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# Modeling of Fluidized Bed Silicon Deposition Process

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Jet Propulsion Laboratory California Institute of Technology Pasadena, California 91103 JPL PUBLICATION 77-25

# Modeling of Fluidized Bed Silicon Deposition Process

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### PREFACE

The work described herein was performed by the Control and Energy Conversion Division of the Jet Propulsion Laboratory.

# DEFINITION OF SYMBOLS

CA	concentration of gas A, $g \cdot mol/cm^3$
C <sub>d</sub>	drag coefficient
C <sub>AD</sub> , C <sub>AC</sub> , C <sub>Ae</sub> , C <sub>Ag</sub>	concentration of A in the gas bubble, in the cloud-wake region, in the emulsion phase, and at the particle surface, respectively, g mol/cm <sup>3</sup>
Ē₄₽	average concentration of A in the bubble, g mol/cm <sup>3</sup>
<b>Ē</b> ▲	average concentration of A in the bed
C <sub>Ai</sub>	concentration of A in the entering gas stream, g mol/cm <sup>3</sup>
D	molecular diffusion coefficient of gas, cm <sup>2</sup> /sec
db	effective bubble diameter, cm
dp	particle diameter, cm
dp	surface mean particle size, cm
dt	tube diameter, cm
F <sub>0</sub> , F <sub>1</sub> , F <sub>2</sub>	feed rate of solids, outflow rate of solids, and carryover rate of solids by entrainment, respectively, gm/sec
Fr <sub>mf</sub>	Froude number at minimum fluidization condition, $U_{mf}/d_{pg}$ , dimensionless
g	980 cm/sec <sup>2</sup> , acceleration of gravity
h	height, cm
(K <sub>be</sub> ) <sub>b</sub> , (K <sub>be</sub> ) <sub>e</sub> , (K <sub>be</sub> ) <sub>f</sub>	overall coefficient of gas interchange between bubble and emulsion based on volume of bubbles, volume of emulsion, and total volume of bed, respectively, sec <sup>-1</sup>
k	entrainment coefficient
kd	mass transfer coefficient between fluid at a particle, cm/sec
k d	mass transfer coefficient in fluidized bed, sec-1
(k <sub>d</sub> ) <sub>b</sub>	overall mass transfer coefficient for bubbling bed, $sec^{-1}$
(k <sub>d</sub> ) <sub>mf</sub>	mass transfer coefficient between fluid and a particle at minimum fluidization, cm/sec
k <sub>dt</sub>	mass transfer coefficient for particles in bubbles, cm $sec^{-1}$

#### 1 height, cm height of a bubbling fluidized bed, cm Lr bed height at minimum fluidization condition, cm Lmf molecular weight Mer bubble frequency, $sec^{-1}$ η number of moles of A NA NAb number of moles of A in bubble pressure drop, gm • wb/sm<sup>2</sup> Δр size distribution of feed solids, outflow solids, entrained solids, and solids in the bed, respectively, $cm^{-1}$ Po, P1, P2, Pb particle radius, cm ro minimum particle radius in feed particles, cm rn, minf maximum particle radius in feed particles, cm r<sub>D</sub>, max<sub>f</sub> R half the distance between particles in particulate bed or emulsion, cm $Re_{D}$ particle Reynolds number, $d_D u_0 P_g/\mu$ , dimensionless particle Reynolds number at minimum fluidization condition, Remf $d_p u_{mf} \rho g/\mu$ , dimensionless Sc Schmidt-number, $\mu/\rho_g D$ , dimensionless Sh Sherwood number, k<sub>d</sub>d<sub>p</sub>/D, dimensionless Sht Sherwood number for particles in bubbles, $k_{d,t}d_p/D$ , dimensionless Sherwood number for particles in emulsion or at minimum Shmf fluidization conditions, $K_{d,mf}d_p/D$ , dimensionless Uh velocity of a bubble rising through a bed, cm/sec Ubr velocity of a bubble with respect to the emulsion phase, cm/sec Uf upward velocity of gas at minimum fluidizing conditions, cm/sec Umf superficial fluid velocity at minimum fluidizing conditions, cm/sec Ut terminal velocity of a falling particle, cm/sec

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- superficial fluid velocity (measured on an empty tube basis) U<sub>0</sub> through a bed of solids, cm/sec volume of a gas bubble, cm<sup>3</sup> Vh ¥. weight of solids, g specific surface or surface of solid per volume of bed,  $cm^{-1}$ α α' specific surface or surface of solid per volume of solid, cm<sup>-1</sup> γ<sub>b</sub> ratio of solids dispersed in bubbles to the volume of bubbles in the bed, dimensionless ratio of solids in the cloud-wake region to volume of bubbles  $\gamma_{c}$ in the bed, dimensionless ratio of solids in the emulsion to volume of bubbles in γ<sub>e</sub> the bed, dimensionless δ fraction of fluidized bed consisting of bubbles, dimensionless void fraction, dimensionless € void fraction in the emulsion phase of a bubbling bed, €<sub>e</sub>, <sup>€</sup>f, in a bubbling bed as a whole, in a bed at minimum fluidizing €mf, €m conditions, and in a packed bed, respectively, dimensionless μ viscosity of gas, g/cm.sec. density of gas and solid, respectively, g/cm<sup>3</sup>  $P_{\rm g}, P_{\rm s}$
- $\phi_s$  sphericity of a particle, dimensionless

#### ABSTRACT

Modeling of the fluidized bed for silicon deposition is described. The model is intended for use as a means of improving fluidized bed reactor design and for the formulation of the research program in support of the contracts of the Silicon Material Task for the development of the fluidized bed silicon deposition process. A computer program derived from the simple modeling is also described. Results of some sample calculations using the computer program are shown.

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# SECTION I

#### INTRODUCTION

The Low-Cost Silicon Solar Array (LSSA) project sponsored at JPL by ERDA has the responsibility for developing the technology and the industry-capability for producing low cost solar arrays. The objective is the achievement of a production capacity of 500 megawatts (peak) at a cost of \$500 per kW by 1986. The program of LSSA is divided into four technology tasks, each of which has the responsibility for advancing a particular technical area so as to achieve the production and cost goals. The first of these tasks is the Silicon Material Task, for which the 1986 objective is to reduce the price of Si material, suitable for the fabrication of solar cells having satisfactory performance, from the present price of about \$65/kg (for semiconductor grade Si) to less than \$10/kg.

To achieve the price objective of the Silicon Material Task, new areas of chemical processing and solar cell technology must be studied and developed, since no modification of the basic processes presently used commercially will lead to the attainment of the 10/kgprice. The inability of the present commercial process to meet the task objective is revealed from a consideration of the features of this process. The first step is the reaction of metallurgical grade Si, having a purity of about 98.5%, with HCl in a fluidized bed reactor to yield the intermediate SiHCl<sub>3</sub> in a mixture of chlorinated silanes. After chemical treatment and fractional distillation to obtain very pure SiHCl<sub>3</sub>, semiconductor grade Si  $\therefore$ s produced by chemical vapor deposition resulting from the H<sub>2</sub> reduction of SiHCl<sub>3</sub>. This method of producing extremely pure Si is costly and energy intensive, the final deposition consuming an estimated 385 kWh/kg Si product.

Several different chemical processes are being investigated under JPL contracts in the task program. Two of these, at Union Carbide and Battelle, incorporate fluidized bed reactor technology. The contract with Union Carbide involves the hydrogenation of SiCl<sub>4</sub> to SiHCl<sub>3</sub> in a fluidized bed as well as a process for the deposition of Si from SiH<sub>4</sub> in another fluidized bed. In the contract at Battelle the process is for the 2n reduction of SiCl<sub>4</sub> in a fluidized bed reactor. These two efforts are presently the most advanced in the task program and are being appropriately emphasized.

To support the developments in fluidized bed technology, which is the basic element of these two important contracts, the task program includes an in-house JPL subtask for studies of fluidized bed reactor technology as well as a subtask for consultation in this area by Professors O. Levenspiel and T. Fitzgerald of Oregon State University. The inhouse program consists of efforts in modeling of the deposition of Si in a fluidized bed reactor, experimental studies of SiH<sub>4</sub> pyrolysis and fine particle fluidization, and thermodynamic and chemical engineering analysis of the reactions in the fluidized process for silicon production. The initial phase of the effort in modeling is described in this report.

#### SECTION II

#### APPROACH

The purpose of this study is to develop an analytical model of a particular chemical reaction--the pyrolysis of SiHu--occurring in a fluidized bed reactor. The model is intended for use in determining guidelines for reactor design and for the structuring of experimental investigations to achieve system optimization. The methodology of this study is (1) to specify the system, (2) to describe the particular and general assumptions, (3) to state the appropriate physical laws to be used at each step, (4) to apply the limitations of the system characteristics and assumptions in the derivations of the mathematical expressions, and (5) to develop a suitable computer program. To facilitate the systematic development of the computer program, this report is divided into sections for (1) a general description of the process, (2) modeling of the gross bed behavior, (3) modeling of the particulate bed, (4) modeling of the bubbling bed, (5) a description of gas interchange between bubble, cloud, and emulsion, (6) an analysis of mass transfer rate to solid particles in a bubbling bed, (7) particle growth rate in a particular bed, (8) particle growth rate in a bubbling bed, (9) entrainment, (10) overall mass balance of the bed, and (11) results, conclusions, and recommendations.

This paper deals with the fluidized bed silicon deposition process designed to eliminate the difficulties associated with the current state-of-the-art. In Figure 2-1, a schematic diagram of a fluidized bed is shown. From the bottom left-hand side, small feed-particles of silicon are introduced while the feed gas of silane and hydrogen (carrier gas) comes in from the bottom of the bed. The silane is pyrolyzed at the surface of the silicon particles, the resulting Si deposits causing the increase in size of the seed particles, which are eventually removed as the product. Unreacted silane and hydrogen gas escape through the top of the bed concurrently elutriating small amounts of smallsize particles. This process is continuous and has the advantage of using a very large reaction surface area to produce pure silicon on a much larger scale than the conventional chemical vapor deposition (Siemens) process.

Our problem can be stated as follows: Given a set of operating conditions, which include the bed size, the feed particle characteristics, and the feed gas characteristics, determine (1) the type of fluidization (i.e., whether it is bubbling or particulate type), (2) the optimum gas flow rate, (3) the power requirement, (4) the silicon particle growth rate, (5) the entrainment rate, and (6) the deposition rate of Si.

Several assumptions and a number of limiting conditions were employed in the modeling of this process. They are as follows:



Figure 2-1. Fluidized Bed Concept for Cilicon Production

(1) At temperatures above  $1000^{\circ}$  C, the primary reaction is the heterogenous pyrolysis of SiH<sub>4</sub> on the surface of the silicon particles.

The rates of adsorption and reaction are much faster than the transport of the reactant species,  $SiH_4$ , to the reaction zone (the hot surface), and thus the growth rate of the particle size is diffusion-limited.

(2) The bed is either bubbling or particulately fluidized. In other words, the fluidization of particles smaller than 50  $\mu$ , which would cause abnormal fluidization, will not be considered.

These two types of fluidization are schematically shown in Figure 2-2. For larger particles, bubbles moving up are observed (Figure 2-2a), and for smaller particles (but still larger than 50  $\mu$ ) uniform fluidization is observed (Figure 2-2b). This uniform phase in the particulate bed and the bubbling bed (outside the bubbles) is called the emulsion.

The basic flow chart for the modeling is given in Figure 2-3. As shown here, first, the set of input parameters is given. From this, the gross behavior of the bed is obtained including the operating bed weight, the pressure drop across the bed, the distributor requirement and the type of fluidization. If the bed is particulate fluidized, the mass transfer rate of gas onto solid particles and thus the particle growth rate can then be obtained relatively simply. If the bed is bubbling, the bubble and the emulsion characteristics must be studied separately with the aid of pertinent experimental data. Then the interaction between the two phases must be investigated to determine the mass transfer rate of the gas onto the solid particles in order to permit the calculation of the particle growth rate as a function of the particle diameter.



Figure 2-2. Types of Fluidization

When this growth rate is obtained, the mass balance of silicon particles in the feed, product, entrainment streams and the bed is then calculated. The particle size distribution of the bed and the deposition rate can also be determined.



Figure 2-3. Flowchart for Modeling

#### SECTION III

#### MODELING OF GROSS BED BEHAVIOR

The input parameters necessary for the definition of the fluidized bed are as follows: feed particle size distribution  $P_0(d_p)$ ; production rate  $F_1$ ; sphericity of particles  $\phi_s$ , which is assumed to be uniform regardless of the particle size; void fraction in packed bed  $\epsilon_m$ , as a function of  $\phi_s$  (Ref. 3-1); voidage at minimum fluidizing condition  $\epsilon_{mf}$ , and as a function of  $\phi_s$ ; gas density  $\rho_g$ ; solid density  $\rho_s$ ; viscosity  $\mu$ ; diffusion coefficient D; concentration of silane in the feed gas  $C_{Ai}$ ; bed weight W; and the bed diameter  $d_t$ .

In order to estimate the bed characteristics, it is necessary to know the average particle size in bed. However, without the knowledge of the bed particle size distribution  $P_b(d_p)$  this is not possible. Thus, at the beginning,  $\overline{d}_p$  is obtained from  $P_0$ . This will be replaced by  $\overline{d}_P(P_b)$  later. Since the important parameter in the bed is the ratio of surface area to volume of solid particles, which is inversely proportional to  $d_p$ , the average particle size is obtained as the inverse of the average of the inverse of the particle size. That is,

$$\overline{d}_{p} = \frac{1}{\int \frac{P_{b}(d_{p})}{d_{p}} d(d_{p})}$$
(1)

Using the above information, the gross behavior of the fluidized bed is then predicted as follows:

(1) Bed height at minimum fluidizing conditions: There is a certain velocity of gas for the given bed below which the solid particles are packed together and no fluidization is observed. Above this velocity, the particles are moving around in the bed with gas to create a fluid-like phase in the bed. This velocity is called the minimum fluidizing velocity, and the requirement to reach this velocity is called the minimum fluidizing condition.

$$L_{mf} = \frac{W_{4}}{d_{f}^{2}} \frac{1}{\pi (1 - \epsilon_{mf}) (\rho_{s} - \rho_{g}) g}$$
(2)

where g is the gravitational constant.

(2) The pressure drop across the bed is obtained by balancing the pressure loss with the bed weight.

$$\Delta p = \frac{W}{d^2} \frac{4}{\pi}$$
(3)

(3) The superficial fluid velocity at minimum fluidizing conditions  $U_{mf}$  can be obtained by balancing the pressure loss with either the viscous force for the small-particle-size bed or the kinetic force for the large-particle-size bed. For an assumed value for the superficial fluid velocity of the bed  $U_0$ , then

$$U_{mf} = \frac{\bar{d}_{p}^{2} (\rho_{s} - \rho_{g})_{g}}{1650\mu}$$
 when  $Re_{p} \equiv \frac{\bar{d}_{p} \rho_{g} U_{0}}{\mu} < 20$  (4)

or

.

$$\frac{2}{u_{\text{mf}}} = \frac{\tilde{d}_{p} (\rho_{s} - \rho_{g})g}{24.5 \rho_{g}} \text{ when } \text{Re}_{p} > 1000$$
(5)

If 20 < Re < 1000, an interpolated value of  $\textbf{U}_{mf}$  would be used.

The superficial fluid velocity of the bed  $U_0$  can be estimated from this information. If a vigorously mixing bed is assumed for maximum silicon production, then, according to literature observations (Reference 3-1):

$$U_{\rm U} > 2U_{\rm mf} \tag{6}$$

However, there is an upper limit for  $U_0$ , since the  $U_0$  is larger than the terminal velocity of the particles, then

$$U_{t} = \left(\frac{{}^{4}gd_{p} (\rho_{s} - \rho_{g})}{3\rho_{g}C_{d}}\right)^{1/2}$$
(7)

where  $d_p$  is the minimum particle size in bed and  $C_d$  can be obtained empirically; then some particles are lost through entrainment. This tendency of entrainment would be increased as  $U_0$  increases.

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- (4) The type of fluidization of the bed can be determined by an empirical formula (References 3-2, 3-3) under normal fluidization conditions. If the product of four dimensionless groups

$$Fr_{mf}, Re_{\rho mf}, \frac{\rho_{s} - \rho_{g}}{\rho_{g}}, \frac{L_{mf}}{d_{t}}$$

is larger than 100, the bed is bubbling; otherwise, the bed is particulately fluidized. Here

$$Fr_{mf} = \frac{U_{mf}^2}{\overline{d}_{pg}},$$
 (8)

$$\operatorname{Re}_{\rho \mathfrak{m} f} = \frac{U_{\mathfrak{m} f} \cdot \overline{d}_{p} \cdot \rho_{g}}{\mu}$$
(9)

#### SECTION IV

#### PARTICULATE BED

If the bed is particulately fluidized, which is depicted in Figure 4-1, the mass transfer rate of gas onto the solid particles is obtained in the following way (Ref. 4-1). The individual particles of radius  $r_0$  are considered to be separated from other particles by a distance of 2R, where R can be derived easily from the voidage of the bed:

$$R = \frac{r_0}{(1 - \epsilon)^{1/3}}$$
 (10)

Gas enters from the bottom with the velocity  $U_0$ . The amount of gas transferred to the individual particle surfaces by diffusion, as well as by this forced convection, is to be calculated.

This is a very complex two-dimensional flow problem for each particle. The description can be approximated by use of the penetration theory as follows. Assume that at t = 0, the concentration of the silane at r = R is the same as that of the incoming gas, that at  $r = r_0$ , the concentration is zero, and that the diffusion which is one-dimensional in the radial direction only proceeds until t = T. At t = T, the original situation is reestablished and the ensuing diffusion process is repeated again. This is repeated at every mT interval where m is an integer. The period T is proportiona to the ratio between the incoming velocity  $U_0$  divided by particle radius  $r_0$ .

The result is summarized in a formula for the mass transfer coefficient,  $k_{\rm d}$ ,



Figure 4-1. Particulate Bed

$$Sh = \frac{k_{d}d_{p}}{D} = \frac{2 + \left[\frac{2\zeta^{2} (1 - \epsilon_{f})^{1/3}}{[1 - (1 - \epsilon_{f})^{1/3}]^{2}} - 2\right] \tanh \zeta}{\frac{\zeta}{1 - (1 - \epsilon_{f})^{1/3}}}$$
(11)

where

$$\zeta = \left[\frac{1}{(1 - \epsilon_{\rm f})^{1/3}} - 1\right] \ge 0.3 \ {\rm Re}_{\rm p}^{1/2} \ {\rm S}_{\rm c}^{1/2} \tag{12}$$

$$Re_p = \frac{d_p \ U_0 \rho_g}{\mu}$$

and

Sc = 
$$\frac{\mu}{\rho D}$$

At the limit when  $R \rightarrow \infty$ ,

$$Sh \rightarrow 2 + 0.6 Rep^{1/2} Sc^{1/3}$$
 (13)

which is known as a single-sphere diffusion formula. This result will be used later in the bubble phase analysis.

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#### SECTION V

#### LUBBLING BED

To obtain the mass transfer rate of gas in the bubbling phase it is necessary to understand the bubble and the emulsion characteristics first. From the literature (Reference 3-1) it is noted that the emulsion phase behaves very much like a bed at minimum fluidizing condition. Thus, the upward velocity of gas in the emulsion phase is defined as  $U_{\rm f}$ . Then, by assuming that the emulsion phase behaves approximately according to the minimum fluidizing condition, one obtains,

$$U_{f} = \frac{U_{mf}}{\epsilon_{mf}}$$
(14)

The bubble phase is analyzed as follows. First the bubble diameter  $d_b$  is defined assuming that  $d_b$  is constant throughout the bed (although this is not true in the beginning of the bed), and that the bubble frequency passing by a certain point in the bed is n. Then the velocity of the rise of bubbles  $U_{br}$  is similar to the velocity observed in the system of a bubbling liquid of low viscosity, in which case inertial forces predominate. By equating the inertial force to the gravity force, the relation for a single bubble is obtained:

$$U_{\rm br} = 0.711 \; (gd_{\rm b})^{1/2}$$
 (15)

For bubbles rising together in the bed, the absolute velocity would be, then,

$$U_{b} = (U_{0} - U_{mf}) + U_{br}.$$
 (16)

Depending on the bubble velocity there are two types of bubble formations as shown in (Figure 5-1).

If  $U_b > U_f$ , a cloud will form around the bubble (Figure 5-1a) in which the gas circulates and never escapes to the outside. The thickness of the cloud decreases as  $U_b$  becomes larger. For vigorously bubbling beds, where  $U_b > 5U_f$ , the cloud thickness becomes negligible. If  $U_b < U_f$  (Figure 5-1b), no cloud forms and the gas passes through the bubble as a shortcut to the top of the bed. The higher mass transfer rate is obtainable for the first case; i.e.,  $U_b > U_f$  and this condition will be used.

The superficial velocity  $U_0$  can be expressed as follows:

$$U_{0} = (1 - \delta) U_{mf} + \delta U_{b} \tag{17}$$



Figure 5-1. Bubbles

where  $\delta$  is the volume fraction of bubbles in the bed. The first term is the velocity contribution from the emulsion phase and the second is from the bubble phase.

Rewriting the above equation (17), one obtains, for vigorously bubbling beds:

$$U_{b} = \frac{U_{0} - (1 - \delta)U_{mf}}{\delta} \cong \frac{U_{0} - U_{mf}}{\delta}$$
(18)

If the height between two successive bubbles is h, then

$$n = \frac{U_b}{h}$$
(19)

and

$$\delta = \frac{\frac{\pi}{3}}{\frac{d_b}{\frac{\pi}{4}}} = \frac{2}{3} \frac{\frac{d_b}{h}}{\frac{\pi}{4}}$$
(20)

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The values of  $d_b$ ,  $U_{br}$ ,  $U_b$ ,  $\delta$ , and h can be determined from (15), (16), (17), (19), and (20), with a known value of n. The value of n can be obtained from experimental data.

On the other hand, the tendency for the bubbles to break up increases with bubble size. This limiting size is computed as follows: when the bubble breaks up, it does so in such a way that the solid particles go up through the center of the bubble and cause the separation of one cavity into two smaller cavities, as shown in Figure 5-2.

The upward velocity of gas through a large rising bubble is assumed to be nearly  $U_{br}$ . If  $U_{br} > U_t$ , then small entrained particles go up through the middle of the bubble and the bubble breaks up. For this condition, a new n should be introduced to make  $U_{br} = U_t$ .

Figure 5-2. Mechanism of Bubble Breakup

#### SECTION VI

#### GAS INTERCHANGE BETWEEN BUBBLE, CLOUD, AND EMULSION

The flow pattern of gas through the fluidized bed can now be obtained from the above analysis. First, mass transfer coefficients  $(K_{be})_b$ ,  $(K_{bc})_b$ , and  $(K_{ce})_b$  are defined in the following way, which includes consideration of diffusion and gas circulation:

$$-\frac{1}{V_{b}}\frac{dN_{Ab}}{dt} = (K_{be})_{b} \cdot (C_{Ab} - C_{Ae})$$
$$= (K_{bc})_{b} \cdot (C_{Ab} - C_{Ac})$$
$$= (K_{ce})_{b} \cdot (C_{Ac} - C_{Ae})$$
(21)

Here  $V_b$  is the volume of bubble;  $N_{Ab}$  is the number of moles of silane in the bubble; and  $C_{Ab}$ ,  $C_{Ac}$ , and  $C_{Ae}$  are the mean c<sup>^</sup> centrations of silane in bubble, cloud, and emulsion, respectively. Thus  $(K_{be})_b$  is the volume of gas going from bubble to emulsion divided by volume of bubbles in bed per unit time. The other two are defined similarly. From the above equations:

$$\frac{1}{(K_{be})_{b}} = \frac{1}{(K_{bc})_{b}} + \frac{1}{(K_{ce})_{b}}$$
(22)

 $(K_{bC})_b$  is now obtained in the following way. There are two modes of gas movement between the bubble and the cloud. The first is gas flow into and out of a single bubble, and the second is the mass transfer by diffusion. Assuming a Davidson's model (Reference 3-1) for bubbles, then

$$(K_{bc})_b = 4.5 \frac{U_{mf}}{d_b} + 5.85 \frac{D^{1/2} g^{1/4}}{d_b^{5/4}} \text{ and}$$
 (23)

$$(\mathbf{K}_{ce})_{b} = 6.78 \frac{\epsilon_{mfDU_{b}}}{d_{b}}$$
(24)

where  $(K_{ce})_b$  involves the diffusion process only.

#### SECTION VII

#### MASS TRANSFER RATE TO SOLID PARTICLES IN BUBELING BED

The mass transfer rate to solid particles can now be derived using  $\gamma_b$  as the volume of solids dispersed in bubbles divided by volume of bubbles. The terms  $\gamma_c$  and  $\gamma_e$  are similarly defined in the Definition of Symbols. The quantity  $\gamma_b$  is experimentally determined.

For convenience the mass transfer process is considered to be an absorption by the solid of the silane gas present in the fluidizing gas stream. Since the flow of gas in the emulsion is very small, its minor contribution to total flow can reasonably be ignored. Thus, the fresh gas enters the bed only in the form of gas bubbles; moreover, for steady-state operations the measure of adsorption of silane is given by the decrease in its concentration within the bubbles. The mass transfer coefficient for such processes can be reported in a number of ways.

Based on total surface of particles, an overall mass transfer coefficient  $(k_d)_h$  (cm/sec) can be defined as

$$-\frac{1}{\text{surface } dt} = (k_d)_b (C_{Ab} - C_{As})$$
(25)

or in terms of the falling concentration of silane in the rising bubbles:

$$-\frac{dC_{Ab}}{dt} = -U_b \frac{dC_{Ab}}{d\ell} = (k_d)_b \frac{\text{surface of solids}}{\text{volume of bubble}} (C_{Ab} - C_{As})$$
(26)
$$(k_d)_b^a$$

$$= \frac{1}{\delta} (C_{Ab} - C_{As}) = (K_d)_b (C_{Ab} - C_{As})^*$$

where  $C_{Ab}$  is the mean concentration of silane in the bubble,  $C_{AS}$  is the proper concentration measure of silane at the surface of the solid, and  $a = 6(1 - \epsilon_f)/d/\phi_8$ .

The morphology of the silane present in a bubble as the bubble rises through the bed is considered now. Some of the silane is adsorbed by solids within the bubble; another portion is transferred to the

<sup>\*</sup>Although expressed in bubble-related terms, this equation covers the deposition process in all phases.

cloud where a part of it is adsorbed and where the rest is transferred further into the emulsion. The silane in the emulsion is assumed to be completely adsorbed, which is reasonable in light of the long contact time in the emulsion and the rapidity of the overall adsorption process. Thus we have

> adsorption in the transfer to overall adsorption = cloud by solids + the cloud

where

transfer to adsorption in the transfer to the cloud = cloud by solids + the emulsion

and where

transfer to adsorption in the the emulsion = emulsion by solids

In symbols, the above becomes

$$-\frac{dC_{Ab}}{dt} = -U_b \frac{dC_{Ab}}{d\ell} = (K_d)_b (CA_b - C_{As})$$
(27)

$$= \gamma_{b}K_{d,t}a' (C_{Ab} - C_{As})$$
$$+ (K_{bc})_{b}(C_{Ab} - C_{Ac})$$

and

$$(K_{bc})_{b} (C_{Ab} - C_{Ac}) = \gamma_{c} k_{d,mf} a' (C_{Ac} - C_{As}) + (K_{bc})_{b} (C_{Ac} - C_{Ae})$$
(28)

$$(K_{ce})_b (C_{Ac} - C_{Ae}) = \gamma_e K_{d,mf} a' (C_{Ae} - C_{As})$$
(29)

and

$$a' = \frac{\text{surface area}}{\text{volume of solid}} = \frac{6}{\phi_s d_p}$$
(30)

By eliminating  $C_{AC}$  and  $C_{Ae}$  from Equation (27), the general expression for the mass transfer coefficient, or Sherwood number, is obtained

$$(K_{d})_{b} = \frac{6(1 - \epsilon_{f})D}{\delta \phi_{s} d_{p}^{2}} Sh_{overall}$$

$$= \gamma_{b} B_{d} \frac{Sh_{t}}{Sh_{m}f} + \frac{1}{\frac{1}{(K_{b}c)_{b}}} + \frac{1}{\gamma_{c} B_{d} + \frac{1}{\frac{1}{(K_{c}c)_{b}} + \gamma_{e} B_{d}}}$$
(31)

where

$$B_{d} = \frac{6D}{\phi_{s}d^{2}} Sh_{mf}(sec^{-1})$$
(32)

Thus with known values for  $Sh_t$  and  $Sh_{mf}$ , and calculated gas interchange rates, mass transfer coefficients and Sherwood numbers in fluidized beds can be estimated.

 $K_{d,t}$  is the mass transfer coefficient obtainable by using the single sphere diffusion formula

$$Sh_t = \frac{K_{d,t}d_p}{D} = 2.0 + 0.6 S_C^{1/3} Re_{p,t}^{1/2}$$
 (33)

where

$$S_C = \frac{\mu}{\rho D}$$

$$Re_{p,t} = \frac{d_{p}U_{t}\rho_{g}}{\mu}$$

#### SECTION VIII

#### F'RTICLE GROWTH RATE IN A PARTICULATE BED

Based on total surface of particles, an overall mass transfer equation can be written

 $\frac{1}{\text{surface of particles}} \frac{dN_A}{dt} = \frac{-\text{volume of bed}}{\text{surface of particles}} \frac{dC_A}{dt}$ 

$$= -\frac{\phi_{ed_{p}}}{d(1 - \epsilon_{f})} \frac{dC_{A}}{dt}$$
$$= K_{d}(C_{A} - C_{s})$$

Since  $C_s = 0$ , due to the fact that this case is diffusion-controlled (Reference 8-1), the above equation can be easily integrated. The above equation can be rewritten

$$-\frac{dC_A}{dt} = K_d C_A$$

where

$$K'_{d} = K_{d} \cdot g(1 - \epsilon'_{f})/\phi_{s}d_{p}$$
$$dlnC_{A} = -dl$$
$$C_{A} = C_{A1} \exp(1K_{d}'1)$$

'The average concentration of silane in the bed which could be used in average bed deposition calculation is

$$\bar{C}_{A} = \frac{C_{A1}(1 - e^{-k_{d}} L_{f})}{\frac{k_{d}}{L_{f}}}$$
(35)

Therefore, the average mass transfer in the bed per unit surface of solids is given by

$$-\frac{1}{\text{surface}}\frac{dN_{A}}{dt} = k_{d}\bar{c}_{A}$$
(36)

Finally, the particle growth rate is calculated from this result as

$$\frac{dR}{dt} = \frac{1}{surface} \frac{dN_A}{dt} \frac{M_W}{\rho_s} = k_d \bar{C}_A \qquad (37)$$

where Mw is the molecular weight of silicon, and  $ho_{\rm S}$  is its density.

#### SECTION IX

#### PARTICLE GROWTH RATE IN A BUBBLING BED

A similar procedure can be followed to obtain the particle growth rate for the bubbling bed, except that  $U_b$ ,  $(k_d)_b$  should be used in place of  $U_0$ ,  $k_d$ . The result is that the average concentration of silane in the bubbles is

$$\bar{c}_{Ab} = \frac{U_b + C_{Ai} \left(1 - e \frac{\left(-(k_d)_b + L_f\right)}{U_b}\right)}{(k_d)_b + L_f}$$
(38)

The average mass transfer in the bed and the particle growth rate are given as,

$$-\frac{1}{\text{surface}}\frac{dN_{Ab}}{dt} = (k_d)_b \bar{C}_{Ab}, \qquad (39)$$

$$\frac{dR}{dt} = (k_d)_b \tilde{C}_{Ab} \cdot \frac{M_W}{\rho_s}$$
(40)

#### SECTION X

#### ENTRAINMENT

Experimental data indicate that the entrainment rate can be expressed as the entrainment coefficient k, which is given in Figure 10-1.





$$\Psi = \left[\frac{(u_0 - u_t)^2}{g^d p}\right]^{0.5} \left(\frac{d_p u_t \rho_g}{\mu}\right)^{0.725} \left(\frac{\rho_s - \rho_g}{\rho_g}\right)^{1.15}$$

#### SECTION XI

#### OVERALL MASS BALANCE OF THE BED

The following definitions are used:

- $F_0$  feed rate,  $F_1$ : overflow rate,
- F<sub>2</sub> elutriation rate
- P<sub>0</sub> partic's size distribution in feed
- P<sub>1</sub> particle size distribution in overflow
- P<sub>2</sub> particle size distribution in elutriation
- P<sub>b</sub> particle size distribution in bed

If  $F_0$  and  $P_0$  are known, then there are five unknowns to be calculated and these are obtained by the following five relationships (refer to Reference 10-1):

- (1)  $P_1 = P_b$ , for a well-mixed fluidized bed
- (2)  $F_1 + F_2 F_0 = \text{total solid generation in bed.}$
- (3) From the definition of k, it follows that (see Reference 10-1)

$$P_2(R) = k(R) WP_b (R)/F_2$$
.

(4) By definition,

$$\int_{P_1}^{R} dR = 1.$$

(5) In unit time, the mass balance on particles of size between R and R + dR is given as follows:

 $\begin{pmatrix} \text{solids} \\ \text{entering in} \\ \text{feed} \end{pmatrix} - \begin{pmatrix} \text{solids} \\ \text{leaving in} \\ \text{overflow} \end{pmatrix} - \begin{pmatrix} \text{solids} \\ \text{leaving in} \\ \text{carryover} \end{pmatrix} + \begin{pmatrix} \text{solids growing into} \\ \text{the interval from} \\ \text{a smaller size} \end{pmatrix}$  $- \begin{pmatrix} \text{solids growing out} \\ \text{of the interval to} \\ \text{a larger size} \end{pmatrix} + \begin{pmatrix} \text{solids generation} \\ \text{due to growth} \\ \text{within interval} \end{pmatrix} = 0$ 

This rewrites as:

$$F_0P_0(R) - F_1P_1(R) - Wk(R)P_1(R)$$

$$-W \frac{d \frac{dR}{dt} (R) P_1(R)}{dR} + \frac{3W}{R} P_1(R) \frac{dR}{dt} (R) = 0$$
(41)

#### SECTION XII

#### CALCULATION SAMPLES

A computer program, incorporating the mathematical model described so far, was written. A listing of the program is attached as an appendix. The properties of the gas stream and silicon particles, the composition of the gas stream, bed diameter, initial bed weight, particle size distribution of feed particles, production rate, maximum particle size in the bed, the differential particle size interval and the number of orifices in the gas distributor were the input parameters to the model. The initial value for the personal particle size in the bed is assumed to be the harmonic average of the feed particle size distribution. The computer program was found to converge to final value of average bed particle size in two iterations. The mattenatical modeling equations were organized in various subroutines. The main program defines the variables, arrays and functions, sets the starting values for computation, provides the calling sequence for the subroutines. and outputs the calculated data. The output of the program consists of gross fluidization characteristics, bubble characteristics, mass transfer coefficients, particle size distributions and mass flow rates of feed, outflow or entrainment and overall growth rate of particles. The minimum particle size of the feed p,min.f and the superficial velocity  $U_0$  are varied in three calculations as shown in the table for simplicity. The particle size distribution of the feed was assumed to be uniform. Table 12-1 shows the results of some sample modeling calculations using this computer program.

The results show that for the given set of values of variables, the minimum fluidizing velocity  $U_{mf}$ , the terminal velocity  $U_t$ , the bed height  $L_f$ , the necessary feed rate  $F_0$ , the entrainment rate  $F_2$ , and the average particle size  $\overline{d}_p$  are listed. The convergence of the computation is very fast; at the second iteration, the asymptotic solution is obtained.

 $F_1$  was chosen after several trial and error calculations so that smooth bed operation is achieved. Such choice of numbers is delicate due to the simplistic approach taken in the modeling.

As compared to the first example, the second example shows the results when the superficial velocity is increased. This shows a smaller amount of  $F_0$  necessary than in the first case due to more deposition from the higher flow rate. The third example is for the higher average feed particle size, showing the reduced reaction due to smaller surface area.

The results of the computer program were listed against experimental fluidization data obtained from fluidization of silicon particles with argon in a 1-in. fluidization column. The results of the comparison are shown in Table 12-2. The mode of fluidization indicated by the model is consistently wrong. It shows that the simple Froude number criterion used in the model is not sufficient to predict the mode of fluidization. The agreement between bed pressure drop data and calculated

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Table 12-1. Examples of Calculational Results

• Input Parameters

 $d_{t} = 5 \text{ cm} \qquad C_{Ai} = 5.0 \times 10^{-6} \text{ g-mole/cm}^{3}$   $\rho_{g} = 1.23 \times 10^{-4} \text{ g/cm}^{3} \qquad r_{p,max,f} = 75 \mu$   $\rho_{s} = 2.44 \text{ g/cm}^{3} \qquad \overline{W} = 200 \text{ g}$   $\rho = 3.45 \times 10^{-4} \text{ poise} \qquad F_{1} = 0.92 \text{ g/sec}$   $D = 5.809 \text{ cm}^{2}/\text{sec}$ 

• Results

	$r_{p,min,f} = 25 \mu$	25 µ	45 µ	
	U <sub>0</sub> = 19.2 cma/sec 24	.0 cm/sec	19.2 cm/sec	
Umf	3.78 cm/sec	4.69	5.36	
Ut	9.62 cm/sec	9.62	31.2	
L <sub>f</sub>	8.5 cm	8.5	9.4	
FO	0.032 g/sec	0.023	0.048	
F <sub>2</sub>	0.011 g/sec	0.010	0.009	
āp	150.1 μ	167.2	178.8	

bed pressure drop is excellent. The agreement between experimental and calculated values for minimum fluidization velocity is rough. This discrepancy may be due to several reasons. The model equation used for minimum fluidization velocity is a simplified low Reynolds number approximation of the more rigorous form. The experimental data itself was prone to considerable error. In many runs (1, 2, 3, and 7)the minimum fluidization velocity was determined by visual observation of bed behaviour. In cases where the U<sub>mf</sub> was determined from combined packed bed and fluidized bed data (6, 8, 9 and 10) the agreement is much better. Considering the possible significant experimental error in determining the minimum fluidization velocity, the computer model prodicted the fluidized bed performance quite well.

Run No.	Particle Size, $\mu$	Weight of Particles, g	Particle Diameter, $\mu$	Umf' cm/sec	ΔP, Em H <sub>2</sub> 0	Mode of Fluidization
-	74-104	48.2	89.00ª 88.24b	0.405° 0.513d -26.6°	77.000 76.20d 1.56e	Bubbling <sup>c</sup> Particulate <sup>d</sup>
2	74-104	6.97	89.00 88.24	0.404 0.513 -26.6	135.0 126.5 7.04	Bubbling Particulate
£	74-104	106.9	89.00 88.24	0.406 0.513 -26.6	180.0 172.1 4.38	Bubbling Particulate
ور	53 <b>-</b> 74	29.0	63.50 65.74	0.33 0.28 15.15	44.00 45.84 -4.18	Bubbling Particulate
7	53 <b>-</b> 74	2° trtt	63.50 65.74	0.44 0.28 36.4	67.00 69.88 -4.3	Bubbling Particulate
œ	74-104	30.7	89.00 88.24	0.520 0.513 1.35	46.00 48.54 -5.52	Bubbling Particulate
6	104-147	30.9	125.5 132.2	0.997 1.151 -15.45	51.00 48.84 4.24	Bubbling Particulate

Table 12-2. Comparison of Experimental Fluidization Data with Computer Model Results

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Table 12-2.	Comparison of	Experimental	Fluidization	Data	with	Computer	Model	Results
	(Continuation	:						

Run No .	Particle Size,μ	Weight of Particles, g	Particle Diameter, $\mu$	Unnf. cn/sec	ΔP, 100 H <sub>2</sub> 0	Mode of Fluidization
<b>0</b>	104-147	45.8	125.5 132.2	1.000 1.151 -15.1	78.00 72.40 8.2	Bubbling particulate

dCalculated value from the computer model. Percent deviation of calculated value from the experimental value.

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#### SECTION XIII

#### CONCLUSIONS

As mentioned before, this modeling was intended for a simple description of the fluidized bed. Thus there are many assumptions and treatments which may not be practical. Further improvements for the model will be conducted as experimental data become available.

One such improvement area is the modeling of the fine-particle fluidized bed modeling. Although it may not be necessary if one wants to use larger-size particles when recycling some of the products by crushing them and using as the bed, it would still be beneficial to have this option of using fine particles. This modeling would be difficult at this time because very few experimental data are available. However, the JPL in-house experimental work is likely to yield the needed information for this important area of fluidized bed silicon production.

Another improvement may come from consideration of gas interchange rate at the surface of solid particles. Unlike the implicit assumption that the same number of moles of gas come out as the number of moles of gas going in, two moles of hydrogen come out for each mole of silane. This might help the fluidization of fine particles, too.

This report was reviewed by Professor T. Fitzgerald of OSU, acting as a consultant to LSSA. Dr. Fitzgerald (Reference 13-1) suggested that it might be useful to control the bubble size by artificial means: for example, vertical rods in the bed to break the bubbles larger than the size of the spacing. The reason is that, in the fluidized bed modeling, the prediction of the size of the bubble is the most difficult task (the error could be as high as 500). This would improve the accuracy of the modeling.

He also suggested that the following assumptions may prove troublesome, and may be modified to fit real data, although these considerations will make the model complex, and the improved accuracy may or may not justify the effort for this particular task.

- (1) Assumption that  $C_{AS} = 0$ .
- (2) Assumption that  $P_b$  in bubble is same as  $P_{-b}$  in emulsion.
- (3) No consideration of nucleation.
- (4) Neglect of flow contribution entering emulsion phase.

This modeling is yet to be confirmed by experimental data. The experiments are underway.

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- 13-1 Fitzgerald, T., private communication.

APPENDIX

Mathematical Model Program Listing

```
-FUR, IS SILICON
      REAL J
 AAIR(I), AN ARRAY, IS EQUIVALENT TO AIR(RPMIN+I*DELR-0.5*DELR), A FUNCTION.
C
C THIS IS INTRODUCED TO SAVE THE COMPUTER TIME BY STORING ONCE COMPUTED NUMBERS.
C ALL OTHERS ARE SIMILAR.
       COMMON AAIR(200) + AABR(200) + APO(200) + AP1(200) + AP2(200)
       COMMON ARRE(200), AAK(200)
       COMMON UO, UMF, UT, DP, DT, H, CS, CSIL, CH2, ALMF, ALF, RHOS, RHOG, AMU
       COMMON EMF + W + F0 + F1 + F2 + G + RE + DELP + RET + CDP + UOR + NOR + TDH + AN + DB
       COMMON DELROUBROUB OELTAOUF ALPHAOUS , IOAKCEBSOUE DSAODSRORCO
       COMMON AKDBA , CABAV2
       COMMON SHMF
COMMON JKL, SH1, ZETA, BD,
                                         GAMMAE + SHT + AKDBAV + CABAV
       COMMON EF . AKBCB . AKCEB . AKBEB . D. GAMMAC . GAMMAB . ETA . SH . AKDB . SC
       COMMON REP.ZAA.ZBA.VA.AT.GROWTH.PHIS.FR.AOR.Y.CAB
       COMMON AMW. RPMIN. RPMAXF, RPMAXB, TOT
       DT = DIAMETER OF BED
C
       DP = PARTICLE DIAMETER
C
C
   EMF = MINIMUM FLUIDIZING VOIDAGE
Ċ
       RHOG = GAS DENSITY
      RHOS=SOLID DENSITY
¢
       AMU = VISCOSITY COEFF
С
                                                والممصد والمادر ماردين والوار
Ĉ
       PHIS=SPHERICITY
C
      DELPMIN = PRESSURE LOSS ACROSS DISTRIBUTERS
  D = DIFFUSION COEFFICIENT (CM**2/SEC)
Y=LUGARITHMIC MEAN FRACTION OF TNERT GAS
C
C
       W=BED WEIGHT
C
  CABEMEAN CONCENTRATION OF SILANE IN THE BUBBLE IGR-MOLE/CC)
C
       RPMIN = MIN PARTICLE SIZE
Ć
C
       RPMAXB = MAX PARTICLE SIZE IN LED
  RPMAAF = MAX PARTICLE SIZE IN FEED
RRR = PARTICLE GROWTH RATE IN CM/LEC
L
C
      F1 = OUTFLOW FROM BED
C
      PU = PARTICLE SIZE DISTRIBUTION - FEEDING

P1 = PARTICLE SIZE DISTRIBUTION - BED AND OVERFLOW

P2 = PARTICLE SIZE DISTRIBUTION - ENTRAINMENT
C
C
C
      FU = MASS FLOW RATE - FEEDING
F1 = MASS FLOW RATE - OVERFLOW
F2 = MASS FLOW RATE - ENTRAINMENT
C
C
С
       G = GRAVITATIONAL CONSTANT
С
       ARBITRARILY ASSUME THE MAXIMUM PARTICLE SIZE IN BED.
C
       READ 1000.DT.PHIS.RHOG.RHOS.AMJ.W.FI.EMF.Y.CAB
      *. RPMAXF, RPMAXB, RPMIN, NOR, AMW, D, G, DELR
C EVERYTHING IS EXPRESSED IN CGS UNITS! NO CONVERSION FACTOR IS THUS NEEDED.
       PRINT 888.DT.PHIS.RHOG.RH' S.AMU.W.FI.EMF.Y.CAB
      *+ XPMAXF + RPMAXB + RPMIN + NOR + AMW + D + G + DEL R
  686 FORMATCIN +///- DT=-+C10+4+- PHIS=-+E10+4+- RHOG=++E10+4+
      1- RHUS=-+EI0+4+- AMJ=++E10+4+- W=++E10+4+/- F1=++E10+4+- EMF=++E10
      2.4.9- Y=-.E10.4.9- CAD=-.E10.4.9- RPMAXF=-.E10.4.9- RPMAXB=-.E10.4.9/
3- RPMIN=-.E10.4.9- NOR=-.E10.4.9- AMW=-.E10.4.9- DF-.E10.4.9- G=-
      4 .E10.4. DELR=-.E10.4)
       DFMIN=RPMIN*2.
       11J=Ū
    6 IIJ=IIJ+1
       IF(IIJ+EQ+1) GO TO 153
C PRINT COMPUTED QUANTITIES AFTER EACH CYCLE.
       RPMAX=RPMAXB
       NN=(RPMAX-RPMIN)/DELR +C.5
```

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```

**A-2** 

فيودف بالبور الباد الالا

C IMP	URIANT REMINAREMAXE AND REMAXE SHOULD BE MULTIPLES OF DELE
	DO 151 I=1+NN+5
	RJ=RPMIN+I*DELR-0.5*DELR
	20J=AP0(1)
	P1J=AP1(I)
	ADRJ-AADRII) DDINI 152-01-02 1-01 1-000 1-00 1-410 1-400 1
152	PRINI IJ2 FROSP2 JP1 J SRRRJSP0 JSAIROSP0 RJ = 7510-41
151	CONTINUE
153	CONTINUE
1000	FORMAT (8E10-4)
•	IF(IIJ-NE-1) GO TO 47
C	ARBITRARILY ASSUME THE MAXIMUM PARTICLE
C	SIZE IN BED MAYBE 1000 MICRONS = DPMAXE
с	
Ç	AVERAGE PARTICLE SIZE))) INITIAL
	ARP=0.
	NN#(RPMAXF-RPMIN)/DELR+0.5
	DO 11 I=1+NN
	R = RPMIN+I*DELR -0.5*DELR
	ARP=ARP+PG(R)/R*DELR
	RP=10/AKP
55	FRINI 229 KF FORMAT/ 140-/ - RD:F10 40
	GO TO 13
C	
č	AVERAGE PARTICLE SIZEDD ITERATION
47	
•••	
	NN= (RPMAXB-RPMIN)/DELR+0.5
	DO 12 1=1,NN
	R ⇒RPMIN+I*DELR-0.5*DELR
	BRP=BRP+P1(R)/R*DELR
12	CONTINUE
	RP=1./BRP
	PRINT 55, RP
C	
13	CONTINUE
<u> </u>	
~	UT = PED ADEA
C	AI = DEU AKEA AT-DT++2+3,14159/4,
č	COMPUTE LUG
•	CALL TESTU
C	
č	DETERMINE THE TYPE OF FLUIDIZATION.
	CALL TYPE
C	
Ç	DETERMINE THE DISTRIBUTOR PARAMETERS.
	CALL DISTRI
C	
C	COMPUTE TDH
	CALL TDHS
C	

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~			
<u> </u>		CHARACTERIZE BUBBLES.	
c		CALL BUDBLE	
2			
<u> </u>		CHARACTERIZE EMULSION PHASE.	<ul> <li>Here and here and the second se </li> </ul>
~		CALL EMULSI	
ç			
<u> </u>		CALCULATE GAS INTERCHANGE COEFFS. BET	WEEN BUBBLE AND EMULSION.
		CALL GASINT	
C			
<u>_</u> C		CALCULATE MASS TRANSFER COEFFS.	
		CALL TRANSF	
C			
		IF(11J.NE.1) GO TO 121	
		NN=(RPMAXB-RPMIN)/DFLR+0.5	n na kananan kanan kanan pertanan pertanan pertanan pertanan pertanan pertanan kanan kanan kanan kanan kanan ka
C			
		DU 111 I=1+NN	
		IF (JKL + EQ + 2) 30 TC 211	and a second
		ARR(I)=RR2(RPMIN+T#DELR=0.5*DELR)	
	211	APPD/INSPPD2/20MINATEDELD_0 EEDELDA	an an ann an shearann an
	111		
	111		
-		DU 112 1=1 INN	
		AAN IIJTAN IRPMINTITUELK-UADTUELK)	
	112	CONTINUE	
		<u>CO 113 I=1,NN</u>	
		APU (I)=PU (RPMIN+I*DELR-0.5*DELR)	
	113	CONTINUE	
		DO 114 I=1+NN	
		AAIR(I)=AIR(RPMIN+I*DELR=0.5*DELP)	
	114	CUNTINUE	
		DO 115 I=1.NN	
		AABR(I)=ABR(RPMIN+I*DELR-0.5*DELR)	
	115	CONTINUE	
	121	CONTINUE	
C	· · · · · · · · · · · · · · · · · · ·		
		TOT=TOTAL (RPMAXB)	
r			
		DO 116 1=1+NN	ստող շարչ գր տեղերությունը, ալցեր գիրեստերիներու
		AP1 (I)=P1 (RPMIN+I*DELR=0.5*DELR)	
	116	CONTINUE	
-			and design applied to be a second and a second and a second second second second second second second second se
ē	i	BALANCE MASS FLOWS.	
•		CALL MASSEL	
Ľ		DO 117 1-1-NN	
		492 (1)*02 (00M1N+1#0EL0-0 6#06L0)	
•	117	CONTINUE	a
~	111		
C		UNLY TWO ITERATION IS ENOUGH.	
		IF(IIJeLEe3) GU 10 6	to tage on the transmission of the second
		STOP	
Ç			
		FUNCTION PU(Z3)	
C	1 Ni	PUT PARTICLE SIZE DISERITUTION	
		IF (Z3.GE.RPMIN.AND.Z3.LE.RPMAXE) PO	=1./(RPMAXE-RPMIN)
		RETURN	
C			
C			
		SUBROUTINE TESTU	
		A-4	
			· · · · · · · · · · · · · · · · · · ·

# ORIGINAL PAGE IS OF FOUR ONLINGE BOLICITY OF POOR QUALITY

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```
INTS SUBROUTINE IS TO CALCULATE THE OPERATIONAL VELOCITY RANGE ....
     ALME = BED HEIGHT AT ME
     ALM:=+/3+14159#4+/07##2/(1+-EMF)/(RHOS+RHOG)/6
     UELP=#/3.14159#4./01##2
                                                                       ----
C UNTIL ME KNOW JUNNE DON-T KNOW RE. SO THIS IS TRIAL AND ERPOR METHOD.
  1 ASSUME REALTARD 2 COMPUTE UNF C DECIDE UC(UMFAUT) 4 CALCULATE RE
HUNEVERA IN INIS MARTICULAR CASE UC-20+UT
C
                                                                 RE = 1
      IPASS=+
     DELP = PRESSURE LOSS ACROSS BED
RE = REYNOLDS NO.
C
                                                            Ċ
     UMF = MIN FLUIDIZING VELOCITY
L
     UT = TERMINAL VELOCITY
Ĉ
                                               11 IPASS = IPASS+1
     UNF = UP##2#(RHOS-RHOG)#C/1650./AMU
     UT = G#(RHOS-RHOG)#DPMIN##2/12./AMU
     IF (RE. (E. 20.) UMF = SGRT(CC*(EHOS-RHOG)*6/24.5/RHOG)
      IF (RE.GE.20.) PRINT 51
    USE ANY UC. JUST PLACE THE DESTRED ONE IN THE LAST POSITION.
C
     UU=U.5#UT
     U0=+25#UT
     u0=1.5*UT
                                                .....
      UU=2.+UT
     UMF2=2. +UHF
      00=2.5*UT
                                                     UU=19.23
      IF(UU.LT.JMF2) UC=UMF2
      RE=DP#RHOG*UU/AMU
                                                             -----
      I - (IFA55.EQ.1) GO TO 11
   51 FORMAT (1000- RE IS LARGER THAN 20-)
      IF (UMF .LE.UT) GC TO 32
                                                       .....
                                                             -----
   21 PRINT 31
   31 FORMAT(1H0,- UT IS SMALLER THAN UMF-)
   32 CONTINUE
      PRIN 61. UMF. UT. RE. ALMF. DELP. JO
   61 FORMAT(1HC)- UMF;UT;RE;ALMF;DELP;UO=-;6E10.4)
   41 RETURN
С
C
      SUBROUTINE TYPE
                                                                 FR = FROUDE NG
¢
      REPME = RE AT ME CONDITION
Ċ
      ANUMBER - CRITERION OF TYPE OF FLUIDIZATION
C
   THIS SUBROUTINE IS TO CHECK THE DEGREE OT FLUIDIZATION IN BED
C
      FR = UMF##2/DP/G
      REPMF = UP+UMF+RHCG/AMU
                                                               ANUMBE = I K + REPME + (R:: DS + RHOS) / RHOG # ALME / DT
      IF (ANUMBE.GE. 100.) PRINTL
      IF (ANUMBE-LT-100-) GO TO 5
                                                                1 FORMAT (1HG+///- BUBBLUNG FLUIDIZATION-)
      UTEST = 2*UMF
      IF (UU+GE+UTEST) PRINT 2
                                                                         . . . . . . . . . . . .
    2 FORMAT (1H0+ THIS IS VIGOROUS-)
IF(00+LT+UTEST) PRINT 3
    5 FURMAT (1HC)- THIS IS NOT VIGOROUS-)
                                                                   ----
    5 CONTINUE
      IFIANUMBE .LT. 100.1 PRINT 4
    4 FORMAT (INUS- PARTICULATE TEUIDIZATION-)
      IF (ANUMB.CE.100.) UKL=1
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# ORIGINAL PAGE IS OF POOR QUALITY

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77-25

	1 F F Annual Martin 1 Chail - 1 Kris 2	
c		
è		
C	SUPPORTING DISTOL	—
r	SUBRUCTINE DISTRI	
2	NES SORO INCLOSING CALCOLATE THE STRATEGIOR	
Ç		
Č	AUR = GRIFICE AREA	
C	CDP = GRIFICE COEFFICIENT	
C	NOR = NUMBER OF ORIFICE	
C	UOR = GRIFICE VELOCITY	
	DELP1 = DELP*G.1	
	DELP2=3.5E+04	_
Ċ.	DELP2 IS EQUIVALENT TO 35 CM H20	
C	REFER TO P67 OF KUNII, EQ 34. THE THÌRD TERM	
С	IS NEGELECTED HERE	
	DELPD=DELP1	-
	IF (DELP2.GE.DELP1: DELFD=DELP2	
	IF (D) P2-6: ADE( 21) P2INT 11	
	A FURMALLINGATION OF CAN INCREASE WEIGHT OF THE BED WITHOUT DENALLZING THE	-
	The star distribution opersons to see all of the best and best and the star started the	
	DISTRIBUTER - RESSURE EUSS-/	
÷	RET - DINRIGONOGAMO	-
C		
	1F(REIGLIG30) CDF=0.4*(ALUG(REI)-ALUG(2.))/(ALUG(30.)-ALCG(2.))	
	*+U+2	
	UUR = CDP* SGRT(2. *DELPD/RHOG)	
	VELRAT-UC/UCR	
	AOR = VELRATZNOR	
	PRINT 21,RET,CDP,UUR,VELRAT,AOR	
	21 FURMATEIHU9-RET9COP9UOR9VELRAT9AOR=-95510041	
	<b>NETURN</b>	
C		
С		
	SUBROUTINE TOHS	-
ć	THIS SUBROUTINE IS TO CALCULATE TOH	
ĩ	REFER IN 294	
ē.	TOH - TRANSPORT DISEMGACING HEIGHT	-
2		
C		
~	RE LURIA	—
C		
C		
	SUBRUCT INC DUBBLE	
Ç	UF = GEWARD VELOCITY OF GAS IN EMULSION AT ME	
C	DELTA = VOLUME FRACTION OF BUBBLES	
Ċ	RB = RADIUS OF BUBBLE	
Ċ,	THIS SUBROUTINE COMPUTES EUROPERTIES.	
C.	REFER TO COAF 4	
ŭ	US = JIAMITEN OF BUBBLE	_
C	AN BUBBLÉ FRÉQUENCY	
Ċ	UBR = BUBBLE RIGING VELOCITY	
C	UB = ABSOLUTE RISE VELOCITY OF BUBBLES	
ĉ	H = HEIGHT BETWEEN TWO SUCCESSIVE PUBBLES	
ċ	SC=SCHMIDT NO.	
ĉ	FUR SIMPLICITY OF THE CALCULATION, BASED ON THE INFORMATION 14	
ċ	FIG 20, P1291 LET-S ASSUME THAT THE BUBPLE EREQUENCY IS APPROXIMATELY	• ·
č	4 REGARDIESS OF THE SIZE OF THE PED FOR THE MOST PART OF THE BED-	
•	AN 2 As	
	DB=1.5/AN*(UC-UMF)	

	••
<u> </u>	PRINT 1.008.AN
	I FURMAT (ING)//- CUBBLE SIZE, FREQUENCY =?E10.4)
~	$USR = 22.26 \pm 0.00 \pm 1.0000$
<u> </u>	THE BUBBLE SIZE CANNOT BE LARGER THAN MAX STABLE SIZE. E0.9.PIZI
	DB=UBR++2/22+26++2
	RB=DB/2.
	UB=UC-UME+UBR
	H = UB/AN
	UF = UMF/EMF
	DELTA=2./3.*DB/H
	PRINT 2 JUBR JUB JH JCF JDEL TA JDB
<u></u>	2  FORMAT(IHU, 7- UBR, UB, H, UF, DELTA, B=-,6E10.4)
-	RETURN
C	
<u> </u>	
~	
C	EMULSION PHASE CHARACTERISTICS
<u> </u>	REFER TO CHAF 4 AND 5
C C	KL = KAUIUS OF LLOUD
Č	W = FLOW KATE OF GAS INTO AND OUT OF A BUBULE
	(*117) N.E LETCHT OF AUROLING AFD (*122)
Č	ALF = HEIGHI OF BUDGLING BED (MISI)
ç	EF = VOID + FRACTION IN BOBBLING BED(PIST)
<u> </u>	UE = OPWARD VELOCITY OF GAS IN EMULSION (PIS2)
Č	ALMA - KAILO UN WARE VOLUME IO BUBBLE VOLUME
ž	US = MEAN DUWNWARD VELOCITI OF SULUS IN EMUSION
	ARCEDS (P157) = COEFF OF SOLID INTERCHARGE SLIMEEN
2	CLUDD-WARE REGION AND EMOLSION PHASE
Ċ	DSA = AATAL DISPERSION COEFF OF SCIUS
<u> </u>	DSR = RADIAL DISPERSION COEFF OF SOLIES
~	$RC = 0.0370B^{-1}(108R+2.40F)/(103R+0.1)78(0.0333)$
Ç	DEMAX WOLD NOT BE DEFINED (PI22 FIG.14)
	$G = 3 \cdot V F \times V F \times 2 \cdot 1 + V = 2 \cdot 2$
	ALT = ALMI / (1-TOLLIA)
	$EF = I = VI = DE [A] \times (I = -EMF)$
	PRINT 19 KC9 G9 ALTS LT
~	I FORMAL (INU)/~ RCSUSALTSETS=>44EU04)
	FOR SIMPLICITY, DASED ON FIG. 9, 9190, LET-S ASSUME THAT ALPHA IS CONSTANT
	US = ALPHA*JELTA*UU/(I++DELTA*JELTA*ALPHA)
	UE#UF=UU 1 - 11 Duaxof: 11# 2#0406211 - 5451
	ANNEDD - JOF(10-TEMF)FUMF/(10-TUEL(A)/EMF/UD NC N= AFDUARA DEFMEENDER(UD) IMENERD /2 /NEF TA //M/
	UDA-ALFRANKZALMEKUDALUU-UMEJKAZ/D0/UELIA/UME DCD - 2 /15 ADELTA//1 - DELTA/X/WEXD0/SVE
	TRINI ZY ALTHANUJIUJAALUDJULIUDAJUAN 2 Eoduatiili za 11 dulaius kartest istron (ned 701) za
	Z FURMATNINUSZY – ALFRADUSZUJANCEUSDUCZUSADUSADUSKEMDIEŻUCA) dztorn
2	
	CLEDDITTNE CACTNE
	GAS INTERCHANCE DETAFF, HUDRLE AND ENVELLEDN-
č	WAS INTENCHANGE BETWEEN DUBBEL AND EMULIQUE With we Addrien to the case of visodons
Č	WILL DE AFFLIED IN INE EASE OF VISUANDO Buow ing were fither unter or
	BUDBLING DEUG EINNER UUDGEDZUMF UR
ç	UD-UD-UD-UT Arbad - Interachance coefficient setupet
Č	ANDLD = INTERCHANGE CULTETCIENT DETWEEN
Ę.	BUDBLE AND LLUUD Arcel 1- Detwork of or and entry stom
<u>د</u>	ANCED + DEINLEN LEUUD AND ENULGIUN
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C MAGES - DETURENE RUBBLE AND FULSION C THESE COEFFS. ARE ASSUMED TO BE INDEPENSENT OF INDIVIDUAL PARTICLE SIZE ARECA+4.5PUMF/DD45.8D5HD#22472D8+51*E(C-25) ARECA+4.5PUMF/DD45.8D5HD#22472D8+51*E(C-25) ARECA+4.5PUMF/DD45.8D5HD#24472D8+51*E(C-25) ARECA+4.5PUMF/DD45.8D5HD#24472D8+51*E(C-25) ARECA+4.5PUMF/DD45.8D5HD#24472D8+51*E(C-25) ARECA+4.5PUMF/DD45.8D5HD#24472D8+51*E(C-25) ARECA+4.5PUMF/DD45.8D5HD#24472D8+51*E(C-25) ARECA+4.5PUMF/DD45.8D5HD#24472D8+51*E(C-25) C GFAIN TO HE TRANSF C GFAINA TO THE TRANSF C GFAINA TO HE TRANSF C GFAINA TO THE TRAN		ORIGINAL PAGE IN OF POOR QUALITY
C THESE COLFFS. ARE ASSUMED TO BE INDEPENDENT OF INDIVIDUAL PARTICLE SIZE ARGEM-S-SUMPTODS-8.55/10#226/JD8151+1(C+25) ARGEM-S-1/12-/ARGEG01-/ARGED1 PRINT 1: ARGEG0ARGEEARGEED+ARGED1 PRINT 1: ARGEG0ARGEEARGEED+ARGED1-JG10,4) RETURN C C SUBROUTINE TRANSF C OBTAIN DIFFUSION COFFFICIENT ON TO SILICON SOLIDS ETA1. C ETA IS TAKEN TO BE L. SINCE THE PROCESS IS DIFFUSION CONTROLLED C ETA IS TAKEN TO BE L. SINCE THE PROCESS IS DIFFUSION CONTROLLED C ETA IS TAKEN TO BE L. SINCE THE PROCESS IS DIFFUSION CONTROLLED C ETA IS TAKEN TO BE L. SINCE THE PROCESS IS DIFFUSION CONTROLLED C ETA IS THE SILARE CONCENTRATION ON SOLID PARTICLES,CAS. IS NOI C ETA IS TAKEN TO BE L. SINCE THE PROCESS IS DIFFUSION CONTROLLED C AND THUS THE SILARE CONCENTRATION ON SOLID PARTICLES,CAS. IS NOI C GAMMAGE VOLUME FRACTION OF SOLIDS IN BUBBLE C GAMMAGE VOLUME FRACTION OF SOLIDS IN SUBJELE G GAMMAGE VOLUME FRACTION OF SOLIDS IN CLOUD GAMMAGE-VOLUME FRACTION OF SOLIDS IN SUBJELE C GAMMAGE VOLUME FRACTION OF SOLIDS IN SUBJELE C SCARWAGENDO SOL C SC ASKUTHOGO/ANU C RET = DPUNFARIOCS/ANU Z ETA- 1. VARIABLE INTRODUCED IN NELSON'S GALLDWATE KITH UG Z ETA-1. VARIABLE INTRODUCED IN NELSON'S GALLDWATE KITH UG Z ETA-1. VARIABLE INTRODUCED IN NELSON'S GALLDWATE KITH UG Z ETA-1.2.2.2.1.4.1.4.1.4.1.4.1.4.1.4.2.3.1.1.2.3.3.RE WE+*(0.5.1)*SC**(1.4./3.1) C Z ETA-1.2.2.2.2.1.4.1.4.3.1.1.2.3.1.2.3.0.3.8.E WE+*(0.5.1)*SC**(1.4./3.1) C Z ETA-1.2.2.2.2.1.4.1.4.3.1.1.4.1.4.2.2.3.1.4.4.4.4.4.4.4.4.4.4.4.4.4.4.4.4.4.4	C. ARBER = BETWEEN BUBBLE AND EMULSION	Mana and a second s
AKBC3+4.5*UNF/D0*5.45*LD*226/20*51*1(-25) AKBE3+1/11-AKBC3+1/AKCE3 PRINT 17 AGGC5+1/AKCE3 1 FGRNAT(1)h-J/-AKBC5+AKCE3+AKSE3 1 FGRNAT(1)h-J/-AKBC5+AKCE3+AKSE3 1 FGRNAT(1)h-J/-AKBC5+AKCE3+AKSE3 1 FGRNAT(1)h-J/-AKBC5+AKCE3+AKSE3 C C C SUBROUTINE TRANSF C C C GBTAIN DIFFUSION COEFFICIENT ON TO SILICON SOLIDS ETA=1. C C GETA IS TAKEN TO BE 1. SINCE THE PROCESS IS DIFFUSION CONTROLLED JND THUS THE SILARE CONCENTRATION ON SOLID PARTICLES, CAS+ IS NOI C C HADANAS VOLUME FRACTOR C G GAMMAS-0, OG G GAMMAS-0, OG G GAMMAS-0, OG G GAMMAS-0, OG G GAMMAS-0, OG G GAMMAS-0, OG C C GAMMAS-0, OG C C GAMMAS-0, OG C C ALL PARTIC CHOSEN(FERCION OF SOLIDS IN BUBBLE G GAMMAS-0, OG G GAMMAS-0, OG C C GAMMAS-0, OG C C C GAMMAS-0, OG C C C GAMMAS-0, OG C C C GAMMAS-0, OG C C C GAMMAS-0, OG C C C C GAMMAS-0, OG C C C C C C C C C C C C C	C THESE COEFFS. ARE ASSUMED TO BE IND	EPENDENT OF INDIVIDUAL PARTICLE SIZE
AKCEB = 6478 = (EMPSPUB/DB/SB-31*(0.5) AKBCED =//1./KASCG01./KASCGD1./KASCED PRINT 1: A ACBC0-AKCED-AKCED PRINT 1: A ACBC0-AKCED-AKCED ARETURN C SUBROUTINE TRANSF C OBTAIN DIFFUSION COEFFICIENT ON TO SILICON SOLIDS E TABL C ETA IS TAKEN TO BE 1. SINCE THE PROCESS IS DIFFUSION CONTROLLED C ETA IS TAKEN TO BE 1. SINCE THE PROCESS IS DIFFUSION CONTROLLED C ETA IS TAKEN TO BE 1. SINCE THE PROCESS IS DIFFUSION CONTROLLED C ETA IS TAKEN TO BE 1. SINCE THE PROCESS IS DIFFUSION CONTROLLED C ETA IS TAKEN TO BE 1. SINCE THE PROCESS IS DIFFUSION CONTROLLED C ETA IS TAKEN TO BE 1. SINCE THE PROCESS IS DIFFUSION CONTROLLED C ETA IS TAKEN TO BE 1. SINCE THE PROCESS IS DIFFUSION CONTROLLED C ANDAD= VOLUME FRACTION OF SOLIDS IN BUBBLE C GAMMAD= VOLUME FRACTION OF SOLIDS IN BUBBLE C GAMMAD= VOLUME FRACTION OF SOLIDS IN CLOUD GAMMAD= VOLUME FRACTION OF SOLIDS IN CLOUD GAMMAL= 11 -ETM 11.3.*UM/FEMF/INDR.UMF-EMFIALPHAL C GAMMAD= VOLUME FRACTION OF SOLIDS IN ERULSION GAMMAL= 11 - ETM 11.3.*UMF/FEMF/INDR.UMF-EMFIALPHAL C GAMMAD= VOLUME FRACTION OF SOLIDS IN ERULSION GAMMAD= VOLUME FRACTION OF SOLIDS IN ERULSION GAMMAD= VOLUME FRACTION OF SOLIDS IN ERULSION GAMMAD= VOLUME FRACTION OF SOLIDS IN ERULSION C ARMAL= 11-ETM 1.3.*UMF/FEMF/INDR.UMF-EMFIALPHAL C ETA = A VARIABLE INTRODUCED IN NELSON'S GALLDWAT* RITH UG Z ETA = A VARIABLE INTRODUCED IN NELSON'S SC++(1,/3+) C ZEMF = SHERMOOD NO.* #ITH UMF Z EMF = SHERMOOD NO.* #ITH UMF C EMF = SHER	AKBC8=4-5+UMF/D8+5-85+(D##245/0)	8##51##(C+25)
AKBEG-1//1./AKBCG-1./AKCED PRINT 1, AKBCG-1./AKCED 1 FGRMAT(1)K/-AKBCED.AKCED*AKGED=-,3E10,4) RETURN C SUBGOUTINE TRANSF C OBTAIN DIFFUSION COEFFICIENT ON TO SILICON SOLIDS ETA-1. C OBTAIN DIFFUSION COEFFICIENT ON TO SILICON SOLIDS ETA-1. C EFFCCTIVENESS FACTOR C EFFCCTIVENESS FACTOR C EFFCCTIVENESS FACTOR C EFFCCTIVENESS FACTOR C EFFCCTIVENESS FACTOR C EASIST THE SILAKE CONCENTRATION ON SOLID PARTICLES.CAS. IS NOT C MADDITANT IN OUR CASE. C GAPAGE VOLUME FRACTION OF SOLIDS IN BUBBLE C GAPAGE VOLUME FRACTION OF SOLIDS IN SUBBLE C GAPAGE VOLUME FRACTION OF SOLIDS IN SUBBLE C GAPAGE VOLUME FRACTION OF SOLIDS IN SUBBLE C GAPAGE.COLUME FRACTION OF SOLIDS IN SUBJON G GAPMACE VOLUME FRACTION OF SOLIDS IN SUBJON C GAPMACE VOLUME FRACTON OF SOLIDS IN SUBJON C SCARWINGO/D C SCARWINGO/D C RETT= DPPUTFRHOG/AMU C RENF= DPPUTFRHOG/AMU C ZETA-11-CEF1*11./3.)-L.)*D.3*RE**10.51*SC**11./3.) C ZEMF=12.*ZEMF*12.*ZEMF*2211.*EF1*10.51*SC**11./3.) C ZEMF=12.*ZEMF*12.*ZEMF*2211.*EF1*10.51*SC**11./3.) C SHRF= SHERMODD NO.* WITH UWF RENF=2.2CIMPTODD NO.*WITH WE CONDITIONS. TO BE USED IN LMULSION C PHASE IN EUBBLING GED SHMF=2.2.2CIMPTIZ.*ZEMF*22.*IF*22.*IF*22.*IF*11./3.) C SHRF=2.2.2CIMPTIZ.*ZEMF*22.*IF*22.*IF*11./3.) C SHRF=2.2.2.1F*11./2EMF/11CEF1**11./3.) C SHRF=2.2.2.1F*11./2EMF/11CEF1**11./3.) C SHRF=2.2.2.1F*12.*ZEMF*22.*IF*22.*IF*12.*II.*CF1**1.*ZEMF1.*II.* SHREMODD NO.*IITH UD. TO BE USED IN PARTICULATE BED. SHREMODD NO.*IITH UD. TO BE USED IN PARTICULATE BED. SHREMODD NO.*IITH UD. TO BE USED IN PARTICULATE BED. SHREMODD NO.*IITH UNCTON SILANE IN PARTICULATE BED. ACDBA2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CADAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CADAV2=AVERAGE CONCENTRATION	AKCEB = 6.78 * (EMF+D+UB/CB++3)	P+(0,5)
PRINT 1: ACBCGS-AKCEG-AK	AK6E5=1+/(1+/AK5C5+1+/AKCE8)	
L FORMATLIN/- AKBCE-AKCEB-AKSEB,3E10,4) RETURN C SUBJOUTINE TRANSF C GATAIN DIFFUSION COEFFICIENT ON TO SILICON SOLIDS ETA-1: E EFFECTIVENESS FACTOR C EFFECTIVENESS C GAMMAB-0 GOS C GAMMAB-VOLUME FRACTION OF SOLIDS IN BUBBLE C GAMMAB-0.003 C GAMMACE VOLUME FRACTION OF SOLIDS IN CLOUD GAMMACE VOLUME FRACTION OF SOLIDS IN CNULSION G GAMMACE VOLUME FRACTION OF SOLIDS IN CNULSION G AMMACE VOLUME FRACTOR VOLOS NO. WITH UNF RENT= DPUNFRAHOCISNO. WITH UNF RENT= DPUNFRAHOCIANU C EFFECTIVENEDS NO. WITH UNF RENT= DPUNFRAHOCIANU C EFFECTIVENEDS NO. WITH UNF C EMF= SAMEVODI NO. WITH UNF C SHMF = SAERWODI NO. WITH UNF C SHMF = SAERVODI NO. WITH UNF C SHMF	PRINT 1, AKBCB, AKCEE, AKBEB	
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C AND THUS THE SILARE CONCENTRATION ON SOLID PARTICLES, CAS. IS NOT INPORTANT IN OUR CASE. GAMMAB VOLUME FRACTION OF SOLIDS IN BUBBLE GAMMAB VOLUME FRACTION OF SOLIDS IN CLOUD GAMMAC = VOLUME FRACTION OF SOLIDS IN EXUSION GAMMAC = SOLENDARY C ETA = 1 VARIABLE INTRODUCED IN NELSON S GALLOWAY = WITH UG ZETA = 1 VARIABLE INTRODUCED IN NELSON S GALLOWAY = WITH UG ZETA = 1 VARIABLE INTRODUCED IN NELSON S TO BE USED IN LAWLSION PHASE IN SUBBLING UED SHMF = 12.*ZEMF+12.*ZCMF ##2011=EF) #*(1./3.)/(1.*(1.=-EF) #*(1./3.)) +**2-2.*TANHIZEMF)//ZETA*(2.*ZCMF ##2011=CF) #*(1./3.)/(1.*(1.=-EF) #*(1./3.)) +**2-2.*TANHIZEMF)//ZETA*(2.*ZCTA*#2011=EF) #*(1./3.)/(1.*(1.=-EF) #*(1./3.)) C SHT = SHERWOOD NO. WITH UD. TO BE USED IN FARICULATE BED. SHT = SHERWOOD NO. WITH UD. TO BE USED IN CLOUES IN BUBBLES SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT = S	C ETA IS TAKEN TO BE 1. SINCE THE PROD	CESS IS DIFFUSION CONTROLLED
<pre>C IMPORTANT IN OUR CASE. GAPHAB :s ARBITRARLLY CHOSEN(P202) GAPMAC= volume FRACTION OF SOLIDS IN BUBBLE GAPMAC= volume FRACTION OF SOLIDS IN CLOUD GAPMAC= volume FRACTION OF SOLIDS IN CLOUD GAPMAC= volume FRACTION OF SOLIDS IN CLUUS GAPMAC= volume FRACTION OF SOLIDS IN ENULSION GAPMAC= volume FRACTION OF SOLIDS IN ENULSION C Sc=APU/PHOG/AU C REHF = DFEVNOLDS NO. WITH UT REIT=DPAUTERHOG/AMU C ZETA = A VARIABLE INTRODUCED IN NELSOR, S GALLOWAY.E HITH UG ZETA = I A VARIABLE INTRODUCED IN NELSOR, S GALLOWAY.E HITH UG ZETA = I A VARIABLE INTRODUCED IN NELSOR, S GALLOWAY.E HITH UG ZETA = I A VARIABLE INTRODUCED IN NELSOR, S GALLOWAY.E HITH UG ZETA = I A VARIABLE HITH UMF REMF = DFEVNOLDS NO. WITH UNF ZEMF = SAME VARIAULE HITH UMF ZEMF = SAME VARIAULE HITH UMF ZEMF = SAME VARIAULE HITH UMF C SAME = SAME VARIAULE HITH UMF ZEMF = SAME VARIAULE HITH UMF ZEMF = SAME VARIAULE HITH UMF I ZEMF = SAME VARIAULE HITH UMF ZEMF = SAME VARIAULE HITH UMF C SAMIT = SHERMOOD NO. WITH UG SOLUSED TOR SOLUSED IN ENDES SHITEZO = SAME VARIAULE HITH UMF SHITE = SAME VARIAULE HITH UMF SHITE = SAME VARIAULE HITH UMF SHITE = SAME VARIAULE AND THE SOLUTIONS. TO BE USED IN ENALTICE SHITEZO = SAMITZETA = ZETA =</pre>	C AND THUS THE SILARE CONCENTRATION	ON ON SOLID PARTICLES, CAS, IS NOT
C GAMAGE VOLUME FRACTION OF SOLIDS IN BUBBLE GAMMAGE SARABLING CHOSEN(P202) GAMMACE VOLUME FRACTION OF SOLIDS IN CLOUD GAMMACE VOLUME FRACTION OF SOLIDS IN EXULSION GAMMACE VOLUME FRACTION OF SOLIDS IN EXULSION C RENT = REYNOLDS NO. WITH UT REIT=DPUTFRHOGANN C RENT = NEYNOLDS NO. WITH UMF RENT= DPUNFFRHOGANN C ZETA (1./(1EF)**(1./3.)-1.)*0.3*RE**(0.5)*SC**(1./3.) C ZETA (1./(1EF)**(1./3.)-1.)*0.3*RE**(0.5)*SC**(1./3.) C SHMF = SAME VARIABLE WITH UMF ZETA=(1./(1EF)**(1./3.)-1.)*0.3*RE**(0.5)*SC**(1./3.) C SHMF = SAMENDOD NO. WITH UMF ZETA=(1./(1EF)**(1./3.)-1.)*0.3*RE**(0.5)*SC**(1./3.) C SHMF=12.*ZEMFH(2.*ZEMF/WZENCH=EF)**(1./3.)/(1.*(1EF)**(1./3.)) C SHMF=12.*ZEMFH(2.*ZEMF/WZENCH=EF)**(1./3.)/(1.*(1EF)**(1./3.)) C SH1 = SHERWOOD NO. WITH UD. TO BLUSED IN PARTICULATE BED. SH1 = 2.*ZETA+(2.*ZETA*ZE(1.*EF)**(1.*/3.)-TAXH(ZETA)] C ANDBA2* AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2* AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. C GABAV2=AVERAGE MASS TRANSFER COEFF. FOR BUBELING GED. AKDBA2* AVERAGE MASS TRANSFER COEFF. FOR BUBELING GED. AKDBA2* AVERAGE MASS TRANSFER COEFF. FOR BUBELING GED. AKDBA2* AVERAGE MASS TRANSFER COEFF. FOR BUBELING GED. C ABAV=AVERAGE MASS TRANSFER COEFF. FOR BUBELING GED. C ABAV=AVERAGE MASS TRANSFER COEFF. FOR BUBELING GED. C ABAV=UBPCAB*(1.*-EXP(-AKDBAY*ALF/UD))/AKDBAZ/ALF PRINT 5.CABAV*.CABAV2*	C INPORTANT IN OUR CASE.	
C GAMMAGE 400LME FRACTION OF SOLIDS IN CLOUD GAMMAGE 400LME FRACTION OF SOLIDS IN CLOUD GAMMAGE 400LME FRACTION OF SOLIDS IN EXULSION GAMMAGE 41EMF #13.*UMF/EMF/UDR-LMF-EMF)+ALPHA1 C GAMMAGE 41EMF #13.*UMF/EMF/UDR-LMF-EMF)+ALPHA1 GAMMAGE 41EMF) #13.*UMF/EMF/UDR-LMF-EMF)+ALPHA1 GAMMAGE 41EMF) #13.*UMF/EMF/UDR-LMF-EMF)+ALPHA1 GAMMAGE 41EMF) #13.*UMF/EMF/UDR-LMF-EMF)+ALPHA1 GAMMAGE 41EMF) #13.*UMF/EMF/UDR-LMF-EMF)+ALPHA1 C SC-AMJ/RHOG/D C REMF = REYNOLDS NO. #1TH UT REIT=DPAUT*RHOG/AMU C ZETA = A VARIABLE INTRODUCED IN NELSON 5 GALLDWAY.* #1TH UG ZETA=1.*(1EF)**11.*/3.)-1.*0.3*RE**(0.5)*SC**11.*/3.) C ZEMF = SAME VARIABLE WITH UMF ZEMF=11.*(1EF)**11.*/3.)-1.*0.3*RE***(0.5)*SC**11.*/3.) C SHMF = SAME VARIABLE WITH UMF ZEMF=11.*(1EF)**11.*/3.)-1.*0.3*RE***(0.5)*SC**11.*/3.) C SHMF=12.*ZEMF*12.*ZEMF**2*11EF)**(1.*/3.)-TANH(ZEMF)] C SHMF=12.*ZEMF*12.*ZEMF**2*11EF)**(1.*/3.)-TANH(ZEMF)] C SH1 = SHERWOOD NO.* WITH WF CONDITIONS. TO BE USED IN LANUSIGN PHASE IN SUBBLING UED SHMF=12.*ZETA+12.*ZETA**Z*11EF)**(1.*/3.)-TANH(ZEMF)] C SH1 = SHERWOOD NO.* WITH UO. TO BE USED IN FARTICULATE DED. SH1 = SHERWOOD NO.* WITH UT. TO BE USED IN FARTICULATE DED. SH1 = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN EUGBLES. SH1 = SHERWOOD NO.*WITH UT. TO BE USED FOR SOLIDS IN EUGBLES. SH1 = SHERWOOD NO.*WITH UT. TO BE USED FOR SOLIDS IN EUGBLES. SH1 = SHERWOOD NO.*WITH UT. TO BE USED FOR SOLIDS IN EUGBLES. SH1 = SHERWOOD NO.*WITH UT. TO BE USED FOR SOLIDS IN EUGBLES. SH1 = SHERWOOD NO.*WITH UT. TO BE USED FOR SOLIDS IN EUGBLES. SH1 = SHERWOOD NO.*WITH UT. TO BE USED FOR SOLIDS IN EUGBLES. SH1 = SHERWOOD NO.*WITH UT. TO BE USED FOR SOLIDS IN EUGBLES. SH1 = SHERWOOD NO.*WITH UT. TO BE USED FOR SOLIDS IN EUGBLES. SH1 = SHERWOOD NO.*WITH UT. TO BE USED FOR SOLIDS IN EUGBLES. SH1 = SHERWOOD NO.*WITH UT. TO BE USED FOR SOLIDS IN EUGBLES. SH1 = SHERWOOD NO.*WITH UT. TO BE USED FOR SOLIDS IN EUGBLES. SH0 = AN INTERMEDIATE VARIABLE. BD = AN INTERMEDIATE VARIABLE. BD = AN INTERMEDIATE	C GARLANS VOLUME FRACTION OF SOLI	DS IN BUBBLE
<pre>GAMMAC= ULAWE FRACTION OF SOLIDS IN CLOUD GAMMAC= ULAWE FRACTION OF SOLIDS IN CLOUD GAMMAC= ULAWE FRACTION OF SOLIDS IN ENULSION GAMMAE=(1EMF)*(1DELTA//DELTA-(GAMMAE+GAMMAC) GAMMAE=(1EMF)*(1DELTA//DELTA-(GAMMAE+GAMMAC) GAMMAE=(1EMF)*(1DELTA//DELTA-(GAMMAE+GAMMAC) C SC = SCHMIDT NO. SC-AMU/RNOG/D C REHF = REYNOLDS NO. #ITH UT REIT=DP*UNF#RNOG/AMU C REMF = REYNOLDS NO. #ITH UMF REMF= DP*UNF#RNOG/AMU C ZETA = 1. VARIABLE INTRODUCED IN NELSON S GALLDWAY. WITH UG ZETA=[1./(1EFF)**(1./3.)-1.*D.3*RE**(0.5)*SC**(1./3.) C ZETA = 1./(1EFF)**(1./3.)-1.*D.3*RE**(0.5)*SC**(1./3.) C ZETA = 1./(1EFF)**(1./3.)-1.*D.3*RE**(0.5)*SC**(1./3.) C SHMF = SHERWOOD NO. #ITH NF CONDITIONS. TO BE USED IN LMULSION PHASE IN BUBBLING UED SHMF=Z2*ZETA*(1.2*ZETA**Z=(1EF)**(1./3.))-TANH(ZETF) C SH1 = SHERWOOD NO. #ITH UG. TO BE USED IN PARTICULATE UED. SH1 = (2.*ZETA*(2.*ZETA**Z=(1EF)**(1./3.))-TANH(ZETF) C SH1 = SHERWOOD NO. WITH UG. TO BE USED IN PARTICULATE UED. SH1 = (2.*ZETA*(2.*ZETA**Z=(1EF)**(1./3.))-TANH(ZETF) C SH1 = SHERWOOD NO. WITH UT, TO BE USED IN PARTICULATE UED. SH1 = SHERWOOD NO. WITH UT, TO BE USED FOR SOLIDS IN BUBBLES. SH1 = SHERWOOD NO. WITH UT, TO BE USED FOR SOLIDS IN BUBBLES. SH1 = SHERWOOD NO. WITH UT, TO BE USED FOR SOLIDS IN BUBBLES. SH1 = CO+OSSC#*(1EXP(-ARDBZ*ALF/UD))/ANDBZZ/ALF C ADBA2* AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. CABA2*2-WERAGE MASS TRANSFER COEFF. FOR BUBBLING GED. AKDBA2*AVERAGE MASS TRANSFER COEFF. FOR BUBBLING GED. AKDBA2*AVERAGE MASS TRANSFER COEFF. FOR BUBBLING GED. AKDBA2*AVERAGE MASS TRANSFER COEFF. FOR BUBBLING GED. AKDBA3*AVERAGE MASS TRANSFER COEFF. FOR BUBBLING GED. CABA4*AVERAGE MASS TRANSFER COEFF. FOR BUBBLING GED. AKDBA3*AVERAG</pre>	C GAMMAB IS ANBITRARILY CHOSEN(P202)	
<pre>C GAMMAC=: VOLUME FRACTION OF SOLIDS IN CLOUD GAMMAC=: VOLUME FRACTION OF SOLIDS IN ENULSION GAMMAE=:(1=-EMF)*(1=-DELTA)/DELTA-(GAMMAE+GAMEAC) C GAMMAE=:(1=-EMF)*(1=-DELTA)/DELTA-(GAMMAE+GAMEAC) C SC = SCHMIDT NO. SC=AMUJRHOG/D C REIT = REYNOLDS NO. WITH UT REIT=DP#UMF#RHOG/ANU C REMF = DFWUNF#RHOG/ANU C ZETA = A VARIABLE INTRODUCED IN NELSON'S GALLDWAY* WITH UG ZETA(1=/(1=-EF)**(1-/3=)=1=0=0=3#RE#*(0=5)*SC**(1=/3=) C ZEMF = SAME VARIABLE WITH UMF ZEMF=(1=/(1=-EF)**(1=/3=)=1=0=0=3#RE#*(0=5)*SC**(1=/3=) C ZEMF = SAME VARIABLE WITH UMF ZEMF=(1=/(1=-EF)**(1=/3=)=1=0=0=3#RE#*(0=5)*SC**(1=/3=) C SHMF = SHERWOOD NO. WITH WAF CONDITIONS. TO BE USED IN LMULSION PHASE IN BUBBLING UED SHMF=(2=2EMF+(2=2ETA**2*(1=-EF)**(1=/3=)/(1=-(1=-EF)**(1=/3=)) C SHMF=(2=2EMF+(2=2ETA**2*(1=-EF)**(1=/3=)/(1=-(1=-EF)**(1=/3=)) C SHM = SHERWOOD NO. WITH UO. TO BE USED IN FARTICULATE UED. SHI = SHERWOOD NO. WITH UT. TO BE USED IN FARTICULATE UED. SHI = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN EWBBLES. SHI=22.0+0.6=SC**(1=/3=)=50RTIRETI. C AKOBA2=AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKOBA2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. AKOBA2=AVERAGE CONCENTRATION IN BED. REFER TO MY WRITEUP. D IS THE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C CABAV2=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKOBAY=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKOBAY=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKOBAY=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. MEDE. D = AN INTERREDIATE VARIABLE. BD=6.0=SOMMF/PHIS/DP#=2 AKOBAY=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKOBAY=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKOBAY=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. PRINT 5:CABAY:CABAY:CABAY2=-*2EI0.4) RETURN</pre>		
C GAMAGE VOLUME FACTION OF SOLIDS IN ENLISION GAMAGE VOLUME FACTION OF SOLIDS IN ENLISION GAMAGE VOLUME FACTION OF SOLIDS IN ENLISION SC=AMU/RHOG/D C RETT = REYNOLDS NO. WITH UT RETTOPPUTERHOG/AMU C REMF = REYNOLDS NO. WITH UMF REMF = DP=UNFFRHOG/AMU C ZETA = A VARIABLE INTRODUCED IN NELSON S GALLDWATE WITH UG ZETA = A VARIABLE INTRODUCED IN NELSON S GALLDWATE WITH UG ZETA = A VARIABLE NOT DOWN SOLON STORE #*(0.5)*SC#*(1./3.) C ZEMF = SAME VARIABLE WITH UMF ZEMF = SMERMOOD NO. WITH MF CONDITIONS. TO BE USED IN LMULSION SHMF=12.*ZEMF+12.*ZEMF #*Z*(1EF) **(1./3.)/(1(1EF) **(1./3.)) +**22-2.)*TANHIZENF)//ZEMF/1CF)**(1./3.)/(1(1EF) **(1./3.)) +**22-2.)*TANHIZENF)//ZEMF/1CF)**(1./3.)/(1(1EF) **(1./3.)) C SHI = SHERMOOD NO. WITH UT. TO BE USED IN FARTICULATE DED. SHI = SHERMOOD NO. WITH UT. TO BE USED IN BUBBLES. SHI=2.0+0.6±3C#*(1./3.)*SGRTIRETI). C AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2=SHI*D/DP C CABAV2=AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2=SHI*D/DP C CABAV2=AVERAGE SILAWE CONCENTRATION IN BED. REFER TO MY #RITEUP. C DP IS THE AVERAGE SILAWE CONCENTRATION IN BED. REFER TO MY #RITEUP. C DP IS THE AVERAGE SILAWE CONCENTRATION IN BED. REFER TO MY #RITEUP. C DP IS THE AVERAGE SILAWE CONCENTRATION IN BED. REFER TO MY #RITEUP. C DABAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBA2=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBA2=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBA2=CABMHAE/BDISHT/SHMF+1://1./AK3CB+1./(GAMMAC*BD11. +/1./AKCB+1./GAMMABBD/SHT/SHMF+1:/1./AK3CB+1./(GAMMAC*BD11. +/1./AKCB+1./GAMMAE/BDISHT/SHMF+1:/1./AK3CB+1./(GAMMAC*BD11. +/1./AKCB+1./CABAV.CABAV2=2E10.4) RETURN	C GAPHACE VOLUME FRACTION OF SOLI	DS IN CLOUD
<pre>C DAMALE VULUME FRACTION OF SOLIDS IN EXCLUSION GAMALE*(1)-CERF)*(1)-DELTA)/DELTA-(GAMMAB+GAMMAC) SC=AMU/RNGG/D C RETT = REYNOLDS NO. #ITH UT REIT=DP#UT#RNOG/AMU C RENF = DP#UMF#RHOG/AMU C ZETA = A VARIABLE INTRODUCED IN NELSON &amp; GALLDWAY. WITH UG ZETA*(1/(1-EF)**(1./3.)-1.)*0.3*RE**(0.5)*SC**(1./3.) C ZEMF = SAME VARIABLE WITH UMF ZEMF*(1.2.(1EF)**(1./3.)-1.)*0.3*RE**(0.5)*SC**(1./3.) C SHMF = SHERWOOD NO. #ITH UMF C PMASE IN SUBBLING UED SHMF*(2.*ZEMF*12.*ZEMF**2*(1EF)**(1./3.)/(1(1EF)**(1./3.)) C SHMF*(2.*ZEMF*12.*ZEMF**2*(1EF)**(1./3.)/(1(1EF)**(1./3.)) C SHMF*(2.*ZEMF*12.*ZEMF**2*(1EF)**(1./3.)/-TANH(ZEMF)) C SHMF*(2.*ZEMF*2*(1EF)**(1./3.)/(1(1EF)**(1./3.)) C SHMF*(2.*ZEMF*2*(1EF)**(1./3.))-TANH(ZEMF)) C SHM1*(2.*ZEMF*2*(1F)**(1./3.)/(1(1EF)**(1./3.)) C SHM1*(2.*ZEMF*2*(1EF)**(1./3.))-TANH(ZEMF)) C SHM1*(2.*ZEMF*2*(1EF)**(1/3.))-TANH(ZEMF)) C SHM1*(2.*ZEMF*2*(1EF)**(1/3.))-TANH(ZEMF)) C SHM1*(2.*ZEMF*2*(1EF)**(1/3.))-TANH(ZEMF)) C SHM1*(2.*ZEMF*12.*ZEMF*12*(1EF)**(1./3.))-TANH(ZEMF)) C SHM1*(2.*ZEMF*12.*ZEMF*12*(1EF)**(1/3.))-TANH(ZEMF)) C SHM1*(2.*ZEMF*12.*ZEMF*12*(1EF)**(1/3.))-TANH(ZEMF)) C SHM1*(2.*ZEMF*12.*ZEMF*12*(1EF)**(1/3.))-TANH(ZEMF)) C SHM1*(2.*ZEMF*12.*ZEMF*12*(1EF)**(1/3.))-TANH(ZEMF)) C SHM1*(2.*ZEMF*12*(1EF)**(1/3.))-TANH(ZEMF)) C SHM1*(2.*ZEMF*12*(1EF)**(1/3.))-TANH(ZEMF)) C CABAV2=AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED.     AKDBAV=AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP.     DP 15 THE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP.      DP 0.*DF*12*(AMMAD*BD*SHT/SMMF*12*(1.)/AKDBA2/ALF</pre>	GAMMAC=(10-EAF) * (30*UMF/EMF/(UB)	(-UMF-ENF)+ALPHA)
C ADMARENT, "CHAIDT DO. C SC=AMU/RHOG/D C RETT = REYNOLDS NO. WITH UT RETT=DP=UT=RHOG/AMU C REMF = DPEWNFFRHOG/AMU C ZETA = A VARIABLE INTRODUCED IN NELSON & GALLDWAY. WITH UG ZETA=1://l-EFI=1://3.)-l.)*0.3*RE #F0.51*SC**(1./3.) C ZEMF = SAME VARIAULE WITH UMF ZEMF=1://l-EFI=*(1./3.)-l.)*0.3*RE #F0.51*SC**(1./3.) C ZHMF = SAME VARIAULE WITH UMF ZEMF=1://l-EFI**(1./3.)-l.)*0.3*RE #F0.51*SC**(1./3.) C SHMF = SHERWOOD NO. WITH UMF HASE IN SUBBLING UED SHMF=12.*ZEMF+12.*ZEMF**2*(1EF)**(1./3.)/(1(1EF)**(1./3.)) C SHMF=2.2.)*TANHIZEHF)//ZEMF*/1EFI**(1./3.)/(1(1EFI**(1./3.)) C SHI = SHERWOOD NO. WITH UD. TO BE USED IN FARTICULATE BED. SHI = (2.*ZETA*2*(1.*ZETA*2*(1EF)**(1./3.)/(1(1EFI**(1./3.))) C SHI = SHERWOOD NO. WITH UT. TO BE USED IN FARTICULATE BED. SHI = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHI=2.0+0.6/3CE*(1./3.)*SCRT(RETI) C AKDBA2=AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. C CABAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. C CABAV2=AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SILANE. BD=6.*D*SHMF/PHIS/DP#*2 C AKDBA2= AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. C ABAV2=AVERAGE CONCENTRATION OF SILANE IN UNGAZ/ALF C COMPUTE AVERAGE SILANE. CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SILE. BD=6.*D*SHMF/PHIS/DP#*2 C AKDBAV=CAMMAE/BD/SHT/SHMF+1./(1.*/AKBCB+1./(GAMMAC+BD+1. +/11./AKCB+1./GAMMAE/BD/SHT/SHMF+1./(1.*/AKBCB+1./(GAMMAC+BD+1. +/11./AKCB+1./GAMMAE/BD/SHT/SHMF+1./(1.*/AKBCB+1./(GAMMAC+BD+1. +/11./AKCB+1./GAMMAE/BD/SHT/SHMF+1./(1.*/AKBCB+1./(GAMMAC+BD+1. +/11./AKCB+1./GAMAE/BD/SHT/SHMF+1./(1.*/AKBCB+1./(GAMMAC+BD+1. +/11./AKCB+1./GAMAE/AD/2,ZE10.4) RETURN	C. GAMMAE= VOLUME FRACTION OF SOLI	DS IN ERULSION
C SLEARD/RNUG/D SC=ARD/RNUG/D C RETT = REYNOLDS NO. WITH UT RETT=DP=UT=RHOG/ANU C REMF = REYNOLDS NG. WITH UMF REMF= DP=UMF=RHOG/ANU C ZETA = 1 vARIABLE INTRODUCED IN NELSON & GALLDWAY. WITH UG ZETA=(1/(1-EF)=#=(1./3.)-1.)*0.3*RE *F=*(0.5)*SC=*(1./3.) C ZEMF=(1./(1-EF)=*(1./3.)-1.)*0.3*RE *F=*(0.5)*SC=*(1./3.) C ZEMF=(1CF)=*(1./3.)-1.)*0.3*RE *F=*(0.5)*SC=*(1./3.) C ZEMF=(1CF)=*(1./3.)-1.)*0.3*RE *F=*(0.5)*SC=*(1./3.) C ZEMF=(1CF)=*(1./3.)-1.)*0.3*RE *F=*(0.5)*SC=*(1./3.) C SHMF = SHERWOOD NO. #ITH WF C DPHASE IN 5UBBLING UED SHMF=(2.*ZEMF+12.*ZEMF+2*(1CF)=*(1./3.)/(1.*-CF)=*(1./3.))-TANH(ZEMF)) C SH1 = SHERWOOD NO. #ITH W0. TO BE USED IN PARTICULATE UED. SHI=(2.*ZETA+2.*ZETA+22:(1CF)=*(1./3.)/(1(1CF)=*(1./3.))-TANH(ZEMF)) C SH1 = SHERWOOD NO. WITH UD. TO BE USED IN PARTICULATE UED. SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN PUBBLES. SHT=2.0+0.6455C*#(1./3.)*SC#TIRLT). C AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY #RITEUP. C DP IS THE AVERAGE PARTICLE SIZE. BD=6.*0*SHMF/PHIS/DP=*2 C AKDBAV=CAMMA#BD*SHI/SHMF+1./(1.*/AKBCB+1.*/(1.6/AMAC*BD+1.*/ +/(1./AKCEB+1.*/GAMMAE/BD)) C CABAV=AVERAGE CONCENTRATION OF SILANE IN UBBLING BED. AKDBAV=CAMMA#BD*SHI/SHMF+1./(1.*/AKBCB+1.*/(1.6/AMAC*BD+1.*/ C AKDBAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING BED. C AGAV2=UD*CAB*(1EXP(-AKDBA2*ALF/UC))/AKDBA2/ALF C AKDBAV=AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY #RITEUP. C AKDBAV=CAMMAB#BD*SHI/SHMF+1.*/(1.*/AKBCB+1.*/(1.6/AMAC*BD+1.*/ (1.6/AMAB#BD*SHI/SHMF+1.*/(1.*/AKBCB+1.*/(1.6/AMAC*BD+1.*/ (1.6/AMAB#BD*SHI/SHMF+1.*/(1.*/AKBCB+1.*/(1.6/AMAC*BD+1.*/ (1.6/AMAB#BD*SHI/SHMF+1.*/UE))/AKDBAV/ALF PRINT 5.*CABAV.CABAV2=*ZEI0.4) RETURN	C SC	I-(GAMMAB+GAMMAC)
C RETT = REYNOLDS NO. #ITH UT RETT=DP#UT#RHOG/AMU C REMF = DP#UT#RHOG/AMU C ZETA = A VARIABLE INTRODUCED IN NELSON S GALLDWAY. WITH UG ZETA=11./(1EF)##11./3.)-1.)*0.3*RE#*(0.5)*SC#*(1./3.) C ZEMF = SAME VARIABLE WITH UMF ZEMF=11./(1EF)##(1./3.)-1.)*0.3*RE#*(0.5)*SC#*(1./3.) C SHMF = SAME VARIABLE WITH UMF C SHMF=12.*ZEMF+12.*ZEMF#*2*(1EF)##(1./3.)/(1(1EF)##(1./3.)) C SHMF=12.*ZEMF+12.*ZEMF##2*(1EF)##(1./3.)/(1(1EF)##(1./3.)) C SHMF=12.*ZEMF+12.*ZEMF##2*(1EF)##(1./3.)/(1(1EF)##(1./3.)) C SHMF=12.*ZEMF+12.*ZEMF##2*(1EF)##(1./3.)/(1(1EF)##(1./3.)) C SH1 = SHERWOOD NO. WITH UO. TO BE USED IN FARTICULATE BED. SH1 = SHERWOOD NO. NUTH UT. TO BE USED IN PARTICULATE BED. SH1 = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SH1=2.0+0.63SC#*(1./3.)*SGRI(RLTI). C AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2=SHI#0/DP C CABAV2=AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C SHD = AN INTERMEDIATE VARIABLE. BD = AN INTERMEDIATE VARIABLE. BD = AN INTERMEDIATE VARIABLE. BD = AN INTERMEDIATE VARIABLE. C AKDBAV=SIMMF/PHIS/DP#*2 C AKDBAV=SIMMF/PHIS/DP#*2 C AKDBAV=SIMMF/PHIS/DP#*2 C AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. C CABAV2=UD*CAB*IIEXPI-AKDBA2*ALF/UDI)/AKDBA2/ALF C CABAV2=UD*CAB*IIEXPI-AKDBA2*ALF/UDI)/AKDBA2/ALF C CABAV2=UD*CAB*IIEXPI-AKDBA2*ALF/UDI)/AKDBA2/ALF C AKDBAV=SIMMF/PHIS/DP#*2 C AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. C CABAV2=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. C CABAV=CAMMAE/BD#SHT/SIMF*1./11./AKSCB+1./(GAMMAC*BD+1. +/11./AKCB+1./CAMMAE/BDJ)] C CABAV=CAMMAE/BD#SHT/SIMF*1./11./AKSCB+1./(GAMMAC*BD+1. +/11./AKCB+1./CAMMAE/BDJ)] C CABAV=CABAV+CABAV2=2E10.4] RETURN		
<pre>C REIT=DP#UT#RHOG/AMU C REMF = REYNOLDS NC, WITH UNF REMF= DP#UMF#RHOG/AMU C ZETA = A VARIABLE INTRODUCED IN NELSON &amp; GALLDWAT* HITH UG ZETA = A VARIABLE INTRODUCED IN NELSON &amp; GALLDWAT* HITH UG ZETA = A VARIABLE INTRODUCED IN NELSON &amp; GALLDWAT* HITH UG ZETA = A VARIABLE INTRODUCED IN NELSON &amp; SC**(1*/3*) C ZEMF = SAME VARIABLE WITH UMF ZEMF=1(*/1*-EF)**(1*/3*)-1*D*0*3*RE **(0*D)*SC**(1*/3*) C SHMF = SHERWOOD NO. #ITH WF CONDITIONS* TO BE USED IN LMULSION C PHASE IN BUBBLING BED SHMF=(2*ZEMF+12*2EMF*#2*(1*-EF)**(1*/3*)/(1*-(1*-EF)**(1*/3*)) C SHMF=12*ZEMF+12*2EMF*#2*(1*-EF)**(1*/3*)/(1*-(1*-EF)**(1*/3*)) C SH1 = SHERWOOD NO. WITH WO* TO BE USED IN PARTICULATE DED. SH1 =(2*ZETA+12*ZETA+12*ETA*2*(1*-EF)**(1*/3*)/(1*-(1*-EF)**(1*/3*)) C SH1 = SHERWOOD NO. WITH WO* TO BE USED IN PARTICULATE DED. SH1 =2(*ZETA+12**ZETA*2*(1*-EF)**(1*/3*)/(1*-(1*-EF)**(1*/3*)) C SH1 = SHERWOOD NO. WITH UT, TO BE USED FOR SOLIDS IN EUGBLES. SHT=2*O+0*G*3C**(1*/3*)*ORT(RETI) C AKDBA2* AVERAGE MASS TRANSFER COEFF* FOR PARTICULATE BED. AKDBA2*SH1*D/DP C CABAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY #RITEUP. C DP IS THE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY #RITEUP. C DP IS THE AVERAGE MASS TRANSFER COEFF* FOR BUBBLING BED. AKDBA2*AVERAGE MASS TRANSFER COEFF*. FOR BUBBLING BED. CABAV2=AVERAGE MASS TRANSFER COEFF*. FOR BUBBLING BED. AKDBA2*AVERAGE MASS TRANSFER COEFF*. FOR BUBBLING BED. CABAV2=AVERAGE MASS TRANSFER COEFF*. FOR BUBBLING BED. CABAV2=AVERAGE MASS TRANSFER COEFF*. FOR BUBBLING BED. CABAV=AMMAE/BD*SHT/SHMF*L*/11*/AKBCB+1*/(GAMMAC*BD+1* */11*/AKCBB+1*/(GAMMAC*BD+1* */11*/AKCBB+1*/(GAMMAC*BD+1* */11*/AKCBB+1*/(GAMMAC*BD+1* */11*/AKCBB+1*/(GAMMAC*BD+1* */11*/AKCBB+1*/(ABAV#ALF/UB))/AKDBAV/ALF PRINT 5*CABAY(CABAV2=-*ZEI0*4) S FORMAT(1H0*- CABAV*CABAV2=-*ZEI0*4) </pre>		
<pre>REMF = REYNOLDS NG. WITH UNF REMF = DP#UMFPRHOG/ANU C ZETA = A VARIABLE INTRODUCED IN NELSON \$ GALLDWAY. WITH UG ZETA=(1./(1EF)#*(1./3.)-1.)*0.3*RE**(0.5)*SC**(1./3.) C ZEMF = SAME VARIABLE WITH UNF ZEMF=(1./(1EF)**(1./3.)-1.)*0.3*RE**(0.5)*SC**(1./3.) C SHMF = SHERWOOD NO. #ITH WF CONDITIONS. TO BE USED IN LMULSION C PHASE IN SUBBLING BED SHMF = 2.*ZEMF+(2.*ZEMF**2*(1EF)**(1./3.)/(1(1EF)**(1./3.)). C SHIF = SHERWOOD NO. WITH UNF (</pre>	S RETTERPHITERPHAGIAMU	
<pre>RENF = DP#UHF#HOG/ANU C ZETA = A VARIABLE INTRODUCED IN NELSON \$ GALLDWAY. WITH UG ZETA=(1./(1EF)##(1./3.)-1.)*0.3*RE#*(0.5)*SC#*(1./3.) C ZEMF = SAME VARIAULE WITH UMF ZEMF=(1./(1EF)#*(1./3.)-1.)*0.3*RE*(0.5)*SC#*(1./3.) C SHMF = SHERWOOD NO. WITH MF CONDITIONS. TO BE USED IN LMULSION C PHASE IN SUBBLING BED SHMF=12.*ZEMF+(2.*ZEMF**2*(1CF)**(1./3.))-TANH(ZEMF)) C SHM = SHERWOOD NO. WITH UO. TO BE USED IN FARTICULATE DED. SHI = SHERWOOD NO. TO BE USED IN FARTICULATE DED. SHI = SHERWOOD NO. TO BE USED IN FARTICULATE DED. SHI = SHERWOOD NO. TH UO. TO BE USED FOR SOLIDS IN BUBBLES. SHI = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHI = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHI = SHERWOOD NO. STHUE USED FOR SOLIDS IN BUBBLES. SHI = SHERWOOD NO. STHUE USED FOR SOLIDS IN BUBBLES. SHI = 2.0+0.6435C**(1./3.)*SORI(REII) C AKDBA2=AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2=SHI*0/DP C CABAV2=AVERAGE SILANE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD = AN INTERREDIATE VARIABLE. BD=6.*0*SHMF/PHIS/DP#2 C AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBAV=SHMF/PHIS/DP#2 C AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. CABAV2=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. CABAV2=MERAGE SILANE IN ARTICULATE BED. C AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. C AKDBAV=AVERAGE PARTICLE SIZE. C AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. C AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. C AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. C ABAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING BED. C AKDBAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING BED. C ABAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING JED. C CABAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING JED.</pre>	C REME = REYNOLDS NO. WITH LIME	
<pre>C ZETA = A VARIABLE INTRODUCED IN NELSOR \$ GALL2WAY. WITH UG ZETA=(1*/(1*CF)**(1*/3*)-1*)*0*3*RE**(0*5)*SC**(1*/3*) C ZEMF = SAME VARIABLE WITH UNF ZEMF=(1*/(1*CF)**(1*3*)-1*)*0*3*RE WF**(0*5)*SC**(1*/3*) C SHMF = SHERWOOD NO* WITH UNF CONDITIONS* TO BE USED IN LMULSION C PHASE IN BUBBLING UED SHMF=(2*ZEMF*+(2*ZEMF**2*(1*CF)**(1*/3*)/(1*C1*CF)**(1*/3*)) +**2-2*)*TANH(ZEMF)//(ZEMF/(1*CF)**(1*/3*))-TANH(ZEMF)) C SH1 = SHERWOOD NO*WITH UO* TO BE USED IN FARTICULATE UED SHMF=(2*ZETA+12*ZETA**2*(1*CF)**(1*/3*))-TANH(ZEMF)) C SH1 = SHERWOOD NO*WITH UO* TO BE USED IN FARTICULATE UED SH1=(2*ZETA+12*ZETA**2*(1*CF)**(1*/3*))-TANH(ZETA)) C SH1 = SHERWOOD NO*WITH UT* TO BE USED FOR SOLIDS IN BUBBLES* SH1=2*O+0*STACK**(1*/3*)*SQRT(RLTI) C AKDBA2=SH1*D/DP C CABAV2=AVERAGE MASS TRANSFER COEFF* FOR PARTICULATE BED* AKDBA2=SH1*D/DP C CABAV2=AVERAGE SILANE CONCENTRATION OF SILANE IN PARTICULATE BED* CABAV2=AVERAGE SILANE CONCENTRATION IN BED* REFER TO MY WRITEUP* C DP IS THE AVERAGE SILANE CONCENTRATION IN BED* REFER TO MY WRITEUP* C DP IS THE AVERAGE PARTICLE SIZE* C AKDBAV= AVERAGE MASS TRANSFER COEFF* FOR BUBBLING BEC* AKDBAV=CAMMAB*BD*SHT/SHMFF1*/(1*/AKBCB+1*/(GAMMAC*BD+1* +/1*/AKCEB+1*/GAMMAFFD*))) C CABAV=2*O*AMAAFFD*))) C CABAV=CAMMAB*BD*SHT/SHMFF1*/(1*/AKBCB+1*/(GAMMAC*BD+1* +/1*/AKCEB+1*/GAMMAFFD*SHT/SHMFF1*/0*))/AKDBAV/ALF PRINT 5*CABAV*CABAV2 5 FORMAT(1H0*- CABAV*CABAV2=**ZE10*4) RETURN</pre>		
<pre>2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2</pre>	C ZETA = A VARIARIE INTRODUCED IN	NELCON & CALLOWAY, STALL IN
<pre>C ZENF = SAME VARIABLE WITH UMF ZEMF=(1./(1EF)**(1./3.)-1.)*0.3*RE MF**(0.5)*SC**(1./3.) C SHMF=:SHERWOOD NO. #ITH MF CONDITIONS. TO BE USED IN LMULSION C PHASE IN 6UBBLING UED SHMF=12.*ZEMF+(2.*ZEMF**2*(1EF)**(1./3.)/(1(1EF)**(1./3.)) C SH1 =:SHERWOOD NO. WITH UO. TO BE USED IN FARTICULATE DED. SH1 =:SHERWOOD NO. WITH UO. TO BE USED IN FARTICULATE DED. SH1 =:(2.*ZETA+(2.*ZETA**2*(1EF)**(1./3.)/(1(1EF)**(1./3.)) C SH1 =:SHERWOOD NO. WITH UT. TO BE USED IN FARTICULATE DED. SH1 =:2.0+D.65*SC**(1./3.)*SORTIREII) C SHT =:SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN DUBALES. SH1=2.0+D.65*SC**(1./3.)*SORTIREII) C AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2=SHI#0/DP C CABAV2=JO*CAB*(1EXP(-AKDBA2*ALF/UD))/AKDBA2/ALF C OMPUTE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY #RITEUP. C DP IS THE AVERAGE PARTICLE SIZE. BD = AN INTERMEDIATE VARIABLE. BD=6.*D*SHMF/PHIS/DP**2 C AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR BUBBLING DED. AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR BUBBLING DED. C ABAV2=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING DED. C AKDBA2= AVERAGE PARTICLE SIZE. BD = 6.*D*SHMF/PHIS/DP**2 C AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBBLING DED. AKDBAV= AVERAGE CONCENTRATION OF SILANE IN CUBBLING DED. AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBBLING DED. AKDBAV= AVERAGE CONCENTRATION OF SILANE IN CUBBLING DED. AKDBAV= AVERAGE CONCENTRATION OF SILANE IN CUBBLING DED. AKDBAV= AVERAGE CONCENTRATION OF SILANE IN CUBBLING DED. AKDBAV= AVE</pre>	ZETA=(1+/(1+=FE)##(1+/3+)=)=)#2	APPEARIO STACCARITE ALTA UN
ZEMF=(1./(1EF)**(1./3.)-1.)*0.3*REMF**(0.5)*SC**(1./3.) C SHMF = SHERWOOD NO. #ITH MF CONDITIONS. TO BE USED IN LMULSIGN C PHASE IN BUBBLING UED SHMF=12.*ZEMF+12.*ZEMF+*Z*(1EF)**(1./3.)/(1(1EF)**(1./3.)) +**2-2.*TANH(ZEMF))/(ZEMF/(1(1EF)**(1./3.))-TANH(ZEMF)) C SH1 = SHERWOOD NO. WITH UO. TO BE USED IN FARTICULATE UED. SH1 =(2.*ZETA+(2.*ZETA**Z*(1EF)**(1./3.)/(1(1EF)**(1./3.)) +**2-2.*TANH(ZETA))/(ZEMF/(1(1EF)**(1./3.))/(1(1EF)**(1./3.)) C SH1 = SHERWOOD NO. WITH UO. TO BE USED IN FARTICULATE UED. SH1 =2.*ZETA+(2.*ZETA**Z*(1EF)**(1./3.)/(1(1EF)**(1./3.)) C SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN EUGBLES. SHT=2.0+0.6*35C**(1./3.)*SORI(RETI) C AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. C ABAV2=AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. C CABAV2=JU*CAB*(1EXP(-AKDBA2*ALF/UG))/AKDBA2/ALF C COMPUTE AVERAGE SILANE CONCENTRATION OF SILANE IN PARTICULATE BED. C CABAV2=JU*CAB*(1EXP(-AKDBA2*ALF/UG))/AKDBA2/ALF C DP IS THE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. D P IS THE AVERAGE MASS TRANSFER COEFF. FOR BUBBLING GED. AKDBAV= AVERAGE CONCENTRATION OF SILANE IN GUBBLING GED. AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AKBCB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAE/BD))) C CABAV=UB#CABAV(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5+CABAV.CABAV2 5 FORMAT(1H0 CABAV.CABAV2=-,2E10.4) RETURN	C ZEME = SAME VARIABLE WITH UME	/J~RC == (U+J/ +JC~ + (I+/J+)
C SHMF = SHERWOOD NO. #ITH MF CONDITIONS. TO BE USED IN LMULSION PHASE IN BUBBLING BED SHMF=12.#ZEAF+12.#ZEAF##Z#(1.=EF)##(1./3.)/(1.=(1.=EF)##(1./3.)) +*#2-2.)#TANH(ZEMF)//(ZEMF/(1.=(1.=EF)##(1./3.))-TANH(ZEMF)) C SH1 = SHERWOOD NO. WITH UO. TO BE USED IN FARTICULATE BED. SH1=(2.#ZETA+(2.#ZETA##Z#(1.=EF)##(1./3.)/(1.=(1.=EF]##(1./3.)) +##2-2.]#TANH(ZETA)//(ZETA/(1.=(1.=EF)##(1./3.))-TANH(ZETA)) C SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT=2.00+0.63SCH#(1./3.)#SORT(RETI) C AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2=SH1#0/DP C CABAV2=4VERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=400+CABE(1.=EXP(-AKDBA2*ALF/U0))/AKDBA2/ALF C OMPUTE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. DP IS THE AVERAGE PARTICLE SIZE. C BD = AN INTERMEDIATE VARIABLE. BD=6.*D0*SHMF/PHIS/D##2 C AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING GED. AKDBAV=GAMMAB#BD#SHT/SHMF+1./(1./AKBCB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAC/ED))) C CABAV=UB#CABE(CONCENTRATION OF SILANE IN GUBBLING GED. AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING GED. CABAV=UB#CABE(ASS TRANSFER COEFF. FOR BUBBLING GED. CABAV=UB#CABE(ASS TRANSFER COEFF. FOR BUBBLING GED. AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING GED. C ABAV=UB#CABE(CONCENTRATION OF SILANE IN GUBBLING GED. C CABAV=UB#CABE(CONCENTRATION OF SILANE IN GUBBLING GED. AKDBAV=GAMMAB#BD#SHT/SHMF+1./(1./AKBCB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAC/ED))) C CABAV=UB#CABE(CONCENTRATION OF SILANE IN GUBBLING GED. CABAV=UB#CABE(CONCENTRATION OF SILANE IN GUBBLING GED. C ABAV=UB#CABE(CONCENTRATION OF SILANE IN GUBBLING GED. C ABAV=UB#CABE(CONCENTRATION OF SILANE IN GUBBLING GED. C CABAV=UB#CABE(CONCENTRATION OF SILANE IN GUBBLI	$ZEMF = (1_{0}/(1_{0} - EF) + (1_{0}/3_{0}) - 1_{0}) + 0_{0}$	3#RF 4F##10,51#5C##11,/2.1
<pre>C PHASE IN BUBBLING UED SHMF=12*ZEMF+(2*ZEMF**2*(1*EF)**(1*/3*)/(1*EF)**(1*/3*)) +**2-2*)*TANH(ZEMF))/(ZEMF/(1*EF)**(1*/3*))-TANH(ZEMF)) C SH1 = SHERWOOD NO* WITH UO* TO BE USED IN PARTICULATE UED* SH1 =(2*ZETA+(2*ZETA**2*(1*EF)**(1*/3*))-TANH(ZETA)) C SH1 = SHERWOOD NO* WITH UT* TO BE USED FOR SOLIDS IN BUBBLES* SHT=2*0+0*6*3C#*(1*/3*)*SGRT(RETT) C AKDBA2= AVERAGE MASS TRANSFER COEFF* FOR PARTICULATE BED* AKDBA2=SH1*0/DP C CABAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED* CABAV2=AVERAGE SILANE CONCENTRATION IN BED* REFER TO MY #RITEUP* C OMPUTE AVERAGE SILANE CONCENTRATION IN BED* REFER TO MY #RITEUP* C DP IS THE AVERAGE PARTICLE SIZE* C BD = AN INTERMEDIATE VARIABLE* BD=6*D*SHMF/PHIS/DP**2 C AKDBAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING BED* AKDBAV=AVERAGE MASS TRANSFER COEFF* FOR BUBBLING BED* C BD = AN INTERMEDIATE VARIABLE* BD=6*D*SHMF/PHIS/DP**2 C AKDBAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING BED* C CABAV*=AVERAGE MASS TRANSFER COEFF* FOR BUBBLING BED* C BD = AN INTERMEDIATE VARIABLE* BD=6*D*SHMF/PHIS/DP**2 C AKDBAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING BED* AKDBAV=AVERAGE MASS TRANSFER COEFF* FOR BUBBLING BED* C CABAV*=AVERAGE MASS TRANSFER COEFF* FOR BUBBLING BED* AKDBAV*=AVERAGE MASS TRANSFER COEFF* FOR BUBBLING BED* PRINT 5*CABAV*CABAMAE/BD)) C CABAV*UB#CAB*(1*C*DF(-*KDBAV*ALF/UE))/AKDBAV/ALF PRINT 5*CABAV*CABAV2 5 FORMAT(1HO*- CABAV*CABAV2=-*ZE10*4) RETURN</pre>	C SHMF = SHERWOOD NO. WITH MF CON	DITIONS TO BE USED IN FMULSION
<pre>SHMF=12.*ZEMF+12.*ZEMF**Z*(1EF)**(1./3.)/(1(1EF)**(1./3.)) +**2-2.)*TANH(ZEMF))/(ZEMF/(1(1EF)**(1./3.))-TANH(ZEMF)) C SH1 = SHERMOOD NO. WITH UO. TO BE USED IN FARTICULATE DED. SH1 =(2.*ZETA+(2.*ZETA**Z*(1EF)**(1./3.)/(1(1EF)**(1./3.))) C SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SH1=2.0+0.63SC**(1./3.)*SQRI(REII) C AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2=SH1*D/DP C CABAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=U0*CAB*(1EXP(-AKDBA2*ALF/U0))/AKDBA2/ALF C OMPUTE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD = AN INTERMEDIATE VARIABLE. BD=6.*D*SHMF/PHIS/DP**2 C AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBBLING DED. AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING DED. C ABAV2=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING DED. C CABAV2=U0*CAB*(1EXP(-AKDBA2*ALF/U0))/AKDBAV/ALF PRINT 5.CABAV.EABAV2=2E10.4) RETURN</pre>	C PHASE IN BUBBLING BED	
<pre>+**2-2*)*TANH(ZEMF))/(ZEMF/(1*-(1*-EF)**(1*/3*))-TANH(ZEMF)) C SH1 = SHERWOOD NO. WITH UO. TO BE USED IN FARTICULATE DED. SH1 =(2*ZETA+(2*ZETA**2*(1*-EF)**(1*/3*)/(1*-(1*-EF)**(1*/3*)))-TANH(ZETA)) C SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT=2*0+0*6*3CE*(1*/3*)*SORT(RETI) C AKDBA2* AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2*AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2*AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD * AN INTERMEDIATE VARIABLE. BD=6*0*\$HMF/PHIS/D**2 C AKDBAV*AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBAV*AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. CABAV2*AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD * AN INTERMEDIATE VARIABLE. BD=6*0*\$HMF/PHIS/D**2 C AKDBAV*AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. CABAV*AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. CABAV*AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. C ABAV*AVERAGE CONCENTRATION OF SILANE IN CUBBLING SED. C ABAV*AVERAGE CONCENTRATION OF SILANE IN CUBBLING</pre>	SHMF=12.#ZENF+12.#ZENF##2#11EF	*)##(1=/3=)/(1==(1==EF)=##(1=/3=))
<pre>C SH1 * SHERWOOD NO. WITH UO. TO BE USED IN FARTICULATE DED. SH1 *(2.*2ETA+(2.*ZETA**2*(1EF)**(1./3.)/(1(1EF)**(1./3.)) ***2-2.)*TANHIZETA))/(ZETA/(1(1EF)**(1./3.))-TANH(ZETA)) C SHT * SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT=2.0+0.63SC**(1./3.)*SGRI(RETI) C AKDBA2* AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2*SHI*D/DP C CABAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=JUERAGE SILANE CONCENTRATION OF SILANE IN PARTICULATE BED. C CABAV2=JUERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD * AN INTERMEDIATE VARIABLE. BD=6.*D*SHMF/PHIS/DP**2 C AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AKBCB+1./(GAMMAC*BD+1. */(1./AKCBB+1./GAMMAE/BD))) C CABAV *AVERAGE CONCENTRATION OF SILANE IN CUEBLING BED. CABAV=UB*CAB*(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5:CABAV.CABAV2 5 FORMAT(1H0 CABAV.CABAV2=2E10.4) RETURN</pre>	+##2-2.)#TANH(ZEMF))/(ZEMF/(1()	(-EF) ++ (1./3.)) -TANH(ZEMF))
<pre>SH1 =(2.*ZETA+(2.*ZETA+#2*(1EF)**(1./3.)/(1(1EF)**(1./3.)) +**2-2.)*TANHIZETA))/(ZETA/(1(1EF)**(1./3.))-TA:H(ZETA)) C SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT=2.0+0.63SC**(1./3.)*SORT(RETT) C AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2=SH1*0/DP C CABAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=U0*CAB*(1EXP(-AKDBA2*ALF/U0))/AKDBA2/ALF C COMPUTE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD = AN INTERMEDIATE VARIABLE. BD=6.*D*SHMF/PHIS/DP**2 C AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AKBCB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAE/BD))) C CABAV=AVERAGE CONCENTRATION OF SILANE IN CUEBLING BED. CABAV=UB*CABE(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5.CABAV.CABAV2 5 FORMAT(1H0 CABAV.CABAV2=2E10.4) RETURN</pre>	C SH1 = SHERWOOD NO. WITH UD. TO	D BE USED IN FARTICULATE HED.
<pre>+##2-2.) #TANHIZETA) //(ZETA/(1(1EF)##(1./3.))-TAMH(ZETA)) C SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT=2.0+0.6*SC##(1./3.) #SORT(RETI) C AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2=SHI#D/DP C CABAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=JU#CAB#(1EXP(-AKDBA2*ALF/UC))/AKDBA2/ALF C COMPUTE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD = AN INTERMEDIATE VARIABLE. BD=6.*D#SHMF/PHIS/DP##2 C AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. C AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. C AKDBAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING BED. C AKDBAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING BED. C CABAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING DED. C CABAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING DED. C CABAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING DED. C CABAV=UB*CAB*(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5.CABAV.CABAV2 5 FORMAT(1H0 CABAV.CABAV2=2E10.4) RETURN</pre>	SH1 =(2.#ZETA+(2.#ZETA##2#(1EF	1++(1+/3+)/(1+-(1+-EF)++(1+/3+1)
<pre>C SHT = SHERWOOD NO. WITH UT. TO BE USED FOR SOLIDS IN BUBBLES. SHT=2.0+0.6*3C**(1./3.)*SQRT(RETI) C AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2=SHI#D/DP C CABAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=U0*CAB*(1EXP(-AKDBA2*ALF/UC))/AKDBA2/ALF C COMPUTE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD = AN INTERMEDIATE VARIABLE. BD=6.*D*SHMF/PHIS/DP**2 C AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AK3CB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAE/BD))) C CABAV = AVERAGE CONCENTRATION OF SILANE IN GUBBLING BED. CABAV=UB*CAB*(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5.CABAV.CABAV2=-,2E10.4) RETURN</pre>	+##2-2+)#TANH(ZETA))/(ZETA/(1-()	-EF) ##(1./3.))-TANH(ZETA))
SHT=2.0+3.635C**(1./3.)*SQRT(RETT) C AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2=SH1*D/DP C CABAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=JO*CAB*(1EXP(-AKDBA2*ALF/U0))/AKDBA2/ALF C COMPUTE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD = AN INTERMEDIATE VARIABLE. BD=6.*D*SHMF/PHIS/DP**2 C AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBGLING BED. AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AK3CB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAE/BD))) C CABAV=AVERAGE CONCENTRATION OF SILANE IN GUBBLING DED. CABAV=AVERAGE CONCENTRATION OF SILANE IN GUBBLING DED. C CABAV=AVERAGE CONCENTRATION OF SILANE IN GUBBLING DED. C CABAV=AVERAGE CONCENTRATION OF SILANE IN GUBBLING DED. C CABAV=CAB*(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5+CABAV.CABAV2 5 FORMAT(1HO,- CABAV.CABAV2=2E10.4) RETURN	C SHT = SHERWOOD NO. WITH UT. TO	BE USED FOR SOLIDS IN BUBBLES.
<pre>C AKDBA2= AVERAGE MASS TRANSFER COEFF. FOR PARTICULATE BED. AKDBA2=SH1#D/DP C CABAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=U0*CAB*(1EXP(-AKDBA2*ALF/UC))/AKDBA2/ALF C COMPUTE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD = AN INTERMEDIATE VARIABLE. BD=6.*D*SHMF/PHIS/DP**2 C AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBGLING BED. AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBGLING BED. AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AKBCB+1./(GAMMAC*BD+1. */(1./AKCEB+1./GAMMAE/BD))) C CABAV=AVERAGE CONCENTRATION OF SILANE IN CUBBLING BED. CABAV=UB*CAB*(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5.CABAV.CABAV2 5 FORMAT(1H0 CABAV.CABAV2=-,2E10.4) RETURN</pre>	SHT=2.0+0.6%SC##(1./3.)#SORT(RET	(1)
AKDBA2=SH1#D/DP C CABAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=U0*CAB*(1EXP(-AKDBA2*ALF/U0))/AKDBA2/ALF C COMPUTE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD = AN INTERMEDIATE VARIABLE. BD=6.*D*SHMF/PHIS/DP#*2 C AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBAV=AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AKBCB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAE/BD))) C CABAV=AVERAGE CONCENTRATION OF SILANE IN SUBBLING DED. CABAV=UB*CAB*(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5.CABAV.CABAV2 5 FORMAT(1H0 CABAV.CABAV2=-,2E10.4) RETURN	C AKDBA2= AVERAGE MASS TRANSFER CO	DEFF. FOR PARTICULATE BED.
C CABAV2=AVERAGE CONCENTRATION OF SILANE IN PARTICULATE BED. CABAV2=U0*CAB*(1EXP(-AKDBA2*ALF/U0))/AKDBA2/ALF C COMPUTE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD = AN INTERMEDIATE VARIABLE. BD=6.*D*SHMF/PHIS/DP**2 C AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AK3CB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAE/BD))) C CABAV = AVERAGE CONCENTRATION OF SILANE IN CUBBLING JED. CABAV=UB*CAB*(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5.CABAV.CABAV2 5 FORMAT(1H0 CABAV.CABAV2=2E10.4) RETURN	AKDBA2=SH1=D/DP	
CABAV2=U0*CAB*(1EXP(-AKDBA2*ALF/U0))/AKDBA2/ALF C COMPUTE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD = AN INTERMEDIATE VARIABLE. BD=6.*D*SHMF/PHIS/DP**2 C AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AKBCB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAE/BD))) C CABAV=AVERAGE CONCENTRATION OF SILANE IN GUBBLING BED. CABAV=UB*CAB*(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5.CABAV.CABAV2 5 FORMAT(1H0 CABAV.CABAV2=-,2E10.4) RETURN	C CABAV2=AVERAGE CONCENTRATION OF	SILANE IN PARTICULATE BED.
C COMPUTE AVERAGE SILANE CONCENTRATION IN BED. REFER TO MY WRITEUP. C DP IS THE AVERAGE PARTICLE SIZE. C BD = AN INTERMEDIATE VARIABLE. BD=6.*D*SHMF/PHIS/DP#*2 C AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AKBCB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAE/BD))) C CABAV=AVERAGE CONCENTRATION OF SILANE IN GUBBLING JED. CABAV=UB*CAB*(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5.CABAV.CABAV2 5 FORMAT(1H0 CABAV.CABAV2=-,2E10.4) RETURN	CABAV2=JO*CAB*(1EXP(-AKDBA2*A	F/UC))/AKDBA2/ALF
C DP IS THE AVERAGE PARTICLE SIZE. C BD = AN INTERMEDIATE VARIABLE. BD=6.*D*SHMF/PHIS/DP#*2 C AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBBLING BED. AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AK3CB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAE/BD))) C CABAV=AVERAGE CONCENTRATION OF SILANE IN GUBBLING JED. CABAV=UB*CAB*(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5.CABAV.CABAV2 5 FORMAT(1H0 CABAV.CABAV2=-,2E10.4) RETURN	C COMPUTE AVERAGE SILANE CONCENTRA	TION IN BED. REFER TO MY WRITEUP.
<pre>L BD = AN INTERMEDIATE VARIABLE. BD=6.*D*SHMF/PHIS/DP#*2 C AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBGLING BED. AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AKBCB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAE/BD))) C CABAV=AVERAGE CONCENTRATION OF SILANE IN GUBBLING DED. CABAV=UB*CAB*(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5+CABAV.CABAV2 5 FORMAT(1H0+- CABAV+CABAV2=-+2E10.4) RETURN</pre>	C DP IS THE AVERAGE PARTICLE SIZE.	
BU=6.*D*SHMF/PHIS/DP**2 C AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBGLING GED. AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AKBCB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAE/BD))) C CABAV =AVERAGE CONCENTRATION OF SILANE IN GUBBLING GED. CABAV=UB*CAB*(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5+CABAV.CABAV2 5 FORMAT(1H0+- CABAV+CABAV2=-+2E10+4) RETURN	C BD = AN INTERMEDIATE VARIABLE	•
L AKDBAV= AVERAGE MASS TRANSFER COEFF. FOR BUBGLING BED. AKDBAV=GAMMAB*BD*SHT/SHMF+1./(1./AKBCB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAE/BD))) C CABAV =AVERAGE CONCENTRATION OF SILANE IN GUBBLING GED. CABAV=UB*CAB*(1EXP(-AKDBAV*ALF/UE))/AKDBAV/ALF PRINT 5.CABAV.CABAV2 5 FORMAT(1H0 CABAV.CABAV2=2E10.4) RETURN	BD=6.+D+SHMF/PH1S/DP++2	
AKUDAV=GAMMAD=BD=SHT/SHMF+1./(1./AK3CB+1./(GAMMAC*BD+1. +/(1./AKCEB+1./GAMMAE/BD))) C CABAV=AVERAGE CONCENTRATION OF SILANE IN GUEBLING GED. CABAV=UB=CAB=(1EXP(-AKDBAV=ALF/UE))/AKDBAV/ALF PRINT 5+CABAV+CABAV2 5 FORMAT(1H0+- CABAV+CABAV2=-+2E10+4) RETURN	L AKDBAVE AVERAGE MASS TRANSFER CO	JEFF. FOR BUBBLING BED.
C CABAV =AVERAGE CONCENTRATION OF SILANE IN GUEBLING DED. CABAV=UB+CAB=(1EXP(-AKDBAV=ALF/UE))/AKDBAV/ALF PRINT 5;CABAV;CABAV2 5 FORMAT(1H0;- CABAV;CABAV2=-;2E10.4) RETURN	AKUBAV=UAMMAB#UD#SHT/SHMF+1./(1.	/AKBCB+1./(GAMMAC*BD+1.
C CABAV =AVERAGE CONCENTRATION OF SILANE IN GUEBLING SED. CABAV=UB*CAB*(1EXP(-AKDBAV#ALF/UE))/AKDBAV/ALF PRINT 5+CABAV+CABAV2 5 FORMAT(1H0+- CABAV+CABAV2=-+2E10+4) RETURN	T/(I+/ARCEDTI+/GAMMAL/DJ))	
PRINT 5+CABAV+CABAV2 5 FORMAT(1H0+- CABAV+CABAV2=-+2E10+4) RETURN	CABAVENERCADE CONCENTRATION OF	SILANE IN CUEBLING SED.
5 FORMAT(1H0,- CABAV)CABAV2=->2E10.4) RETURN	CRORV-UDTCROTILSTCAT (TAKUBAVTAL)	/UE))/AKUBAV/ALF
RETURN	FRINI FILADAVILADAVE 5 FORMATIING CAMAV.CARAV2	1.4.1
	RETURN	Jon January and Anna Anna Anna Anna Anna Anna Anna

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-----FUNCTION AIR(A) C AIR = INTEGRAL EQ.32. P339 C TO COMPUTE THE INTEGRAL I(R,RI) NH= (A-RPMIN)/DELR+U.5 AIRLOG=. <u>00 1 1=1.00</u> R9=RPHIN+I+DELK-0.5+DELR AIRLOG=AIRLOG+(F1/W+AAK(I))/ARRR(I)\*DELR I CONTINUE - -----AIR=EXP(-AIRLOG) RETURN C ----C FUNCTION ABR(21) C CONPUTE AN INTERGRAL C ABR = INTEGRAL SHOWN IN EQ.36. P340 ABR=G. NN=(21-RPHIN)/DELR+3.5 DO 51 I=1+NN RI=RPMIN+I=DELR-0.5+DELR ABR=ABR+APO(1)/RI##3/AAIR(1)#DELR 51 CONTINUE RETURN C FUNCTION TOTAL(24) C COMPUTE AN INTEGRAL W/FO (EQ. 37, P340) TOTAL=6. NN=(Z4-RPMIN)/DELR+0.5 20 1 I =1.NN R6=RPMIN+IFDELR-0.5+DELR TOTAL=TOTAL+R8##3/ARRR(I)#AAIR(I)#DELR#AABR(I) 1 CONTINUE RETURN С С SUBROUTINE MASSEL DELR = PARTICLE SIZE INCREMENT USED FOR C ¢ COMPUTING THE INTEGRALS FU=W/TOT CONPUTE FU+F2+P1+P2 C GROWTH = PARTICLE GROWTH RATE IN BED(EG.23.P337) GROWTH=0 سيعتمد المستحد والتاريخ والت NN=(RPMAXB-RPMIN)/DELR+C.5 00 1 1=1,NN R6=RPHIN+I#DELR-0.5#DELR GROWTH=GROWTH+DELR#3.#W#AP1(1)#ARRR(1)/RG 1 CONTINUE F2 = GROATH - F1+FG PRINT 2. FO.F1.GROWTH.F2 2 FORMAT(1HU, //- F0, F1, GROWTH, F2=-, 4E10.4) RETURN C ¢ FUNCTION BRR(X1) c TO COMPUTE DR/DT FOR BUBBLING BED X=2. \*X1 RRR=(DELTA+X+PHI5/6./(1.-EF))+(CABAV+AM&/RHOS)+(GAMMAB+6.+D+SHT/ +PHIS/X\*\*2+1+/(1+/AKECB+1+/(GAMMAC\*6+#D#SHMF /PHIS/X##2+1+/

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*(1./AKCEB+1./(GAMMAE*6. 0*SHMF/Fall/X**2))))
٠
      RETURN
C
      FUNCTION RRR2(X)
C
       TO COMPUTE DRIDT FOR PARTICULATE BED
       RRR2=SH1=D=AMH=CABAV2/RHOU/2./X
       RETURN
C
       FUNCTION AKIA)
   THIS ROUTINE COMPUTED THE ELUTRIATION COEFFICIENT FRUM TRANSFE RRA=ZAA/DP+ZBA*DP+
۲
ŝ,
      KSI - REFER TO P315. FIG 13
Ú,
ũ
       AK = ELUTRIATION CONSTANT AS A FUNCTION OF RADIUS
       KSI = IUU-UTI/SCRTIGI#(UT#RHOC/AMU)##0.725
¢
ć
       *( (RhOS-RHOS) / RHOG) ** 1.15 * DF**0.225
Ĉ
       = VA*DP*#0.225
      NO ELUTRIATION IF UG.LE.UT
      IFIU-LE-UT) GO TU 1
       VA = (UU-UT)/SQRT(G) # (UT#RHCG/AMU) #40.725
      ## ( (RHOS-RHOG) /RHOG) ## 1.15
      AK == EXP(ALOG(0.15)+(ALOG(17.)-ALOG(0.15;)*( ALOG(VAK(2.*A/**
      $0.2251 -ALOG(10000.,)/(ALOG(1000000.)-ALOC(10000.)))*RHCG
      *
           +(UU-UT)*AT/W
      60 TO 2
    1 CONTINUE
      AK=U
    2 CONTINUE
      RETURN
C
Ċ
      FUNCTION FILZON
¢
      20.35.P340
      P1=Z6##3/ARRR(I)#AAIR(I)#AABR(I)/TOT
      RETURN
L
С
      FUNCTION FRIZIG)
C
      EQ.7. P329
      P2=AAK(1)#W/F2#AP1(1)
      RETURN
      END
-MAP
-XŨI
      E+01 •86 E+00 •1236E-03 •244 E+01 •3454E-03 •176 E+06 •9 E+03 •5 E+00
E+00 •5 E-05 •75 E-02 •7 E-01 •45 E-02 •1 E+03 •2809E+02 •5609E+04
 ۰Ö
 •4
 • 98
                E-03
      E+03 .5
-FIN
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