ITERATIONS; COMPARISON = 0.0000
GAS PHASE DIFFUSIVITY OF SO2 = $0.15606\text{E}-04$ M2/SEC
GAS PHASE MASS TRANSFER COEFFICIENT = $0.11235\text{E}+03$ GM-MOLES/SEC.M2.ATM
EFFECTIVE DIFFUSIVITY = $0.58441\text{E}-06$ M2/SEC
LIQUID PHASE MASS TRANSFER COEFFICIENT = $0.73918\text{E}-02$ M/SEC
DISSOLUTION MASS TRANSFER COEFFICIENT = $0.60000\text{E}-04$ M/SEC
SO2 MASS TRANSFER = $0.21429\text{E}-01$ GM-MOLES/SEC.M2
SOLUTION CONVERGES AFTER 2 ITERATIONS; ERROR = 0.003761

RESULTS

PREDICTED SPRAY DRYER EFFICIENCY = 22.5467 %
EXPERIMENTAL SPRAY DRYER EFFICIENCY = 28.7000 %

APPENDIX D

VERIFICATION OF THE DRY SCRUBBING MODEL ASSUMPTIONS

TABLE D-1

VERIFICATION OF LONG CONTACT TIMES FOR THE CONSTANT RATE PERIOD

Run	$D_{AL} \times 10^9 \text{ (m}^2/\text{sec)}$	$t_C \text{ (sec)}$	$R_d \times 10^6 \text{ (m)}$	$(D_{AL} t_C / R_d^2)^{1/2}$
1	2.956	1.248	38.053	1.596
2	2.792	1.085	30.536	1.802
3	2.792	1.205	34.934	1.660
4	2.956	1.340	36.137	1.742
5	2.825	1.213	38.083	1.535
6	2.825	1.208	36.375	1.606
7	2.808	1.624	35.596	1.897
8	2.825	1.550	34.455	1.921
9	2.825	1.480	32.852	1.968
10	2.760	1.257	39.508	1.491
11	2.760	1.357	39.313	1.557
12	2.825	1.277	35.304	1.701
13	2.760	1.531	32.942	1.973
14	2.792	1.444	33.019	1.923
15	2.760	1.336	34.477	1.761
16	2.792	1.484	31.534	2.041
17	2.857	1.024	34.011	1.590
18	2.857	1.121	31.395	1.803
19	2.825	1.239	39.228	1.508
20	2.857	1.270	33.045	1.823
21	2.825	1.211	33.626	1.739
22	2.825	1.355	35.988	1.719
23	2.825	1.243	33.615	1.763
24	2.857	1.253	32.007	1.869
25	2.825	1.280	31.642	1.900

TABLE D-2

VERIFICATION OF LONG CONTACT TIMES FOR THE FALLING RATE PERIOD

Run	$D_{AL} \times 10^9$ (m ² /sec)	t_F (sec)	$R_c \times 10^6$ (m)	$(D_{AL} t_F / R_c^2)^{1/2}$
1	2.956	1.394	4.260	15.069
2	2.792	0.648	4.300	9.892
3	2.792	1.241	4.206	13.995
4	2.956	1.192	4.260	13.934
5	2.825	1.479	4.224	15.303
6	2.825	1.074	4.293	12.831
7	2.808	1.155	4.195	13.576
8	2.825	0.883	4.260	11.724
9	2.825	0.590	4.299	9.497
10	2.760	1.838	3.183	17.027
11	2.760	1.500	4.274	15.054
12	2.825	1.465	4.183	15.379
13	2.760	0.866	4.260	11.476
14	2.792	1.092	4.183	13.200
15	2.760	1.094	4.274	12.857
16	2.792	0.572	4.299	9.296
17	2.857	0.934	4.299	12.016
18	2.857	0.737	4.299	10.674
19	2.825	1.371	4.260	14.609
20	2.857	0.995	4.154	12.835
21	2.825	0.930	4.260	12.032
22	2.825	1.332	4.183	14.665
23	2.825	0.708	4.299	10.403
24	2.857	0.714	4.250	10.627
25	2.825	0.493	4.299	8.681

TABLE D-3

VERIFICATION THAT SOLID DISSOLUTION DURING THE CONSTANT RATE PERIOD IS UNIMPORTANT IN THE LIQUID FILM CONTAINING THE REACTION ZONE

Run	$D_{AL} \times 10^9 (\text{m}^2/\text{sec})$	$D_{BL} \times 10^9 (\text{m}^2/\text{sec})$	$k_{AL} \times 10^3 (\text{m}/\text{sec})$	$A_P \times 10^{-6} (\text{m}^2/\text{m}^3)$	$\frac{k_S A_P D_{AL}^2}{4k_{AL}^2 D_{BL}}$
1	2.956	2.731	0.874	1.368	0.086
2	2.792	2.580	1.029	1.031	0.044
3	2.792	2.580	0.899	1.015	0.057
4	2.956	2.731	0.920	1.019	0.057
5	2.825	2.610	0.834	1.375	0.091
6	2.825	2.610	0.874	1.401	0.084
7	2.808	2.595	0.888	0.547	0.032
8	2.825	2.610	0.922	0.568	0.031
9	2.825	2.610	0.967	0.570	0.028
10	2.760	2.551	0.786	1.535	0.111
11	2.760	2.551	0.790	1.580	0.114
12	2.825	2.610	0.900	1.127	0.064
13	2.760	2.551	0.943	0.625	0.032
14	2.792	2.580	0.951	0.615	0.031
15	2.760	2.551	0.901	1.140	0.063
16	2.792	2.580	0.996	0.608	0.028
17	2.857	2.640	0.945	1.589	0.083
18	2.857	2.640	1.024	1.136	0.050
19	2.825	2.610	0.810	1.377	0.096
20	2.857	2.640	0.973	0.483	0.024
21	2.825	2.610	0.945	0.831	0.043
22	2.825	2.610	0.883	0.822	0.048
23	2.825	2.610	0.945	0.835	0.043
24	2.857	2.640	1.004	0.487	0.022
25	2.825	2.610	1.004	0.489	0.022

TABLE D-4

VERIFICATION THAT SOLID DISSOLUTION DURING THE FALLING RATE PERIOD IS UNIMPORTANT IN THE LIQUID FILM CONTAINING THE REACTION ZONE

Run	$D_{AL} \times 10^9 \text{ (m}^2/\text{sec)}$	$D_{BL} \times 10^9 \text{ (m}^2/\text{sec)}$	$k_{AL} \times 10^2 \text{ (m/sec)}$	$A_P \times 10^{-6} \text{ (m}^2/\text{m}^3)$	$\frac{k_S A_P D_{AL}^2}{4k_{AL}^2 D_{BL}}$
1	2.956	2.731	0.781	4.156	0.003
2	2.792	2.580	0.731	4.314	0.004
3	2.792	2.580	0.747	3.936	0.003
4	2.956	2.731	0.781	4.198	0.003
5	2.825	2.610	0.752	4.011	0.003
6	2.825	2.610	0.740	4.286	0.004
7	2.808	2.595	0.753	3.890	0.003
8	2.825	2.610	0.746	4.156	0.003
9	2.825	2.610	0.739	4.308	0.003
10	2.760	2.551	0.742	3.839	0.003
11	2.760	2.551	0.727	4.212	0.004
12	2.825	2.610	0.760	3.839	0.003
13	2.760	2.551	0.729	4.156	0.004
14	2.792	2.580	0.751	3.839	0.003
15	2.760	2.551	0.727	4.212	0.004
16	2.792	2.580	0.731	4.308	0.004
17	2.857	2.640	0.748	4.308	0.004
18	2.857	2.640	0.748	4.308	0.004
19	2.825	2.610	0.746	4.156	0.003
20	2.857	2.640	0.774	3.713	0.003
21	2.825	2.610	0.746	4.156	0.003
22	2.825	2.610	0.760	3.839	0.003
23	2.825	2.610	0.739	4.308	0.004
24	2.857	2.640	0.756	4.118	0.004
25	2.825	2.610	0.739	4.308	0.004

APPENDIX E

COMPUTER PROGRAM, RESULTS, AND PLOTS USED FOR DETERMINING
THE RATIO OF POROSITY TO TORTUOSITY AS A FUNCTION
OF STOICHIOMETRIC RATIO

```

C
C      BKL
C
      DIMENSION EFF(25),EFFSD(25),PERDIF(25),B(25)
      DIMENSION SR(25),DELTAT(25),BLOG(25),ITER(25),XX(25)
      REAL LMTDC,KD,LMTDF,MWAVG,NH2O,KG,NSO2,MSO2,NSO2RX,
SMCCA,N2PS,KL,KGW,KS
      INTEGER RUN,PAGE
      KS=2.0E-05
101 READ(5,34)RUN,PAGE
34  FORMAT(2I3)
      IF(RUN.EQ.999)GO TO 100
      READ(5,1)YN2,YCO2,YO2,YH2O,YSO2
      1  FORMAT(5F8.6)
      READ(5,2)SO2ONC,TEMP1C,SLCONC,SCFM1C
      2  FORMAT(F6.1,F5.1,F5.3,F5.1)
      READ(5,3)GPM,PBAR,SP1,SP2,TSLURR
      3  FORMAT(F5.3,F5.2,2F3.1,F5.1)
      READ(5,4)TEMP2,TW2,DRODPI,PRODDN
      4  FORMAT(2F5.1,E10.2,F6.1)
      READ(5,37)EFFSD(RUN),BW2
37  FORMAT(F5.2,F8.6)
      YFIX=YH2O+YSO2
      YADJST=1.-YFIX
      YN2=(YADJST/.95)*YN2
      YCO2=(YADJST/.95)*YCO2
      YO2=(YADJST/.95)*YO2
      SLDEN=1000.+86.3795*SLCONC
      W1=6.3118/SLCONC-0.4545
      DELTAT(RUN)=TEMP2-TW2

C
C      NUMBER OF DROPS ENTERING THE SYSTEM
C
      DPS=(GPM/(DRODPI)**3.)*1.204E-04

C
C      SPRAY DRYER OPERATING PRESSURE
C
      PT=(PBAR/29.921)-((SP1+SP2)/810.62)

C
C      MOLES OF GAS ENTERING THE SYSTEM
C
      GGASPS=SCFM1C*1.9545E-02
      YSO2I=YSO2
      SO2PS=GGASPS*YSO2
      SO2PSI=SO2PS
      SO2AVG=SO2PSI/2.
      N2PS=GGASPS*YN2
      CO2PS=GGASPS*YCO2
      O2PS=GGASPS*YO2
      H2OPS=GGASPS*YH2O

C
C      MOLES OF CA(OH)2 PER DROP
C
      TMCCA=SLCONC*2.137E+03
      CAPD=TMCCA*0.5236*(DRODPI**3.)

C
C      STIOCHIOMETRIC RATIO CALCULATION
C
      SR(RUN)=CAPD*DPS/SO2PS
C

```

C FINAL MOISTURE CONTENT APPROXIMATION

C

```

GWATPS=GPM*SLDEN*6.3115E-02*W1/(1.+W1)
GCOHPS=(GPM*SLDEN*6.3115E-02)-GWATPS
DTSLUR=(TW2-TSLURR)/1.8
HWAT=DTSLUR*GWATPS/1000.
HCOH=DTSLUR*(21.4/74.1)*GCOHPS/1000.
HSLUR=HWAT+HCOH
CP=((29.141*YN2)+(38.166*YC02)+(29.526*Y02)+(33.727*YH20))
$*2.39E-04
HGAS=CP*GGASPS*(TEMP1C-TEMP2)/1.8
HVAP=-0.3290*TW2+608.2879
HRISE=.22722*DELTAT(RUN)
W3=4.4732E+04/(DELTAT(RUN)**4.3463)
W2=W3/(1.-W3)
WVAP=(W1-W2)*GCOHPS/1000.
HEAT=(HVAP*WVAP)+(HRISE*WVAP)+HSLUR-HGAS
DC=DROD1*((SLDEN/PRODDN)*((1.+W2)/(1.+W1)))**(.1/3.)
WC=((SLDEN-158.3354*SLCONC)-1000.)+(1000.*
$(DC/DROD1)**3.)/(158.3354*SLCONC)
AVGDEN=(SLDEN+PRODDN)/2.
KD=8.64E-05*((TW2-32.)/1.8)+273.)-1.196E-02
TSLURR=(TSLURR-32.)/1.8
TEMP1C=(TEMP1C-32.)/1.8
TEMP2=(TEMP2-32.)/1.8
TW2=(TW2-32.)/1.8
T=TW2

```

C

C

C

AVERAGE DENSITY CALCULATIONS

```

WCAVG=(W1+WC)/2.
WFAVG=(WC+W2)/2.
SLCC=6.3118/(WCAVG+.4545)
SLCF=6.3118/(WFAVG+.4545)
SLDC=1000.+86.3795*SLCC
SLDF=1000.+86.3795*SLCF

```

C

C

C

CRITICAL TEMPERATURE ESTIMATION

```

WVAPC=(W1-WC)*GCOHPS/1000.
HEATC=((W1-WC)/(W1-W2))*HEAT
C=CP*GGASPS
A=.22722*1.8*WVAPC
TEMPC=(HEATC+C*TEMP1C-HVAP*WVAPC+A*TW2-HSLUR)/(A+C)

```

C

C

C

CONSTANT RATE PERIOD CALCULATION

```

LMTDC=((TEMP1C-TEMP1C)-(TW2-TSLURR))/
$ALOG((TEMP1C-TEMP1C)/(TW2-TSLURR))
TC=HVAP*AVGDEN*((DROD1)**2.-(DC)**2.)*3600./(8.*KD*LMTDC)

```

C

C

C

FALLING RATE PERIOD CALCULATION

```

LMTDF=(TEMP2+TEMP2)/2.-TW2
TF=HVAP*PRODDN*DC**2.*(WC-W2)*3600./(12.*KD*LMTDF)

```

C

C

C

CA++ DIFFUSION IN WATER - WILKE/CHANG EQN.

```

DOCA=4.781E-12*(T+273.)/(1.002*10.**((1.3272*(20.-T)-
$0.001053*(T-20.))**2.)/(T+105.)))

```

```

C
C   SO2 DIFFUSION IN WATER - WILKE/CHANG EQN.
C
  DOSO2=5.1735E-12*(T+273.)/(1.002*10.**((1.3272*(20.-T)-
  SO.001053*(T-20.))**2.)/(T+105.)))
C
C   GAS PHASE PHYSICAL PROPERTY ESTIMATIONS
C
C   DENSITY OF FLUE GAS
C
  AVGDIA=(( (DROPDI**3.)+(DC**3.))/2.)**(1./3.)
  DROPDI=AVGDIA
  I I=0
  I I I=0
43  MWAVG=YN2*28.02+YC02*44.01+Y02*32.+YH2O*18.016+YSO2*64.06
  FGDEN=(PT*MWAVG/(82.057*(T+273.)))*1000.
C
C   VISCOSITY OF FLUE GAS
C
  UN2=0.0208*((T+273.)/373.)**(3./2.)*(486.484/(T+386.484))
  UC02=0.0178*((T+273.)/373.)**(3./2.)*(658.915/(T+558.915))
  U02=0.0239*((T+273.)/373.)**(3./2.)*(505.3/(T+405.3))
  UH2O=0.0124*((T+273.)/373.)**(3./2.)*(921.31/(T+821.31))
  USO2=0.0163*((T+273.)/373.)**(3./2.)*(759.61/(T+659.61))
  UMI X=(( (YN2*5.2934*UN2)+(YC02*6.6340*UC02)+(Y02*5.6569*U02)+
  $(YH2O*4.2445*UH2O)+(YSO2*8.0037*USO2))/((YN2*5.2934)+
  $(YC02*6.6340)+(Y02*5.6569)+(YSO2*8.0037)+(YH2O*4.2445)))/1000.
C
C   GAS PHASE COMPONENT DIFFUSIVITIES
C
  DH2ON2=3.535E-05*((T+273.)/373.)**(7./4.)/PT
  DH2OCO=2.505E-05*((T+273.)/373.)**(7./4.)/PT
  DH2O02=3.525E-05*((T+273.)/373.)**(7./4.)/PT
  DH2OSO=1.979E-05*((T+273.)/373.)**(7./4.)/PT
  DSO2N2=2.090E-05*((T+273.)/373.)**(7./4.)/PT
  DSO2CO=1.466E-05*((T+273.)/373.)**(7./4.)/PT
  DSO2O2=2.044E-05*((T+273.)/373.)**(7./4.)/PT
  DSO2H2=1.979E-05*((T+273.)/373.)**(7./4.)/PT
C
C   TERMINAL VELOCITY CALCULATION
C
  FORCE=5.1348*SLDEN*(DROPDI)**3.
  VINFIN=((2.*UMIX)/(FGDEN*DROPDI))*((9.+(FGDEN*FORCE)/
  $(3.1416*(UMIX)**2.))**((1./2.))-3.0)
  RET=(FGDEN*DROPDI*VINFIN)/UMIX
  IF(RET.LE.10.)GO TO 13
  VINFIN=((4.8*UMIX)/(FGDEN*DROPDI))*((447.+(FGDEN*FORCE)/
  $(3.1416*(UMIX)**2.))**((1./2.))-20.4)
  RET=(FGDEN*DROPDI*VINFIN)/UMIX
  IF(RET.LE.700.)GO TO 14
  GO TO 15
14 IF(RET.GT.10.)GO TO 13
15 VINFIN=(2.4/DROPDI)*(FORCE/FGDEN)**(1./2.)
  RET=(FGDEN*DROPDI*VINFIN)/UMIX
13 CONTINUE
C
C   GAS PHASE MASS TRANSFER CALCULATION
C
  DH2OMX=(1.0-YH2O)/((YN2/DH2ON2)+(YC02/DH2OCO)+(Y02/DH2O02)+
  $(YSO2/DH2OSO))

```

```

    PSAT=EXP(-7.2465822E+03/(T+273.))+77.641232+(5.74471242
    $E-03*(T+273.))+(-8.2470402*ALOG(T+273.))/101325.
    YSAT=PSAT/PT
    YH2OLM=(YSAT-YH2O)/ALOG(YSAT/YH2O)
    KGW=(DH2OMX/(DROPDI*(1.-YH2OLM)))*(2.0+0.6*(UMIX/(FGDEN*DH2OMX))**
    $(1./3.))*((DROPDI*VINFIN*FGDEN)/UMIX)**(1./2.))/(82.057E-06*(T+273.
    $))
    NH2O=KGW*(PSAT-PT*YH2O)
    DS02MX=(1.0-YS02)/((YN2/DS02N2)+(YC02/DS02C0)+(Y02/DS0202)+
    $(YH2O/DS02H2))
    IF(111.GT.0)GO TO 204

```

C
C
C

RATE EQUATION FOR INSTANTANEOUS REACTION

```

    IF(T.LE.30.)HENRY=(10.**((-1285.85/(T+273.))+8.805))*133.32
    IF(T.LE.30.)GO TO 62
    IF(T.GE.52.)HENRY=((29.597*T)-657.2676)*10000.
    IF(T.GE.52.)GO TO 62
    HENRY=((19.265*T)-92.6574)*10000.
62 CONTINUE
    CCA=10.0*((-0.0011*T)+0.185)
    MCCA=CCA*13.495
    XA=PT*YS02/(HENRY/101323.2)
    HC=HENRY*(1.-XA)/5.624E+09
    KL=22.5*DS02/DROPDI
    AP=5.3476E+03*SLDC/(1.+WCAVG)
    VP=DROPDI/6.
    DO 17 I=1,200
    KG=(DS02MX/(DROPDI*(1.-YS02)))*(2.0+0.6*(UMIX/(FGDEN*DS02MX))**
    $(1./3.))*((DROPDI*VINFIN*FGDEN)/UMIX)**(1./2.))/(82.057E-06*(T+273.))
    GG=1./(HC*KG)
    DD=1./KL
    EE=DOCA/(DS02*KS*AP*VP)
    NS02RX=((DOCA*MCCA/DS02)+(PT*YS02/HC))/(GG+DD+EE)
    AAA=KG*PT*YS02
    BBB=KL*DOCA*MCCA/DS02
    IF(AAA.LT.BBB)NS02RX=AAA
    DS02C=(NS02RX-YS02*(NS02RX-NH2O))/((YN2*NS02RX/DS02N2)+(YC02*
    $NS02RX/DS02C0)+(Y02*NS02RX/DS0202)+((YH2O*NS02RX)+(YS02*NH2O))/
    $DS02H2))
    COMPAR=ABS((DS02MX-DS02C)/DS02MX)
    IF(COMPAR.LT.0.05)GO TO 18
    DS02MX=DS02C
17 CONTINUE
    GO TO 20
18 CONTINUE
20 CONTINUE
    S02RXC=NS02RX*TC*3.1416*(DROPDI**2.)*DPS
    S02PS=S02PS1-S02RXC
    IF(S02PS.LT.0.0)S02PS=0.0
    S02AVC=(S02PS1+S02PS)/2.
    GAS=N2PS+C02PS+O2PS+H2OPS+S02AVC
    YAVG=S02AVC/GAS
    ERROR=ABS((YS02-YAVG)/YS02)
    IF(ERROR.LE.0.02)GO TO 200
    IF(11.EQ.50)GO TO 200
    YN2=N2PS/GAS
    YC02=C02PS/GAS
    Y02=O2PS/GAS
    YH2O=H2OPS/GAS

```

```

YS02=YAVG
II=II+1
GO TO 43
200 CONTINUE
IF(II.EQ.50)WRITE(6,202)ERROR,RUN
202 FORMAT('0',5X,'SOLUTION DOES NOT CONVERGE;',
$' ERROR = ',F8.6,20X,'RUN=',I3)
EFMTRC=(S02RXC/S02PSI)*100.
EFFC=EFMTRC
EFFSR=SR(RUN)*100.
IF(EFFC.GE.EFFSR)EFFC=EFFSR
EFMTRC=EFFC
IF(EFMTRC.GT.100.)EFMTRC=100.
IF((EFMTRC.EQ.EFFSR).OR.(EFMTRC.EQ.100.))EFF(RUN)=EFMTRC
IF((EFMTRC.EQ.EFFSR).OR.(EFMTRC.EQ.100.))GO TO 208
C
C FALLING RATE PERIOD MODEL
C
IIII=1
BMAX=1.0
BMIN=1.0E-10
B(RUN)=1.0E-05
401 X=S02RXC
S02PS=S02PSI-X
DRYTOT=N2PS+C02PS+O2PS+S02PS
WETTOT=DRYTOT/(1.-BW2)
H20PS=WETTOT-DRYTOT
YH2O=BW2
YN2=N2PS/WETTOT
YC02=C02PS/WETTOT
YO2=O2PS/WETTOT
YS02=S02PS/WETTOT
YS02I=YS02
ACFS=WETTOT*0.7913*((TEMP2+273.)/273.)*(1./PT)
RESIDT=220./ACFS
C
C CONVERSION FROM DROPS PER SECOND TO PARTICLES PER SECOND
C
VSOLID=CAPD*74.10/2.2E+06
VLIQID=W2*CAPD*74.10E-06
VTOTAL=VSOLID+VLIQID
D=(VTOTAL*1.9099)**(1./3.)
PPS=DPS*((D/7.8E-06)**3.)
DX=((DC**3.)/(PPS/DPS))**(1./3.)
DAVG=((DX**3.)+(7.8E-06**3.))/2.**(1./3.)
DROPDI=DAVG
RCAPD=CAPD-X/DPS
WTS=((X/DPS)*129.15+(RCAPD*74.10))/1000.
WTW=WC*WTS
WTT=WTS+WTW
DEN=WTT/(0.5236*(DC**3.))
SLDEN=DEN
III=IIII+1
R=DAVG/2.
VPART=4.18879*(R**3.)
VAVG=VPART/2.
RC=(VAVG/4.18879)**(1./3.)
GO TO 43
204 XA=PT*YS02/(HENRY/101323.2)
KL=22.5*D0S02/(2.*RC)

```

```

HC=HENRY*(1.-XA)/5.624E+09
VP=RC/6.
AP=5.3476E+03*SLDF/(1.+WFAVG)
DO 85 I=1,200
KG=(DSO2MX/(DROPDI*(1.-YSO2)))*(2.0+0.6*(UMIX/(FGDEN*DSO2MX))**(1.
$/3.))*(DROPDI*VINFIN*FGDEN)/UMIX)**(1./2.))/(82.057E-06*(T+273.))
DE=B(RUN)*DSO2MX
G=(RC**2.)/(HC*KG*(R**2.))
D=RC*(R-RC)*(82.057E-06*(T+273.))/(HC*DE*R)
E=DOCA/(DOSO2*KS*AP*VP)
F=1./KL
NSO2=((DOCA*MCCA/DOSO2)+(PT*YSO2/HC))/(G+D+E+F)
AA1=1./KG
AA2=((82.057E-06*(T+273.))*(R-RC)*R)/(DE*RC)
AAB=PT*YSO2/(AA1+AA2)
BBA=KL*DOCA*MCCA/DOSO2
IF(AAB.LT.BBA)NSO2=AAB
DSO2C=(NSO2-YSO2*(NSO2-NH20))/((YN2*NSO2/DSO2N2)+(YC02*NSO2/
SDSO2C0)+(YO2*NSO2/DSO2O2)+((YH20*NSO2)+(YSO2*NH20))/DSO2H2))
COMPAR=ABS((DSO2MX-DSO2C)/DSO2MX)
IF(COMPAR.LT.0.05)GO TO 89
DSO2MX=DSO2C
85 CONTINUE
GO TO 90
89 CONTINUE
90 CONTINUE
SO2FR=NSO2*TF*12.56637*(RC**2.)*PPS
SO2PS=SO2PSI-SO2RXC-SO2FR
IF(SO2PS.LT.0.0)SO2PS=0.0
SO2AVG=(SO2PSI-SO2RXC+SO2PS)/2.
GAS=N2PS+CO2PS+O2PS+H2OPS+SO2AVG
YAVG=SO2AVG/GAS
ERROR=ABS((YSO2-YAVG)/YSO2)
IF(ERROR.LE.0.02)GO TO 205
IF(III.EQ.50)GO TO 205
YN2=N2PS/GAS
YC02=CO2PS/GAS
YO2=O2PS/GAS
YSO2=YAVG
YH2O=H2OPS/GAS
III=III+1
GO TO 43
205 CONTINUE
IF(III.EQ.50)WRITE(6,202)ERROR,RUN
EFF(RUN)=((SO2FR+X)/SO2PSI)*100.
EFFF=EFF(RUN)
IF(EFFF.GE.EFFSR)EFFF=EFFSR
EFF(RUN)=EFFF
IF((SO2FR+X).GT.SO2PSI)EFF(RUN)=100.
208 CONTINUE
IF((EFMTRC.EQ.EFFSR).OR.(EFMTRC.EQ.100.))GO TO 500
CHECK=ABS(EFF(RUN)-EFFSD(RUN))
IF(CHECK.LE.0.1)GO TO 400
IF(IIII.EQ.40)GO TO 400
IF(EFF(RUN).LT.EFFSD(RUN))BMIN=B(RUN)
IF(EFF(RUN).GE.EFFSD(RUN))BMAX=B(RUN)
DIFF=ABS((BMAX-BMIN)/BMAX)
IF(DIFF.LT.0.01)GO TO 400
B(RUN)=(BMAX+BMIN)/2.
IIII=1

```

```
      I I I I=I I I I+1
      GO TO 401
400  ITER(RUN)=I I I I
      BLOG(RUN)=ALOG10(B(RUN))
500  GO TO 101
100  WRITE(6,450)
450  FORMAT('1',/////,55X,'MODEL PERFORMANCE TABLE')
      WRITE(6,451)KS
451  FORMAT('1',55X,'KS =' ,E12.5,' M/SEC')
      WRITE(6,452)
452  FORMAT('1',41X,'RUN',5X,'SR',4X,'DELTAT',8X,'B',10X,'LOG B',3X,
$' ITER')
      DO 402 RUN=1,25
      WRITE(6,453)RUN,SR(RUN),DELTAT(RUN),B(RUN),BLOG(RUN),ITER(RUN)
453  FORMAT('1',42X,12,4X,F4.2,4X,F4.1,4X,E11.5,3X,F8.4,3X,12)
402  CONTINUE
      KS=KS+1.0E-05
      IF(KS.GT.8.0E-05)GO TO 102
      REWIND 5
      GO TO 101
102  STOP
      END
```

TABLE E-1

RESULTS FROM OPTIMIZING THE RATIO OF POROSITY TO TORTUOSITY
FOR k_s EQUALLING 2.0×10^{-5} m/sec

RUN	SR ^a	DEL TAT ^b	B ^c	LOG B ^d	ITER ^e
1	1.62	25.0	0.14048E-01	-1.8524	14
2	0.57	36.0	0.80087E-01	-1.0964	10
3	0.93	21.0	0.39560E-01	-1.4027	12
4	1.06	25.0	0.25644E-01	-1.5910	13
5	1.57	22.0	0.16978E-01	-1.7701	14
6	1.21	32.0	0.17466E-01	-1.7578	14
7	0.54	20.5	0.41513E-01	-1.3818	12
8	0.48	25.0	0.12949E-01	-1.8878	13
9	0.43	35.0	0.52744E-01	-1.2778	10
10	1.87	20.0	0.97145E-02	-2.0126	15
11	1.93	27.0	0.11057E-01	-1.9564	15
12	0.93	20.0	0.20273E-01	-1.6931	13
13	0.45	25.0	0.45908E-01	-1.3381	11
14	0.42	20.0	0.99219E+00	-0.0034	8
15	0.89	27.0	0.43222E-01	-1.3643	13
16	0.25	35.0	0.99219E+00	-0.0034	8
17	1.12	35.0	0.30527E-01	-1.5153	13
18	0.64	35.0	0.29307E-01	-1.5330	10
19	1.81	25.0	0.14414E-01	-1.8412	13
20	0.33	19.0	0.99219E+00	-0.0034	8
21	0.62	25.0	0.53720E-01	-1.2699	11
22	0.81	20.0	0.21738E-01	-1.6628	13
23	0.57	35.0	0.99219E+00	-0.0034	8
24	0.31	24.0	0.99219E+00	-0.0034	8
25	0.29	35.0	0.99219E+00	-0.0034	8

^aStoichiometric ratio.

^bTemperature approach to saturation.

^cRatio of porosity to tortuosity.

^dCommon logarithm of B.

^eIterations required by program to determine B.

TABLE E-2

RESULTS FROM OPTIMIZING THE RATIO OF POROSITY TO TORTUOSITY
FOR k_s EQUALLING 3.0×10^{-5} m/sec

RUN	SR ^a	DELTA T ^b	B ^c	LOG B ^d	ITER ^e
1	1.62	25.0	0.12827E-01	-1.8919	14
2	0.57	36.0	0.74228E-01	-1.1294	9
3	0.93	21.0	0.38095E-01	-1.4191	11
4	1.06	25.0	0.23813E-01	-1.6232	14
5	1.57	22.0	0.16245E-01	-1.7893	14
6	1.21	32.0	0.15635E-01	-1.8059	7
7	0.54	20.5	0.37607E-01	-1.4247	12
8	0.48	25.0	0.85548E-02	-2.0678	13
9	0.43	35.0	0.43466E-01	-1.3618	12
10	1.87	20.0	0.90431E-02	-2.0437	13
11	1.93	27.0	0.99586E-02	-2.0018	15
12	0.93	20.0	0.19053E-01	-1.7200	12
13	0.45	25.0	0.41025E-01	-1.3869	10
14	0.42	20.0	0.99219E+00	-0.0034	8
15	0.89	27.0	0.40537E-01	-1.3921	12
16	0.25	35.0	0.99219E+00	-0.0034	8
17	1.12	35.0	0.28330E-01	-1.5478	11
18	0.64	35.0	0.26133E-01	-1.5828	13
19	1.81	25.0	0.12827E-01	-1.8919	14
20	0.33	19.0	0.99219E+00	-0.0034	8
21	0.62	25.0	0.50302E-01	-1.2984	12
22	0.81	20.0	0.19541E-01	-1.7091	9
23	0.57	35.0	0.46884E-01	-1.3290	7
24	0.31	24.0	0.99219E+00	-0.0034	8
25	0.29	35.0	0.99219E+00	-0.0034	8

^aStoichiometric ratio.

^bTemperature approach to saturation.

^cRatio of porosity to tortuosity.

^dCommon logarithm of B.

^eIterations required by program to determine B.

TABLE E-3

RESULTS FROM OPTIMIZING THE RATIO OF POROSITY TO TORTUOSITY
FOR k_s EQUALLING 4.0×10^{-5} m/sec

RUN	SR ^a	DELTAT ^b	B ^c	LOG B ^d	ITER ^e
1	1.62	25.0	0.11973E-01	-1.9218	13
2	0.57	36.0	0.69345E-01	-1.1590	11
3	0.93	21.0	0.36631E-01	-1.4362	12
4	1.06	25.0	0.21982E-01	-1.6579	12
5	1.57	22.0	0.15635E-01	-1.8059	7
6	1.21	32.0	0.13926E-01	-1.8562	13
7	0.54	20.5	0.34189E-01	-1.4661	11
8	0.48	25.0	0.48928E-02	-2.3104	11
9	0.43	35.0	0.35166E-01	-1.4539	9
10	1.87	20.0	0.82496E-02	-2.0836	15
11	1.93	27.0	0.90431E-02	-2.0437	13
12	0.93	20.0	0.18076E-01	-1.7429	12
13	0.45	25.0	0.36142E-01	-1.4420	11
14	0.42	20.0	0.24912E-01	-1.6036	12
15	0.89	27.0	0.37363E-01	-1.4276	13
16	0.25	35.0	0.99219E+00	-0.0034	8
17	1.12	35.0	0.26621E-01	-1.5748	13
18	0.64	35.0	0.22959E-01	-1.6390	12
19	1.81	25.0	0.11851E-01	-1.9263	14
20	0.33	19.0	0.99219E+00	-0.0034	8
21	0.62	25.0	0.46884E-01	-1.3290	7
22	0.81	20.0	0.17832E-01	-1.7488	13
23	0.57	35.0	0.42734E-01	-1.3692	13
24	0.31	24.0	0.99219E+00	-0.0034	8
25	0.29	35.0	0.99219E+00	-0.0034	8

^aStoichiometric ratio.

^bTemperature approach to saturation.

^cRatio of porosity to tortuosity.

^dCommon logarithm of B.

^eIterations required by program to determine B.

TABLE E-4

RESULTS FROM OPTIMIZING THE RATIO OF POROSITY TO TORTUOSITY
FOR k_s EQUALLING 5.0×10^{-5} m/sec

RUN	SR ^a	DELTAT ^b	B ^c	LOG B ^d	ITER ^e
1	1.62	25.0	0.10935E-01	-1.9612	15
2	0.57	36.0	0.65439E-01	-1.1842	11
3	0.93	21.0	0.36386E-01	-1.4391	13
4	1.06	25.0	0.20151E-01	-1.6957	14
5	1.57	22.0	0.14780E-01	-1.8303	14
6	1.21	32.0	0.12949E-01	-1.8878	13
7	0.54	20.5	0.30283E-01	-1.5188	11
8	0.48	25.0	0.12307E-02	-2.9099	13
9	0.43	35.0	0.28330E-01	-1.5478	11
10	1.87	20.0	0.78224E-02	-2.1067	8
11	1.93	27.0	0.81886E-02	-2.0868	14
12	0.93	20.0	0.17588E-01	-1.7548	10
13	0.45	25.0	0.31992E-01	-1.4950	13
14	0.42	20.0	0.22471E-01	-1.6484	11
15	0.89	27.0	0.35898E-01	-1.4449	13
16	0.25	35.0	0.99219E+00	-0.0034	8
17	1.12	35.0	0.25400E-01	-1.5952	10
18	0.64	35.0	0.20029E-01	-1.6983	12
19	1.81	25.0	0.11240E-01	-1.9492	12
20	0.33	19.0	0.21982E-01	-1.6579	12
21	0.62	25.0	0.44199E-01	-1.3546	13
22	0.81	20.0	0.15879E-01	-1.7992	13
23	0.57	35.0	0.39316E-01	-1.4054	13
24	0.31	24.0	0.99219E+00	-0.0034	8
25	0.29	35.0	0.80087E-01	-1.0964	10

^aStoichiometric ratio.

^bTemperature approach to saturation.

^cRatio of porosity to tortuosity.

^dCommon logarithm of B.

^eIterations required by program to determine B.

TABLE E-5

RESULTS FROM OPTIMIZING THE RATIO OF POROSITY TO TORTUOSITY
FOR k_s EQUALLING 6.0×10^{-5} m/sec

RUN	SR ^a	DELTAT ^b	B ^c	LOG B ^d	ITER
1	1.62	25.0	0.10020E-01	-1.9991	13
2	0.57	36.0	0.61533E-01	-1.2109	11
3	0.93	21.0	0.35166E-01	-1.4539	9
4	1.06	25.0	0.18564E-01	-1.7313	11
5	1.57	22.0	0.13804E-01	-1.8600	14
6	1.21	32.0	0.11973E-01	-1.9218	13
7	0.54	20.5	0.27598E-01	-1.5591	13
8	0.48	25.0	0.10060E-09	-9.9974	25
9	0.43	35.0	0.21494E-01	-1.6677	10
10	1.87	20.0	0.74562E-02	-2.1275	14
11	1.93	27.0	0.74562E-02	-2.1275	14
12	0.93	20.0	0.16733E-01	-1.7764	14
13	0.45	25.0	0.28818E-01	-1.5403	12
14	0.42	20.0	0.20273E-01	-1.6931	13
15	0.89	27.0	0.34433E-01	-1.4630	13
16	0.25	35.0	0.99219E+00	-0.0034	8
17	1.12	35.0	0.24424E-01	-1.6122	11
18	0.64	35.0	0.17588E-01	-1.7548	10
19	1.81	25.0	0.10447E-01	-1.9810	15
20	0.33	19.0	0.19541E-01	-1.7091	9
21	0.62	25.0	0.42002E-01	-1.3767	11
22	0.81	20.0	0.14536E-01	-1.8375	14
23	0.57	35.0	0.36142E-01	-1.4420	11
24	0.31	24.0	0.99219E+00	-0.0034	8
25	0.29	35.0	0.70322E-01	-1.1529	8

^aStoichiometric ratio.

^bTemperature approach to saturation.

^cRatio of porosity to tortuosity.

^dCommon logarithm of B.

^eIterations required by program to determine B.

TABLE E-6

RESULTS FROM OPTIMIZING THE RATIO OF POROSITY TO TORTUOSITY
FOR k_s EQUALLING 7.0×10^{-5} m/sec

RUN	SR ^a	DELTAT ^b	B ^c	LOG B ^d	ITER ^e
1	1.62	25.0	0.92872E-02	-2.0321	12
2	0.57	36.0	0.58603E-01	-1.2321	9
3	0.93	21.0	0.33945E-01	-1.4692	13
4	1.06	25.0	0.16611E-01	-1.7796	11
5	1.57	22.0	0.13315E-01	-1.8756	14
6	1.21	32.0	0.11240E-01	-1.9492	12
7	0.54	20.5	0.25156E-01	-1.5994	13
8	0.48	25.0	0.10060E-09	-9.9974	25
9	0.43	35.0	0.16123E-01	-1.7926	12
10	1.87	20.0	0.71510E-02	-2.1456	15
11	1.93	27.0	0.67238E-02	-2.1724	14
12	0.93	20.0	0.15879E-01	-1.7992	13
13	0.45	25.0	0.25400E-01	-1.5952	10
14	0.42	20.0	0.18564E-01	-1.7313	11
15	0.89	27.0	0.33213E-01	-1.4787	10
16	0.25	35.0	0.12705E-01	-1.8960	11
17	1.12	35.0	0.23447E-01	-1.6299	8
18	0.64	35.0	0.15635E-01	-1.8059	7
19	1.81	25.0	0.97755E-02	-2.0099	10
20	0.33	19.0	0.17344E-01	-1.7609	13
21	0.62	25.0	0.39560E-01	-1.4027	12
22	0.81	20.0	0.13438E-01	-1.8717	13
23	0.57	35.0	0.33701E-01	-1.4724	12
24	0.31	24.0	0.99219E+00	-0.0034	8
25	0.29	35.0	0.63486E-01	-1.1973	11

^aStoichiometric ratio.

^bTemperature approach to saturation.

^cRatio of porosity to tortuosity.

^dCommon logarithm of B.

^eIterations required by program to determine B.

TABLE E-7

RESULTS FROM OPTIMIZING THE RATIO OF POROSITY TO TORTUOSITY
FOR k_s EQUALLING 8.0×10^{-5} m/sec

RUN	SR ^a	DELTAT ^b	B ^c	LOG B ^d	ITER ^e
1	1.62	25.0	0.84327E-02	-2.0740	14
2	0.57	36.0	0.55673E-01	-1.2544	11
3	0.93	21.0	0.32969E-01	-1.4819	13
4	1.06	25.0	0.15513E-01	-1.8093	14
5	1.57	22.0	0.12949E-01	-1.8878	13
6	1.21	32.0	0.10630E-01	-1.9735	14
7	0.54	20.5	0.22715E-01	-1.6437	13
8	0.48	25.0	0.10060E-09	-9.9974	25
9	0.43	35.0	0.11240E-01	-1.9492	12
10	1.87	20.0	0.69069E-02	-2.1607	15
11	1.93	27.0	0.62355E-02	-2.2051	14
12	0.93	20.0	0.15269E-01	-1.8162	14
13	0.45	25.0	0.21982E-01	-1.6579	12
14	0.42	20.0	0.16611E-01	-1.7796	11
15	0.89	27.0	0.31992E-01	-1.4950	13
16	0.25	35.0	0.83107E-02	-2.0804	12
17	1.12	35.0	0.22715E-01	-1.6437	13
18	0.64	35.0	0.13682E-01	-1.8639	10
19	1.81	25.0	0.91652E-02	-2.0379	14
20	0.33	19.0	0.15391E-01	-1.8127	13
21	0.62	25.0	0.36875E-01	-1.4333	13
22	0.81	20.0	0.12339E-01	-1.9087	14
23	0.57	35.0	0.31260E-01	-1.5050	6
24	0.31	24.0	0.99219E+00	-0.0034	8
25	0.29	35.0	0.56650E-01	-1.2468	10

^aStoichiometric ratio.

^bTemperature approach to saturation.

^cRatio of porosity to tortuosity.

^dCommon logarithm of B.

^eIterations required by program to determine B.

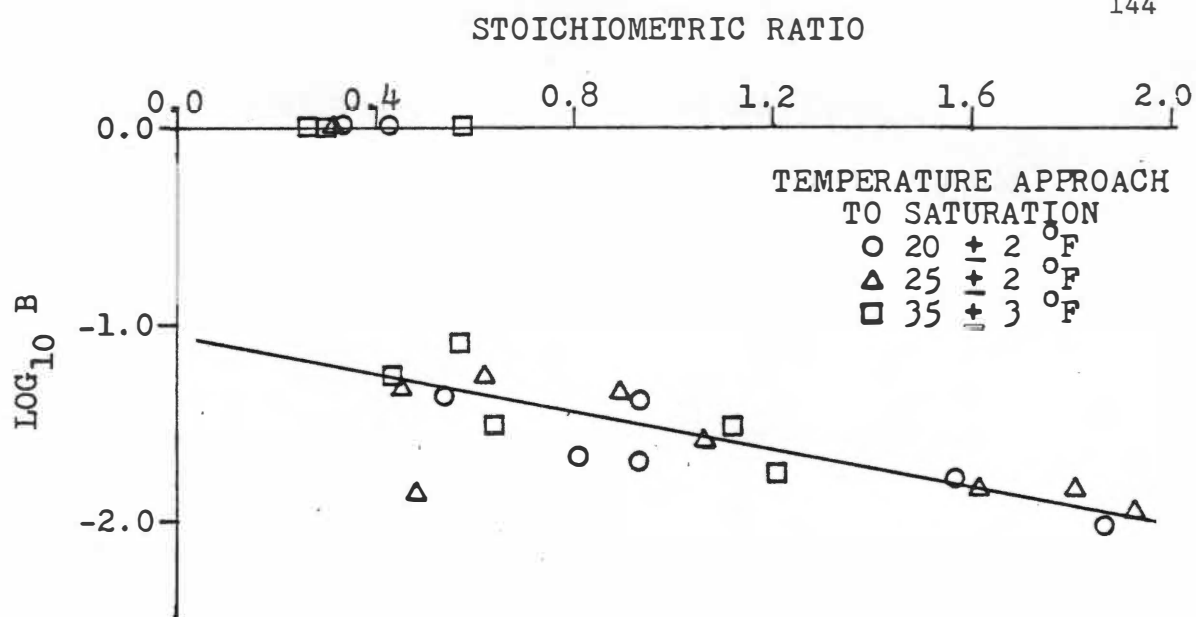


Figure E-1. Effect of stoichiometric ratio on the ratio of porosity to tortuosity for k_s equalling 2.0×10^{-5} m/sec.

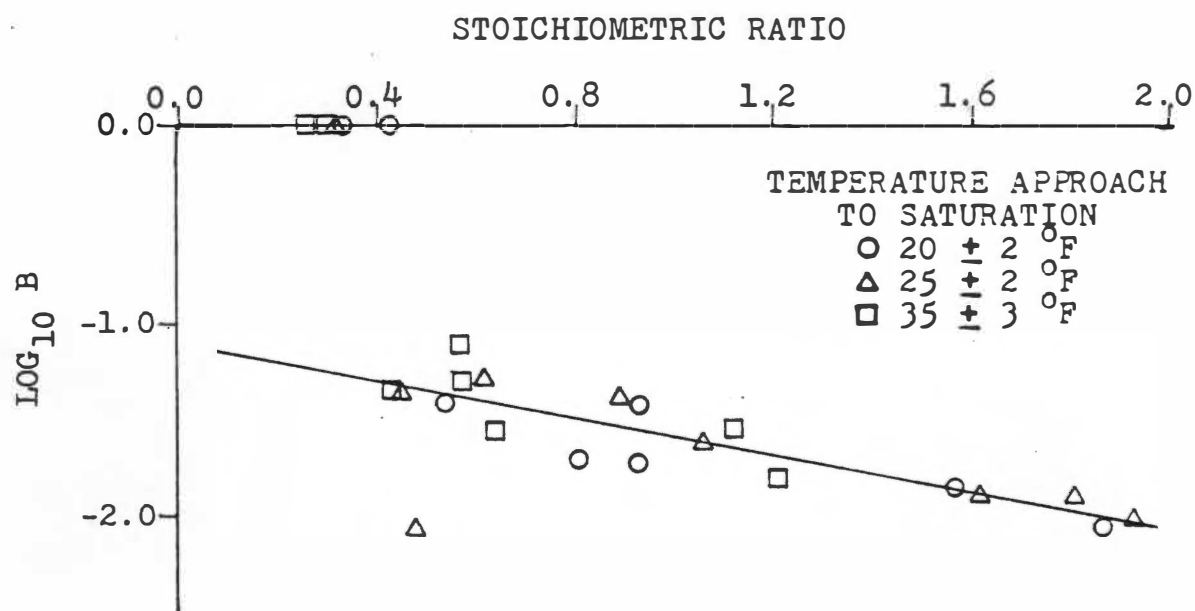


Figure E-2. Effect of stoichiometric ratio on the ratio of porosity to tortuosity for k_s equalling 3.0×10^{-5} m/sec.

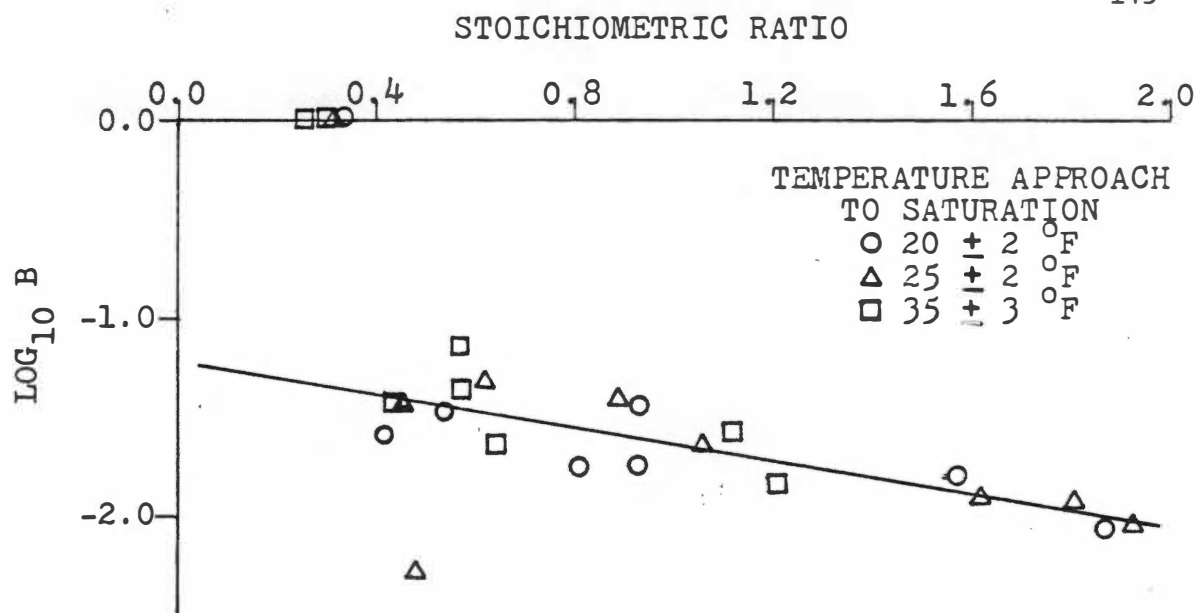


Figure E-3. Effect of stoichiometric ratio on the ratio of porosity to tortuosity for k_s equalling 4.0×10^{-5} m/sec.

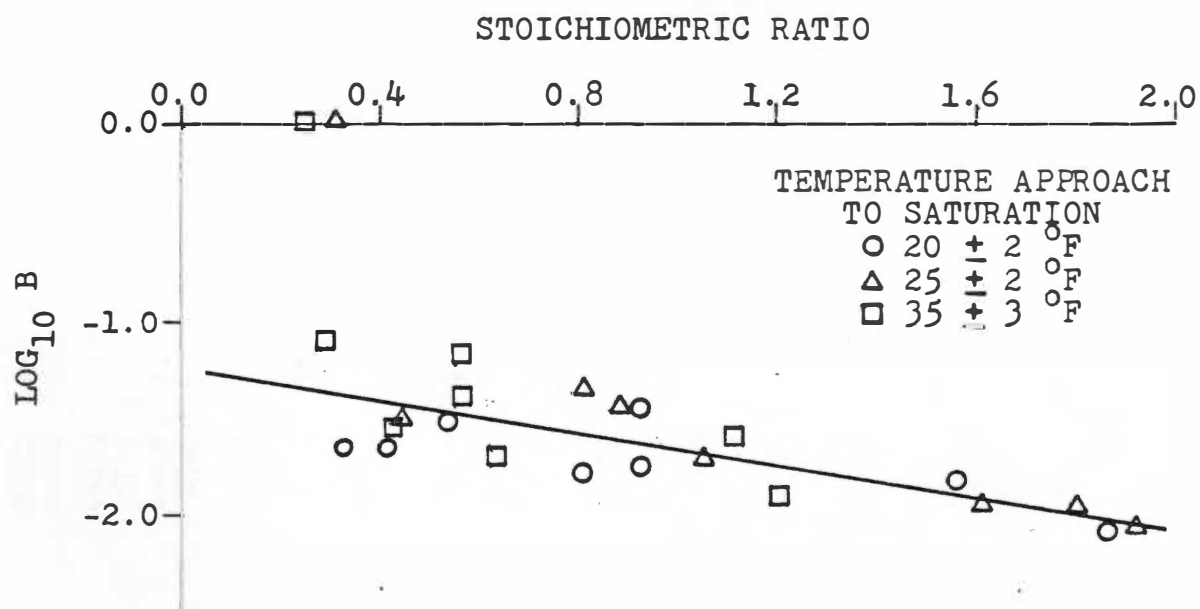


Figure E-4. Effect of stoichiometric ratio on the ratio of porosity to tortuosity for k_s equalling 5.0×10^{-5} m/sec.

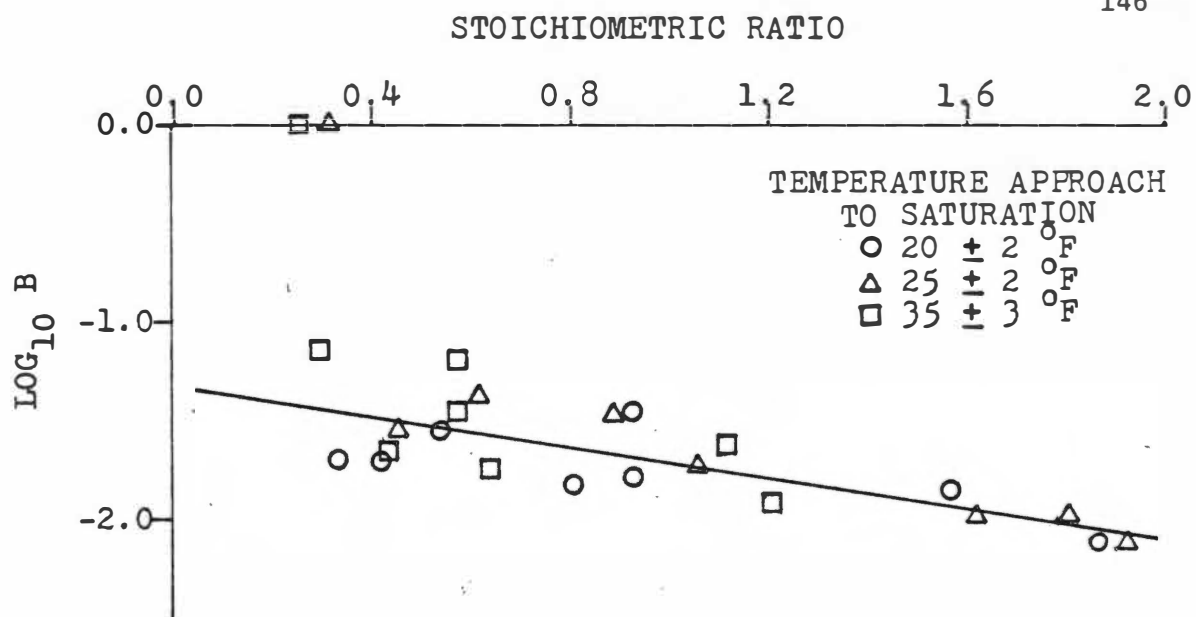


Figure E-5. Effect of stoichiometric ratio on the ratio of porosity to tortuosity for k_s equalling 6.0×10^{-5} m/sec.

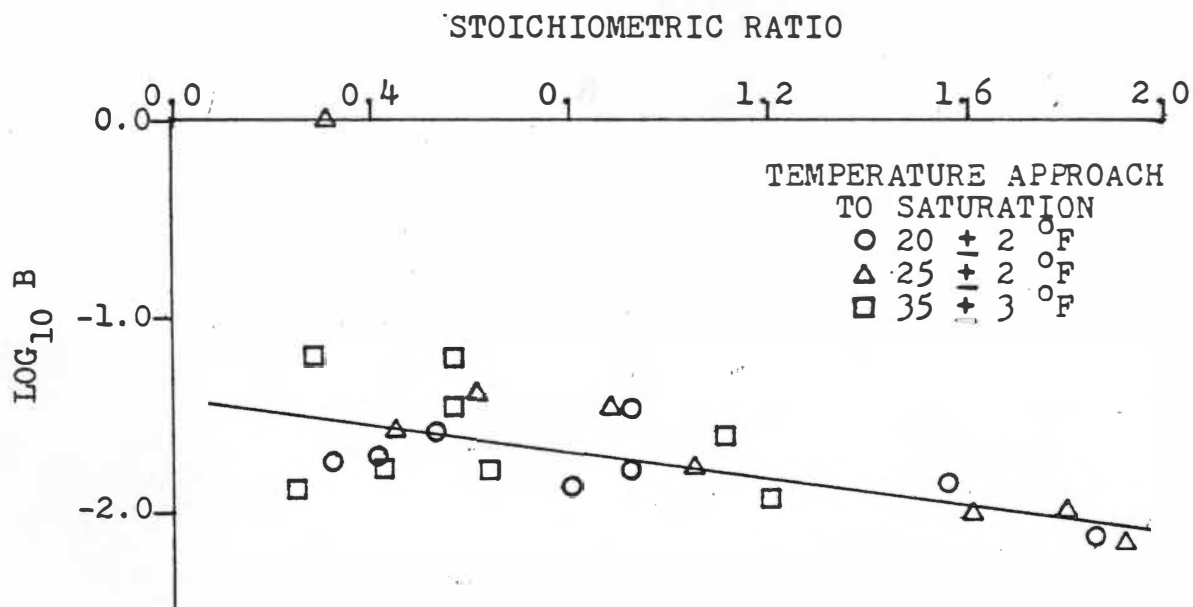


Figure E-6. Effect of stoichiometric ratio on the ratio of porosity to tortuosity for k_s equalling 7.0×10^{-5} m/sec.

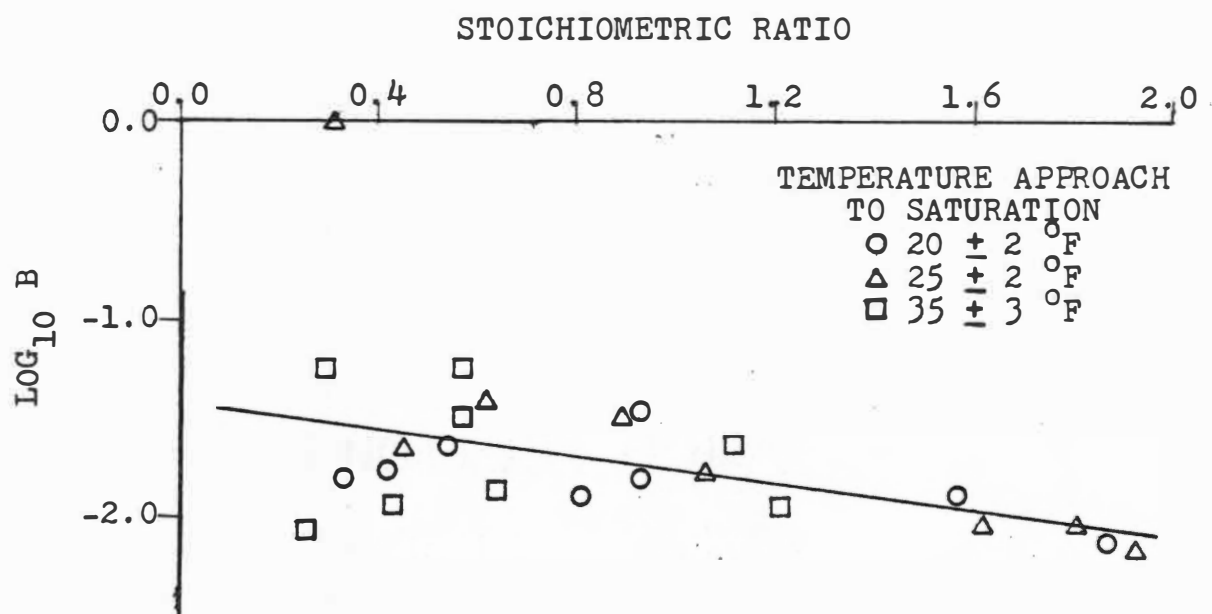


Figure E-7. Effect of stoichiometric ratio on the ratio of porosity to tortuosity for k_s equalling 8.0×10^{-5} m/sec.

APPENDIX F

COMPUTER PROGRAM AND RESULTS USED IN SELECTING THE FINAL COMPUTER MODEL

```

C
C   MODEL.FNL
C
  DIMENSION EFF(29),EFFSD(29),PERDIF(29)
  REAL LMTDC,KD,LMTDF,MWAVG,NH2O,KG,NSO2,MSO2,NSO2RX,
  SMCCA,N2PS,KL,KGW,KS
  INTEGER RUN,PAGE
  IRUN=2
  KS=2.0E-05
101 READ(5,34)RUN,PAGE
34  FORMAT(2I3)
  IF(RUN.EQ.999)GO TO 100
  READ(5,1)YN2,YCO2,YO2,YH2O,YSO2
  1  FORMAT(5F8.6)
  READ(5,2)SO2ONC,TEMP1C,SLCONC,SCFM1C
  2  FORMAT(F6.1,F5.1,F5.3,F5.1)
  READ(5,3)GPM,PBAR,SP1,SP2,TSLURR
  3  FORMAT(F5.3,F5.2,2F3.1,F5.1)
  READ(5,4)TEMP2,TW2,DROPDI,PRODDN
  4  FORMAT(2F5.1,E10.2,F6.1)
  READ(5,37)EFFSD(RUN),BW2
37  FORMAT(F5.2,F8.6)
  YFIX=YH2O+YSO2
  YADJST=1.-YFIX
  YN2=(YADJST/.95)*YN2
  YCO2=(YADJST/.95)*YCO2
  YO2=(YADJST/.95)*YO2
  SLDEN=1000.+86.3795*SLCONC
  W1=6.3118/SLCONC-0.4545
  DELTAT=TEMP2-TW2

C
C   NUMBER OF DROPS ENTERING THE SYSTEM
C
  DPS=(GPM/(DROPDI)**3.)*1.204E-04

C
C   SPRAY DRYER OPERATING PRESSURE
C
  PT=(PBAR/29.921)-((SP1+SP2)/810.62)

C
C   MOLES OF GAS ENTERING THE SYSTEM
C
  GGASPS=SCFM1C*1.9545E-02
  YSO2I=YSO2
  SO2PS=GGASPS*YSO2
  SO2PSI=SO2PS
  SO2AVG=SO2PSI/2.
  N2PS=GGASPS*YN2
  CO2PS=GGASPS*YCO2
  O2PS=GGASPS*YO2
  H2OPS=GGASPS*YH2O

C
C   MOLES OF CA(OH)2 PER DROP
C
  TMCCA=SLCONC*2.137E+03
  CAPD=TMCCA*0.5236*(DROPDI**3.)

C
C   STIOCHIOMETRIC RATIO CALCULATION
C
  SR=CAPD*DPS/SO2PS

```

```

C      FINAL MOISTURE CONTENT APPROXIMATION
C
  GWATPS=GPM*SLDEN*6.3115E-02*W1/(1.+W1)
  GCOHPS=(GPM*SLDEN*6.3115E-02)-GWATPS
  DTSLUR=(TW2-TSLURR)/1.8
  HWAT=DTSLUR*GWATPS/1000.
  HCOH=DTSLUR*(21.4/74.1)*GCOHPS/1000.
  HSLUR=HWAT+HCOH
  CP=((29.141*YN2)+(38.166*YC02)+(29.526*YO2)+(33.727*YH20))
  $*2.39E-04
  HGAS=CP*GGASPS*(TEMP1C-TEMP2)/1.8
  HVAP=-0.3290*TW2+608.2879
  HRISE=.22722*DELTAT
  W3=4.4732E+04/(DELTAT**4.3463)
  W2=W3/(1.-W3)
  WVAP=(W1-W2)*GCOHPS/1000.
  HEAT=(HVAP*WVAP)+(HRISE*WVAP)+HSLUR-HGAS
  DC=DRODPI*((SLDEN/PRODDN)*((1.+W2)/(1.+W1)))**(.1/3.)
  WC=((SLDEN-158.3354*SLCONC)-1000.)/(1000.*
  $(DC/DRODPI)**3.))/(158.3354*SLCONC)
  AVGDEN=(SLDEN+PRODDN)/2.
  KD=8.64E-05*((TW2-32.)/1.8)+273.)-1.196E-02
  TSLURR=(TSLURR-32.)/1.8
  TEMP1C=(TEMP1C-32.)/1.8
  TEMP2=(TEMP2-32.)/1.8
  TW2=(TW2-32.)/1.8
  T=TW2

C      AVERAGE DENSITY CALCULATIONS
C
  WCAVG=(W1+WC)/2.
  WFAVG=(WC+W2)/2.
  SLCC=6.3118/(WCAVG+.4545)
  SLCF=6.3118/(WFAVG+.4545)
  SLDC=1000.+86.3795*SLCC
  SLDF=1000.+86.3795*SLCF

C      CRITICAL TEMPERATURE ESTIMATION
C
  WVAPC=(W1-WC)*GCOHPS/1000.
  HEATC=((W1-WC)/(W1-W2))*HEAT
  C=CP*GGASPS
  A=.22722*1.8*WVAPC
  TEMPC=(HEATC+C*TEMP1C-HVAP*WVAPC+A*TW2-HSLUR)/(A+C)

C      CONSTANT RATE PERIOD CALCULATION
C
  LMTDC=((TEMP1C-TEMPC)-(TW2-TSLURR))/
  $ALOG((TEMP1C-TEMPC)/(TW2-TSLURR))
  TC=HVAP*AVGDEN*((DRODPI)**2.-(DC)**2.)*3600./(8.*KD*LMTDC)

C      FALLING RATE PERIOD CALCULATION
C
  LMTDF=(TEMPC+TEMP2)/2.-TW2
  TF=HVAP*PRODDN*DC**2.*(WC-W2)*3600./(12.*KD*LMTDF)

C      RESULTS FROM TIME PERIOD CALCULATIONS
C
  CA++ DIFFUSION IN WATER - WILKE/CHANG EQN.

```

```

C      DOCA=4.781E-12*(T+273.)/(1.002*10.**((1.3272*(20.-T)-
C      $0.001053*(T-20.))**2.)/(T+105.)))
C
C      SO2 DIFFUSION IN WATER - WILKE/CHANG EQN.
C
C      DOSO2=5.1735E-12*(T+273.)/(1.002*10.**((1.3272*(20.-T)-
C      $0.001053*(T-20.))**2.)/(T+105.)))
C
C      GAS PHASE PHYSICAL PROPERTY ESTIMATIONS
C
C      DENSITY OF FLUE GAS
C
C      AVGDIA=((DROPDI**3.)+(DC**3.))/2. )** (1./3.)
C      DROPDI=AVGDIA
C      II=0
C      III=0
43  MWAVG=YN2*28.02+YC02*44.01+Y02*32.+YH2O*18.016+YSO2*64.06
C      FGDN=(PT*MWAVG/(82.057*(T+273.)))*1000.
C
C      VISCOSITY OF FLUE GAS
C
C      UN2=0.0208*((T+273.)/373. )** (3./2. )*(486.484/(T+386.484))
C      UC02=0.0178*((T+273.)/373. )** (3./2. )*(658.915/(T+558.915))
C      U02=0.0239*((T+273.)/373. )** (3./2. )*(505.3/(T+405.3))
C      UH2O=0.0124*((T+273.)/373. )** (3./2. )*(921.31/(T+821.31))
C      USO2=0.0163*((T+273.)/373. )** (3./2. )*(759.61/(T+659.61))
C      UMIK=((YN2*5.2934*UN2)+(YC02*6.6340*UC02)+(Y02*5.6569*U02)+
C      $(YH2O*4.2445*UH2O)+(YSO2*8.0037*USO2))/((YN2*5.2934)+
C      $(YC02*6.6340)+(Y02*5.6569)+(YSO2*8.0037)+(YH2O*4.2445)))/1000.
C
C      GAS PHASE COMPONENT DIFFUSIVITIES
C
C      DH2ON2=3.535E-05*((T+273.)/373. )** (7./4. )/PT
C      DH2OC0=2.505E-05*((T+273.)/373. )** (7./4. )/PT
C      DH2O02=3.525E-05*((T+273.)/373. )** (7./4. )/PT
C      DH2OS0=1.979E-05*((T+273.)/373. )** (7./4. )/PT
C      DS02N2=2.090E-05*((T+273.)/373. )** (7./4. )/PT
C      DS02C0=1.466E-05*((T+273.)/373. )** (7./4. )/PT
C      DS02O2=2.044E-05*((T+273.)/373. )** (7./4. )/PT
C      DS02H2=1.979E-05*((T+273.)/373. )** (7./4. )/PT
C
C      TERMINAL VELOCITY CALCULATION
C
C      FORCE=5.1348*SLDEN*(DROPDI)**3.
C      VINFIN=((2.*UMIX)/(FGDN*DROPDI))*(9.+(FGDN*FORCE)/
C      $(3.1416*(UMIX)**2.))** (1./2. )-3.0)
C      RET=(FGDN*DROPDI*VINFIN)/UMIX
C      IF(RET.LE.10.)GO TO 13
C      VINFIN=((4.8*UMIX)/(FGDN*DROPDI))*(447.+(FGDN*FORCE)/
C      $(3.1416*(UMIX)**2.))** (1./2. )-20.4)
C      RET=(FGDN*DROPDI*VINFIN)/UMIX
C      IF(RET.LE.700.)GO TO 14
C      GO TO 15
14  IF(RET.GT.10.)GO TO 13
15  VINFIN=(2.4/DROPDI)*(FORCE/FGDN)** (1./2. )
C      RET=(FGDN*DROPDI*VINFIN)/UMIX
13  CONTINUE
C
C      GAS PHASE MASS TRANSFER CALCULATION

```

C

```

DH2OMX=(1.0-YH20)/((YN2/DH2ON2)+(YC02/DH2OC0)+(Y02/DH2O02)+
$(YS02/DH2OS0))
PSAT=EXP(-7.2465822E+03/(T+273.))+77.641232+(5.74471242
$E-03*(T+273.))+(-8.2470402*ALOG(T+273.)))/101325.
YSAT=PSAT/PT
YH2OLM=(YSAT-YH20)/ALOG(YSAT/YH20)
KGW=(DH2OMX/(DROPD1*(1.-YH2OLM)))*(2.0+0.6*(UMIX/(FGDEN*DH2OMX))**
$(1./3.)*(DROPD1*VINFIN*FGDEN)/UMIX)**(1./2.))/(82.057E-06*(T+273.
$))
NH20=KGW*(PSAT-PT*YH20)
DS02MX=(1.0-YS02)/((YN2/DS02N2)+(YC02/DS02C0)+(Y02/DS02O2)+
$(YH20/DS02H2))
IF(111.GT.0)GO TO 204

```

C

C

C

RATE EQUATION FOR INSTANTANEOUS REACTION

```

IF(T.LE.30.)HENRY=(10.**((-1285.85/(T+273.))+8.805))*133.32
IF(T.LE.30.)GO TO 62
IF(T.GE.52.)HENRY=((29.597*T)-657.2676)*10000.
IF(T.GE.52.)GO TO 62
HENRY=((19.265*T)-92.6574)*10000.
62 CONTINUE
CCA=10.0*((-0.0011*T)+0.185)
MCCA=CCA*13.495
XA=PT*YS02/(HENRY/101323.2)
HC=HENRY*(1.-XA)/5.624E+09
KL=22.5*DS02/DROPD1
AP=5.3476E+03*SLDC/(1.+WCAVG)
VP=DROPD1/6.
DO 17 I=1,200
KG=(DS02MX/(DROPD1*(1.-YS02)))*(2.0+0.6*(UMIX/(FGDEN*DS02MX))**
$(1./3.)*(DROPD1*VINFIN*FGDEN)/UMIX)**(1./2.))/(82.057E-06*(T+273.))
GG=1./(HC*KG)
DD=1./KL
EE=DOCA/(DS02*KS*AP*VP)
NS02RX=((DOCA*MCCA/DS02)+(PT*YS02/HC))/(GG+DD+EE)
AAA=KG*PT*YS02
BBB=KL*DOCA*MCCA/DS02
IF(AAA.LT.BBB)NS02RX=AAA
DS02C=(NS02RX-YS02*(NS02RX-NH20))/((YN2*NS02RX/DS02N2)+(YC02*
$NS02RX/DS02C0)+(Y02*NS02RX/DS02O2)+((YH20*NS02RX)+(YS02*NH20))/
$DS02H2))
COMPAR=ABS((DS02MX-DS02C)/DS02MX)
IF(COMPAR.LT.0.05)GO TO 18
DS02MX=DS02C
17 CONTINUE
GO TO 20
18 CONTINUE
20 CONTINUE
S02RXC=NS02RX*TC*3.1416*(DROPD1**2.)*DPS
S02PS=S02PS1-S02RXC
IF(S02PS.LT.0.0)S02PS=0.0
S02AVC=(S02PS1+S02PS)/2.
GAS=N2PS+C02PS+O2PS+H2OPS+S02AVC
YAVG=S02AVC/GAS
ERROR=ABS((YS02-YAVG)/YS02)
IF(ERROR.LE.0.02)GO TO 200
IF(11.EQ.200)GO TO 200
YN2=N2PS/GAS

```

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YC02=C02PS/GAS
Y02=O2PS/GAS
YH20=H20PS/GAS
YS02=YAVG
II=II+1
GO TO 43
200 CONTINUE
IF(II.EQ.200)WRITE(6,202)ERROR
202 FORMAT('O',5X,'SOLUTION DOES NOT CONVERGE;',
$' ERROR = ',F8.6)
EFMTRC=(S02RXC/S02PSI)*100.
EFFC=EFMTRC
EFFSR=SR*100.
IF(EFFC.GE.EFFSR)EFFC=EFFSR
EFMTRC=EFFC
IF(EFMTRC.GT.100.)EFMTRC=100.
IF((EFMTRC.EQ.EFFSR).OR.(EFMTRC.EQ.100.))EFF(RUN)=EFMTRC
IF((EFMTRC.EQ.EFFSR).OR.(EFMTRC.EQ.100.))GO TO 208
C
C
C FALLING RATE PERIOD MODEL
IF(IRUN.EQ.2)B=10.**(-.4607*SR-1.087)
IF(IRUN.EQ.3)B=10.**(-.4602*SR-1.123)
IF(IRUN.EQ.4)B=10.**(-.4199*SR-1.215)
IF(IRUN.EQ.5)B=10.**(-.4098*SR-1.260)
IF(IRUN.EQ.6)B=10.**(-.3936*SR-1.313)
IF(IRUN.EQ.7)B=10.**(-.3308*SR-1.426)
IF(IRUN.EQ.8)B=10.**(-.3511*SR-1.427)
X=S02RXC
S02PS=S02PSI-X
DRYTOT=N2PS+C02PS+O2PS+S02PS
WETTOT=DRYTOT/(1.-BW2)
H20PS=WETTOT-DRYTOT
YH20=BW2
YN2=N2PS/WETTOT
YC02=C02PS/WETTOT
Y02=O2PS/WETTOT
YS02=S02PS/WETTOT
YS02I=YS02
ACFS=WETTOT*0.7913*((TEMP2+273.)/273.)*(1./PT)
RESIDT=220./ACFS
C
C
C CONVERSION FROM DROPS PER SECOND TO PARTICLES PER SECOND
VSOLID=CAPD*74.10/2.2E+06
VLID=W2*CAPD*74.10E-06
VTOTAL=VSOLID+VLID
D=(VTOTAL*1.9099)**(1./3.)
PPS=DPS*((D/7.8E-06)**3.)
DX=((DC**3.)/(PPS/DPS))**(1./3.)
DAVG=((DX**3.)+(7.8E-06**3.)/2.)**(1./3.)
DROPDI=DAVG
RCAPD=CAPD-X/DPS
WTS=((X/DPS)*129.15+(RCAPD*74.10))/1000.
WTW=WC*WTS
WTT=WTS+WTW
DEN=WTT/(0.5236*(DC**3.))
SLDEN=DEN
III=III+1
R=DAVG/2.

```

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VPART=4.18879*(R**3.)
VAVG=VPART/2.
RC=(VAVG/4.18879)**(1./3.)
GO TO 43
204 XA=PT*YSO2/(HENRY/101323.2)
KL=22.5*DOS02/(2.*RC)
HC=HENRY*(1.-XA)/5.624E+09
VP=RC/6.
AP=5.3476E+03*SLDF/(1.+WFAVG)
DO 85 I=1,200
KG=(DSO2MX/(DROPDI*(1.-YSO2)))*(2.0+0.6*(UMIX/(FGDEN*DSO2MX))**((1.
$/3.)*(DROPDI*VINFIN*FGDEN)/UMIX)**(1./2.))/(82.057E-06*(T+273.))
DE=B*DSO2MX
G=(RC**2.)/(HC*KG*(R**2.))
D=RC*(R-RC)*(82.057E-06*(T+273.))/(HC*DE*R)
E=DOCA/(DOS02*KS*AP*VP)
F=1./KL
NSO2=((DOCA*MCCA/DOS02)+(PT*YSO2/HC))/(G+D+E+F)
AA1=1./KG
AA2=((82.057E-06*(T+273.))*(R-RC)*R)/(DE*RC)
AAB=PT*YSO2/(AA1+AA2)
BBA=KL*DOCA*MCCA/DOS02
IF(AAB.LT.BBA)NSO2=AAB
DSO2C=(NSO2-YSO2*(NSO2-NH20))/((YN2*NSO2/DSO2N2)+(YC02*NSO2/
$DSO2C0)+(Y02*NSO2/DSO202)+((YH20*NSO2)+(YSO2*NH20))/DSO2H2))
COMPAR=ABS((DSO2MX-DSO2C)/DSO2MX)
IF(COMPAR.LT.0.05)GO TO 89
DSO2MX=DSO2C
85 CONTINUE
GO TO 90
89 CONTINUE
90 CONTINUE
S02FR=NSO2*TF*12.56637*(RC**2.)*PPS
S02PS=S02PSI-S02RXC-S02FR
IF(S02PS.LT.0.0)S02PS=0.0
S02AVG=(S02PSI-S02RXC+S02PS)/2.
GAS=N2PS+C02PS+O2PS+H20PS+S02AVG
YAVG=S02AVG/GAS
ERROR=ABS((YSO2-YAVG)/YSO2)
IF(ERROR.LE.0.02)GO TO 205
IF(III.EQ.200)GO TO 205
YN2=N2PS/GAS
YC02=C02PS/GAS
Y02=O2PS/GAS
YSO2=YAVG
YH20=H20PS/GAS
III=III+1
GO TO 43
205 CONTINUE
IF(III.EQ.200)WRITE(6,202)ERROR
EFF(RUN)=((S02FR+X)/S02PSI)*100.
EFFF=EFF(RUN)
IF(EFFF.GE.EFFSR)EFFF=EFFSR
EFF(RUN)=EFFF
IF((S02FR+X).GT.S02PSI)EFF(RUN)=100.
208 CONTINUE
GO TO 101
100 CONTINUE
402 WRITE(6,450)
450 FORMAT('1',/////,55X,'MODEL PERFORMANCE TABLE')

```

```

      WRITE(6,456)
456  FORMAT(' ',56X,'EXPERIMENTAL VALUES')
      WRITE(6,451)KS
451  FORMAT(' ',55X,'KS = ',E12.5,' M/SEC')
      WRITE(6,452)
452  FORMAT(' ',28X,'RUN',4X,'PREDICTED EFFICIENCY',4X,
$'EXPERIMENTAL EFFICIENCY',4X,'PERCENT DIFFERENCE')
      TOTAL=0.0
      DO 400 RUN=1,25
      PERDIF(RUN)=ABS((EFFSD(RUN)-EFF(RUN))/EFFSD(RUN))*100.
      TOTAL=TOTAL+PERDIF(RUN)
      WRITE(6,453)RUN,EFF(RUN),EFFSD(RUN),PERDIF(RUN)
453  FORMAT(' ',29X,12,10X,F8.4,17X,F8.4,17X,F8.4)
400  CONTINUE
      AVGDIF=TOTAL/25.
      WRITE(6,454)AVGDIF
454  FORMAT(' ',81X,'AVERAGE = ',F8.4)
C
C      LINEAR REGRESSION MODEL
C
      U=0.0
      V=0.0
      W=0.0
      X=0.0
      Y=0.0
      DO 401 RUN=1,25
      U=U+(EFF(RUN)*EFFSD(RUN))
      V=V+EFF(RUN)
      W=W+EFFSD(RUN)
      X=X+(EFF(RUN))**2.
      Y=Y+(EFFSD(RUN))**2.
401  CONTINUE
      R2=(U-(V*W)/25.))**2./((X-(V**2./25.))*(Y-(W**2./25.)))
      A1=(U-(V*W/25.))/(X-(V**2./25.))
      YBAR=W/25.
      XBAR=V/25.
      A0=YBAR-(A1*XBAR)
      WRITE(6,455)A1,A0,R2
455  FORMAT(' ',29X,'PREDTD = ',E10.3,' * E EFFCY + ',E10.3,15X,
$'R2 = ',F8.6)
      IRUN=IRUN+1
      KS=KS+1.0E-05
      IF(IRUN.GT.8)GO TO 876
      REWIND 5
      GO TO 101
876  STOP
      END

```

TABLE F-1

RESULTS FROM THE DRY SCRUBBING MODEL FOR k_s EQUALLING 2.0×10^{-5} m/sec

PUN	PREDICTED EFFICIENCY(%)	EXPERIMENTAL EFFICIENCY(%)	PERCENT DIFFERENCE
1	66.9855	65.6000	2.1120
2	32.4292	44.9000	27.7745
3	64.7868	73.5000	11.8547
4	63.4542	62.3000	1.8527
5	70.2639	74.2000	5.3047
6	62.2581	53.9000	15.5067
7	54.3772	54.2000	0.3270
8	44.6218	21.7000	105.6305
9	29.0519	29.4000	1.1839
10	79.1186	73.1000	8.2333
11	65.8471	67.2000	2.0132
12	76.1925	63.2000	20.5578
13	41.7625	39.5000	5.7279
14	41.5182	37.9000	9.5468
15	59.5619	68.3000	12.7937
16	21.5034	17.5000	22.8764
17	51.5837	57.0000	9.5022
18	39.2982	32.2000	22.0441
19	64.5240	69.6000	7.2931
20	33.0768	29.3000	12.8902
21	48.5379	54.6000	11.1029
22	69.1626	54.8000	26.2091
23	39.7063	42.8000	7.2283
24	28.8196	32.7000	11.8667
25	20.5479	28.7000	28.4045

AVERAGE = 15.5934

PREDTD = 0.906E+00 * E EFFCY + 0.394E+01

R2 = 0.795210

TABLE F-2

RESULTS FROM THE DRY SCRUBBING MODEL FOR k_s EQUALLING 3.0×10^{-5} m/sec

RUN	PREDICTED EFFICIENCY(%)	EXPERIMENTAL EFFICIENCY(%)	PERCENT DIFFERENCE
1	67.2068	65.6000	2.4495
2	33.0952	44.9000	26.2912
3	64.0149	73.5000	12.9049
4	63.5124	62.3000	1.9461
5	70.1847	74.2000	5.4114
6	61.9441	53.9000	14.9241
7	54.3772	54.2000	0.3270
8	45.1680	21.7000	108.1474
9	30.6442	29.4000	4.2321
10	78.1241	73.1000	6.8729
11	66.2250	67.2000	1.4509
12	75.7317	63.2000	19.8286
13	42.3332	39.5000	7.1727
14	41.5182	37.9000	9.5468
15	58.7562	68.3000	13.9734
16	22.3123	17.5000	27.4987
17	51.5913	57.0000	9.4889
18	39.6359	32.2000	23.0927
19	64.7488	69.6000	6.9701
20	33.0768	29.3000	12.8902
21	48.5586	54.6000	11.0649
22	68.6124	54.8000	25.2050
23	40.1819	42.8000	6.1172
24	29.1743	32.7000	10.7818
25	21.4885	28.7000	25.1271

AVERAGE = 15.7486

PREDICTED = $0.928E+00 * E \text{ EFFCY} + 0.269E+01$

R2 = 0.793590

TABLE F-3

RESULTS FROM THE DRY SCRUBBING MODEL FOR k_s EQUALLING 4.0×10^{-5} m/sec

RUN	PREDICTED EFFICIENCY(%)	EXPERIMENTAL EFFICIENCY(%)	PERCENT DIFFERENCE
1	67.7377	65.6000	3.2587
2	32.0319	44.9000	28.6595
3	61.2716	73.5000	16.6373
4	62.1468	62.3000	0.2460
5	70.8195	74.2000	4.5559
6	60.4774	53.9000	12.2031
7	54.3772	54.2000	0.3270
8	43.9108	21.7000	102.3539
9	30.9387	29.4000	5.2338
10	78.3538	73.1000	7.1871
11	67.9935	67.2000	1.1808
12	71.7670	63.2000	13.5554
13	41.1166	39.5000	4.0926
14	41.5182	37.9000	9.5468
15	57.5680	68.3000	15.7130
16	21.9151	17.5000	25.2293
17	51.2755	57.0000	10.0430
18	38.4620	32.2000	19.4471
19	66.2631	69.6000	4.7944
20	33.0768	29.3000	12.8902
21	47.2618	54.6000	13.4400
22	67.0604	54.8000	22.3730
23	39.0484	42.8000	8.7654
24	27.7468	32.7000	15.1474
25	21.3318	28.7000	25.6730

AVERAGE = 15.3021

PREDTD = $0.934E+00 * E \text{ EFFCY} + 0.303E+01$

R2 = 0.802002

TABLE F-4

RESULTS FROM THE DRY SCRUBBING MODEL FOR k_s EQUALLING 5.0×10^{-5} m/sec

RUN	PREDICTED EFFICIENCY(%)	EXPERIMENTAL EFFICIENCY(%)	PERCENT DIFFERENCE
1	67.4361	65.6000	2.7990
2	32.4094	44.9000	27.8187
3	60.8747	73.5000	17.1772
4	62.3757	62.3000	0.1216
5	70.4130	74.2000	5.1038
6	60.2297	53.9000	11.7435
7	54.3772	54.2000	0.3270
8	44.2886	21.7000	104.0951
9	32.1364	29.4000	9.3074
10	77.1031	73.1000	5.4762
11	68.7494	67.2000	2.3056
12	70.6587	63.2000	11.8017
13	41.4663	39.5000	4.9780
14	41.5182	37.9000	9.5468
15	57.3823	68.3000	15.9849
16	22.4251	17.5000	28.1436
17	50.7881	57.0000	10.8981
18	38.4729	32.2000	19.4810
19	66.9806	69.6000	3.7635
20	33.0768	29.3000	12.8902
21	46.8888	54.6000	14.1231
22	66.1147	54.8000	20.6472
23	39.2140	42.8000	8.3785
24	27.9826	32.7000	14.4264
25	22.0247	28.7000	23.2587

AVERAGE = 15.3838

PREDID = $0.954E+00 * E \text{ EFFCY} + 0.200E+01$

R2 = 0.803117

TABLE F-5

RESULTS FROM THE DRY SCRUBBING MODEL FOR k_s EQUALLING 6.0×10^{-5} m/sec

RUN	PREDICTED EFFICIENCY(%)	EXPERIMENTAL EFFICIENCY(%)	PERCENT DIFFERENCE
1	67.7475	65.6000	3.2737
2	32.5434	44.9000	27.5202
3	60.2697	73.5000	18.0004
4	62.4075	62.3000	0.1725
5	70.0445	74.2000	5.6004
6	59.8079	53.9000	10.9608
7	54.3772	54.2000	0.3270
8	44.4475	21.7000	104.8272
9	33.0931	29.4000	12.5617
10	76.9005	73.1000	5.1990
11	69.3837	67.2000	3.2496
12	69.9982	63.2000	10.7567
13	41.5874	39.5000	5.2847
14	41.5182	37.9000	9.5468
15	57.5484	68.3000	15.7417
16	22.7440	17.5000	29.9658
17	50.1642	57.0000	11.9926
18	38.2529	32.2000	18.7977
19	67.5760	69.6000	2.9080
20	33.0768	29.3000	12.8902
21	46.3134	54.6000	15.1770
22	64.4575	54.8000	17.6231
23	39.1422	42.8000	8.5462
24	28.0290	32.7000	14.2843
25	22.5467	28.7000	21.4399

AVERAGE = 15.4658

PREDTD = 0.966E+00 * E EFFCY + 0.149E+01

R2 = 0.803988

TABLE F-6

RESULTS FROM THE DRY SCRUBBING MODEL FOR k_g EQUALLING 7.0×10^{-5} m/sec

RUN	PREDICTED EFFICIENCY(%)	EXPERIMENTAL EFFICIENCY(%)	PERCENT DIFFERENCE
1	68.5773	65.6000	4.5386
2	31.7464	44.9000	29.2954
3	58.8244	73.5000	19.9668
4	62.4103	62.3000	0.1771
5	69.7189	74.2000	6.0392
6	59.1251	53.9000	9.6941
7	53.9447	54.2000	0.4710
8	43.3525	21.7000	99.7809
9	33.1521	29.4000	12.7624
10	77.9520	73.1000	6.6375
11	71.0082	67.2000	5.6670
12	67.3803	63.2000	6.6144
13	40.1792	39.5000	1.7194
14	41.5182	37.9000	9.5468
15	56.0261	68.3000	17.9706
16	22.2002	17.5000	26.8585
17	49.1466	57.0000	13.7779
18	36.7557	32.2000	14.1482
19	68.9893	69.6000	0.8775
20	33.0768	29.3000	12.8902
21	44.4868	54.6000	18.5224
22	62.6637	54.8000	14.3498
23	37.7171	42.8000	11.8759
24	26.9858	32.7000	17.4745
25	22.2843	28.7000	22.3545

AVERAGE = 15.3604

PREDTD = $0.946E+00 * E \text{ EFFCY} + 0.302E+01$

R2 = 0.798843

TABLE F-7

RESULTS FROM THE DRY SCRUBBING MODEL FOR k_s EQUALLING 8.0×10^{-5} m/sec

RUN	PREDICTED EFFICIENCY(%)	EXPERIMENTAL EFFICIENCY(%)	PERCENT DIFFERENCE
1	68.2943	65.6000	4.1077
2	32.5861	44.9000	27.4252
3	59.5740	73.5000	18.9469
4	62.7868	62.3000	0.7815
5	69.1659	74.2000	6.7845
6	59.3760	53.9000	10.1595
7	54.3772	54.2000	0.3270
8	44.3935	21.7000	104.5781
9	34.7318	29.4000	18.1354
10	77.2988	73.1000	5.7439
11	70.5139	67.2000	4.9314
12	66.3583	63.2000	4.9973
13	41.4937	39.5000	5.0475
14	41.5182	37.9000	9.5468
15	56.3366	68.3000	17.5159
16	23.2123	17.5000	32.6417
17	48.9715	57.0000	14.0850
18	37.4536	32.2000	16.3154
19	68.6383	69.6000	1.3818
20	33.0768	29.3000	12.8902
21	45.1940	54.6000	17.2272
22	63.0571	54.8000	15.0676
23	38.6393	42.8000	9.7213
24	28.0450	32.7000	14.2353
25	23.4402	28.7000	18.3268

AVERAGE = 15.6368

PREDIC = $0.977E+00 * E\text{ EFFCY} + 0.113E+01$

R2 = 0.798490

VITA

Thomas E. Pearson was born in Evergreen Park, Illinois, on November 11, 1956. He attended elementary schools in Chicago and Oak Lawn, Illinois. He was graduated from Harold L. Richards High School in June of 1974. The following August he entered the University of Illinois in Urbana, and in May of 1978 he received a Bachelor of Science degree in Chemical Engineering. In June of 1978 he began working full-time for Union Carbide Corporation's Nuclear Division in Oak Ridge, Tennessee, and enrolled part-time at The University of Tennessee, Knoxville, to begin study toward a Master of Science degree.

After working for Union Carbide Corporation for three years, he went to work for IT Enviroscience, and in September of 1982 accepted a position with The University of Tennessee's Civil Engineering Department as a Research Associate. He received the Master of Science degree in Chemical Engineering with a minor in Environmental Engineering in March 1984.

The author is a member of the American Institute of Chemical Engineers.