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TABLE I

LIST OF PUBLICATIONS DURING THE PROGRAM

Vasalos, I. A., et al., Monthly Progress Report No. 1, FE-2588-1, October, 1977.

Vasalos, I. A., et al., Monthly Progress Report No. 2, FE-2588-2, November, 1977.

Vasalos, I. A., et al., Quarterly Progress Report No. 1, FE-2588-3, December, 1977.

Vasalos, I. A., et al., Monthly Progress Report No. 4, FE-2588-4, January, 1978.

Vasalos, I. A., et al., Monthly Progress Report No. 5, FE-2588-5, February, 1978.

Vasalos, I. A., et al., Quarterly Progress Report No. 2, FE-2588-7, March, 1978.

Vasalos, I. A., et al., Monthly Progress Report No. 7, FE-2588-8, April, 1978.

Vasalos, I. A., et al., Monthly Progress Report No. 8, FE-2588-9, May, 1978.

Vasalos, I. A., et al., H-Coal Fluid Dynamics Topical Report Part I: Literature Search, FE-2588-6, May, 1978.

Vasalos, I. A., et al., Quarterly Progress Report No. 3, FE-2588-10, June, 1978.

Vasalos, I. A., et al., Monthly Progress Report No. 10, FE-2588-11, July, 1978.

Vasalos, I. A., et al., Monthly Progress Report No. 11, FE-2588-12, August, 1978.

Vasalos, I. A., E. M. Bild, and D. F. Tatterson, "Modeling the Fluid Dynamics of the H-Coal Reactor," 87th AIChE Meeting, Boston, August 19-22, 1979.

Vasalos, I. A., et al., Monthly Progress Report No. 13, FE-2588-13, October, 1978.

TABLE I
-2-

Vasalos, I. A., et al., Monthly Progress Report No. 14, FE-2588-14, November, 1978.

Vasalos, I. A., et al., Quarterly Progress Report No. 4, FE-2588-15, December, 1978.

Vasalos, I. A., et al., Monthly Progress Report No. 16, FE-2588-16, January, 1979.

Vasalos, I. A., et al., Monthly Progress Report No. 17, FE-2588-17, February, 1979.

Vasalos, I. A., et al., Annual Progress Report No. 1, FE-2588-18, February, 1979.

Vasalos, I. A., et al., Quarterly Progress Report No. 5, FE-2588-19, March, 1979.

Vasalos, I. A., et al., Monthly Progress Report No. 19, FE-2588-20, April, 1979.

Vasalos, I. A., et al., Monthly Progress Report No. 21, FE-2588-21, May, 1979.

Vasalos, I. A., et al., Quarterly Progress Report No. 6, FE-2588-22, June, 1979.

Vasalos, I. A., et al., Monthly Progress Report No. 22, FE-2588-23, July, 1979.

Vasalos, I. A., et al., Monthly Progress Report No. 23, FE-2588-24, August, 1979.

Vasalos, I. A., et al., Monthly Progress Report No. 25, October, 1979.

Vasalos, I. A., et al., Monthly Progress Report No. 26, November, 1979.

Vasalos, I. A., et al., Monthly Progress Report No. 27, December, 1979

Vasalos, I. A., E. M. Bild, and D. N. Rundell, "Experimental Techniques for Studying the Fluid Dynamics of the H-Coal Reactor," 72nd Annual AIChE Meeting, San Francisco, November 25-29, 1979.

TABLE II

CORRELATIONS FOR THE EXPANSION OF LIQUID FLUIDIZED BEDS

Author	Solids	Equation	Range of Applicability
Richardson and Zaki (6)	Spherical particles	$\epsilon_1^n = U_1/U_t$	
		where:	
		$n = 4.65 + 20\ d/D$	$Re_t < 0.2$
		$n = (4.4 + 18\ d/D)Re_t^{-0.03}$	$0.2 < Re_t < 1.0$
		$n = (4.4 + 18\ d/D)Re_t^{-0.1}$	$1 < Re_t < 200$
		$n = 4.4\ Re_t^{-0.1}$	$200 < Re_t < 500$
		$n = 2.4$	$Re_t > 500$
Richardson and Zaki (6)	Glass or steel cylinders and steel plates	$\epsilon_1^n = U_1/U_t$	
		$n = 2.7\ K^{0.16}$	$Re_t > 500$
		where:	
		$K = (\pi/6)d_s^3/d_p^3 = \left(\frac{\pi}{4}\right)^{5/2}\left(\frac{d}{l}\right)^{1/2}$ (for a cylinder)	
Fouda and Capes (8)	Irregularly shaped particles	$(1 - K'\epsilon_s)^n = U_1/U_t$	
		where:	
		n = same as in Richardson-Zaki correlation	Same as in Richardson-Zaki correlation
		$K' = 1$ for spheres	
		$K' = 1.17$ to 1.43 for equi-dimensional bud irregularly shaped particles	
Barnea and Mizrahi (9)	Spherical particles	$C_{D\infty} = \left(0.63 + \frac{4.8}{\sqrt{Re_m}}\right)$	$10^{-3} < Re_m < 3 \times 10^4$
		where:	
		$Re_m = Re\left(\frac{U_r/U_t}{\exp(5\epsilon_s/3(1-\epsilon_s))}\right)$	
		$C_{D\infty} = C_D\left(\frac{U_r}{U_t}\right)^2\left(\frac{1-\epsilon_s}{1+\epsilon_s^{1/3}}\right)$	
		$\frac{U_r}{U_t} = \frac{1}{1+\epsilon_s^{1/3}}$	

(Table Continued)

TABLE LI

CORRELATIONS FOR THE EXPANSION OF LIQUID FLUIDIZED BEDS

-2-

Author	Solids	Equation	Range of Applicability
Wallis (10)	Spherical particles	$j_1^* = 2/9\ r^{*2} \epsilon_1^{4.7}$	$Re_m < 1.5$
		$j_1^* = 0.307\ r^{*1.21} \epsilon_1^{3.47}$	$1.5 < Re_m < 100$
		$j_1^* = 0.693\ r^{*0.858} \epsilon_1^{2.92}$	$100 < Re_m < 1080$
		$j_1^* = 2.5\ r^{*1.2} \epsilon_1^{2.35}$	$1080 < Re_m$

where:

$$j_1^* = j_1 \left(\frac{\rho_1}{\mu_1 g\ (\rho_s - \rho_1)} \right)^{1/3}$$

$$r^* = \left(\frac{\rho_1 g (\rho_s - \rho_1)}{\mu_1} \right)^2$$

TABLE III

EXPERIMENTAL CONDITIONS FOR BUBBLE COALESCENCE

Investigator	Liquid	Gas	Solid	Solid Dimension (mm)	Bed Diameter (mm)	Character of Bed
Ostergaard (17)	Water	Air	Sand	0.64	250 x 250	Coalescing
Massimilla, et al. (18)	Water	Air	Sand	0.22,0.26	86 x 61	Coalescing
	Water	Air	Glass Beads	0.79,1.09	86 x 61	Coalescing
Viswanatan, et al. (19)	Water	Air	Quartz Particles	0.649,0.928	50.8	Coalescing
	Water	Air	Glass Beads	4.0	50.8	Non-Coalescing
Adlington and Thompson (2)	Water	-	Sand	3.0	76.0	Coalescing
	White Spirit	-	Alumina	0.3-3.0	76.0	Coalescing
Lee (21)	Water	Air	Glass Beads	6		Non-Coalescing

TABLE IV

SUMMARY OF DATA FOR GAS/LIQUID/SOLID FLUIDIZATION

Investigators	System	Particle Size	Experimental Unit	Parameters Studied	Measured Quantities
1) Razumov, Manshilin, Nemets(22)	Air/Water/Sand Air/Water/Glass Beads	0.493 to 1.27 mm	300 mm Diameter Column	U_g, U_l	ϵ_s
2) Michelsen, Ostergaard(23)	Air/Water/Glass Beads	1,3,6 mm	152 mm Diameter Column	U_g, U_l, Particle Size	ϵ_g, ϵ_l
3) Dakshinamurty, Subramanyam, Rao(24,25)	Air/Water/Various Spherical Particles Air/Kerosene/Various Spherical Particles	1.06 to 6.8 mm	56 mm Diameter Column	Particle Size and Density σ, U_g, U_l	ϵ_s
4) Viswanathan, Kakai, Murti(19)	Air/Water/Quartz Particles Air/Water/Glass Beads	0.928,0.649 mm 4 mm	50.8 mm Diameter Column	U_g, U_l, Particle Size	ϵ_l, ϵ_g
5) Kim, Baker, Bergougnou(11)	Air/Water/Glass Beads Air/Water/Irregular Gravel	6 mm 2.6 mm	660x25 mm Rectangular Channel	U_g, U_l	ϵ_l, ϵ_g, Bubble Size and Velocity
6) Kim, Baker, Bergougnou(26)	Air-Water/Acetone-Glass Beads Air-Water/Acetone-Irregular Gravel Air-Sugar/Water-Glass Beads Air-Carboxymethyl Cellulose/Water-Glass Beads Air-Sugar/Water-Irregular Gravel Air-Carboxymethyl Cellulose/Water-Irregular Gravel	1.6 mm 2.6 mm 1.6 mm	660x25 mm Rectangular Channel	μ_l, σ, U_l, U_g	ϵ_g, ϵ_l
7) Blum and Toman(27)	Nitrogen/Light Mineral Oil	3.2x3.2mm	102 mm Diameter Column	U_l, U_g, μ_l	ϵ_s
8) Nemets, Razumov, Manshilin(28)	Air/Water/Sand Air/Heptane/Sand Air-Water/Glycerol-Sand	0.820 mm	90 mm Diameter Column	U_l, U_g, μ_l	ϵ_l, ϵ_g
9) Bruce, Revel-Chion(29)	Air/Water/Glass Spheres	2,4,6,8 mm	46.3 mm Diameter Column	U_l, U_g	ϵ_m, Bubble Size
10) Ostergaard, Thiesen (30)	Air/Water/Glass Ballotini	0.28 to 2.2 mm	51 and 102 mm Diameter Column	U_l, U_g	ϵ_s

TABLE V

EMPIRICAL CORRELATIONS FOR THREE-PHASE BEDS

Author	Correlation	Gas/Liquid	Solids (Dimension)	Column Diameter or Dimensions (mm)	Comments
Kim, Baker, Bergougnou(11)	$(\epsilon_l)_{U_g=0} - \epsilon_l = 0.0025 \left(Fr_l \frac{\rho_s}{\rho_l}\right)^{0.340} \left(Fr_g \frac{\rho_s}{\rho_s}\right)^{0.101} \left(\frac{Re_l}{Re_g}\right)^{0.280}$	Air/Water	Glass Beads (6 mm)	660 x 25	Empirical, no consideration for bed contraction
	$(\epsilon_l)_{U_g=0} = 0.409(Fr_l \rho_s/\rho_l)^{2.182}(Re_l)^{0.074}$				
Kim, Baker, Bergougnou(26)	$(\epsilon_l+\epsilon_g) = 1.60(Fr_l)^{0.17}(We)^{0.070}$ (Expanding Beds)				Empirical for expanding and contracting beds
	$(\epsilon_l+\epsilon_g)_{U_g=0} = 1.3(Fr_l)^{0.178}(We)^{0.073}\exp[0.31U_l/U_g(\epsilon_l)_{U_g=0}]$ (Contracting Beds)	Air/Sugar Solutions Air/Carboxylmethyl Cellulose Solution Air/Water Acetone	Glass Beads (6,1 mm) Irregular Gravel (2.6 mm)	660 x 25	
	$(\epsilon_l)_{U_g=0} = 1.353(Fr_l)^{0.208}(Re_l)^{-0.082}(We)^{0.092}$				
Dakshinamurty, Subrahmanyam, Rao (24,25)	$(\epsilon_g+\epsilon_l) = \left(K\frac{U_l}{U_t}\right)^{m}\left(\frac{\mu l U_g}{\sigma}\right)^{n}$ $n = 0.08$ $K = 2.12,\ m = 0.41,\ Re_t < 500$ $K = 2.65,\ m = 0.6,\ Re_t > 500$	Air/Water Air/Kerosene	Numerous Diameters 1.06 to 6.8 mm	56 mm Diameter	Empirical, no consideration for bed contraction
Blum, Toman(27)	$\frac{(\epsilon_g+\epsilon_l) - (\epsilon_l)_{U_g=0}}{1-(\epsilon_l)_{U_g=0}} = f(U_g)$	Nitrogen/Light Mineral Oil	Cylinders Dia., mm / Length, mm 3.2 / 3.2 4.8 / 2.4 4.8 / 4.8	102	Empirical, no consideration for bed contraction
Razumov,	$\epsilon_s = 0.578 - 3.198\ U_l - 0.538\ U_g$ $\epsilon_l = 0.422 + 0.135\ U_l/d^{0.66} - 1.82\ U_g$ $\epsilon_g = K(1-\epsilon_s)^{2.09}(U_g/U_l)^{0.70}$	Air/Water	Sand, Slag Beads 0.49 to 1.27 mm	300 mm	Empirical, no consideration for bed contractions

TABLE VI

BHATIA-EPSTEIN MODEL

Equations

1) Tabulation of $\epsilon_k''/\epsilon_g''$ vs. ϵ_g (Letan and Kehat*).

2) $\epsilon_1 = \epsilon_k(1 - X_k) + \epsilon_1''_f(1 - \epsilon_g - \epsilon_k + X_k\epsilon_k)$

3) $\epsilon_c + \epsilon_g + \epsilon_1 = 1$

4) $U_g = V_g\epsilon_g$

5) $\epsilon''1_f = \left[\frac{U_1 - V_g\epsilon_k(1 - X_k)}{U_t(1 - \epsilon_g - \epsilon_k)}\right]^{1/n}$

6) $V_g = \frac{u_1 + U_g + \epsilon_1''_f(1 - \epsilon_g - \epsilon_k)V_{g1}'''}{1 - \epsilon_c}$

V_{g1} = relative velocity between bubble phase and liquid in particulate phase

7) $\epsilon_k = \frac{\epsilon_g\epsilon_k''}{\epsilon_g''}(1 - \epsilon_c)^3$

8) $V_{g1}''' = Ut_s + 2\,U_g$

*Letan, R., and E. Kehat, AIChE J, 14, 398, 1969.

TABLE VII

PHYSICAL PROPERTIES OF LIQUIDS USED IN COLD FLOW STUDIES

Viscosity (cp)	50°F	70°F	74°F	100°F	150°F	175°F
Water		1.0		1.0	1.0	
Kerosene		1.39		1.15	0.8	
Mineral Oil		22.4		14.6	6.08	4.2
Surface Tension (Dynes/cm)						
Water	77.6	--	75.5	--	68.3	
Kerosene	30.0	--	28.6	--	24.6	
Mineral Oil	34.0	--	32.6	--	29.1	
Density, g/cc						
Water		0.99		0.99	0.98	
Kerosene		0.79		0.78	0.77	
Mineral Oil		0.85		0.84	0.82	

TABLE VIII

SUMMARY OF GAS/KEROSENE DATA
Temperature = 76°F

Gas	Pressure, psi	cDensity, g/ml	Surface Tension, Dynes/cm.	Remarks
Air	0	0.81	--	
Nitrogen	2	0.82	35.1	Surface tension average of 24.1/24.0/24.2
	15	0.82	26.8	Surface tension average of 27.2/26.5/26.7
Helium	2	0.82	26.8	Surface tension average of 26.9/26.8/26.9
	15	0.82	29.1	Surface tension average of 28.9/29.2/29.3
Freon-12	2	0.84	23.4	Surface tension average of 23.3/22.9/23.8
	15	0.85	20.7	Surface tension average of 20.8/20.5/20.8

TABLE IX

VISCOSITIES OF COAL CHAR/KEROSENE SLURRIES

Temperature, °F	70	72	73	78	86	100	112	143	150	212	Measured By
Kerosene	1.39					1.15			0.80		Rotary Drilling
Kerosene					1.38		1.05		0.88		Battelle
Kerosene/5.1 Vol% Coal Char			3.25			3.0			2.5		Rotary Drilling
Kerosene/5.1 Vol% Coal Char			3.80			3.1		2.2			Battelle
Kerosene/10.5 Vol% Coal Char			6.5			4.5			3.5		Rotary Drilling
Kerosene/10.5 Vol% Coal Char			4.2			3.2			2.2		Battelle
Kerosene/11.9 Vol% Coal Char		3.5									Amoco
Kerosene/15.5 Vol% Coal Char				3.7							Amoco
Kerosene/17.8 Vol% Coal Char			9.25			8.25			6.75		Rotary Drilling
Kerosene/17.8 Vol% Coal Char			7.20				3.6	3.3			Battelle

Note: Viscosities in centipoises.

TABLE X

COMPARISON OF COAL CHAR WITH H-COAL REACTOR FINES

	Coal Char	Recycle Oil Solids (Pyridene Insolubles)
Particle Density, g/cc	1.7	2.3
Density Distribution	90% 0.8-2.2 g/cc. Even distribution.	85% 1.2-2.8 g/cc. Even distribution.
Particle Size	70%--325 Mesh.	90%--325 Mesh.

Source of Information: Reference 35.

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TABLE XI

CUMULATIVE SIZE DISTRIBUTION OF COAL CHAR

CUMULATIVE NUMBER AND NUMBER %
GREATER THAN STATED SIZE

Size, μm	Cumulative Number	Cumulative Number %
0	2916	100
1.1	2635	90.4
2.7	1921	65.9
3.8	1396	47.9
5.4	922	31.6
8.1	529	18.1
13.5	212	7.3
18.7	115	3.9
29.7	64	2.2
51.3	24	0.8
72.8	13	0.4
94.4	8	0.3

TABLE XII

PROPERTIES OF HDS-2A CATALYST

Nominal Diameter: 1.6 mm
Nominal Length: 4.8 mm

Particle Density, g/cc	1.0794
Pore Volume, cm/g	0.66
Surface Area, m^2/g	296
Length Distribution (mm)	
Below 3.8	1
3.8-4.0	0
4.0-4.2	2
4.2-4.4	6
4.4-4.6	9
4.6-4.8	5
4.8-5.0	4
5.0-5.1	7
5.1-5.3	9
5.3-5.5	4
5.5-5.7	0
5.7-5.9	1
5.9-6.1	3
6.1-6.3	4
Over 6.3	5
Average	5.1

TABLE XIII

SUMMARY OF EXPERIMENTAL RUNS

Date	Run No.	Catalyst	Cat. L/D	Gas	Liquid	Fines, Vol%	Temp, °F
8/25/78	200	None	-	Nitrogen	Kerosene	0	72
8/30	201	HDS-2A	3	"	"	0	72
10/12	203	"	"	"	"	1.0	68
10/20	204	"	"	"	"	5.1	70
11/1	205	"	"	"	"	10.4	67
12/13	206	"	"	"	"	15.5	85
1/11/79	207	"	"	Freon-12	"	15.5	81
1/23	208	"	"	Nitrogen	"	15.2	148
2/2	209	"	"	"	"	15.5	97
2/22	210	"	"	"	"	11.9	71
2/16	211	"	"	"	"	17.8	80
4/12	212	"	"	"	"	0	71
4/17	213	"	"	Helium	"	0	70
5/17	214	"	"	Nitrogen	"	15.5	150
5/30	215	"	"	"	"	15.5	71
6/15	216	"	"	Helium	"	15.5	73
6/14	217	"	"	Nitrogen	"	15.5	73
3/13/79	300	None	-	Nitrogen	Kerosene	0	84
3/29	301	HDS-2A	6	"	"	0	74
6/21	310	"	3	"	"	0	72
6/26	311	"	"	Helium	"	0	77
7/2	320	"	2	"	"	0	75
7/11	321	"	"	Nitrogen	"	0	77
7/24/79	400	None	-	Nitrogen	Mineral Oil	0	100
7/25	401	"	-	"	"	0	125
7/27	410	"	-	Helium	"	0	125
8/1	420	HDS-2A	3	Nitrogen	"	0	100
8/2	421	"	"	"	"	0	125
8/3	422	"	"	"	"	0	150
8/9	423	"	"	"	"	0	175
8/13	424	"	"	Helium	"	0	177
8/15	425	"	"	"	"	0	150
8/22	426	"	"	Nitrogen	"	0	154
8/27	427	"	"	"	"	0	99
8/28	428	"	"	"	"	0	127
10/4	429	"	"	"	"	0	176
10/9	430	None	-	"	"	0	170
10/11	431	"	-	"	"	0	149

TABLE XIV

DATA FOR PDU LIQUID SAMPLES

DATE		7/16/79	7/18/79	7/18/79	7/18/79
TIME		1530	1030	1100	1630
SAMPLE NO.		1	2	3	4
PDU RUN NO.		130-88	130-88	130-88	130-88
PDU PERIOD NO.		11A	13A	13A	13A
DATA					
Catalyst Bed Expansion		150%	150%	150%	150%
FEED RATE					
Coal	Avg.	(321)	(323)	(323)	(323)
	Instant	342 #/Hr.	341 #/Hr	341 #/Hr	341 #/Hr.
Liquid	Avg.	(637)	(655)	(655)	(655)
	Instant	675 #/Hr.			
Gas	Avg.	(5820)	Avg.	Avg.	Avg.
	Instant	5600 SCFH	6152 SCFH	6152 SCFH	6152 SCFH
Coal Type		Illinois #6	Illinois #6	Illinois #6	Illinois #6
Coal Concentration					
Conversion	Toluene Extraction	92.8	92.5	92.5	92.5
	(DMF Filtration)	(89.7%)	(88.9)	(88.9)	(88.9)
Catalyst Type		HDS-1442A---------------------------→			
Reactor Temperature	Avg.	840	848	848	848
	Instant	848°F	847°F	847°F	848°F
Reactor Pressure	Avg.	2600	2623	2623	2623
	Instant	2600 PSIG	2610 PSIG	2610 PSIG	2623

←------------ Amoco Bombs ------------------→

7/18/79

TABLE XV

COAL CHAR DISTRIBUTION ALONG THE REACTOR:
HDS-2A CATALYST, L = 4.8 MM, D = 1.6 MM

				Concentration in Wt%						
Test No.	Fines* Vol%	Slurry Flow Cm/Sec	Gas Flow Cm/Sec	Reactor Bottom	152 Cm	305 Cm	457 Cm	Recycle Line	Separator Feed	Average
204-23	5.1	5.5	1.1	7.4	7.5	6.7	11.9	--	--	8.4
205-26	10.4	3.0	7.6	14.5	14.7	16.4	16.7	--	--	15.6
206-05	15.5	4.3	0	21.8	22.0	21.8	20.5	20.3	16.3	21.5
211-07	17.8	3.0	4.6	21.8	24.6	25.2	25.2	23.3	22.2	24.2
211-11	17.8	3.0	6.1	23.9	24.4	25.9	24.8	23.9	22.6	24.7
210-09	11.9	3.0	3.0	17.2	17.2	17.2	17.2	--	--	17.2

TABLE XVI

PARTICLE SIZE DISTRIBUTION OF REACTOR COAL CHAR SAMPLES

Slurry Concentration = 17.8 vol%
Liquid Velocity, Cm/Sec = 3.0
Gas Velocity, Cm/Sec = 4.6

CUMULATIVE NUMBER AND CUMULATIVE NUMBER PERCENT
GREATER THAN STATED SIZE

	Reactor Bottom Sample AU77-13		457 cm Level Sample AU77-16	
Size, μm	Cumulative Number	Cumulative Number %	Cumulative Number	Cumulative Number %
0	4409	100	4142	100
1.1	3588	81.4	3220	77.7
2.7	2485	56.4	2109	50.9
3.8	1971	44.7	1632	39.4
5.4	1472	33.4	1148	27.7
8.1	1017	23.1	714	17.2
13.5	542	12.3	316	7.6
18.9	291	6.6	164	4.0
29.7	113	2.6	61	1.5
51.3	32	0.7	8	0.2
70.2	5	0.1	4	0.1
91.8	2	0.05	2	0.05
Max. Size, μm	-------- 108.0 --------		-------- 118.8 --------	
Avg Size, μm	-------- 3.5 --------		-------- 2.8 --------	

TABLE XVII

VARIATION IN RICHARDSON-ZAKI INDEX

Run No.	Test Nos.	Liquid	Fines, Vol%	Temp, °F	Index n
201	2-11	Kerosene	0	72	2.68
203	1-4	"	1	68	3.07
204	1-6	"	5.1	70	3.44
205	1-8,35	"	10.4	67	3.57
206	1-9	"	15.5	85	3.27
208	1-6,26-28	"	15.5	148	3.42
209	1-4,24-25	"	15.5	97	3.22
210	1,7,13,19	"	11.9	71	3.58
211	1,7,13	"	17.8	80	3.71
212	1,3,7,10	"	0	71	3.58
214	1-11	"	15.5	150	4.98
310	1-5,6,13	Kerosene	0	72	2.46
320	1-5	"	0	75	3.84
427	3-6	Mineral Oil	0	100	3.8
428	3-5	"	0	125	3.5
426	4-7	"	0	150	3.4
423	2-4	"	0	175	3.5

IAV/ml
2/20/80

TABLE XVIII

FIRST AND SECOND MOMENTS CALCULATED BY TWO METHODS

Test	Detector	m (1) Sec	mm (1) Sec	m (2) Sec^2	mm (2) Sec^2
1a	1	--	--		
	2	22.9	22.9	117	120
	3	47.6	47.5	785	786
	4	75.7	74.4	1170	1300
	5	90.5	90.0	1502	1600
2a	1	19.6	19.5	--	850
	2	25.2	25.1	1088	1100
	3	48.6	48.4	2184	2160
	4	78.4	77.4	3040	3048
	5	95.2	95.0	3860	3900
3a	1	14.8	14.8	94.8	95.0
	2	24.2	24.2	394	380
	3	53.8	53.4	2560	2520
	4	69.6	69.0	2604	2608
	5	73.2	72.6	2632	2636

m (1), m (2): Moments calculated using Equations C-2 and C-3.

mm (1), mm (2): Moments calculated using the modified method.

TABLE XIX

CALCULATED GAS LINEAR VELOCITIES

Kerosene, Nitrogen, American Cyanamid
HDS-2A Catalyst, l = 4.8 mm, d = 1.6 mm

				Tracer		Gamma-Ray	
Test	U_l, cm/sec	U_g, cm/sec	Vol% Fines	V_g in Bed cm/sec	V_g Above Bed cm/sec	V_g in Bed cm/sec	V_g Above Bed cm/sec
1a	3.0	3.0	0	13.6	5.6	15.8	12.5
1b	3.0	3.0	0	11.9	5.6	15.8	12.5
2a	3.0	3.0	15.5	14.1	6.2	21.4	25.0
2b	3.0	3.0	15.5	9.8	5.5	21.4	25.0
3a	3.0	4.6	15.5	14.8	10.0	35.3	30.7
3b	3.0	4.6	15.5	14.8	9.5	35.3	30.7

TABLE XX

GAS HOLDUPS CALCULATED FROM GAS TRACER AND GAMMA-RAY TESTS

Test	U_l, cm/sec	U_g, cm/sec	Vol% Fines	Tracer In Bed	Tracer Above Bed	Gamma-Ray In Bed	Gamma-Ray Above Bed
1a	3.0	3.0	0	0.22	0.54	0.19	0.24
2a	3.0	3.0	15.5	0.22	0.49	0.14	0.12
3a	3.0	4.6	15.5	0.31	0.46	0.13	0.15

p

TABLE XXI

RESULTS OF GAMMA-RAY SCANS THROUGH CHORDS OF THE CROSS-SECTION

Ul, cm/sec	Ug, cm/sec	Position 1 (ϵ_g)	Position 2 (ϵ_g)	Position 3 (ϵ_g)	Delta
4.6	6.1	0.19	0.18	--	±0.02
5.8	3.0	0.11	0.11	0.18	±0.03

TABLE XXII

CALCULATION OF DISPERSION COEFFICIENT

Test	Detectors	Gas Velocity, cm/sec	P_e	E_g*
1a	1-2	13.6	5.1	492
	3-4	5.6	3.4	260
2a	1-2	14.1	0.78	3354
	3-4	6.2	2.39	408
3b	1-2	14.8	1.40	1960
	3-4	9.5	1.65	910

*E_g in sec/cm^2.

TABLE XXIII

SOLUTION OF THE BHATIA-EPSTEIN MODEL

1) Select initial values of ϵ_c, ϵ_1, ϵ_g.

2) Compute: $V_{g_1}''' = U_{t_s} + 2\,U_g$.

3) Compute: $\epsilon_k''/\epsilon_g''$ - values given by Letan and Kehat.

4) Compute: $\epsilon_k = \epsilon_g \dfrac{\epsilon_k''}{\epsilon_g''}(1 - \epsilon_c)^3$

5) Compute: $V_g = U_g/\epsilon_g$

6) Compute: $\epsilon_1''_f$ from Richardson-Zaki relationship

7) Compute: $V_g = \dfrac{U_1 + U_g + \epsilon_1''_f\,(1 - \epsilon_g - \epsilon_k)V_{g_1}'''}{1 - \epsilon_c}$

8) Compute: $\epsilon_{1_2} = \epsilon_k(1 - X_k) + \epsilon_{1_f}''(1 - \epsilon_g - \epsilon_k + X_k\epsilon_k)$

9) Compute new ϵ_g: $\epsilon_{g_2} = U_g/V_g$

10) Average: $\epsilon_{g_1} + \epsilon_{g_2} = \epsilon_{g_{avg}}$

11) Compute new ϵ_c from $\epsilon_{g_{avg}}$ and ϵ_{1_2}

Iterate until $\Delta\epsilon_g$ $\Delta\epsilon_1$ are small.

TABLE XXIV

BED SETTLING RATE
Catalyst l/d = 3
Gas: Nitrogen

Test No.	U_l, Ft/Sec	U_g, Ft/Sec	Liquid	Fines, Vol%	Temp, °F	Viscosity, °F	Bed Settling Rate, Ft/Sec	% Bed Expansion	Particle Terminal Velocity, Ft/Sec (1)	Particle Terminal Velocity, Ft/Sec (2)
212-05	0.10	0.10	Kerosene	0	71	1.39	0.17	54	0.45	--
217-01	0.10	0.10	"	15.5	150	6.75	0.12	72	0.45	--
426-13	0.10	0.10	Mineral Oil	0	150	6.08	0.16	107	0.36	0.30
423-12	0.10	0.10	"	15.5	175	4.2	0.17	75	0.35	0.42
217-05	0.15	0.10	Kerosene	15.5	150	6.75	0.23	156	0.45	--
423-17	0.15	0.10	Mineral Oil	0	175	4.20	0.22	153	0.35	0.30
426-17	0.15	0.10	"	0	150	6.08	0.22	203	0.36	0.42

(1) Extrapolated terminal velocity from Richardson-Zaki correlation.

(2) Experimentally measured value.