TABLE 4 (cont'd)

LIQUID DISPERSION COEFFICIENTS: 5" COLD FLOW SIMULATOR

SYSTEM: THREE PHASE

GAS- AIR

LIQUID- WATER

SOLID - SILICON OXIDE

| RUN NO. | SOLID SIZE μM | SOLID AVG WT% | VELOCITY SLURRY FT/SEC | VELOCITY GAS FT/SEC | EZL. 1-2 $KATO^5$ $CM^2/S$ | |
|---|---|---|---|---|---|---|
| 6962-91 | 98.00 | 24.4 | 0.0 | 0.40 | 170.0 | 229.6 |
| 6962-92 | 98.00 | 25.0 | 0.0 | 0.50 | 230.0 | 253.1 |
| 6962-93 | 98.00 | 14.2 | 0.0 | 0.10 | 140.0 | 148.8 |
| 6962-94 | 98.00 | 14.5 | 0.0 | 0.20 | 180.0 | 178.3 |
| 6962-95 | 98.00 | 17.2 | 0.0 | 0.35 | 190.0 | 217.4 |
| 6962-96 | 98.00 | 16.6 | 0.0 | 0.28 | 170.0 | 199.6 |
| 6962-97 | 98.00 | 15.9 | 0.0 | 0.50 | 200.0 | 253.1 |
| 6962-98 | 98.00 | 5.9 | 0.0 | 0.10 | 150.0 | 148.8 |
| 6962-99 | 98.00 | 7.1 | 0.0 | 0.20 | 170.0 | 178.3 |
| 6962-100 | 98.00 | 9.5 | 0.0 | 0.30 | 200.0 | 204.8 |
| 6962-101 | 98.00 | 9.4 | 0.0 | 0.40 | 190.0 | 229.6 |
| 6962-102 | 98.00 | 8.6 | 0.0 | 0.50 | 230.0 | 253.1 |

TABLE 5

GAS HOLDUP AND SOLID FRACTION: 12" COLD FLOW SIMULATOR

PLAIN HEAT TRANSFER INTERNALS

SYSTEM: TWO PHASE

GAS- NITROGEN

LIQUID- ISOPARAFFIN

| RUN NO. | DIST HOLE IN | SOLID SIZE μM | SOLID AVG WT% | VELOCITY SLURRY FT/SEC | VELOCITY GAS FT/SEC | GAS HOLDUP 1-2 VOL % | GAS HOLDUP 2-3 VOL % | GAS HOLDUP 3-4 VOL % | GAS HOLDUP AVG VOL % | SOLID FRACTION 1 WT % | SOLID FRACTION 2 WT % | SOLID FRACTION 3 WT % | SOLID FRACTION 4 WT % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 0.035 | 0.0 | 1.2 | 0.0 | 0.28 | . | . | 19.6 | 19.5 | 1.9 | 1.4 | 0.6 | 1.0 |
| 37 | 0.125 | 0.0 | 0.0 | 0.0 | 0.50 | . | . | 24.9 | 24.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| 38 | 0.125 | 0.0 | 0.0 | 0.0 | 0.16 | . | . | 14.6 | 14.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| 39 | 0.125 | 0.0 | 0.0 | 0.015 | 0.16 | . | . | 13.6 | 13.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 40 | 0.125 | 0.0 | 0.0 | 0.015 | 0.50 | . | . | 25.0 | 23.2 | 0.0 | 0.0 | 0.0 | 0.0 |

TABLE 6

GAS HOLDUP AND SOLID FRACTION: 12" COLD FLOW SIMULATOR

PLAIN HEAT TRANSFER INTERNALS

SYSTEM: TWO PHASE

GAS- AIR

LIQUID- WATER

| RUN NO. | DIST HOLE IN | VELOCITY SLURRY FT/SEC | VELOCITY GAS FT/SEC | GAS HOLDUP 1-2 VOL % | GAS HOLDUP 2-3 VOL % | GAS HOLDUP 3-4 VOL % | GAS HOLDUP AVG VOL % |
|---|---|---|---|---|---|---|---|
| 49 | 0.500 | 0.0 | 0.28 | . | 15.6 | 9.1 | 10.2 |
| 50 | 0.035 | 0.0 | 0.28 | 9.5 | 11.5 | 12.2 | 11.1 |
| 51 | 0.125 | 0.0 | 0.28 | 7.7 | 11.7 | 10.9 | 10.8 |
| 52 | 0.125 | 0.0 | 0.28 | 10.3 | 12.1 | 10.9 | 10.7 |
| 53 | 0.125 | 0.008 | 0.28 | 10.9 | 17.5 | 16.4 | 12.5 |

TABLE 7

GAS HOLDUP AND SOLID FRACTION: 12" COLD FLOW SIMULATOR

PLAIN HEAT TRANSFER INTERNALS

SYSTEM: THREE PHASE

GAS- NITROGEN

LIQUID- ISOPARAFFIN

SOLID- IRON OXIDE

| RUN NO. | DIST HOLE IN | SOLID SIZE μM | SOLID AVG WT% | VELOCITY SLURRY FT/SEC | VELOCITY GAS FT/SEC | GAS HOLDUP 1-2 VOL % | GAS HOLDUP 2-3 VOL % | GAS HOLDUP 3-4 VOL % | GAS HOLDUP AVG VOL % | SOLID FRACTION 1 WT % | SOLID FRACTION 2 WT % | SOLID FRACTION 3 WT % | SOLID FRACTION 4 WT % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 45 | 0.125 | 98.0 | 27.2 | 0.008 | 0.50 | . | 16.4 | 20.6 | 19.4 | 61.3 | 22.7 | 15.5 | 9.3 |
| 46 | 0.125 | 98.0 | 26.1 | 0.008 | 0.16 | . | 9.2 | 11.6 | 11.2 | 78.6 | 12.2 | 8.3 | 5.2 |
| 47 | 0.500 | 98.0 | 32.8 | 0.008 | 0.50 | . | 15.5 | 19.8 | 18.4 | 80.0 | 24.7 | 16.2 | 10.5 |
| 48 | 0.500 | 98.0 | 29.5 | 0.008 | 0.16 | . | 7.5 | 10.4 | 10.2 | 80.0 | 18.0 | 13.2 | 6.8 |

TABLE 8

GAS HOLDUP AND SOLID FRACTION: 12" COLD FLOW SIMULATOR

PLAIN HEAT TRANSFER INTERNALS

SYSTEM: THREE PHASE

GAS- AIR

LIQUID- WATER

SOLID- SILICON OXIDE

| RUN NO. | DIST HOLE IN | SOLID SIZE μM | SOLID AVG WT% | VELOCITY SLURRY FT/SEC | VELOCITY GAS FT/SEC | GAS HOLDUP 1-2 VOL % | GAS HOLDUP 2-3 VOL % | GAS HOLDUP 3-4 VOL % | GAS HOLDUP AVG VOL % | SOLID FRACTION 1 WT % | SOLID FRACTION 2 WT % | SOLID FRACTION 3 WT % | SOLID FRACTION 4 WT % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 54 | 0.125 | 2.5 | 26.1 | 0.008 | 0.28 | 8.2 | 11.4 | 9.6 | 7.7 | 26.1 | 26.2 | 26.1 | 26.2 |
| 55 | 0.035 | 49.0 | 10.0 | 0.0 | 0.28 | 9.9 | 13.5 | 10.7 | 12.6 | 12.7 | 10.5 | 8.9 | 8.1 |
| 56 | 0.035 | 49.0 | 11.3 | 0.011 | 0.28 | 14.4 | 17.9 | 14.8 | 18.1 | 13.9 | 11.9 | 10.3 | 9.0 |
| 57 | 0.500 | 49.0 | 11.7 | 0.0 | 0.28 | 3.5 | 8.8 | 8.8 | 8.9 | 11.4 | 12.8 | 11.7 | 10.8 |
| 58 | 0.500 | 49.0 | 13.6 | 0.010 | 0.28 | 7.5 | 10.2 | 9.8 | 10.6 | 15.5 | 14.2 | 13.1 | 11.8 |
| 59 | 0.125 | 98.0 | 23.5 | 0.008 | 0.28 | 3.2 | 9.8 | 8.6 | 10.3 | 33.1 | 25.9 | 19.8 | 15.1 |

SOLID- IRON OXIDE

| RUN NO. | DIST HOLE IN | SOLID SIZE μM | SOLID AVG WT% | VELOCITY SLURRY FT/SEC | VELOCITY GAS FT/SEC | GAS HOLDUP 1-2 VOL % | GAS HOLDUP 2-3 VOL % | GAS HOLDUP 3-4 VOL % | GAS HOLDUP AVG VOL % | SOLID FRACTION 1 WT % | SOLID FRACTION 2 WT % | SOLID FRACTION 3 WT % | SOLID FRACTION 4 WT % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 0.125 | 2.5 | 15.5 | 0.008 | 0.28 | 11.2 | 14.7 | 17.5 | 15.1 | 15.9 | 15.7 | 15.4 | 15.1 |

TABLE 9

SHELL-SIDE HEAT TRANSFER COEFFICIENTS: 12" COLD FLOW SIMULATOR

PLAIN HEAT TRANSFER INTERNALS

SYSTEM: TWO PHASE

GAS- NITROGEN

LIQUID- ISOPARAFFIN

| RUN NO. | DIST HOLE IN | SOLID SIZE μM | SOLID AVG WT% | VELOCITY SLURRY FT/SEC | VELOCITY GAS FT/SEC | HEAT COEFF. A | HEAT COEFF. A BTU/HR | HEAT COEFF. C FT2 | HEAT COEFF. DECKWER F |
|---|---|---|---|---|---|---|---|---|---|
| 36 | 0.035 | 0.0 | 1.2 | 0.0 | 0.28 | 183.1 | 184.8 | 183.8 | 217.1 |
| 37 | 0.125 | 0.0 | 0.0 | 0.0 | 0.50 | 195.8 | 197.7 | 196.6 | 227.6 |
| 38 | 0.125 | 0.0 | 0.0 | 0.0 | 0.16 | 163.9 | 165.2 | 156.3 | 189.9 |
| 39 | 0.125 | 0.0 | 0.0 | 0.01u | 0.16 | 162.2 | 162.2 | 155.9 | 189.9 |
| 40 | 0.125 | 0.0 | 0.0 | 0.015 | 0.50 | 190.8 | 192.6 | 195.4 | 227.6 |

TABLE 10

SHELL-SIDE HEAT TRANSFER COEFFICIENTS: 12" COLD FLOW SIMULATOR

PLAIN HEAT TRANSFER INTERNALS

SYSTEM: TWO PHASE

GAS- AIR

LIQUID- WATER

| RUN NO. | DIST HOLE IN | SOLID SIZE µM | SOLID AVG WT% | VELOCITY SLURRY FT/SEC | VELOCITY GAS FT/SEC | HEAT COEFF. A BTU/HR | HEAT COEFF. C FT2 | HEAT COEFF. DECKWER F |
|---|---|---|---|---|---|---|---|---|
| 49 | 0.500 | 0.0 | 0.0 | 0.0 | 0.28 | 552.9 | 653.9 | 766.5 |
| 50 | 0.035 | 0.0 | 0.0 | 0.0 | 0.28 | 527.2 | 633.5 | 766.5 |
| 51 | 0.125 | 0.0 | 0.0 | 0.0 | 0.28 | 540.5 | 607.4 | 766.5 |
| 52 | 0.125 | 0.0 | 0.0 | 0.0 | 0.28 | 547.6 | 616.3 | 766.5 |
| 53 | 0.125 | 0.0 | 0.0 | 0.008 | 0.28 | 514.7 | 597.9 | 766.5 |

TABLE 11

SHELL-SIDE HEAT TRANSFER COEFFICIENTS: 12" COLD FLOW SIMULATOR

PLAIN HEAT TRANSFER INTERNALS

SYSTEM: THREE PHASE

GAS- NITROGEN

LIQUID- ISOPARAFFIN

SOLID- IRON OXIDE

| RUN NO. | DIST HOLE IN | SOLID SIZE µM | SOLID AVG WT% | VELOCITY SLURRY FT/SEC | VELOCITY GAS FT/SEC | HEAT COEFF. A BTU/HR FT2 F | B | C | DECKWER |
|---|---|---|---|---|---|---|---|---|---|
| 45 | 0.125 | 98.0 | 27.2 | 0.008 | 0.50 | 213.3 | 215.5 | 226.1 | 288.9 |
| 46 | 0.125 | 98.0 | 26.1 | 0.008 | 0.16 | 171.8 | 168.9 | 180.5 | 238.5 |
| 47 | 0.500 | 98.0 | 12.8 | 0.008 | 0.50 | 209.8 | 214.3 | 224.2 | 253.2 |
| 48 | 0.500 | 98.0 | 9.5 | 0.008 | 0.16 | 168.9 | 174.8 | 156.7 | 205.3 |

TABLE 12

SHELL-SIDE HEAT TRANSFER COEFFICIENTS: 12" COLD FLOW SIMULATOR

PLAIN HEAT TRANSFER INTERNALS

SYSTEM: THREE PHASE

GAS- AIR

LIQUID- WATER

SOLID- SILICON OXIDE

| RUN NO. | DIST HOLE IN | SOLID SIZE µM | SOLID AVG WT% | VELOCITY SLURRY FT/SEC | VELOCITY GAS FT/SEC | A | HEAT COEFF. B BTU/HR FT2 F | C | DECKWER |
|---|---|---|---|---|---|---|---|---|---|
| 54 | 0.125 | 2.5 | 26.1 | 0.008 | 0.28 | 544.5 | 468.3 | 629.3 | 884.3 |
| 55 | 0.035 | 49.0 | 10.0 | 0.0 | 0.28 | 532.6 | 449.6 | 651.0 | 908.4 |
| 56 | 0.035 | 49.0 | 11.3 | 0.011 | 0.28 | 531.9 | 468.3 | 639.9 | 906.9 |
| 57 | 0.500 | 49.0 | 11.7 | 0.0 | 0.28 | 591.2 | 444.2 | 666.8 | 906.3 |
| 58 | 0.500 | 49.0 | 13.6 | 0.010 | 0.28 | 555.9 | 471.5 | 668.4 | 903.7 |
| 59 | 0.125 | 98.0 | 23.5 | 0.008 | 0.28 | 507.2 | 448.1 | 625.0 | 888.9 |

SOLID- IRON OXIDE

| RUN NO. | DIST HOLE IN | SOLID SIZE µM | SOLID AVG WT% | VELOCITY SLURRY FT/SEC | VELOCITY GAS FT/SEC | A | HEAT COEFF. B BTU/HR FT2 F | C | DECKWER |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 0.125 | 2.5 | 15.5 | 0.008 | 0.28 | 474.3 | 0.0 | 555.2 | 834.7 |

FIGURE 1

# 5 INCH COLD FLOW SIMULATOR

**WATER, 0.5–5 μM IRON OXIDE, AIR**

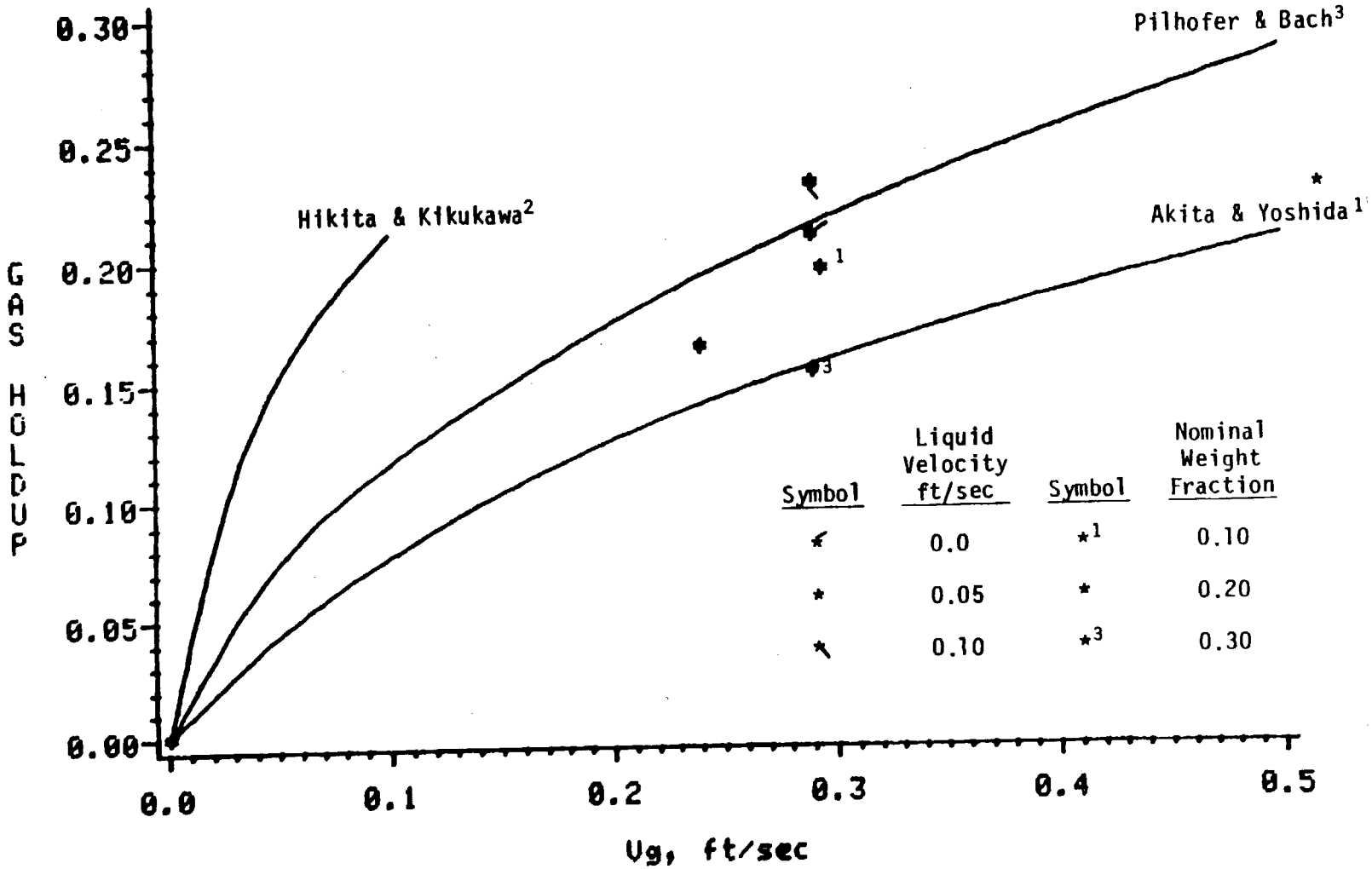


FIGURE 2

# 5 INCH COLD FLOW SIMULATOR

**WATER, 46-53 μM IRON OXIDE, AIR**

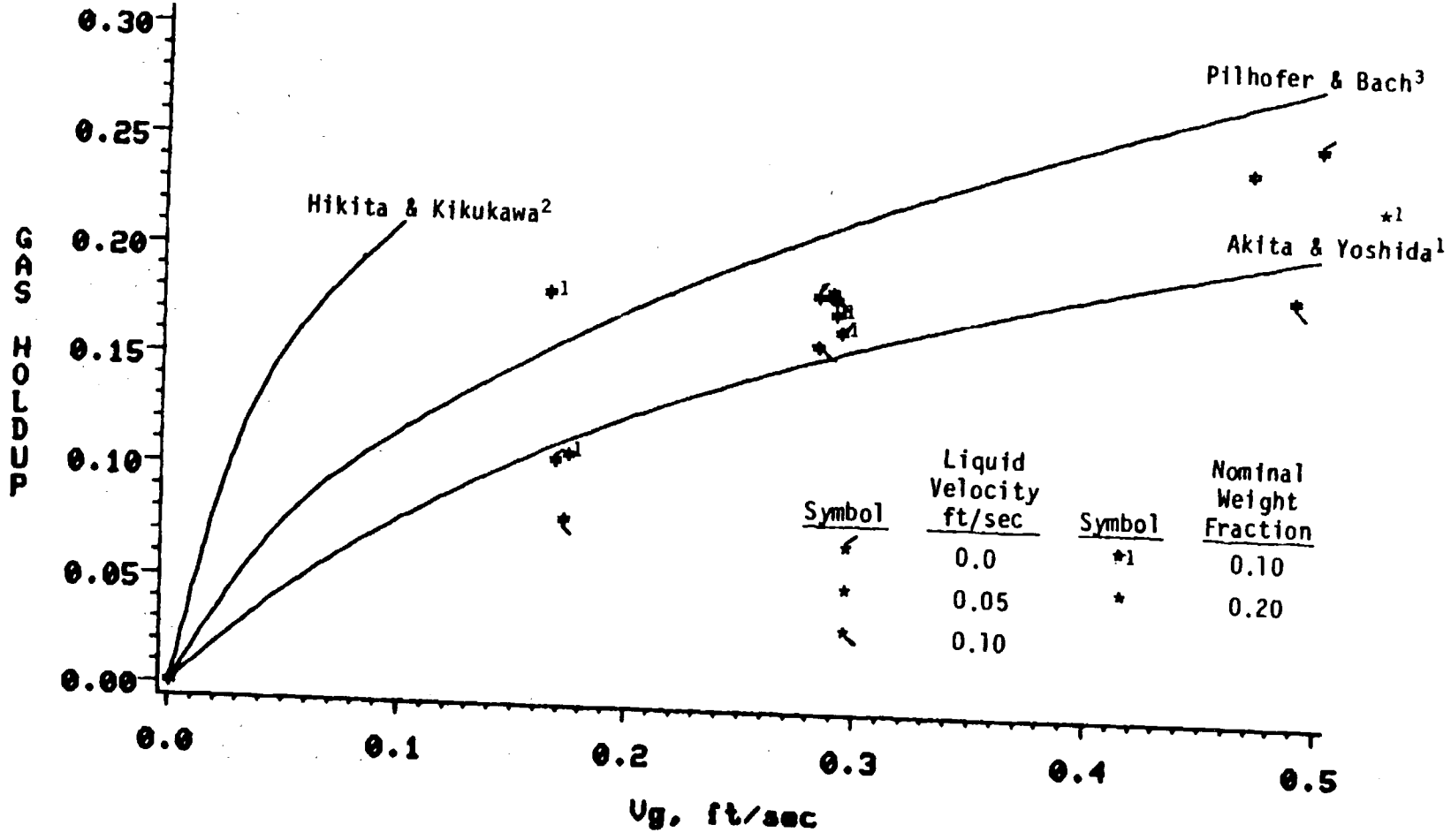


FIGURE 3

# 5 INCH COLD FLOW SIMULATOR

**WATER, 90-115 μM IRCON OXIDE, AIR**

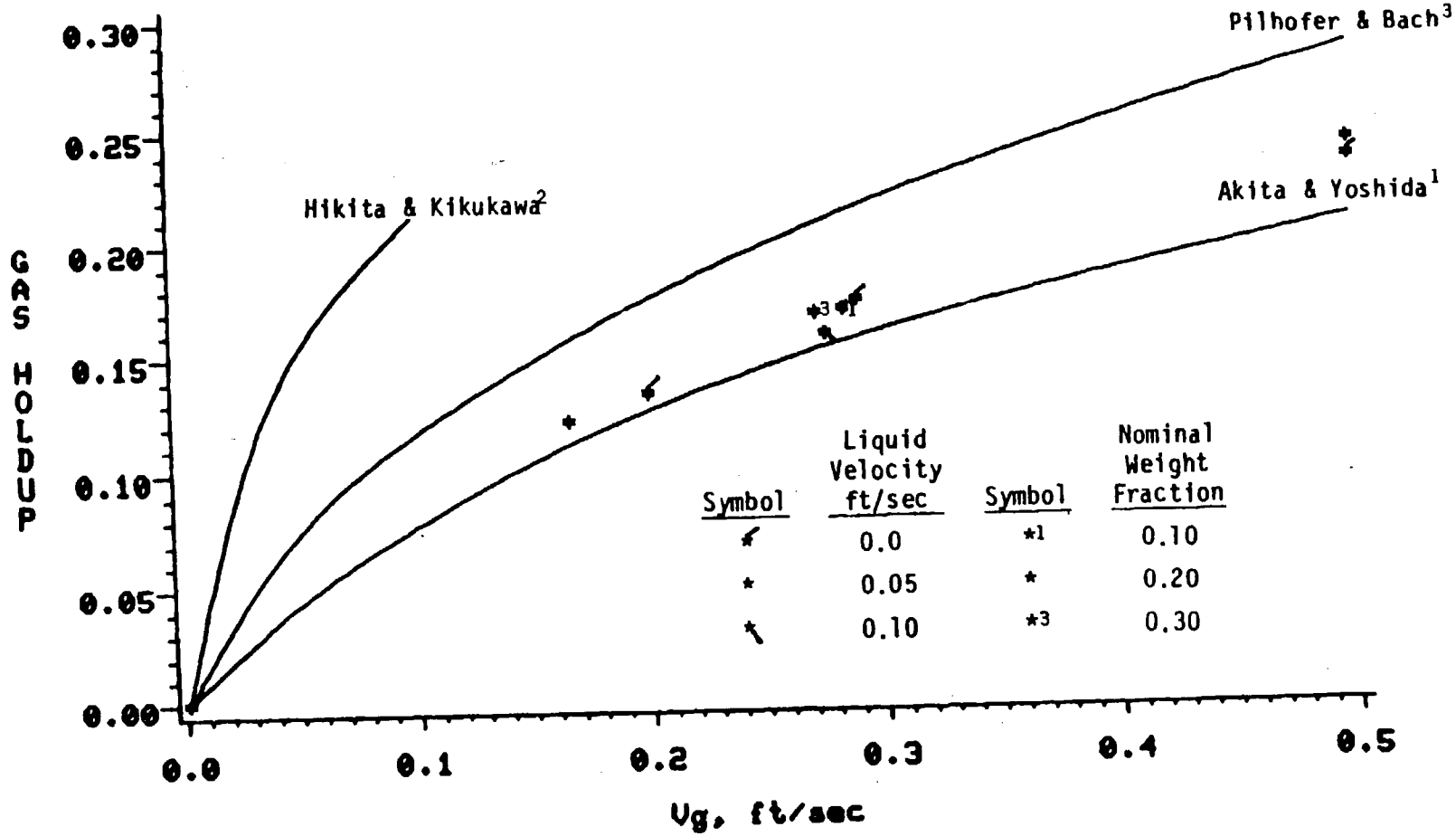


FIGURE 4

# 5 INCH COLD FLOW SIMULATOR

## SOLID CONCENTRATION PROFILES
## WATER, 0.5–5 μM IRON OXIDE, AIR

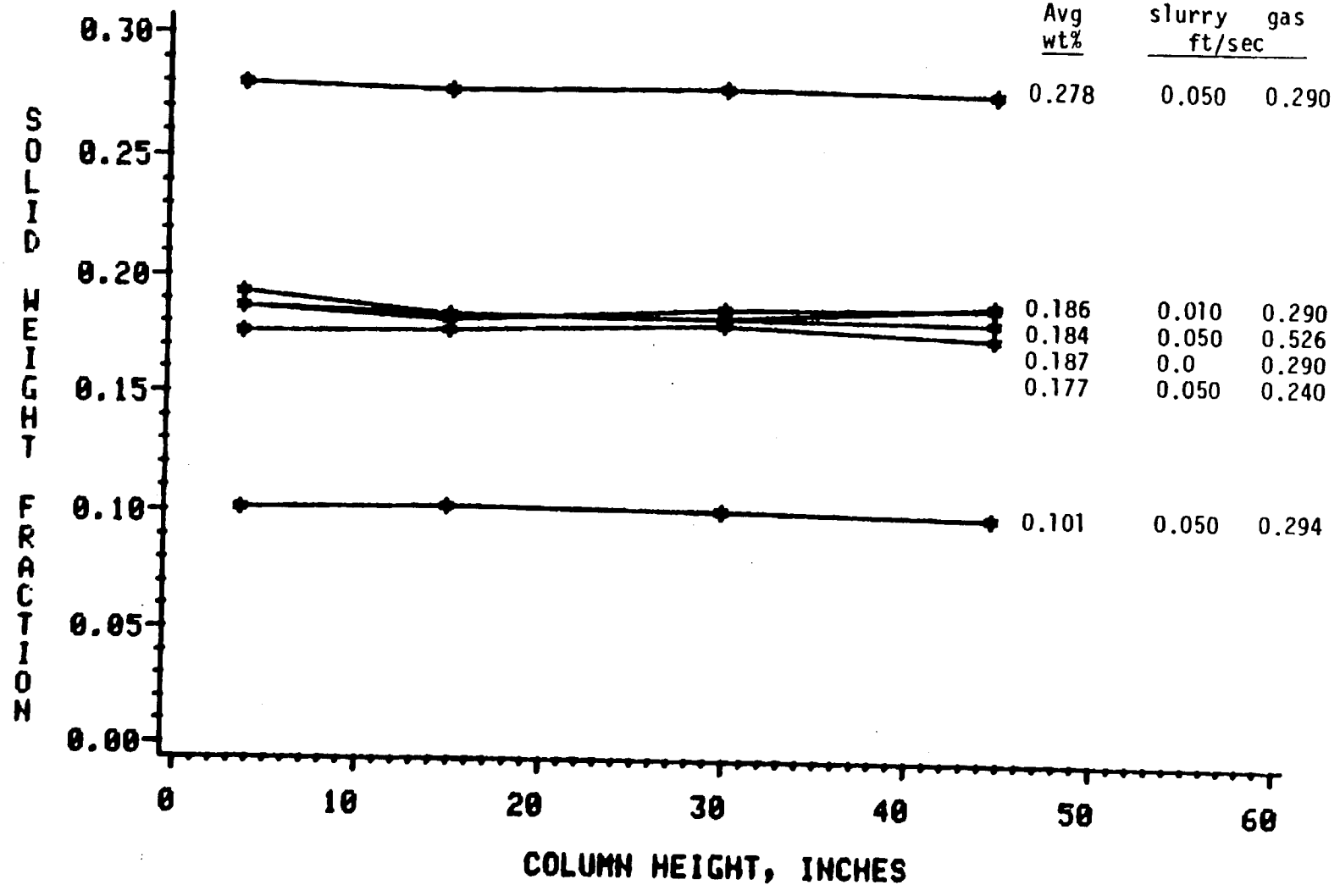


FIGURE 5

# 5 INCH COLD FLOW SIMULATOR

## SOLID CONCENTRATION PROFILES
## WATER, 45–53 μM IRON OXIDE, AIR

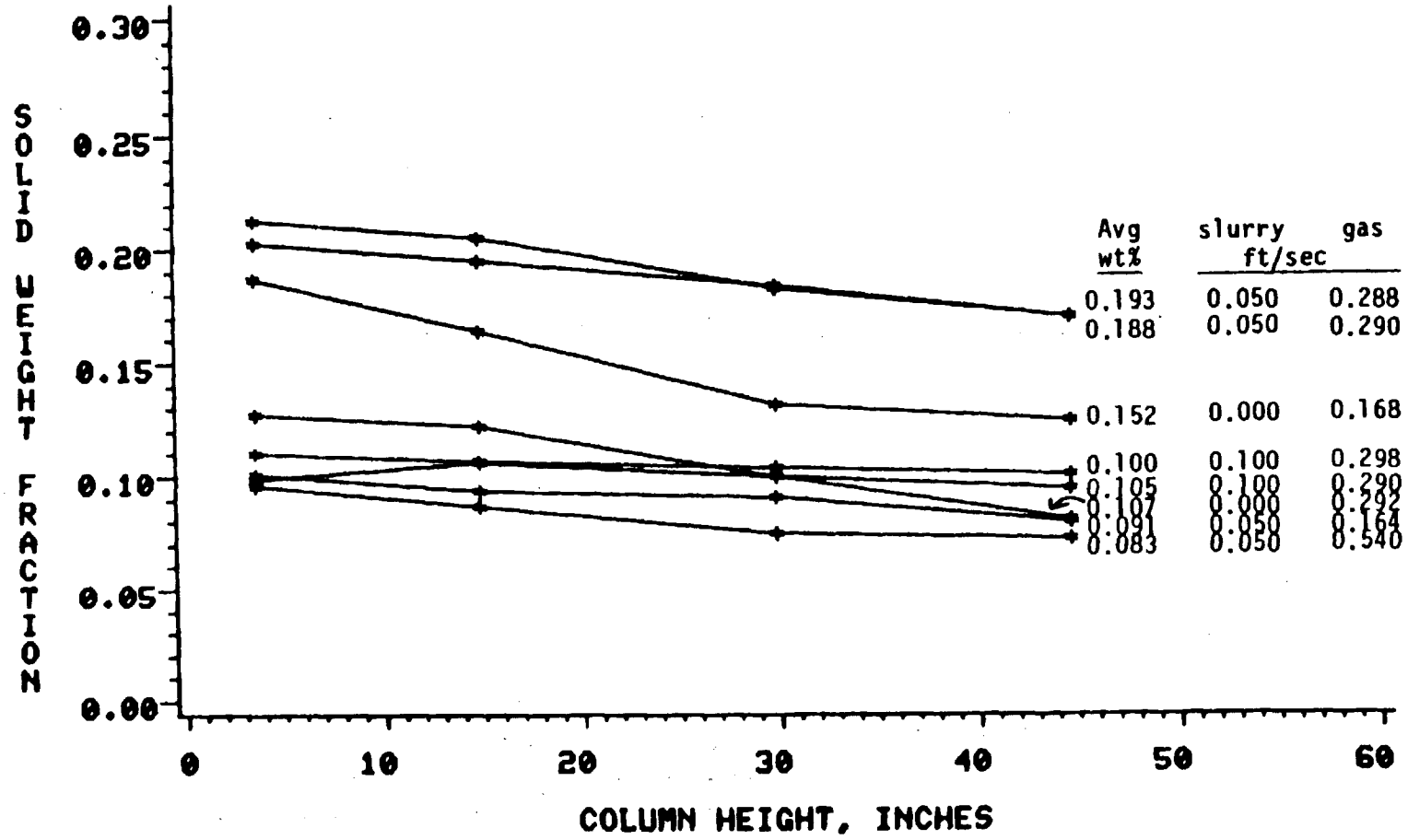


FIGURE 6

# 5 INCH COLD FLOW SIMULATOR

## SOLID CONCENTRATION PROFILES
## WATER, 45–53 μM IRON OXIDE, AIR

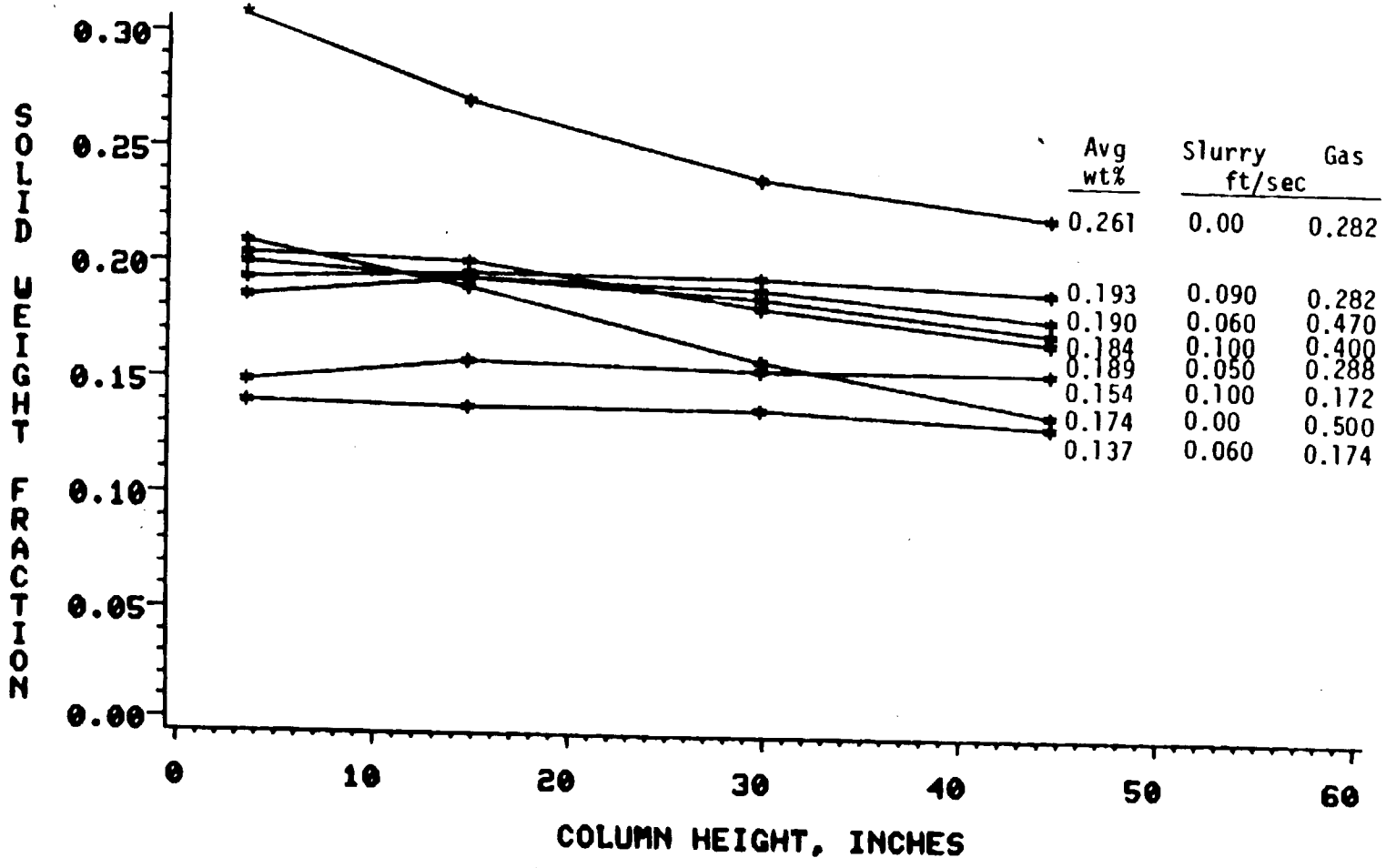


FIGURE 7

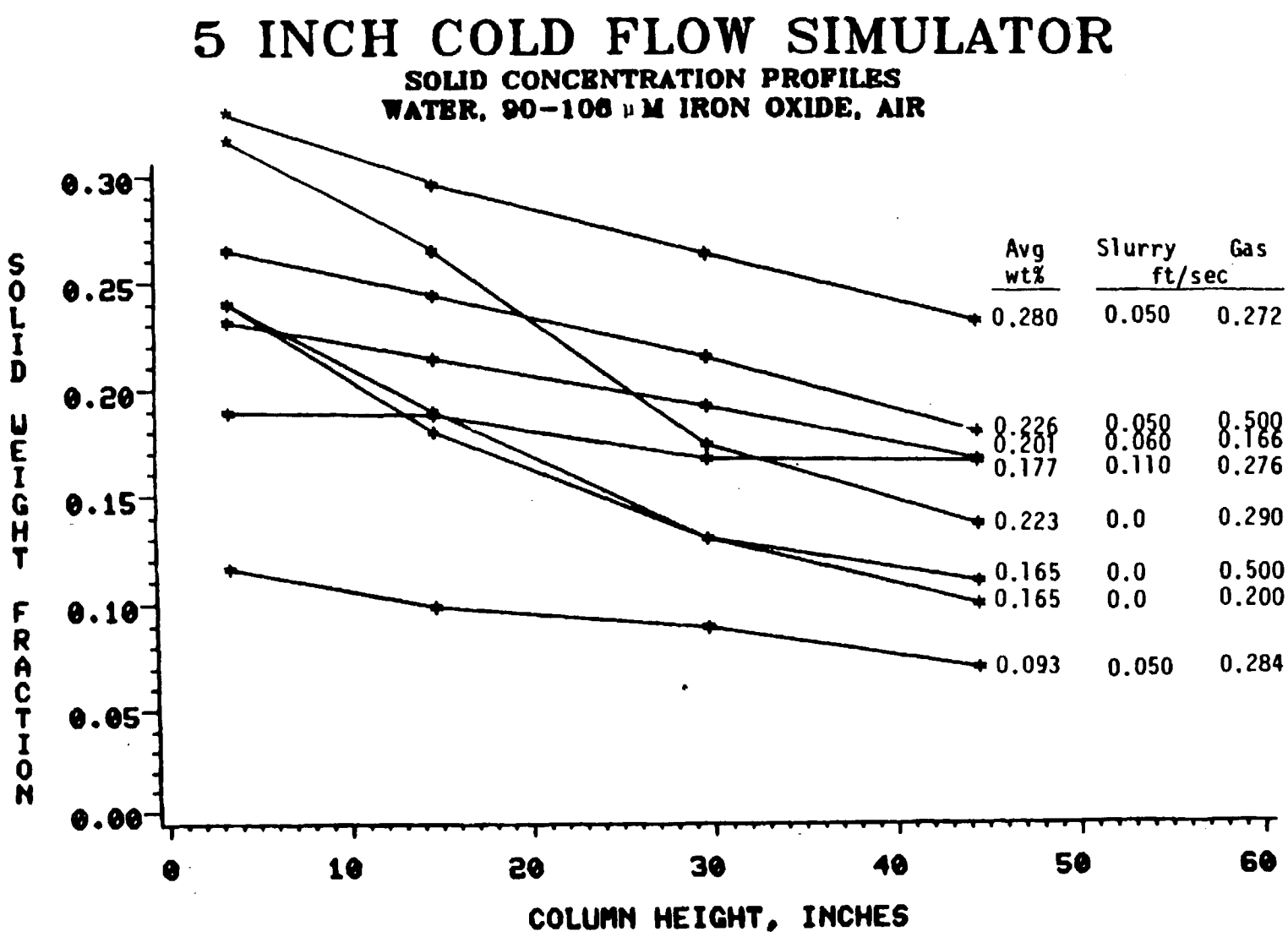

5 INCH COLD FLOW SIMULATOR
SOLID CONCENTRATION PROFILES
WATER, 90-106 μM IRON OXIDE, AIR
SOLID WEIGHT FRACTION
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
10
20
30
40
50
60
COLUMN HEIGHT, INCHES
Avg wt%
Slurry ft/sec
Gas ft/sec
0.280 0.050 0.272
0.226 0.050 0.500
0.201 0.060 0.166
0.177 0.110 0.276
0.223 0.0 0.290
0.165 0.0 0.500
0.165 0.0 0.200
0.093 0.050 0.284

FIGURE 6

# LIQUID DISPERSION COEFFICIENTS

**6 INCH COLD FLOW SIMULATOR**
**WATER,SILICON OXIDE,AIR**

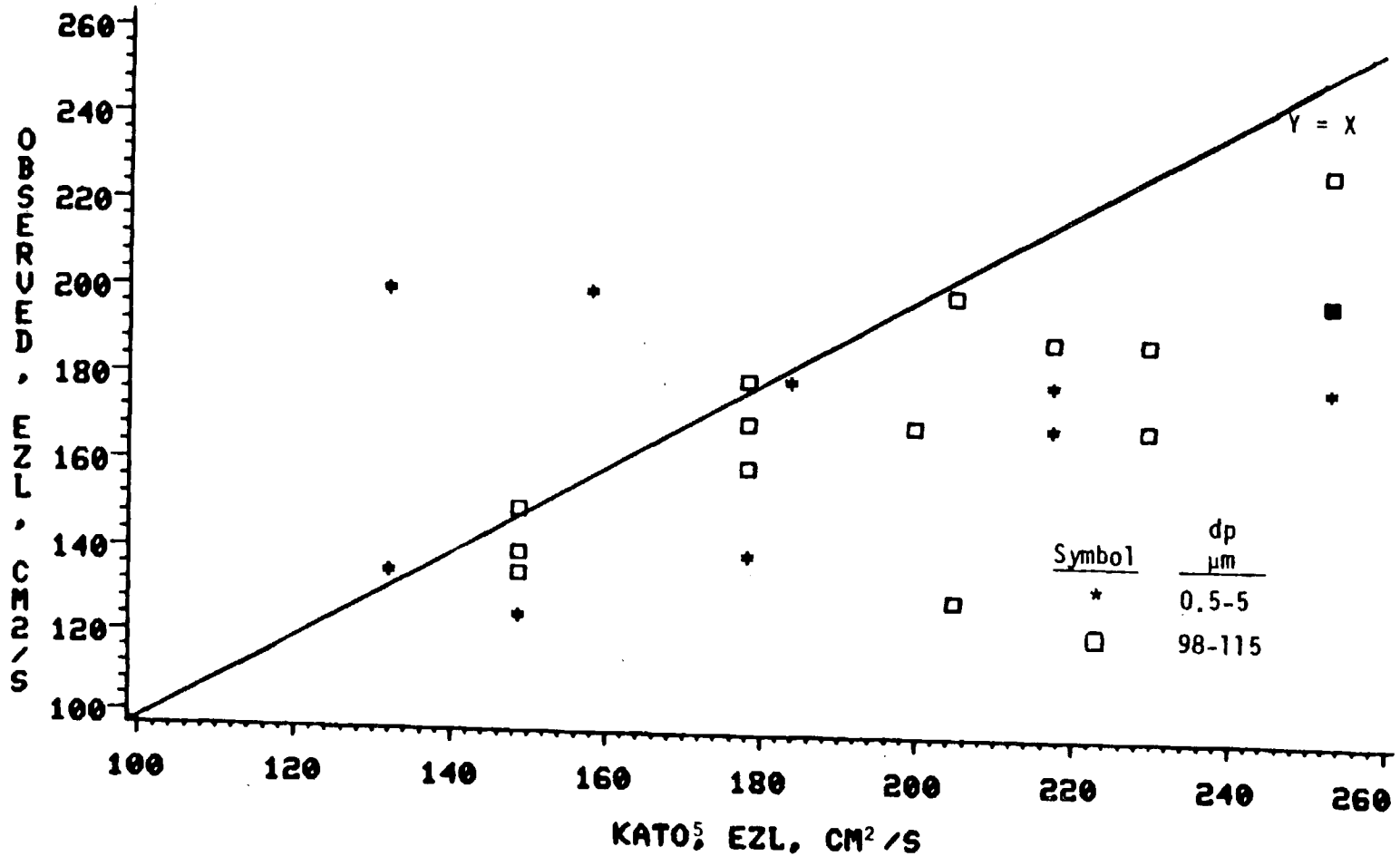


FIGURE 9

# 12 INCH COLD FLOW SIMULATOR

**PLAIN HEAT TRANSFER INTERNALS**
**ISOPARAFFIN, N2**

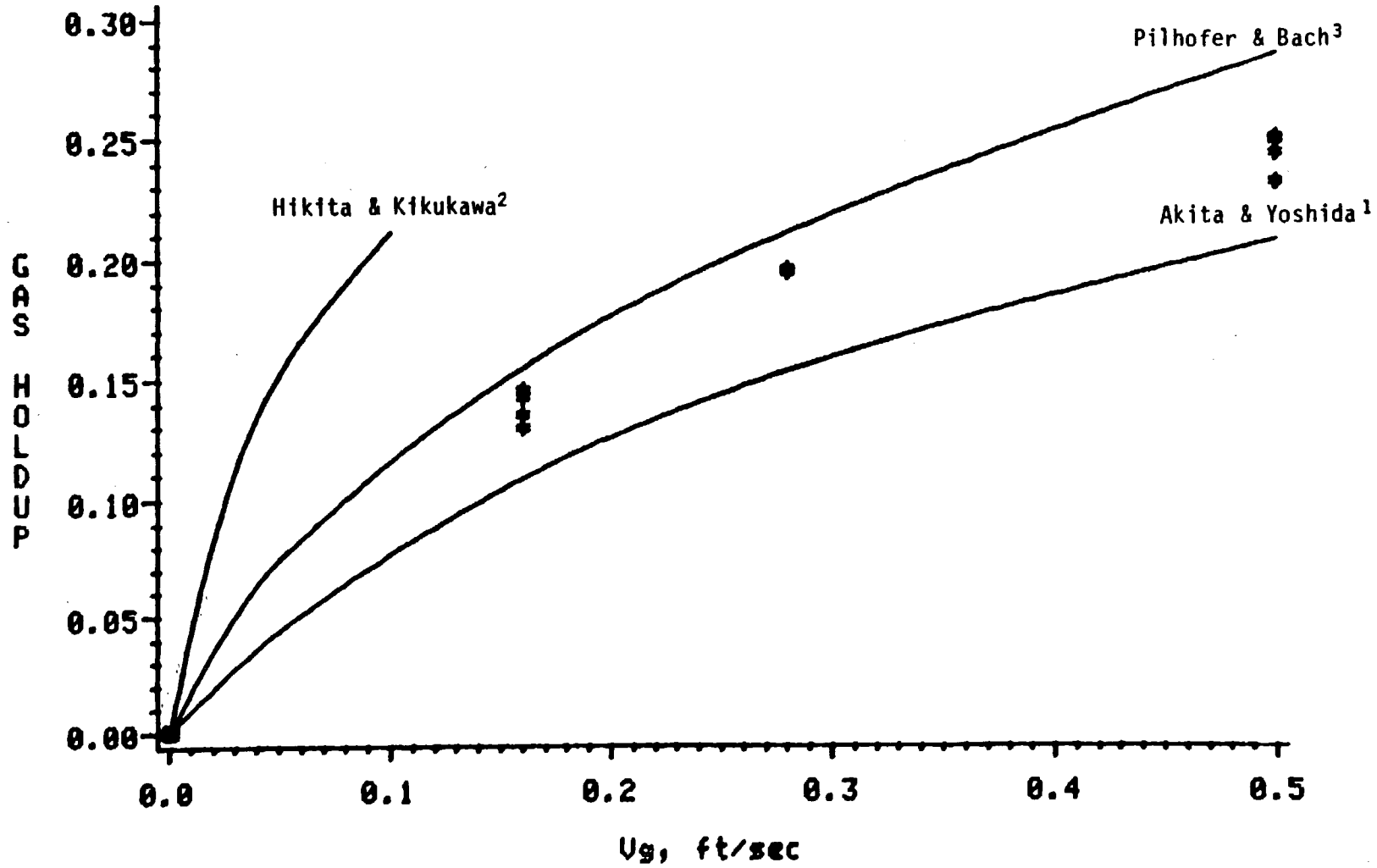


FIGURE 10

# 12 INCH COLD FLOW SIMULATOR

**PLAIN HEAT TRANSFER INTERNALS**
**WATER, AIR**

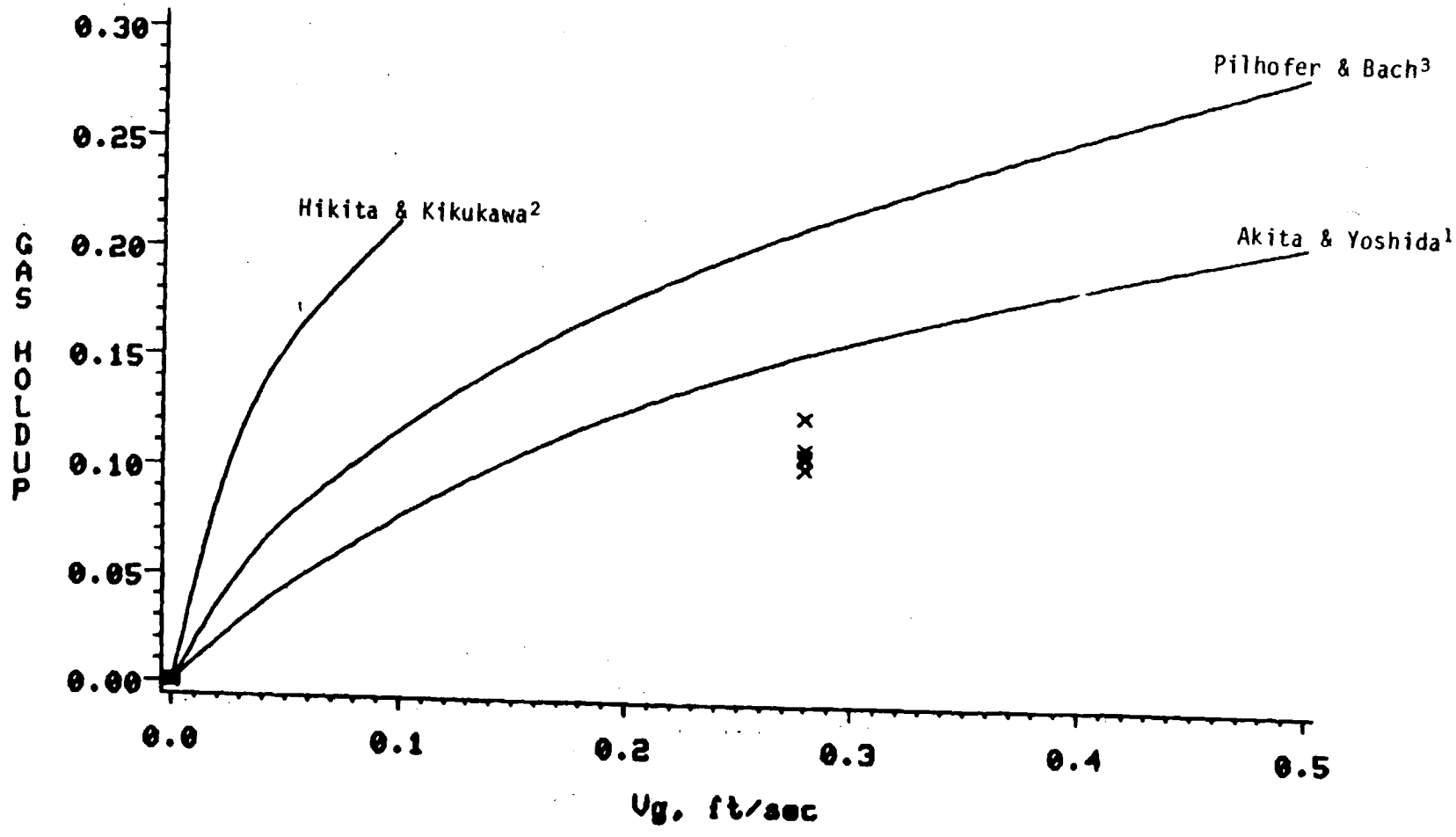


FIGURE 11

# 12 INCH COLD FLOW SIMULATOR

**PLAIN HEAT TRANSFER INTERNALS**
**ISOPARAFFIN,** IRON OXIDE

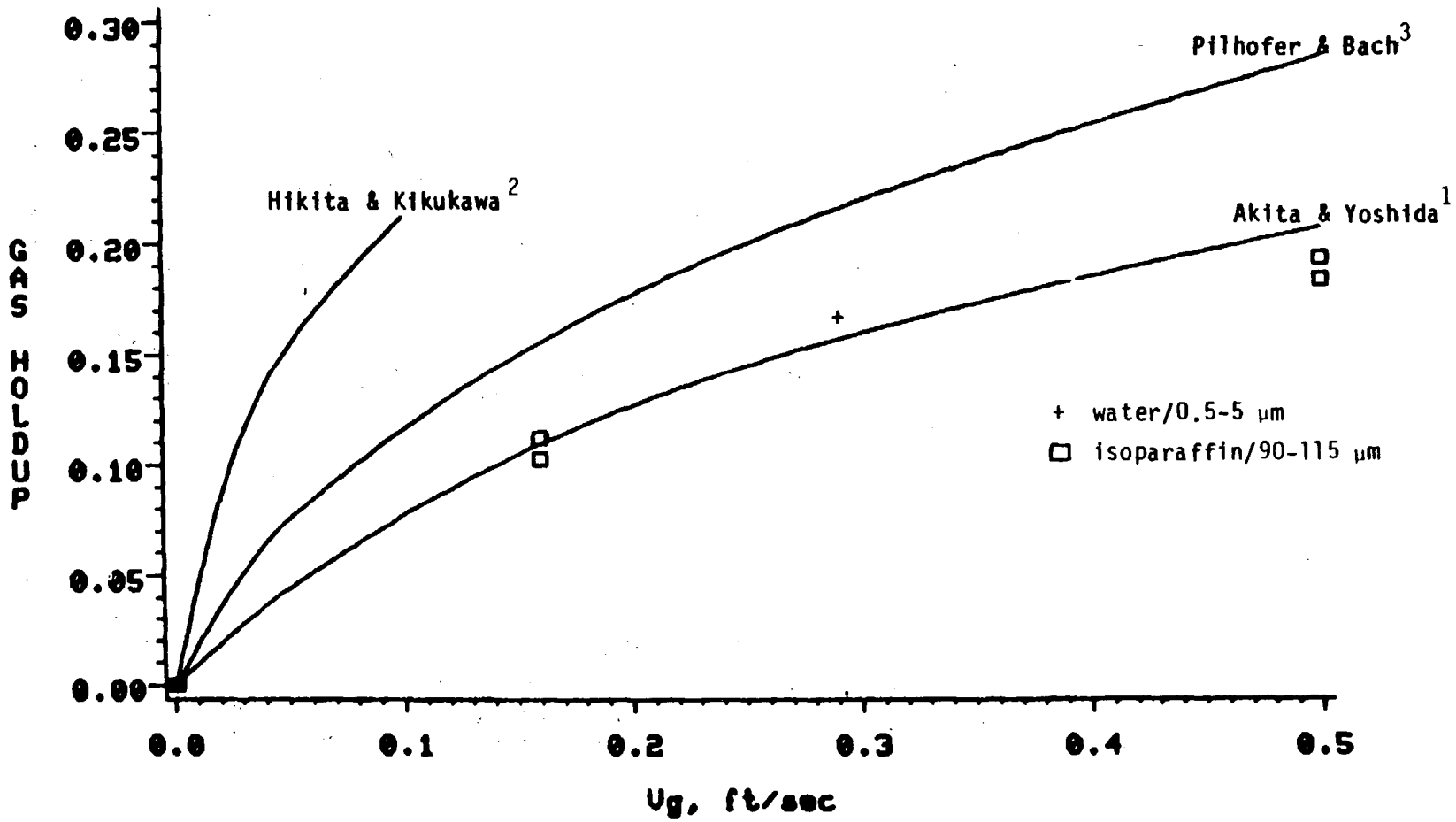


FIGURE 12

# 12 INCH COLD FLOW SIMULATOR

**PLAIN HEAT TRANSFER INTERNALS**
**WATER, SILICON OXIDE, AIR**

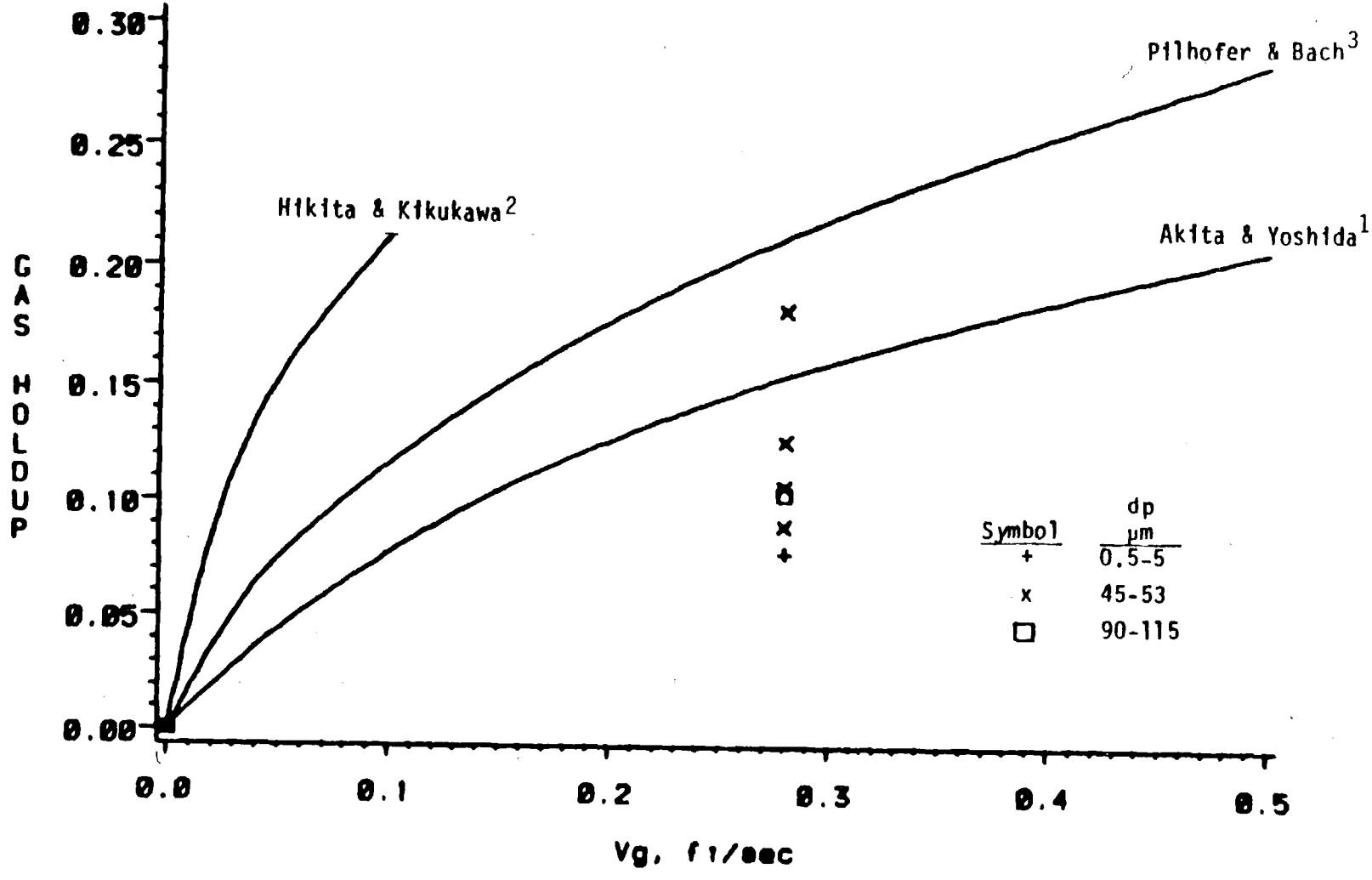
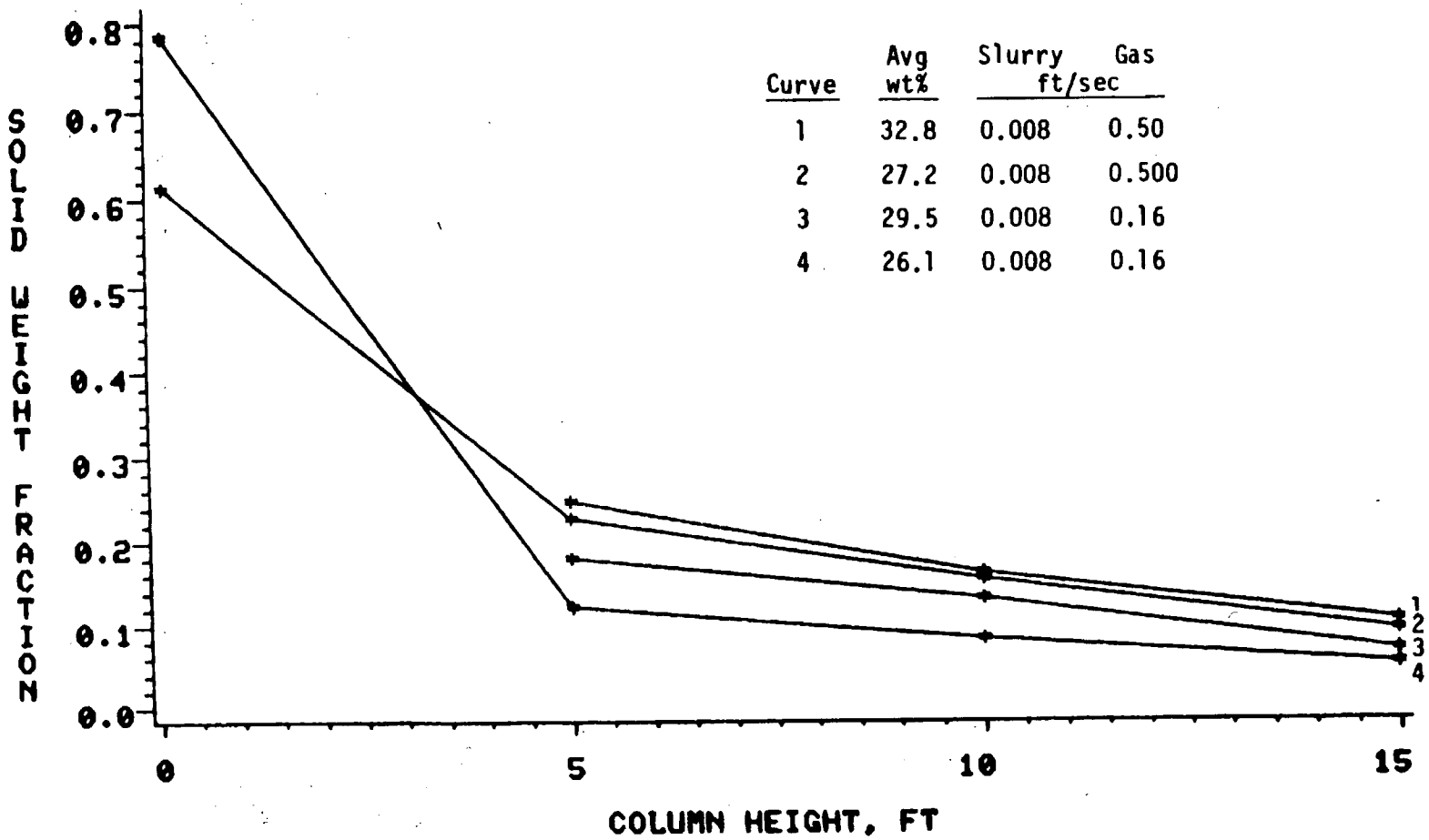


FIGURE 13

# 12 INCH COLD FLOW SIMULATOR

## SOLID CONCENTRATION PROFILES
## ISOPARAFFIN, 90–115 μM IRON OXIDE, N2




| Curve | Avg wt% | Slurry ft/sec | Gas ft/sec |
|---|---|---|---|
| 1 | 32.8 | 0.008 | 0.50 |
| 2 | 27.2 | 0.008 | 0.500 |
| 3 | 29.5 | 0.008 | 0.16 |
| 4 | 26.1 | 0.008 | 0.16 |

FIGURE 14

# 12 INCH COLD FLOW SIMULATOR

## SOLID CONCENTRATION PROFILES

WATER, SILICON OXIDE, AIR = 0.28 FT/SEC

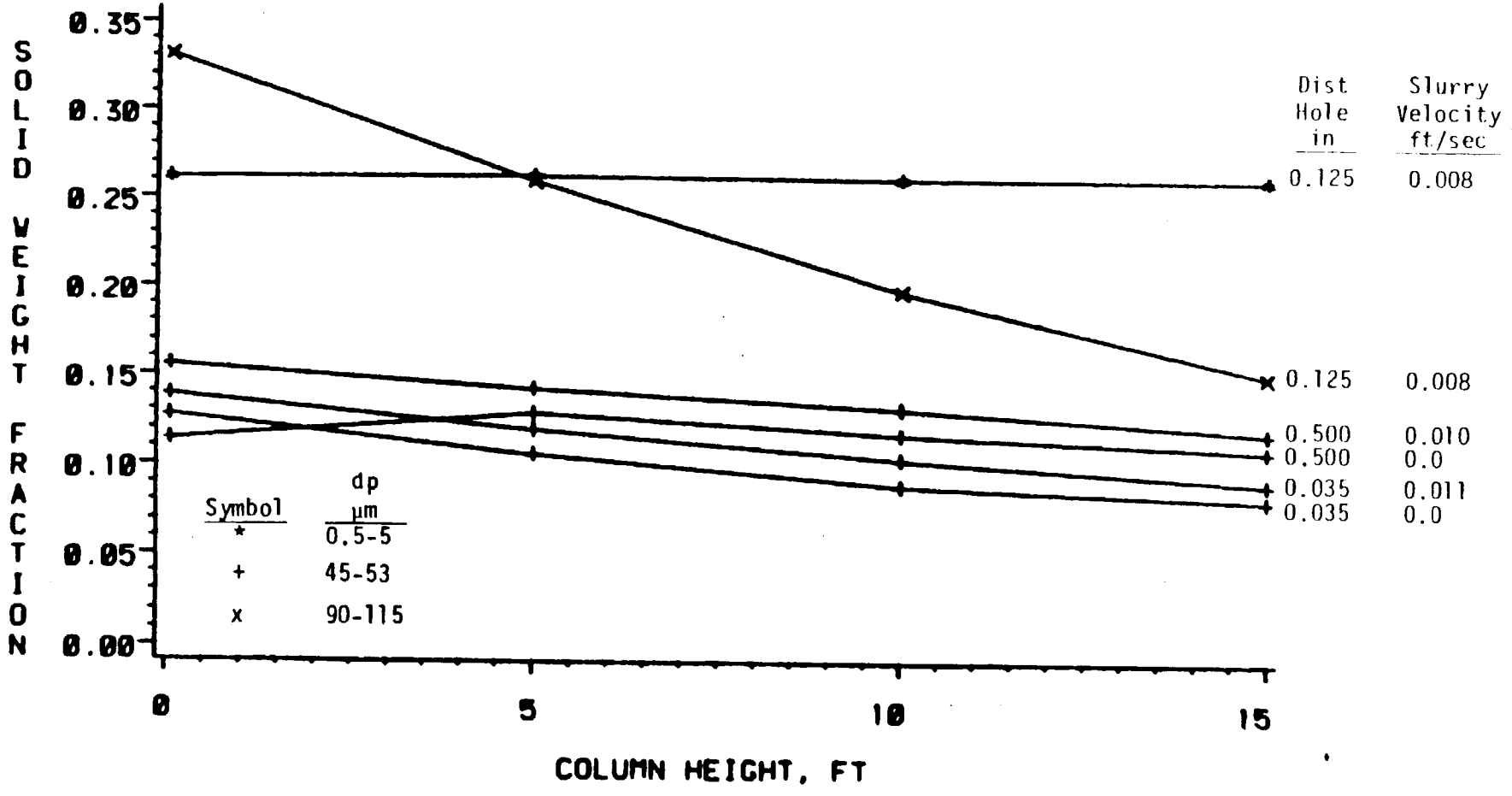


FIGURE 15

# HEAT TRANSFER COEFFICIENTS

**12 INCH COLD FLOW SIMULATOR**
**Plain Heat Transfer Internals**
**ISOPARAFFIN, IRON OXIDE, N2,** 90-106 μm

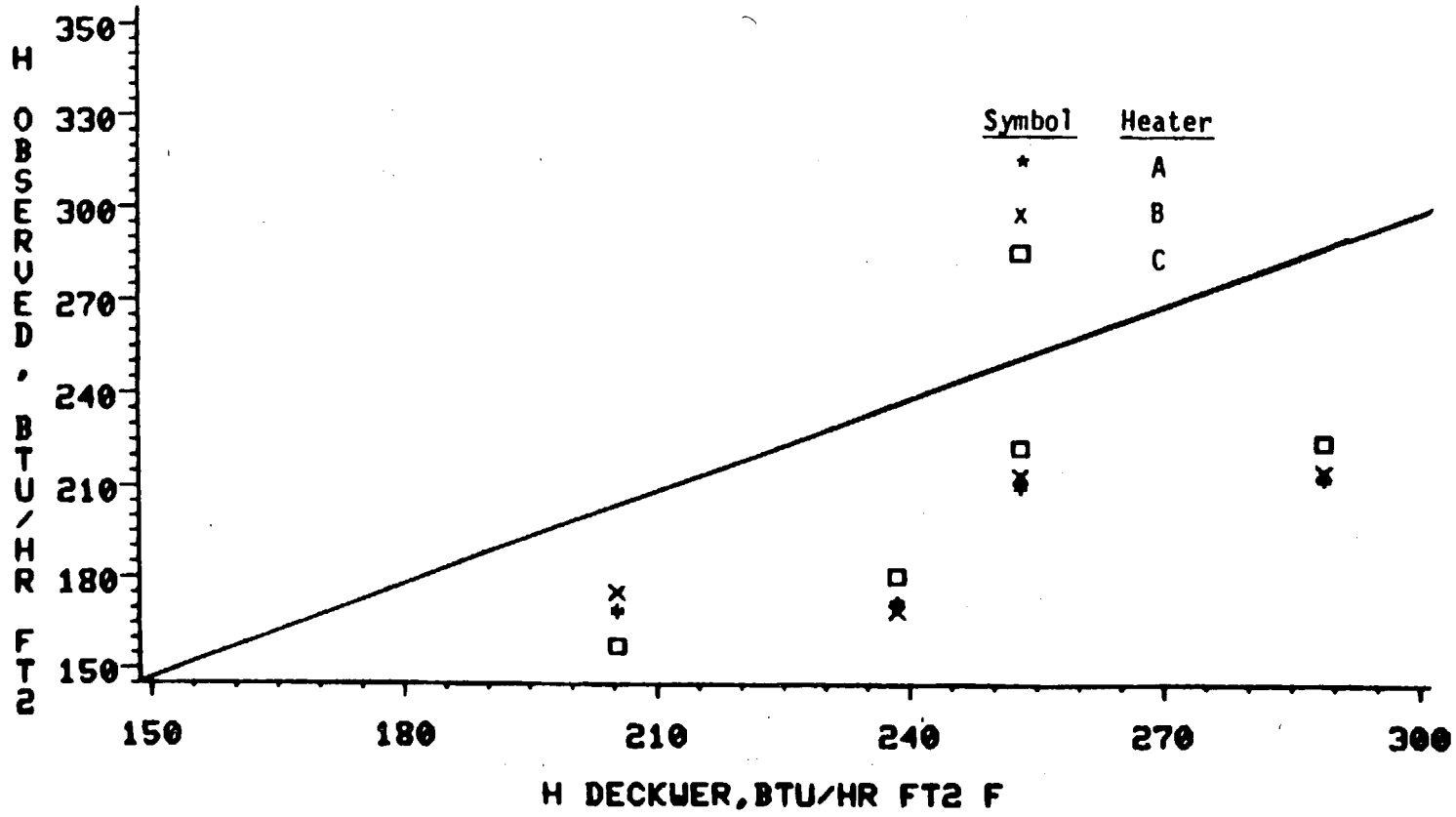


FIGURE 16

# HEAT TRANSFER COEFFICIENTS

**12 INCH COLD FLOW SIMULATOR**
**Plain Heat Transfer Internals**
**WATER.AIR**

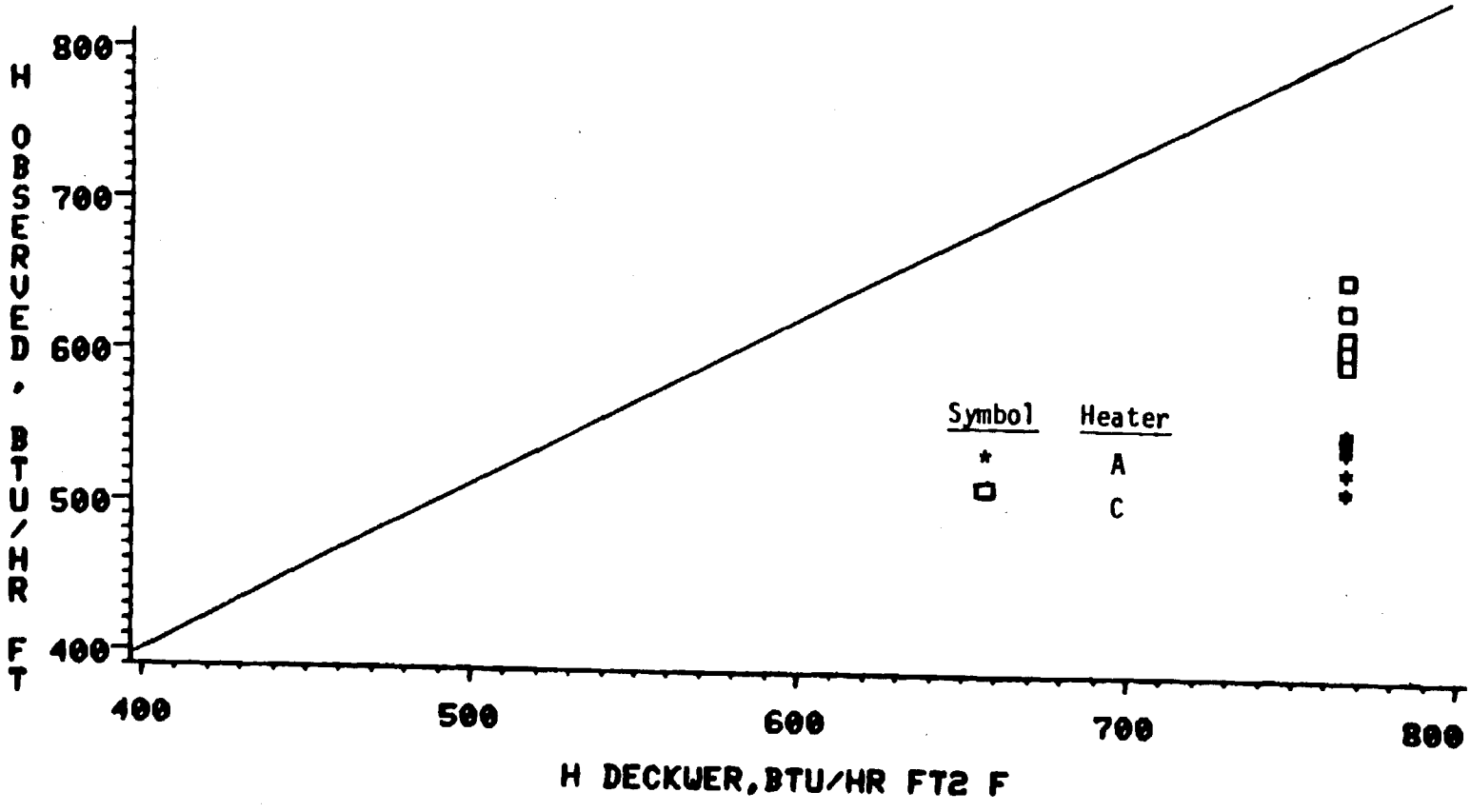


FIGURE 17

# HEAT TRANSFER COEFFICIENTS

**12 INCH COLD FLOW SIMULATOR**
**Plain Heat Transfer Internals**
**WATER, SILICON OXIDE, AIR**

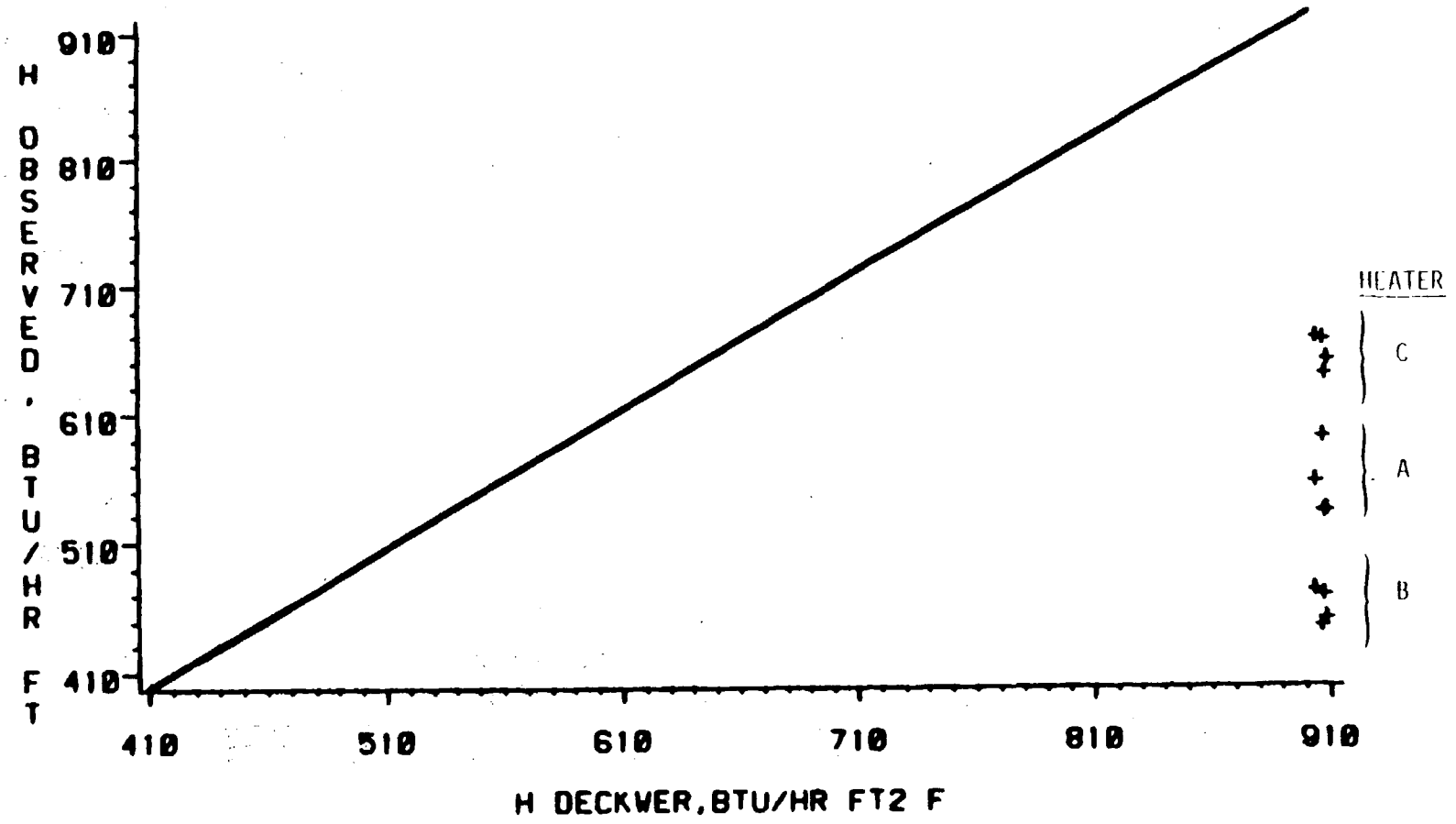


FIGURE 18

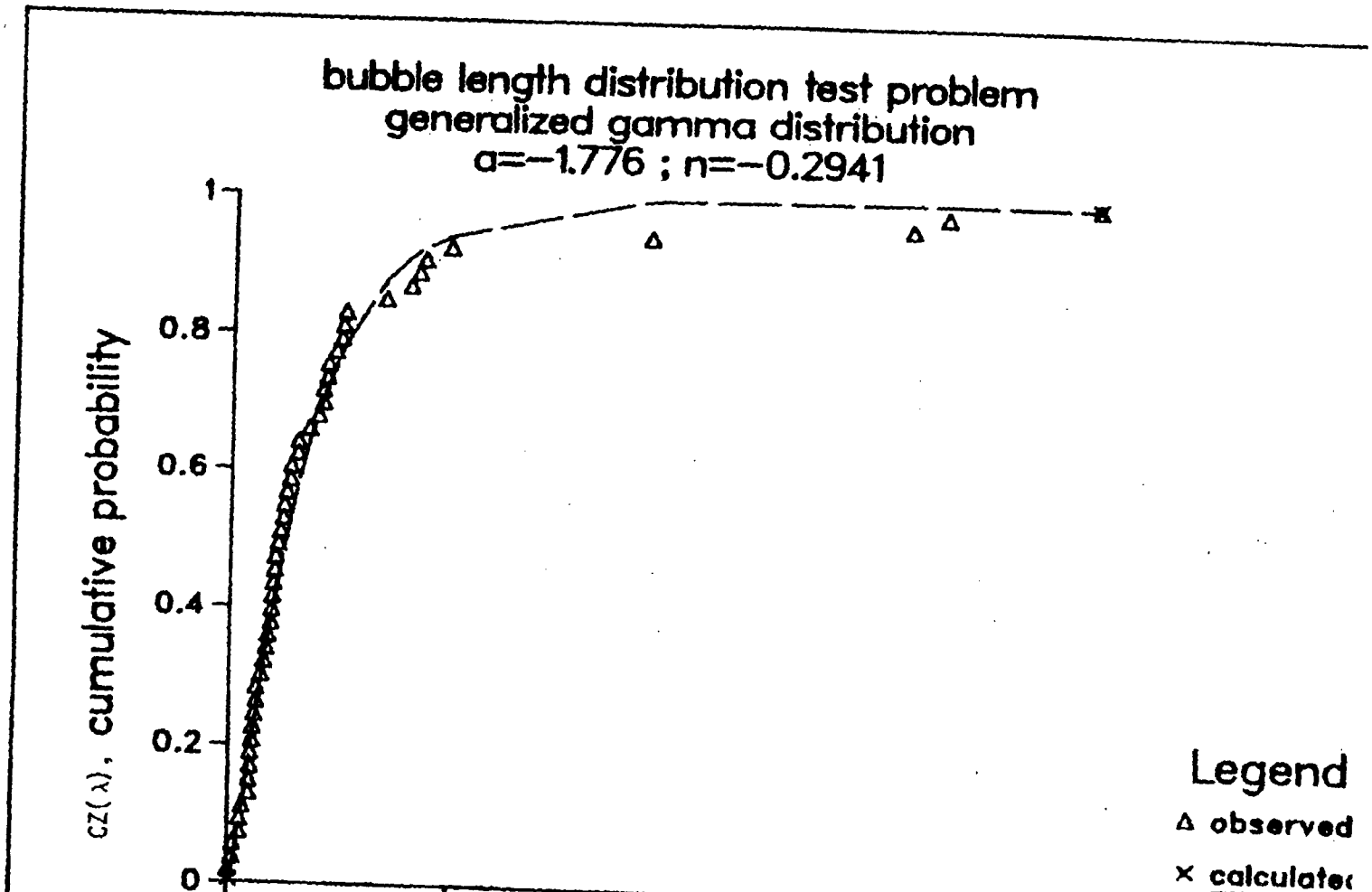
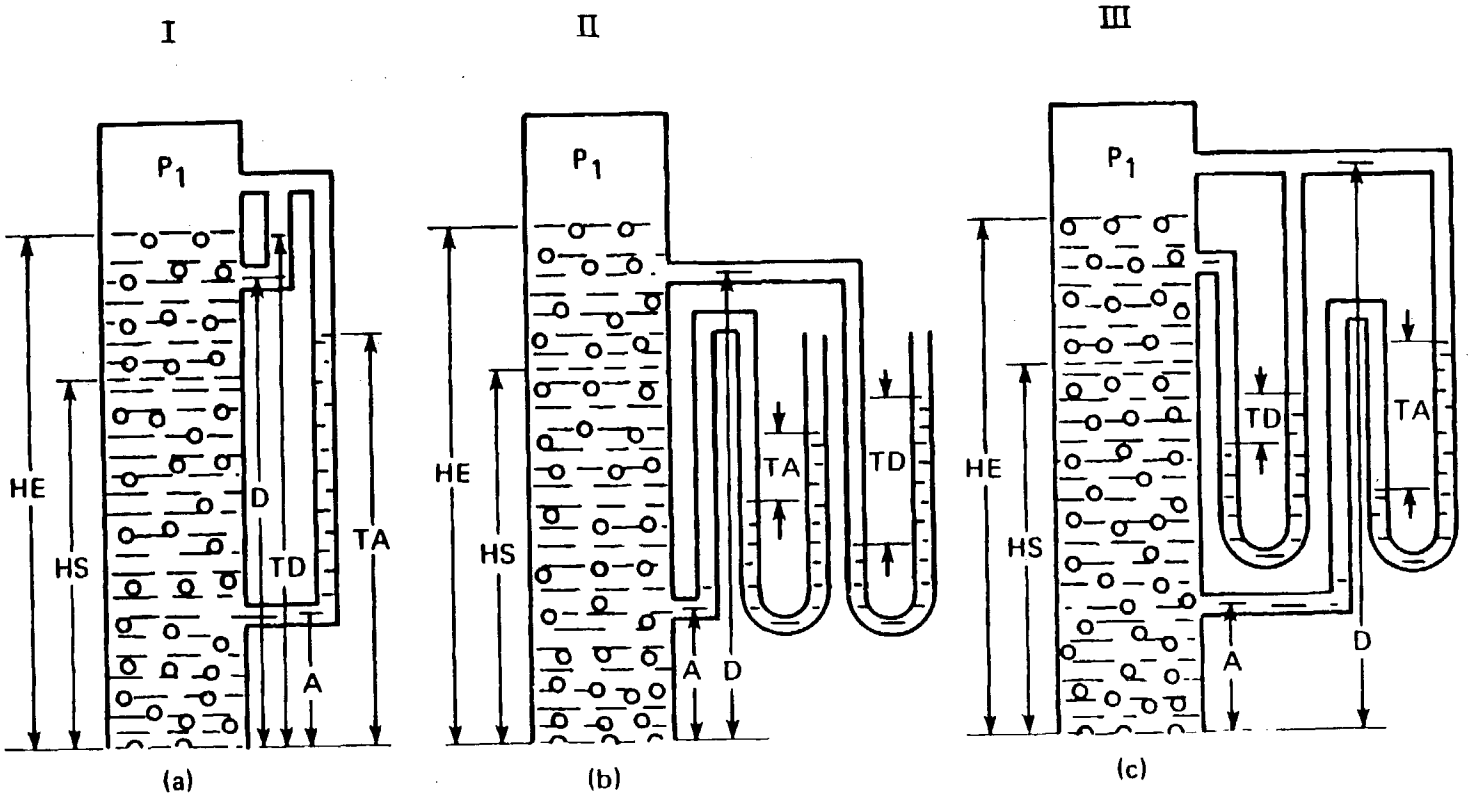

bubble length distribution test problem
generalized gamma distribution
a=−1.776 ; n=−0.2941
cz(λ), cumulative probability
1
0.8
0.6
0.4
0.2
0
Legend
Δ observed
× calculate

FIGURE 19
INTERMEDIATE GAS HOLD-UP METHODS




$$\epsilon_G = 1 - \frac{HS(TA - TD + (D - A))}{TA(D) - TD(A)} \qquad \epsilon_G = 1 - \frac{HS(1 - G)}{A - D(G)} \qquad \epsilon_G = 1 - \frac{HS(TA - TD)}{TA(D) - TD(A)}$$

WHERE

$$G = \frac{g(TA)\rho_{Hg} - P_1}{g(TD)\rho_{Hg} - P_1}$$



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