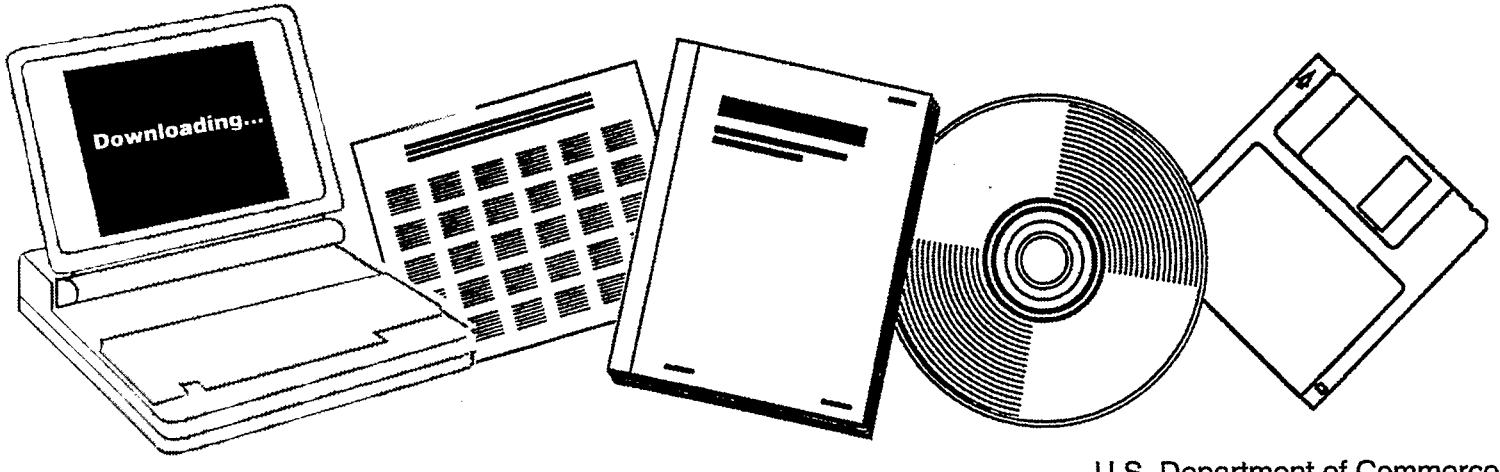
GAS/SLURRY FLOW IN COAL LIQUEFACTION PROCESSES (FLUID DYNAMICS IN 3-PHASE FLOW COLUMNS). QUARTERLY TECHNICAL PROGRESS REPORT, 1 OCTOBER-31 DECEMBER 1980

AIR PRODUCTS AND CHEMICALS, INC.
ALLENTOWN, PA

FEB 1981



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GAS/SLURRY FLOW IN COAL LIQUEFACTION PROCESSES
(Fluid Dynamics in 3-Phase Flow Columns)

Quarterly Technical Progress Report
For Period 1 October-31 December 1980

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Summary

This is the fifth quarterly report under Contract Number DE-AC22-79ET14801 titled, "Gas/Slurry Flow in Coal Liquefaction Processes". This work covers the period 1 October 1980 to 31 December 1980. This work is a continuation of studies initiated by Air Products and Chemicals, Inc., on the fluid dynamics of 3-phase flow to support the design of the 6000 T/D dissolver for the SRC-I demonstration plant which began in July 1978. DOE supported these 3-phase flow studies under the Bridging Task program from 1 July 1979 to 30 September 1979 at the start of the current contract. A background of information developed at Air Products prior to DOE support was included in the first quarterly report.

The 6000 T/D SRC-I demonstration plant will employ vertical tubular reactors feeding slurry and gas concurrently upward through these vessels. In the SRC-I design this reactor is essentially an empty vessel with only a distributor plate located near the inlet. Because the commercial plant represents a considerable scale-up over either Wilsonville or Ft. Lewis, this program is addressing the need for additional data on behavior of three-phase systems in large vessels. Parameters being investigated in this program are being studied at conditions that relate directly to the projected demonstration plant operating conditions. Air/water/sand 3-phase flow system in both a 5-inch diameter and a 12-inch diameter column is used in this cold-flow simulation study program.

During this quarter, the photographic technique developed earlier was applied using distributor number 1 in place. The results indicate that the fraction of gas holdup occupied by large bubbles increases with increasing gas velocity but is independent of liquid flow rate. The distributor configuration does not affect the size distribution of bubbles.

Although, a complete analysis of the entrance effects is not complete, apparently the type of distributor used does not seem to affect the solids distribution profiles. The amount of solids retained in the

column increases linearly with decreasing slurry velocity while changes in linear gas velocity does not affect the solids distribution profiles for the conditions studied in this program (liquid velocity ranging from 0.01 to 0.05 ft/sec and gas velocity ranging from 0.05 to 0.43 ft/sec).

The data clearly indicate that withdrawing solids from the bottom of the column results in a decreased amount of solids in the column and the solids concentration profile changes accordingly. The solids removal results also show that large particles were perferentially removed by virtue of their faster settling rate.

A set of experiments were conducted to investigate the effects of settled particles and particle-particle interaction on solids accumulation. The results indicate that the presence of large particles does not influence the accumulation or distribution of fine particles.

The column enclosure was completed and several screening tests were made to identify the organic liquid/liquid to be used in the 12-inch diameter column. Two liquids will be selected from these and in the next quarter Task 5 will be started.

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1.0 OBJECTIVE

The overall objective of this project is to study the solids accumulation and suspension of various gas/liquid/solid systems in cold-flow tubular columns aimed at providing data for the coal dissolver design in the SRC-I demonstration plant.

The specific objectives are:

1. To check the adequacy of the existing experimental apparatus using a two-phase system (air/water mixture).
2. To study the effects of slurry and gas velocities, solid particle size and concentrations, and liquid viscosity and surface tension on the performance of a cold-flow tubular column.
3. To develop an effective slurry withdrawal technique from the bottom of a tubular column as a means to control the solid concentration in the column.
4. To study the performance of cold-flow tubular column with an improved distributor and in the absence of a distributor.
5. To explore the use of multiple distributors in a tubular column.

2.0 INTRODUCTION

A major element of the coal dissolution section of any liquefaction plant is the dissolver. Although a considerable amount of liquefaction will occur in the preheater, a major amount of necessary chemical change will occur in the dissolver, namely sulfur removal, oil and distillate formation and solvent rehydrogenation.

Vertical tubular reactors are employed in all of the major processes currently under consideration for commercial liquefaction of coal. In all of these processes, SRC, EDS and H-Coal, slurry and gas are concurrently fed upward through these vessels.

In the EDS and SRC processes, the reactors are essentially empty vessels, whereas the H-Coal process a bed of ebullating catalyst is maintained in the reactor. The major differences between the EDS, SRC-I and SRC-II processes in dissolver operation are the composition of the feed streams and reactants within the dissolver. Other hardware differences such as distributor plates, draft tubes or recycle loops can also cause differences in the behavior of slurries in these vessels. A requirement necessary to any design that will be technically feasible and cost effective is an understanding of the physical behavior of three phase systems in tubular columns.

All of the major processes under development require understanding of backmixed three phase systems. Each process employs at least a portion of its dissolver volume in a backmixed mode. As the design of the 6000 T/D SRC-I plant progresses, the increased vessel size (and other considerations) may indicate the use of reactors in series, which would decrease the overall backmixed characteristic of the commerical plant.

The SRC-I demonstration plant dissolver will represent a considerable scale-up over the Wilsonville and Ft. Lewis dissolvers. To intelligently make good design decisions, more information is needed on the flow properties of three phase systems in large vessels. More important from the standpoint of slurry behavior is the difference in gas and liquid superficial velocities. This difference can have considerable impact on the process because the gas and liquid superficial velocities have a strong effect on (a) gas void volume (b) actual solids concentration in the dissolver and (c) the relative degree of back-mixing. As velocity through the dissolver increases, the tendency of solids to remain behind diminishes causing a decrease in the actual concentration of ash particles in the reactor. Those particles that do remain will tend to be larger in size. Since considerable evidence points to a definite catalytic effect of the reactor solids, these larger particles will have decreased

surface areas exposed and will likely have diminished catalytic activity. Knowing the particle sizes that can accumulate under commercial flow conditions will give us some indication of size of dissolver solids that should be examined for catalytic activity.

Considerable work on the behavior of gas/liquid mixtures flowing through vertical columns has been reported in the literature. Information on three phase (gas/liquid/solid) systems is far less extensive. Detailed background information was presented in the first quarterly report (1). Under this contract, work is being conducted in a 5-inch diameter by 5-foot tall Plexiglas column and a 12-inch diameter by 25-foot tall glass column which is located at the contractor's site. The physical dimensions, auxiliary equipment, and some of the experimental techniques employed in this study were extensively discussed in the first quarterly report. This report contains experimental results from runs conducted during this reporting period (1 October-31 December 1980).

3.0 TECHNICAL PROGRESS

3.1 Task 3 - Effect of Distributor on Flow

The objectives of this task are:

- To study the entrance effects on the performance of the 12-inch column.
- To study the performance of the column in the absence of a distributor.
- To design, fabricate and install a new distributor and to compare the performance of the different distributors.

Most of the work on this task was completed during last quarter and were reported in the previous quarterly report (1). In this quarter, analysis of the experimental results were completed and are presented in the results and discussion section.

3.2. Task 4 - Solids Removal Study

The objective of this task is to test the effectiveness of slurry withdrawal from the column bottom as a means to control solids accumulation. During this quarter experiments were conducted in the 5-inch and 12-inch diameter columns to study the effect of solids removal on the axial solids distribution. Since only one month was allotted for this task in the original proposal, only a few preliminary experiments were carried out during this quarter.

3.3 Task 5 - Organic Fluid Phases

The objective of this task is to study the effects of fluid properties (such as viscosity and surface tension) on gas holdup, liquid dispersion and solids distribution. During this quarter the enclosure of the 12-inch diameter glass column was designed and constructed. A list of the chemical solutions to be used in the screening tests were prepared and submitted to DOE. During this quarter some screening tests were conducted in the 5-inch column to select the organic liquid to be used in Task 5.

4.0 EXPERIMENTAL SECTION

4.1 Cold Flow Model Equipment

Both the 5-inch diameter and 12-inch diameter column used in these cold flow studies were described in detail in the first quarterly report (2). The distributors used in the 12-inch column were described in detail in the last quarterly report (1). A walk-in hood was constructed during this quarter to house the 5-inch diameter column for performing screening experiments with organic liquids. The entire 12-inch column was enclosed to provide safe handling of volatile and flammable organic liquids. The existing feed tanks were modified to handle organic liquids.

4.2. Experimental Procedures

Several experimental procedures are normally used in this program depending on the type of experimental run. In this section, a brief description of the experimental procedures for the runs conducted in this quarter are presented.

4.2.1 Photographic Method

In order to get a qualitative understanding of the bubble sizes that exist in the column, a photographic method was used. A discussion of the reasoning behind the method is presented in the experimental discussion section. Only a description of the experimental procedure is presented here.

The experimental procedure was similar to the one used to measure gas holdup. Both liquid and gas were allowed to flow through the column at predetermined flow rates. After waiting for a period of ten minutes to establish steady state, a common valve at the bottom of the column was closed stopping both liquid and gas flow simultaneously. The aerated liquid level dropped as the gas phase leaves the system. This change of aerated liquid level as a function of time was recorded photographically at every one-second interval. This procedure was repeated for various liquid and gas flow rates. A total of 5 experiments were conducted in the last quarter with distributor No. 2 in the column. In this quarter, four experiments were conducted with distributor No. 1 in the column.

4.2.2 Solids Distribution

The effect of liquid and gas velocites on the axial distribution of 60/80 mesh sand particles were studied in the 12-inch column using distributor No. 1 in place. All experiments were conducted in a recycle mode which was described in the second quarterly

report (3). Briefly, the exit from the column was returned to the feed tank thereby creating a closed loop. The recycle loop was allowed to operate for several hours in order to achieve steady state. Solid concentration profiles were measured from slurry samples withdrawn from sampling ports located along the axis of the column.

4.2.3 Solids Removal

The procedure for solids removal experiments were similar to solids distribution experiments with minor modifications. Slurry and gas were allowed to flow through the column in a recycle loop for several hours to achieve steady state. Samples along the column were taken to obtain steady state solids concentration profiles. Then the lowest sample port in the column (just above the distributor plate) was opened and the slurry was allowed to flow into a storage tank while maintaining the slurry and gas flow into the colum. Simultaneously the recycle mode of operation was changed to once-through mode. However, in a once through mode of operation, the length of the experimental run is limited by the slurry inventory in the holding tanks. Most of the experiments were terminated fifteen minutes after the lowest sampling port was opened. In this short duration multiple sets of samples were taken along the axis of the column in order to measure changes in the solids distribution profile.

4.2.4 Particle-Particle Interaction Experiments

A special project consisting of a set of experiments were undertaken during this quarter to investigate the effects of settled particles and particle-particle interaction on solids accumulation in the 12-inch diameter colum. The project consisted of three consecutive experiments in the 12-inch diameter column using various sizes of particles (140 mesh minus, 60/80 mesh, and 20/30 mesh). A slurry containing 140 mesh minus particle

and water was prepared in the feed tank. This fine particle slurry recycled through the column at liquid velocity of 0.05 ft/sec with gas flowing at a velocity of 0.33 ft/sec. Steady state solid concentration profile was obtained by taking samples along the column. At the end of the run, a known quantity of 60/80 mesh sand was added to the feed tanks and the new slurry was recycled through the column at the same operating conditions. Samples were withdrawn from the sampling ports until a new equilibrium state was reached. In these samples, in addition to determining the total solids concentration, the concentration of different particle sizes were also determined. At the completion of this part of the experiment, a known amount of 20/30 mesh particles was added to the column to simulate the presence of settled particles. The slurry was allowed to flow through the column at identical operating conditions. Again, solid concentration of different size particles as well as the total solids concentration were measured for each sample withdrawn from the column. At the end of the experiment, the column was drained and the weight of the sand retained in the column was determined.

4.2.5 Screening Experiments

As part of Task 5, screening experiments were conducted using the 5-inch diameter column to identify the organic liquid/ liquids to be used in the 12-inch diameter column. These experiments consist of measuring liquid holdup at various gas flow rates and identifying the foaming characteristics of the fluid to be used. Attempts were also made to use defoaming agents to decrease the formation of foam.

5.0 RESULTS AND DISCUSSION

5.1 Gas Bubble Size Distribution

A photographic method was developed to identify the fraction of gas void volume occupied by large gas bubbles. Results presented earlier indicate that gas holdup is independent of the type of distributor used. Since gas holdup is related to gas bubble rise velocity which in general increases with increasing gas bubble size, the objective is to investigate the distribution of the large and small gas bubbles resulted from different distributors to further understand the gas holdup dependence.

A detailed description of the photographic method was given in the section on experimental procedure. In brief, the gas void volume is measured from the drop in the liquid level every second after the liquid and gas flows had been shut off.

Data were taken at various liquid and gas velocities. These experiments were conducted with both distributors. Experiments using distributor No. 2 were conducted during the last quarter and results were presented in the last quarterly report (1). During this quarter experiments were conducted with distributor No. 1. In interpreting these data we assumed that the large bubbles will rise faster than the smaller bubbles. A limitation of this photographic method is that it cannot give any quantitative measurements of bubble size. However, one can characterize the bubble population in the column into two distinct groups: 1) a group of bubbles of about the same size rising in the column with a constant velocity and 2) a group of bubbles of various sizes, but larger than those belonging to the prior group, rising at a faster rate. Visual observations indicated that the initial drop in liquid level (after the gas and liquid flows had been shut off) is fast and the liquid surface is wavy. After approximately 10 seconds the liquid surface becomes

calm as the rate diminishes. These two different rates and the fraction of large bubbles present in the column were examined at various flow conditions.

The results show that the fraction of large bubbles increases with gas velocity. This finding agrees with the earlier observation when distributor No. 2 was used. This agreement suggests that the bubble size distribution is practically independent of the distributor design. Increasing gas velocity from 0.25 to 0.43 ft/sec results in an increase of the fraction of large bubbles from 31% to 43% as shown in Figures 1 through 3. However, an increase in liquid velocity from .03 ft/sec to .05 ft/sec at constant gas velocity did not change the size distribution (Figures 2 and 4). In addition a comparison of Figures 1 through 3 indicates that the average size of the smaller bubbles (a group of bubbles of about uniform size) is independent of gas velocity even though the fraction of the large bubble in the column increase with gas velocity. When these curves (Figures 1, 2 and 3) are superimposed on each other, one sees that they are parallel to each other suggesting that their slopes are the same. (Similar results were observed when distributor No. 1 was used). Since the slope of these lines correspond to average velocity of the small bubbles, this finding means that the small bubble rise velocities are independent of gas velocity.

5.2 Axial Solids Distribution

Several experiments were made during this quarter using 60/80 mesh sand to study the effect of liquid and gas velocities on the axial solids distribution in the 12-inch diameter column with distributor No. 1 in place. Experiments using different distributor configurations and different particle sizes have been conducted in the past. The analysis of the entrance effects on solids distribution is not yet completed. Hence, a discussion of the entrance effects on axial solids distribution will be deferred

FIGURE 1. RATE OF THE AERATED LIQUID LEVEL DROP

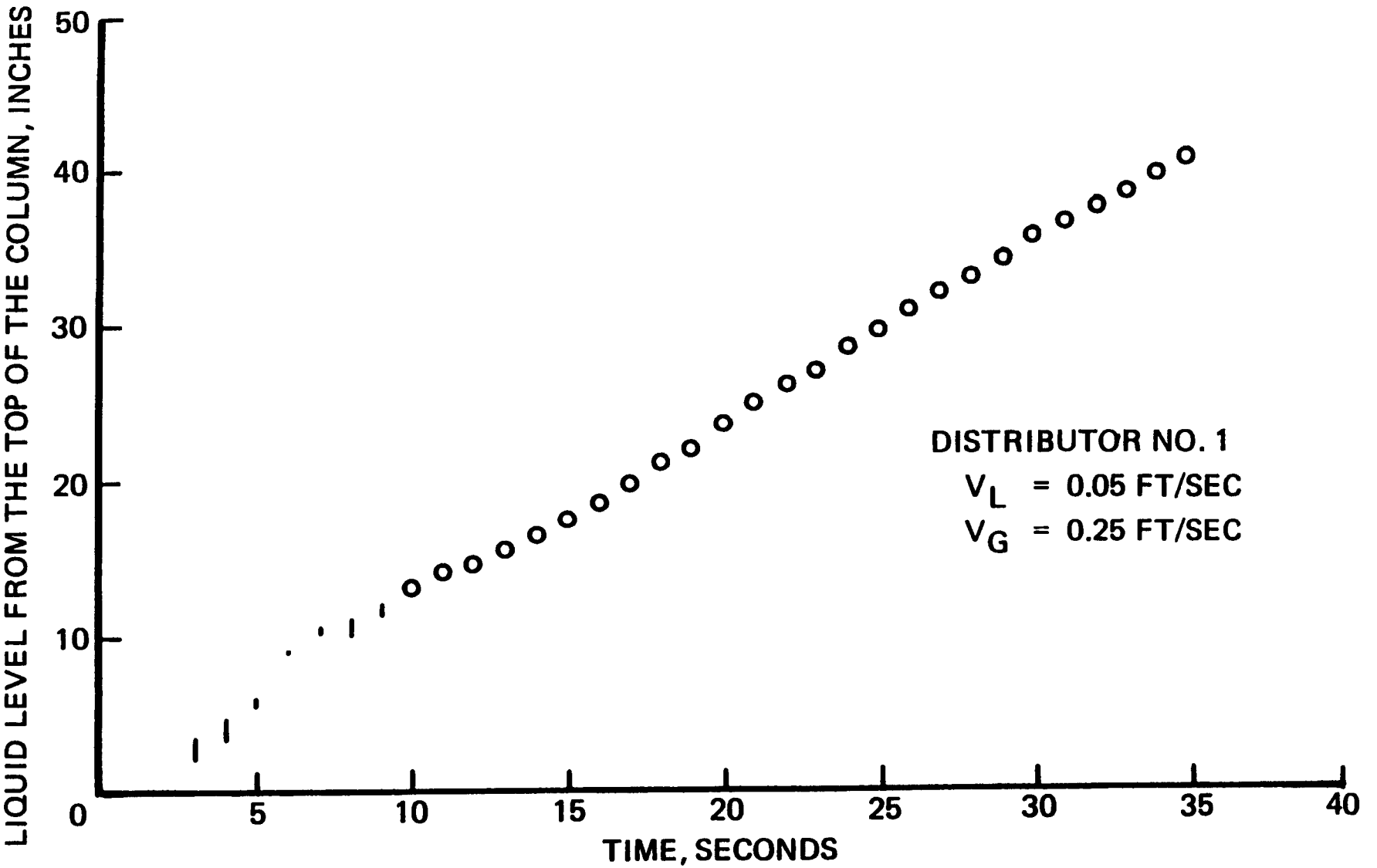


FIGURE 2. RATE OF THE AERATED LIQUID LEVEL DROP

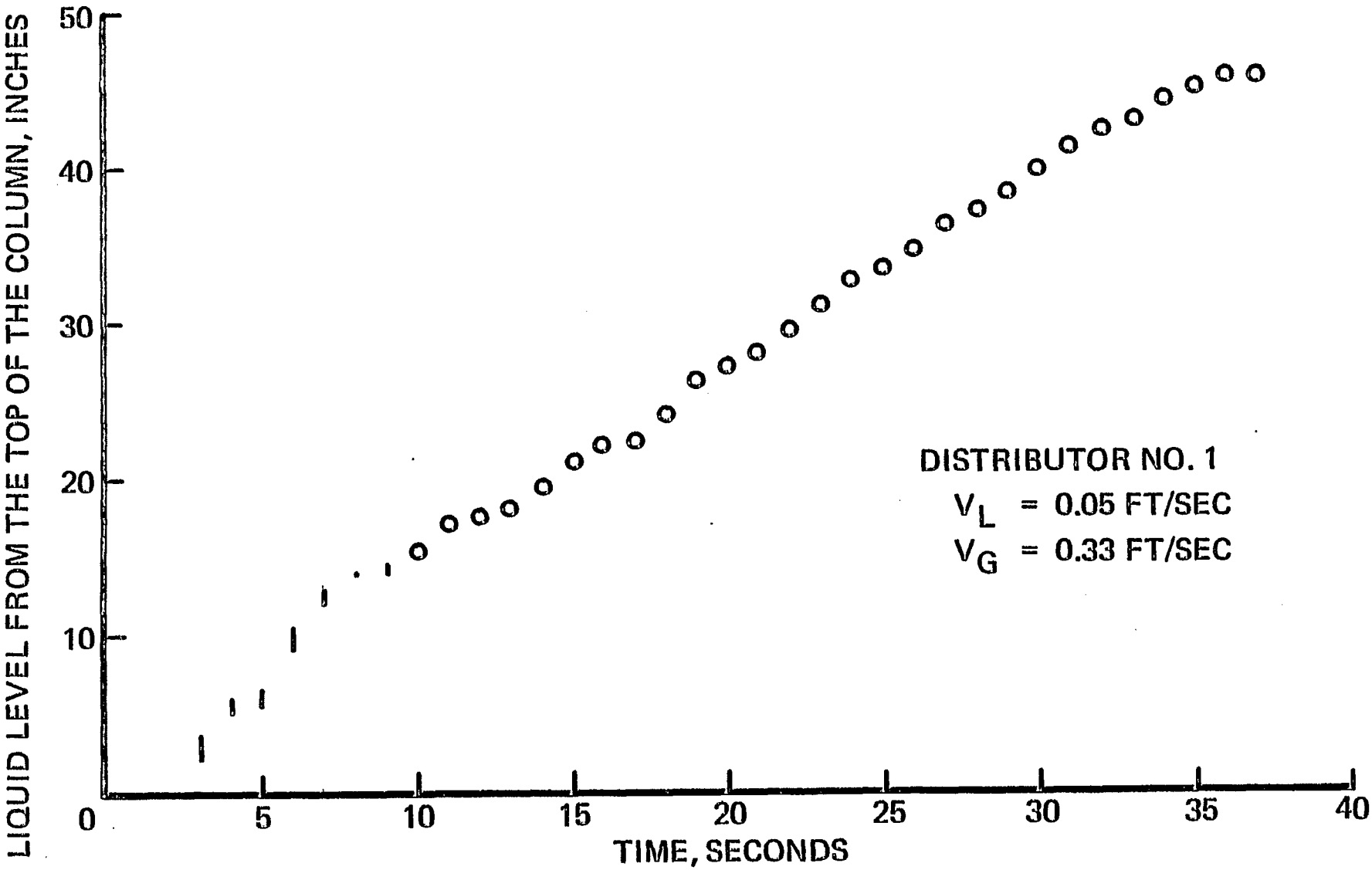


FIGURE 3. RATE OF THE AERATED LIQUID LEVEL DROP

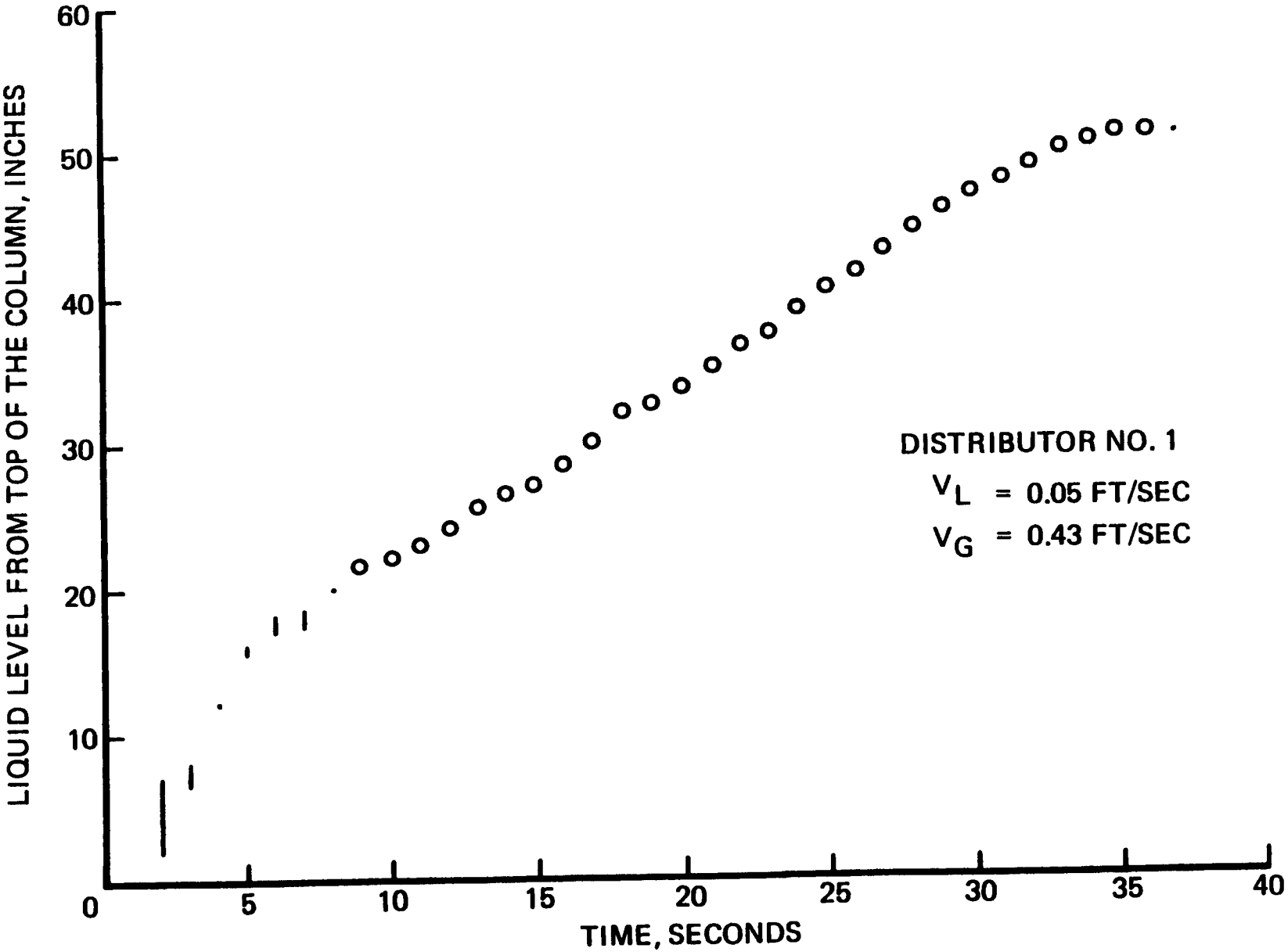
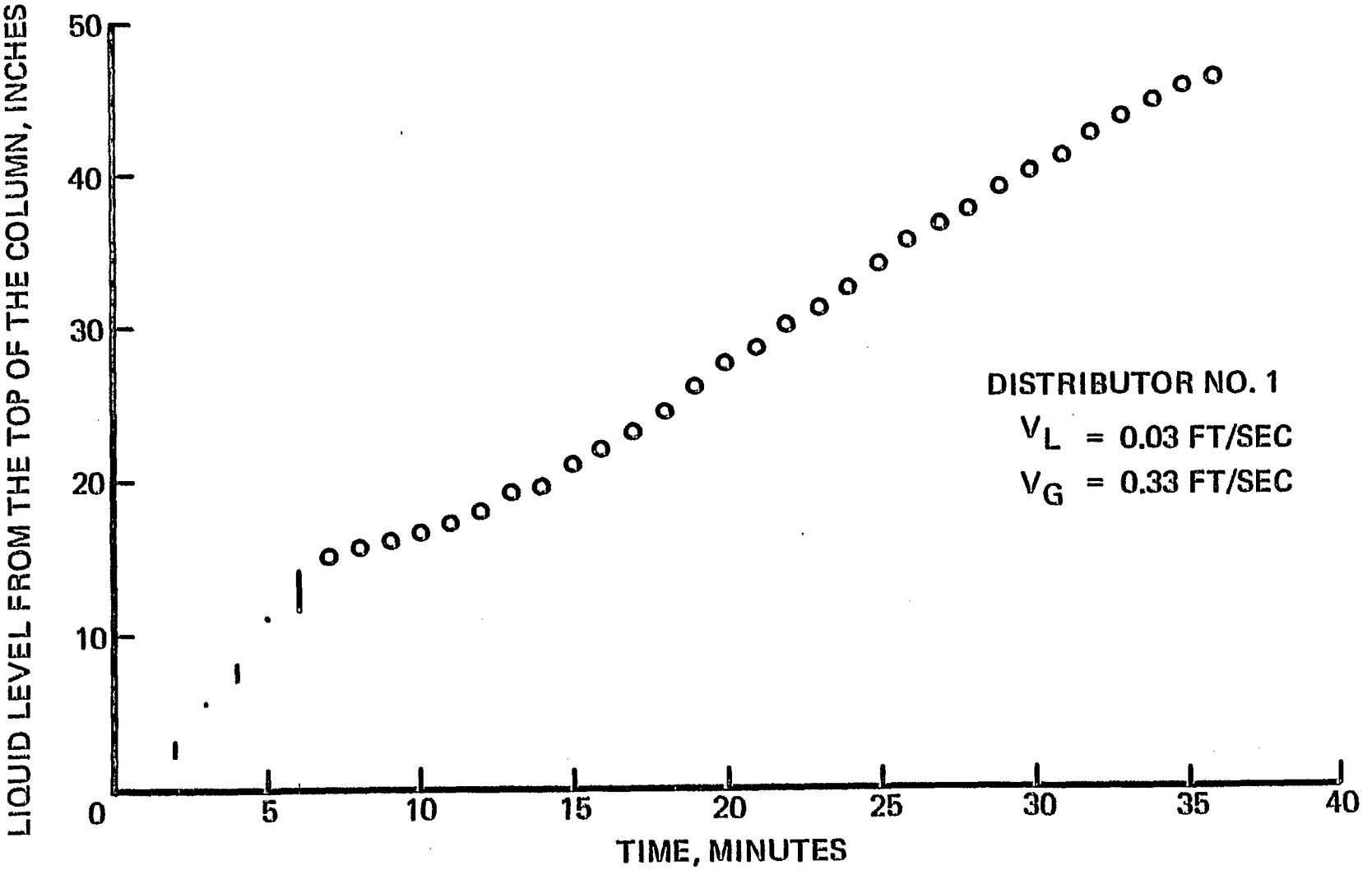


FIGURE 4. RATE OF THE AERATED LIQUID LEVEL DROP



until the next quarterly report. A discussion of results from the experimental runs conducted in this quarter will be presented here.

Gas velocity does not have an effect on the axial solids distribution in the column as shown in Figure 5. Varying gas velocity from 0.15 to 0.43 ft/sec resulted in almost identical concentration profiles. Since the area under the solid distribution curve directly corresponds to the amount of retained solids, this almost identical profile shown on Figure 5 means that the solid accumulation is independent of gas velocity. The actual amount of solid retained in the column at the end of each run was also measured. The results are summarized in Table 1. Although the results (Table 1) show a fair amount of fluctuation in retained solids versus gas velocity, no obvious trend of dependence on gas velocity is observed. This fluctuation could likely result from experimental random error. Therefore it can be tentatively concluded that beyond its critical value, gas velocity has no significant effect on solid accumulation.

However, liquid velocity has a definite effect on solids retained in the column as shown in Figures 6 and 7; increasing liquid velocity results in a decrease in the amount of solids retained in the column. The axial solids distribution curves behave correspondingly to show a decrease in solids accumulation with increasing liquid velocities as shown in Figure 6. The normalized plot (Figure 7) clearly shows that at a gas velocity of 0.33 ft/sec, the solids retained in the column decreases linearly with increasing liquid velocity confirming earlier findings with different distributors.

Although, a complete analysis of the entrance effects is not complete, apparently the type of distributor used (No. 1 and 2) has practically no effect on the solids distribution profiles. A detailed discussion of the effect of distributors on solid dispersion and accumulation will be presented after the data analysis has been completed.

FIGURE 5. EFFECT OF GAS VELOCITY ON AXIAL SOLIDS DISTRIBUTION

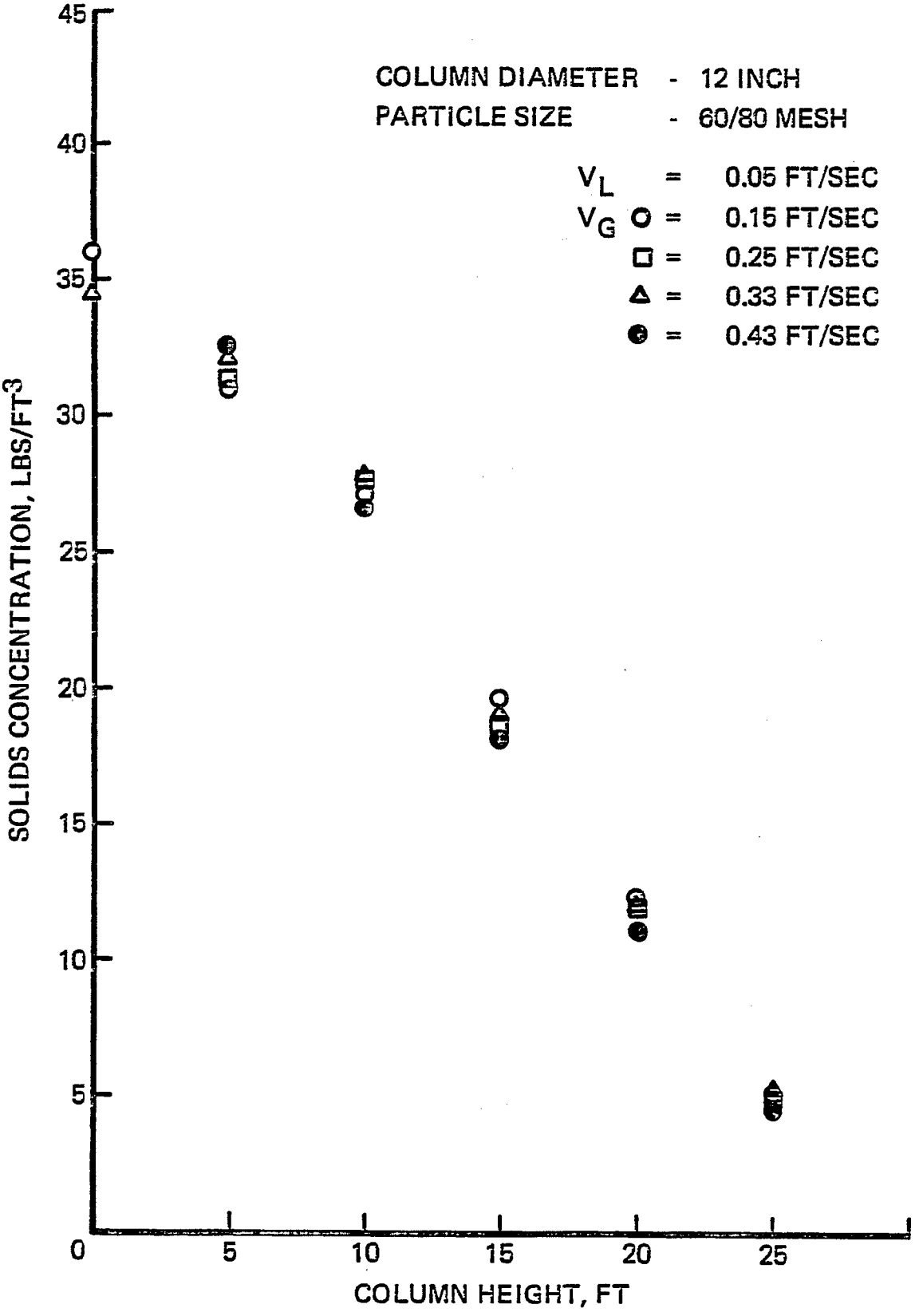


Table 1

Experimental Data - Solids Distribution

Particle Size	60/80 mesh
Column Diameter	12-inch
Distributor	No. 1

VL ft/sec	Vg ft/sec	Solids Concentration, lbs/ft^3						Solids Retained lbs
		L = 0.0 ft	L = 5.0 ft	L = 10.1 ft	L = 15.1 ft	L = 20.1 ft	L = 25.2 ft	
.05	.15	35.9	30.9	26.2	19.5	12.2	5.0	484.5
.05	.25	NA	31.2	26.3	18.6	11.8	4.7	409.5
.05	.33	34.5	32.2	26.8	19.1	12.0	5.1	396.5
.05	.43	35.9	32.5	26.6	18.1	11.9	4.5	461.5
.01	.33	55.2	43.1	30.0	15.0	7.1	2.0	501.0
.03	.33	44.3	38.6	28.8	17.4	9.4	3.0	494.0

FIGURE 6. EFFECT OF LIQUID VELOCITY ON AXIAL SOLIDS DISTRIBUTION

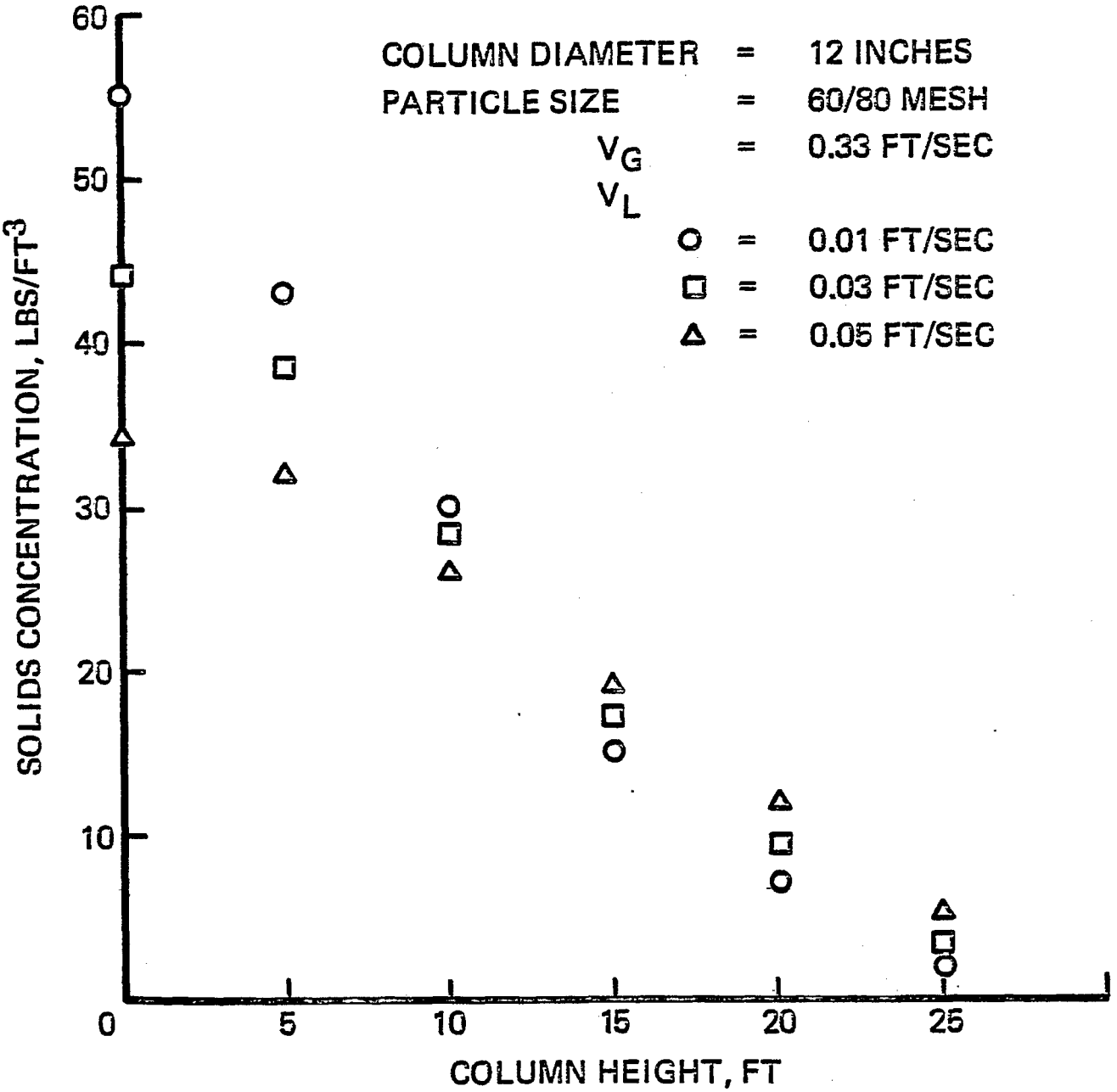
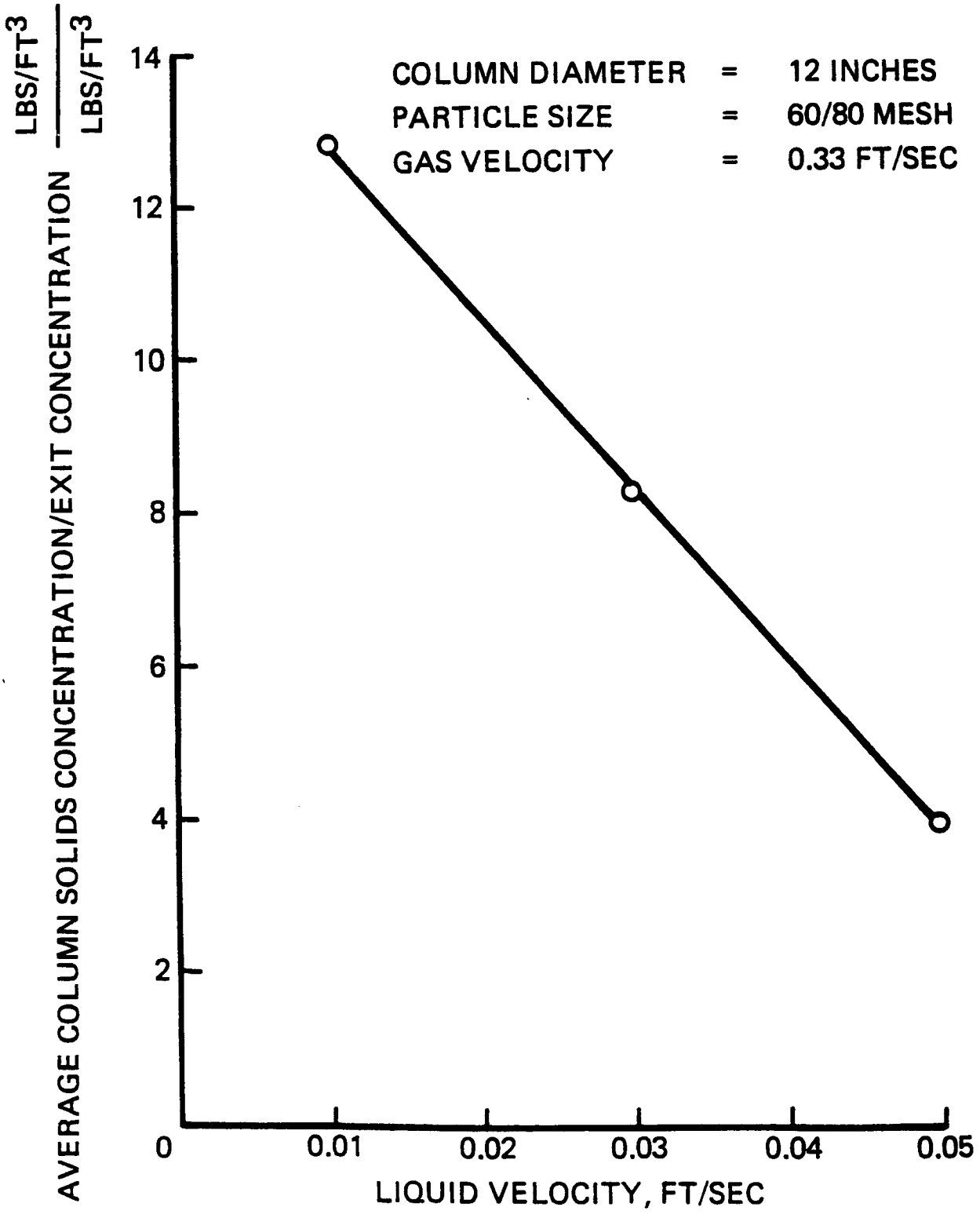


FIGURE 7. EFFECT OF LIQUID VELOCITY ON SOLIDS RETENTION



5.3 Solids Removal

Solids removal experiments were conducted both in the 5-inch and 12-inch diameter columns during this quarter. The objective of these experiments was to test the effectiveness of slurry withdrawal from the column bottom to control solids accumulation. Most of the experiments conducted were terminated before reaching a steady state solid distribution profile. However, some preliminary conclusions can be drawn from the available data.

The results clearly indicate that withdrawing solids from the bottom of the column significantly reduces the solids accumulation and changes the concentration profile of the solids retained in the column. Results from the 5-inch diameter column experiments were presented in Figures 8 and 9. Figure 8 shows the 60/80 mesh solids concentration data obtained at various column heights as a function of time. In the beginning of the experiment, sand/water slurry was allowed to recycle through the column until steady state was obtained. As shown in Figure 8, the samples taken after 90 and 120 minutes of operation clearly indicated that steady-state condition was reached. At 130 minutes the bottom sample port was opened to start the solid withdrawal test, and the recycle mode operation was changed to once-through mode simultaneously. The average rate of slurry withdrawal was about 15% of the slurry volumetric feed rate. Slurry samples were taken along the column at various durations after the start of the withdrawal run. The results shown in Figure 8 indicate that the solid concentration at every column position decreased after the start of solid withdrawal. Figure 9 presents the solid concentration profile reduced from the data shown in Figure 8. After thirty-six minutes of the solids withdrawal operation, the amount of retained solids decreased by 50 percent. Using solids concentration profiles shown in Figure 9, the amount of retained solids in the column was calculated. Figure 10 presents the retained solids as a function of withdrawal time. Figure 10 clearly illustrates that the amount of retained solids decreases with increasing

FIGURE 8. EFFECT OF SOLIDS WITHDRAWAL ON SOLIDS DISTRIBUTION

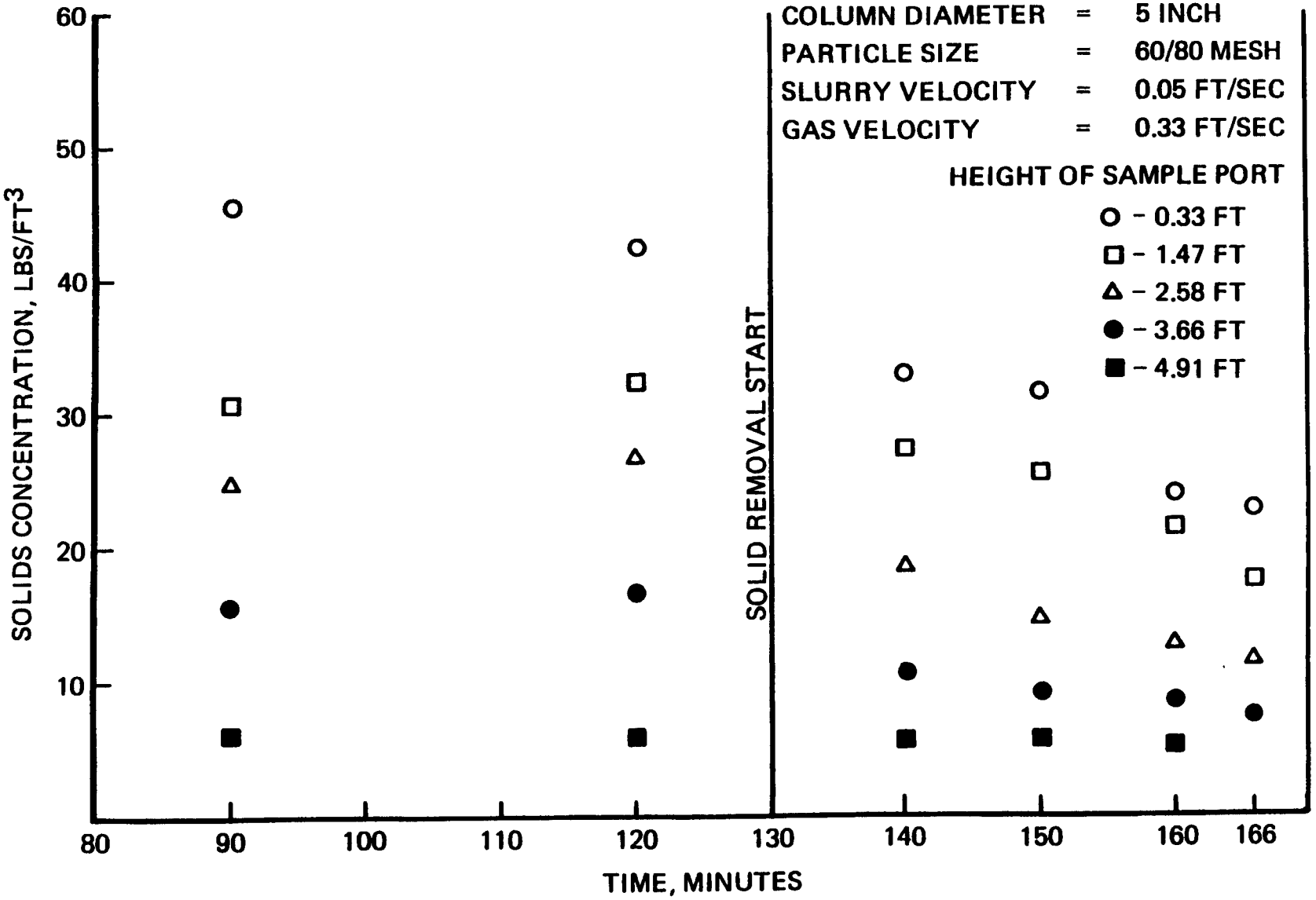


FIGURE 9. EFFECT OF SOLIDS WITHDRAWAL ON AXIAL SOLIDS DISTRIBUTION

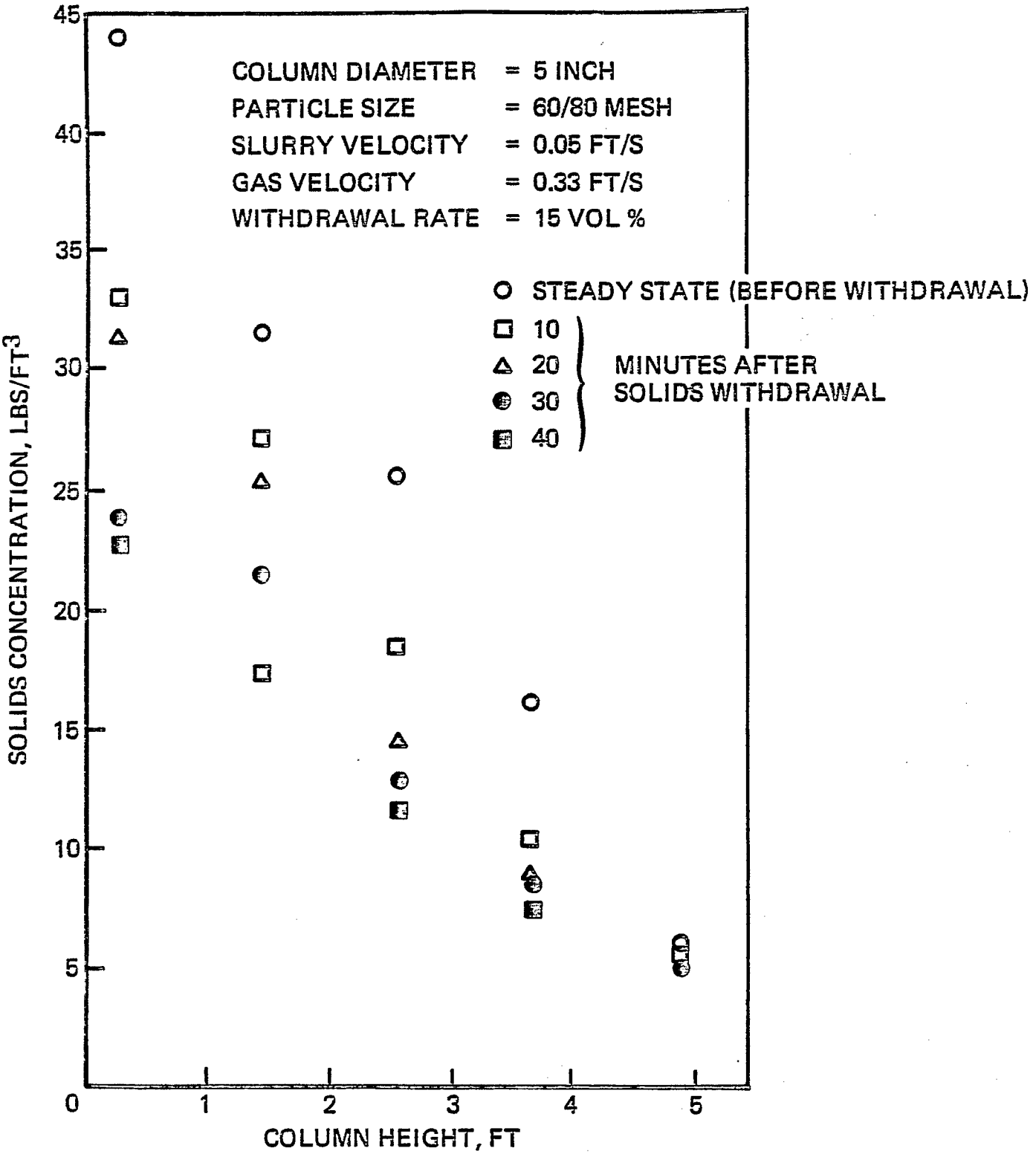
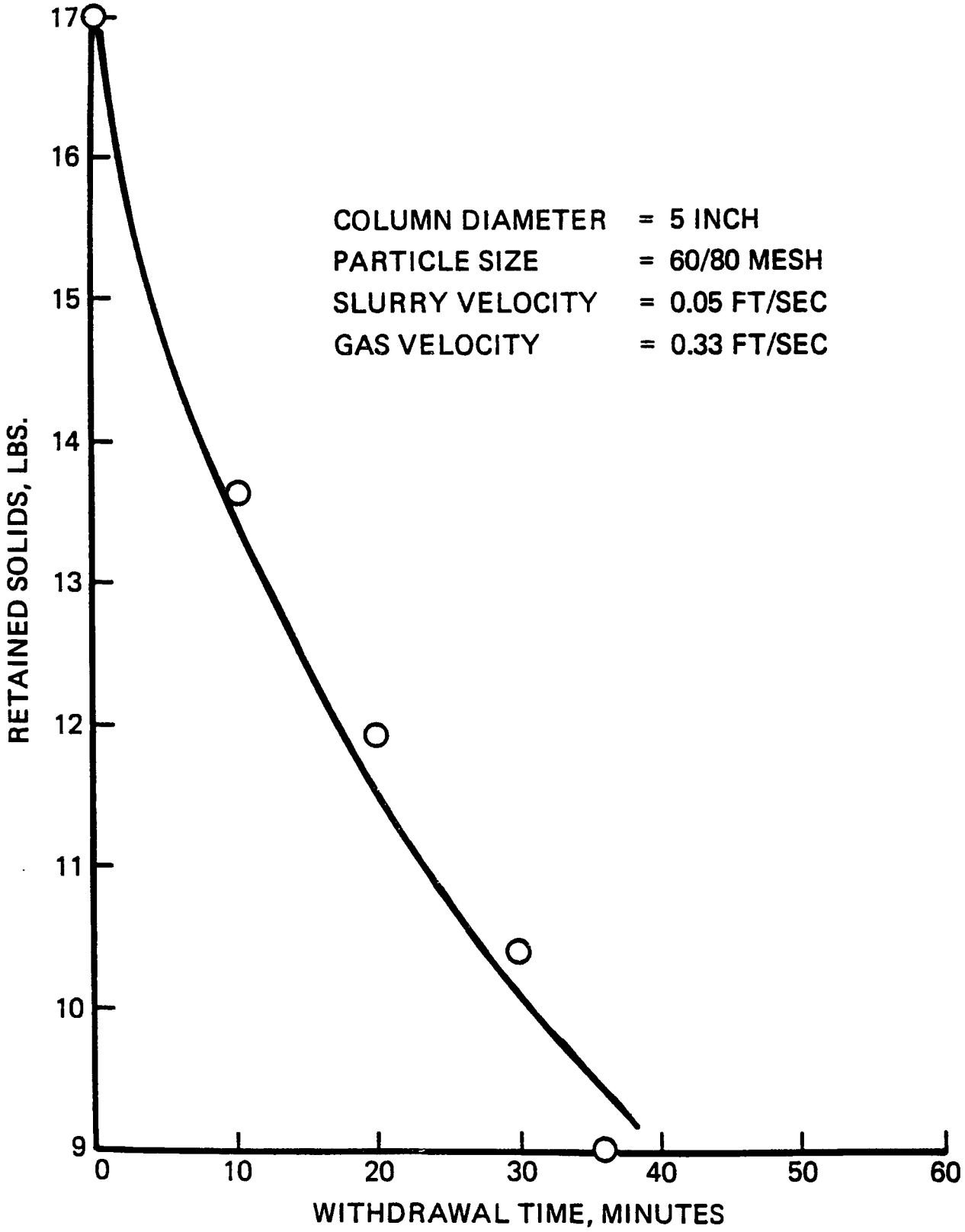


FIGURE 10. EFFECT OF SOLIDS WITHDRAWAL TIME ON RETAINED SOLIDS



operating time; however, a steady state value was not reached at the end of the experiment. In addition to the reduction of retained solids, the concentration profile changes drastically as illustrated in Figure 9.

The withdrawal rate has a significant impact on the amount of solids retained in the column. Results from experiments conducted in the 12-inch column diameter using 60/80 mesh particles at different withdrawal rates are shown in Figures 11 through 13. Precise control of the withdrawal rate was very difficult and the rate varies in each experiment. At a low withdrawal rate (varied between 6 and 9 percent of the volumetric slurry feed rate), solid removal did not seem to affect the solids concentration at all positions along the axis of the column within the experimental time frame. In this experiment the solid withdrawal rate was not steady due to frequent clogging of the withdrawal line. However, at higher withdrawal rates, solids removal definitely changed the distribution profile. Figures 12 and 13 show the experimental results at withdrawal rates of 23-29% and 20-22%, respectively. The solids concentration profile in the column is significantly affected at these high withdrawal rates as compared to the results obtained at low removal rate. Again steady state values have not been reached in this short experimental duration. But the sharp difference in the unsteady-state concentration profiles at low and high removal rates definitely suggests the strong impact of the rate of solids withdrawal on solids accumulation.

Larger particles were preferentially removed by the solids withdrawal system located at the bottom of the column as illustrated in an experiment using both 20/30 and 60/80 mesh sand particles. In this experiment a known amount of 20/30 mesh sand particles were placed in the column and a slurry containing 60/80 mesh particles was recycled through the column. Two steady state samples were withdrawn from all the sample ports and three samples were taken after the start of solids withdrawal.

FIGURE 11. EFFECT OF SOLIDS WITHDRAWAL ON SOLIDS DISTRIBUTION

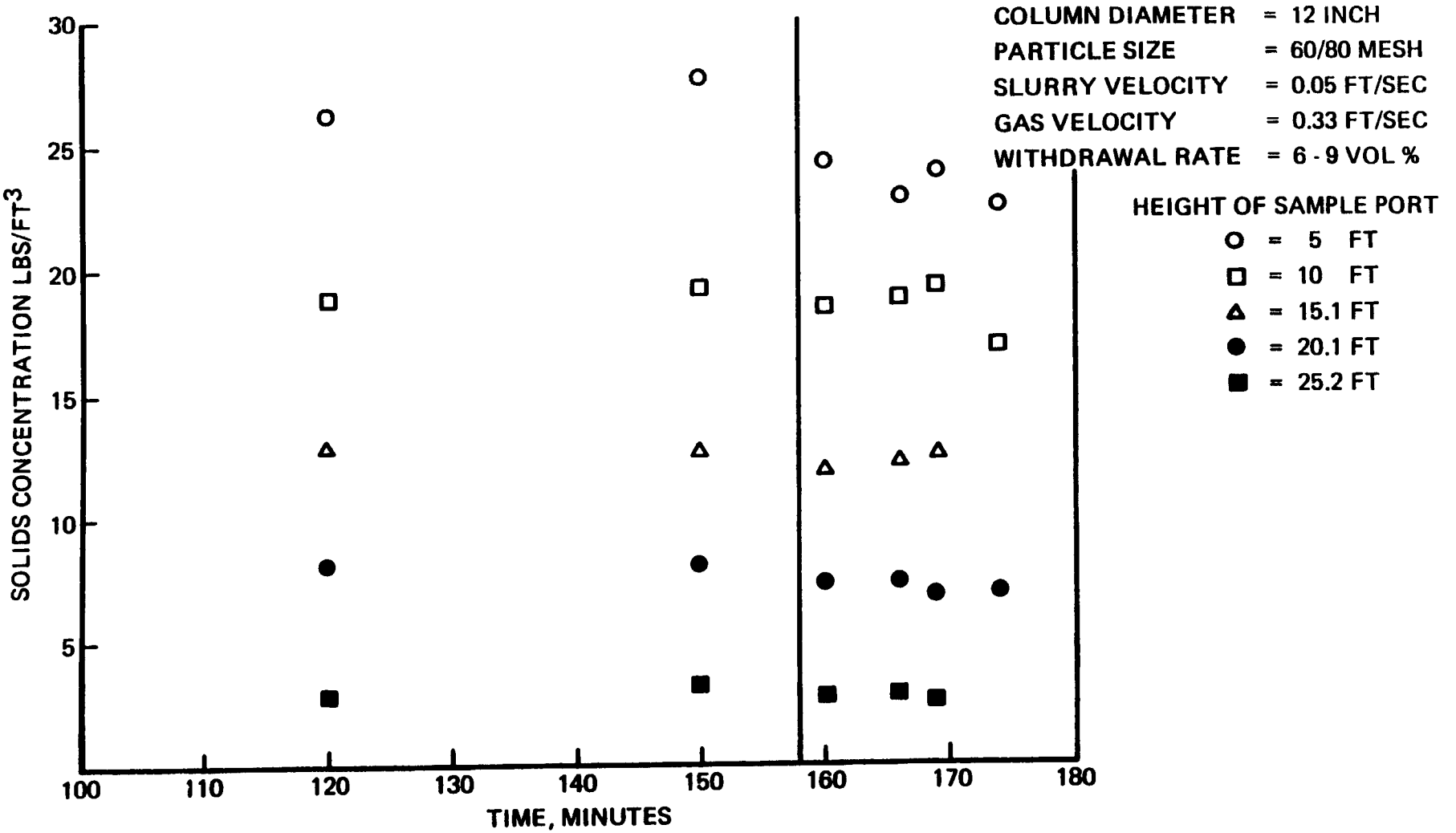


FIGURE 12. EFFECT OF SOLIDS WITHDRAWAL ON SOLIDS DISTRIBUTION

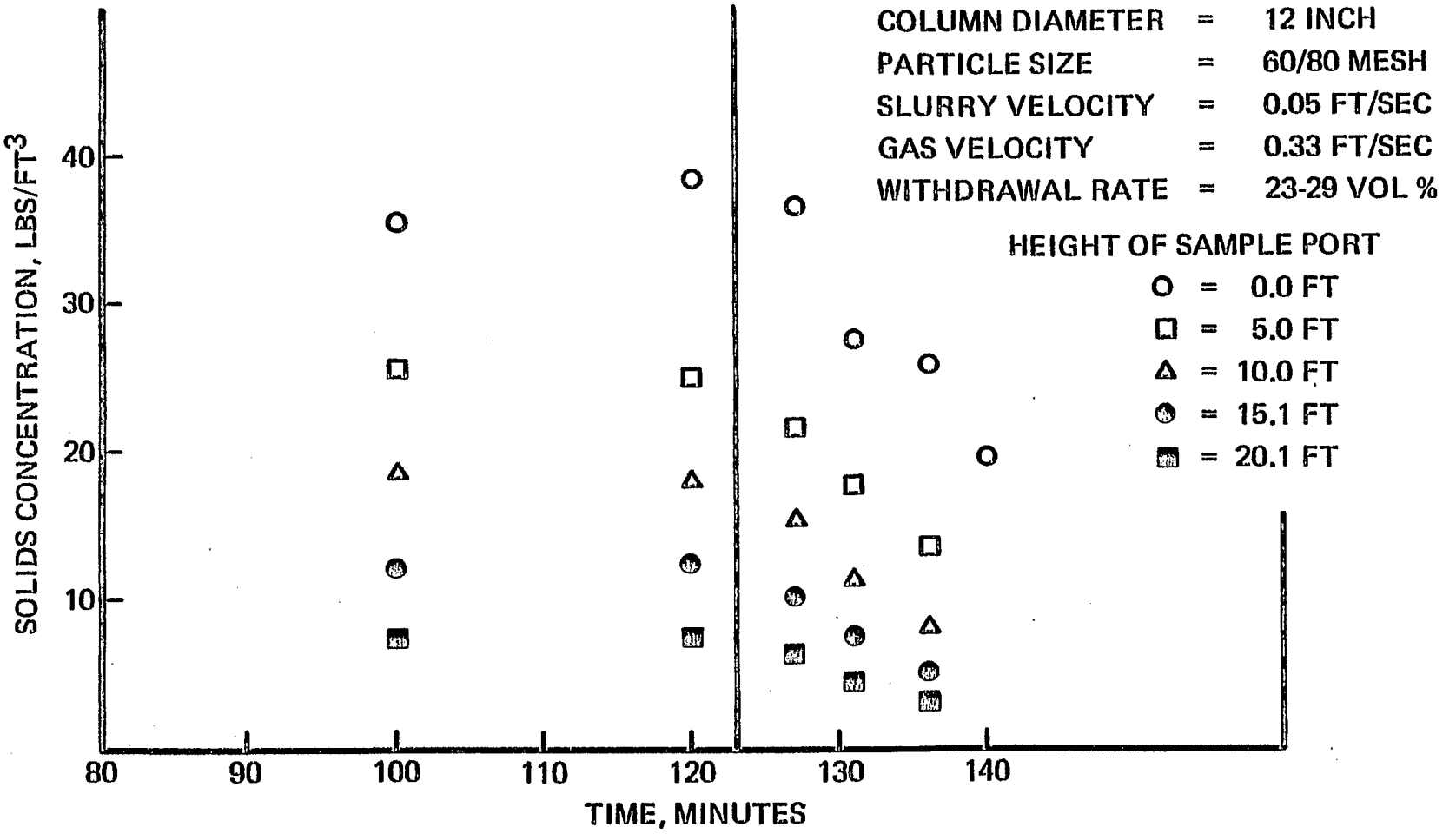


FIGURE 13.
EFFECT OF SOLIDS WITHDRAWAL ON SOLIDS DISTRIBUTION

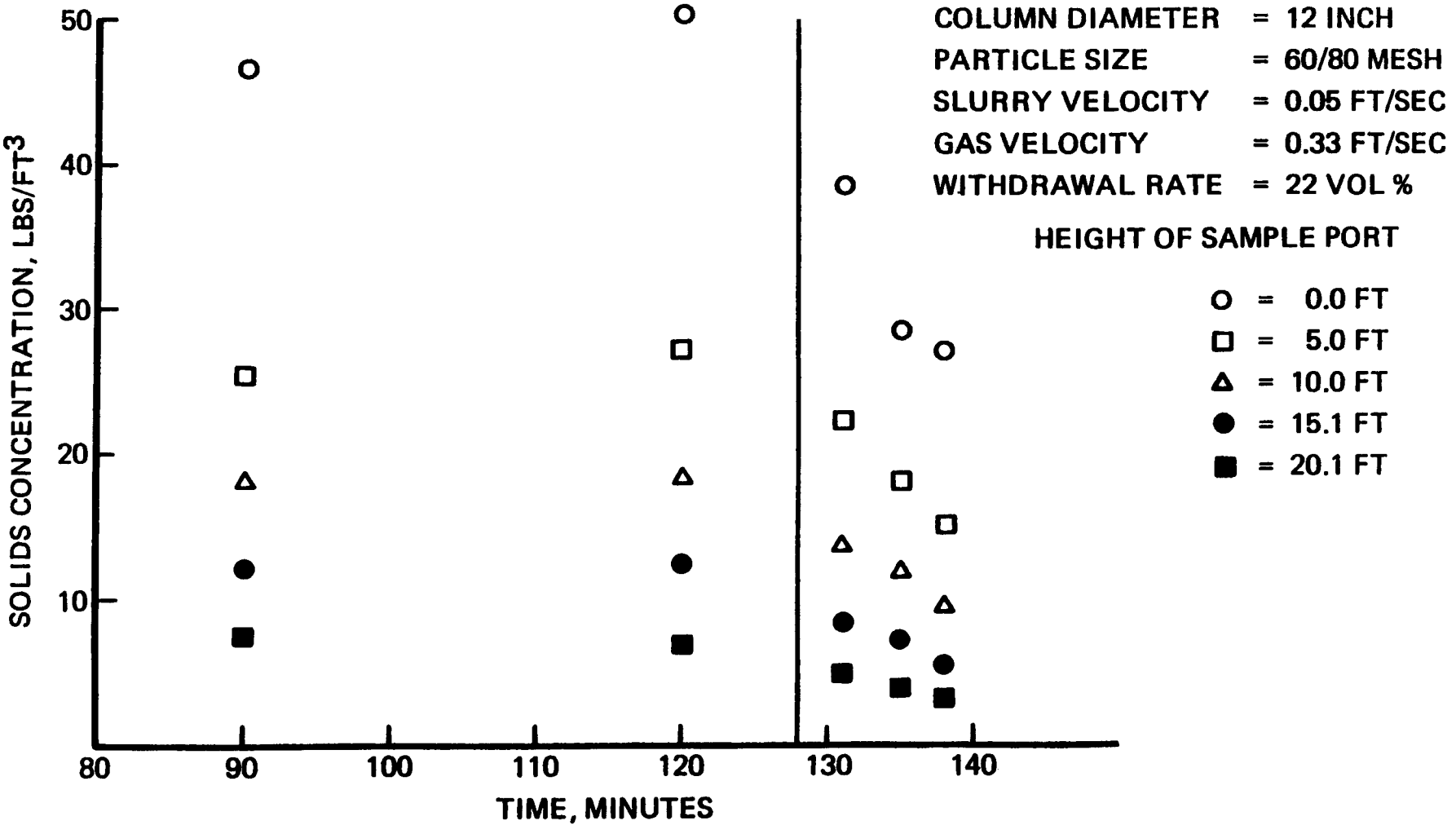


Figure 14 presents the solids concentration at various axial positions in the column as a function of time and Figure 15 shows the axial solids distribution before and after solids withdrawal. Both figures indicate clearly that the solids distribution changes when withdrawal is employed resulting with less retained solids.

In addition, solids withdrawal from the bottom of the column results in a faster depletion of the large particles in the column. In the above experiment using both 20/30 and 60/80 mesh particles, each sample was also screened to provide individual concentration of the particle size. Figure 16 shows the solid concentration profile of the individual particles before and 14 minutes after the start of solids withdrawal. This figure clearly illustrates that the concentration of 20/30 mesh particles drop off more rapidly than the 60/80 mesh particles.

When the column was drained at the end of the experiment, only 0.5 lbs of the 88 lbs that were retained in the column were large particles. Table II shows the variations in the composition of the withdrawal stream as a function of time and clearly indicates that large particles were drained first from the column. As soon as the solids removal started, the concentration of large particles in the withdrawal stream was quite large and this gradually decreased while the concentration of smaller particles increased.

The results presented in this section clearly indicate that the solids withdrawal can reduce solids accumulation and can change the axial solids concentration profile significantly. Data also indicate that larger particles are removed faster by virtue of their faster settling at the bottom. However, these results were obtained under unsteady-state operation and should be viewed with caution. Because of time restraints, this entire task was allotted only one month. Undoubtedly steady-state experiments are needed in the future to determine optimal withdrawal rate.

FIGURE 14. EFFECT OF SOLIDS WITHDRAWAL ON AXIAL SOLIDS DISTRIBUTION

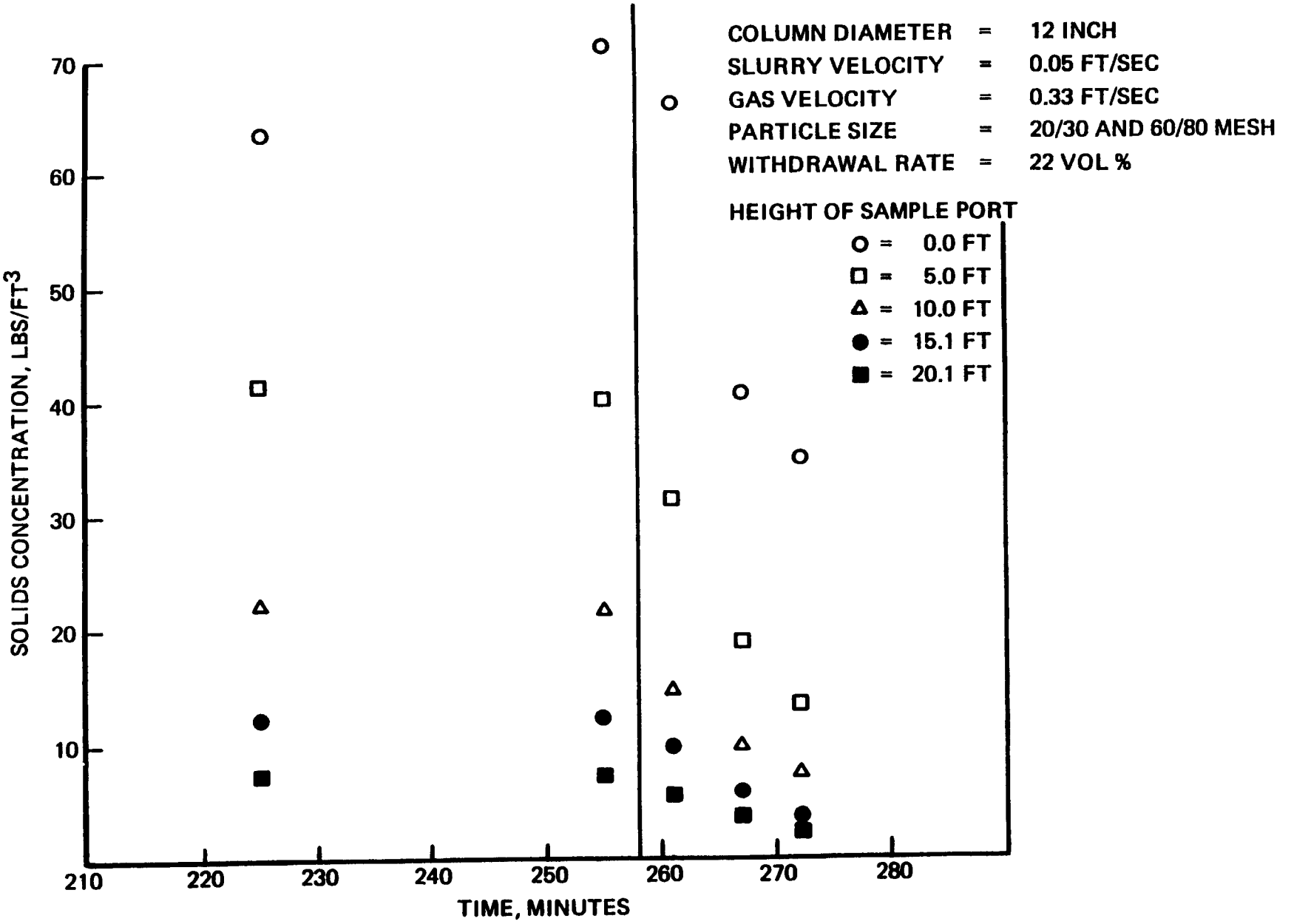


FIGURE 15.
EFFECT OF SOLIDS WITHDRAWAL ON AXIAL SOLIDS DISTRIBUTION (IN THE PRESENCE OF LARGE & FINE PARTICLES)

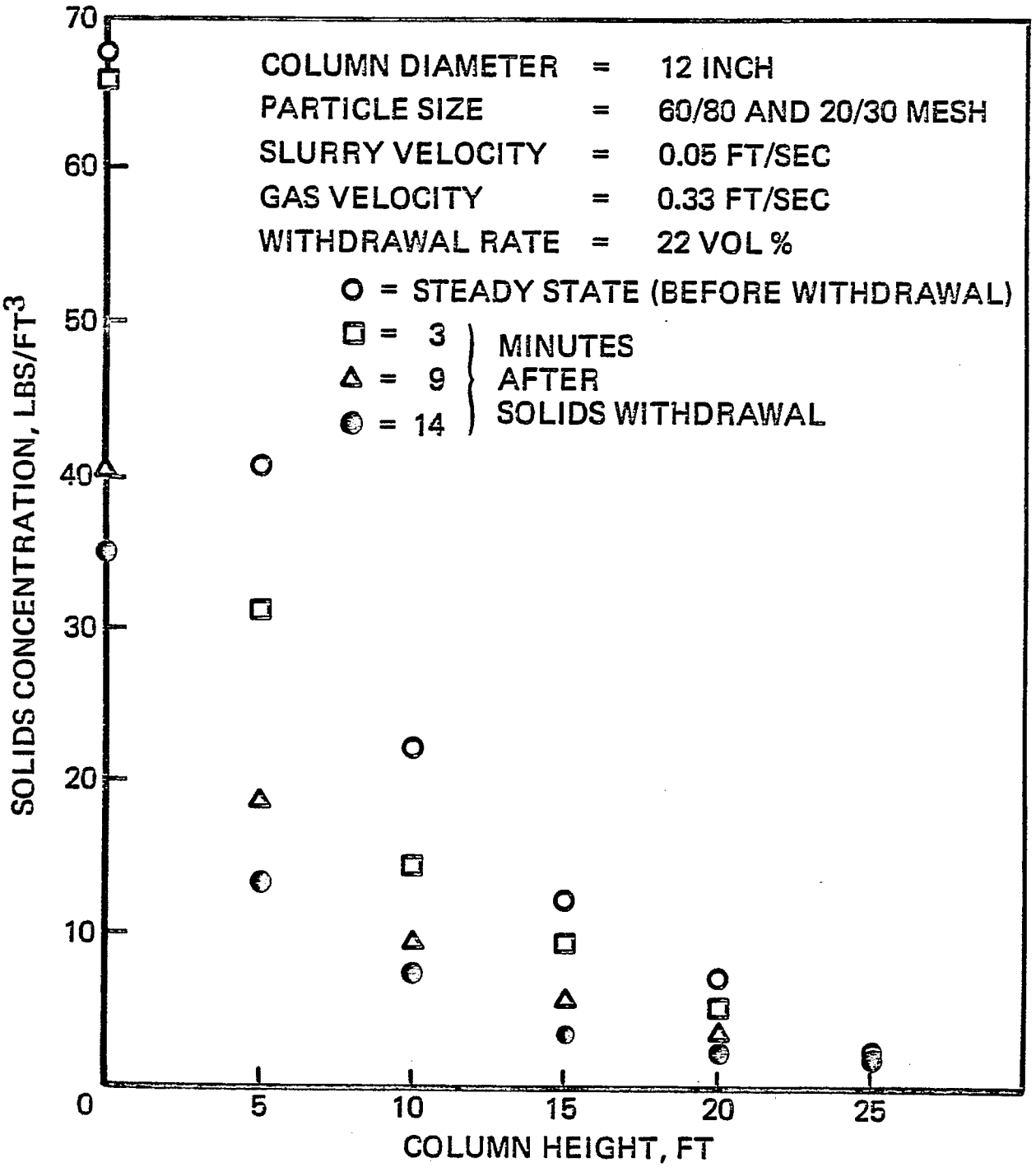


FIGURE 16.
EFFECT OF THE PRESENCE OF LARGE PARTICLES ON SOLIDS REMOVAL

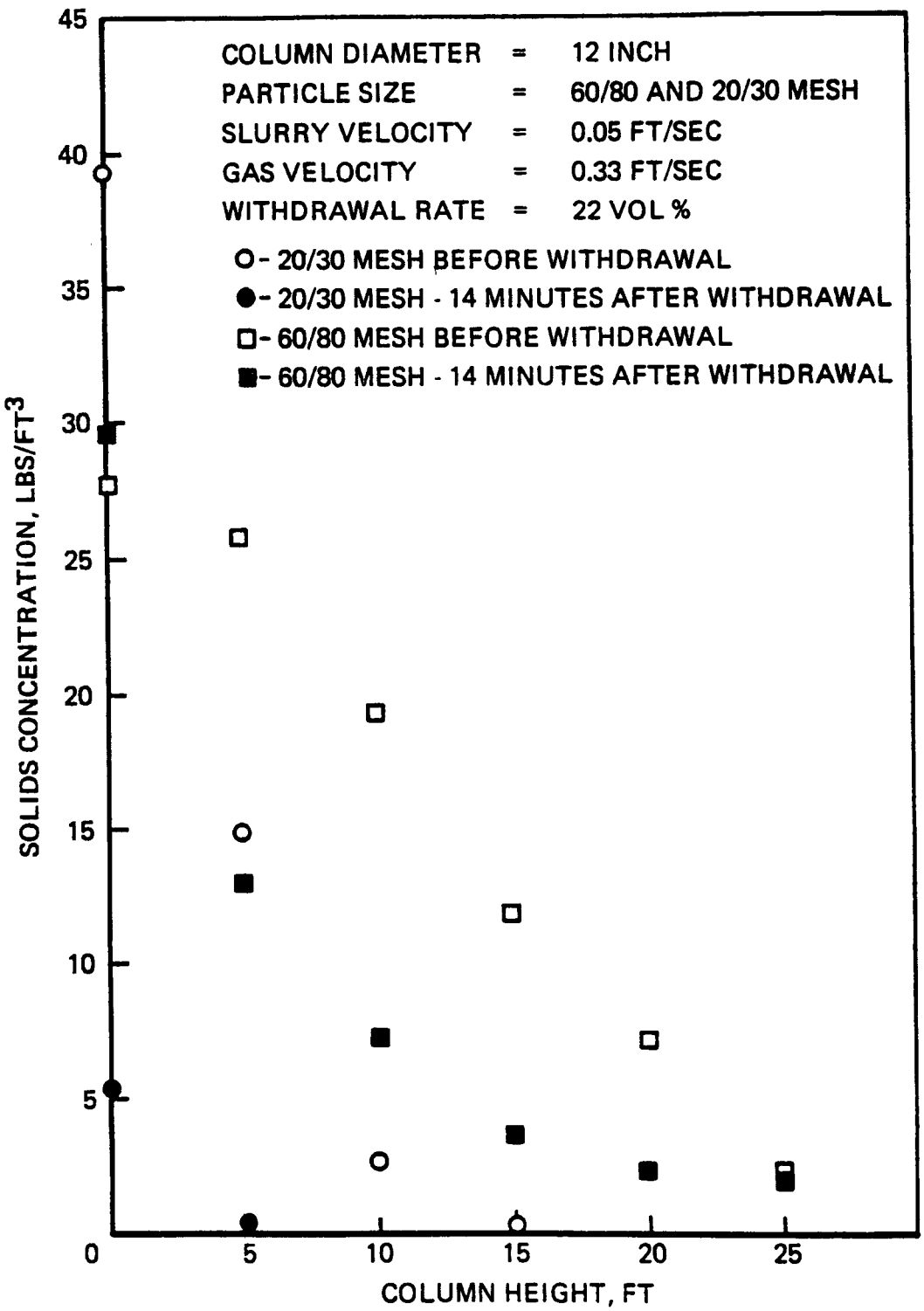


Table II

Variations in the Composition of the Withdrawal Stream

	Time after start of solids removal, minutes		
	3	9	14
Total Solids Concentration, lbs/ft^3	79.7	85.6	68.9
Concentration of 60/80 mesh, lbs/ft^3	33.8	50.7	57.6
Concentration of 20/30 mesh, lbs/ft^3	45.9	34.9	11.3

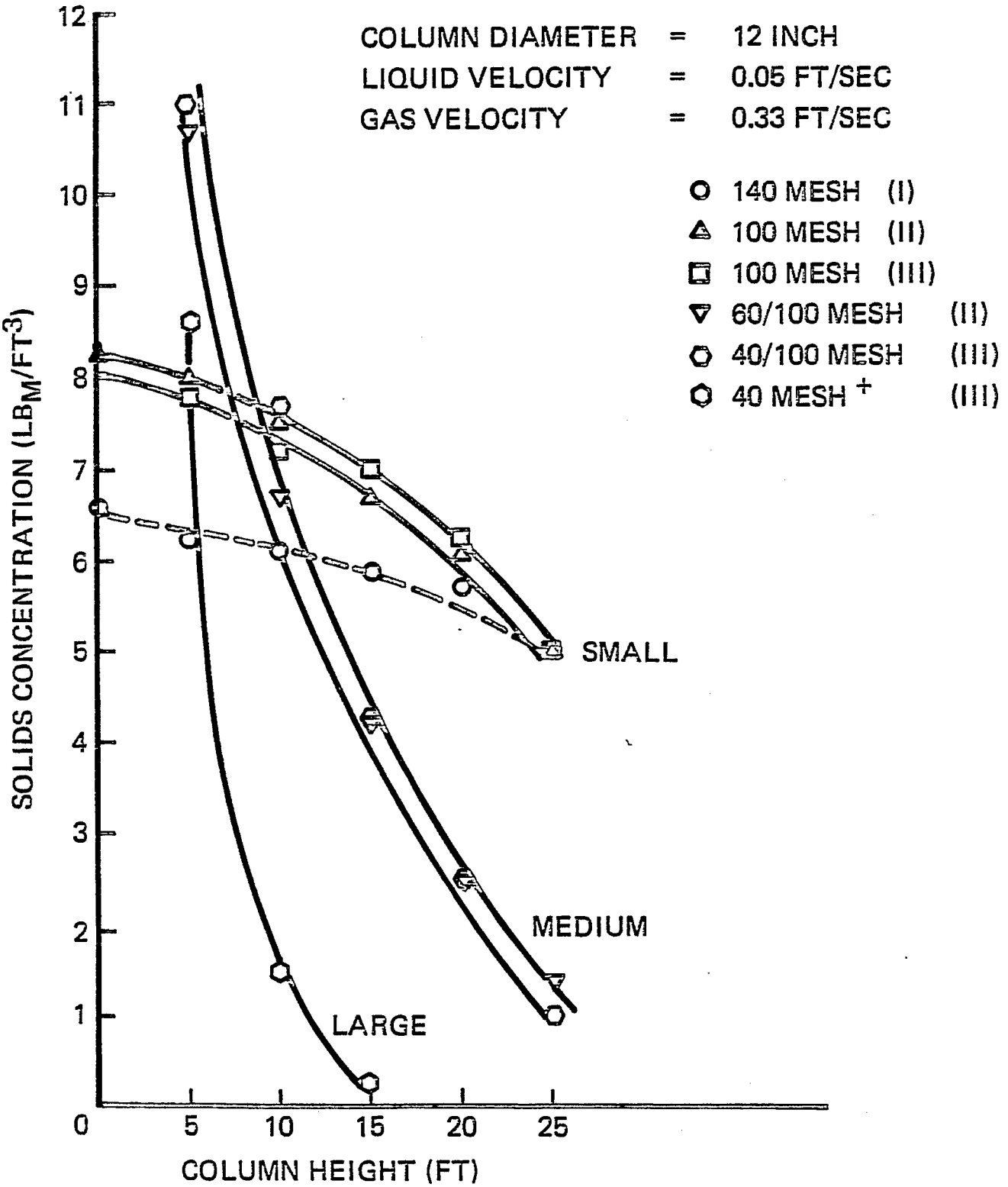
5.4 Particle-Parcticle Interaction

Until this quarter all of the solid distribution experiments were conducted with narrow size range particles. Individual experiments were conducted for large and small particles. In this section, the results from a special set of experiments will be discussed to shed some light on the effect of settled particles and particle-particle interactions on solids accumulation in the 12-inch diameter column.

A detailed description of the sets of experiments were given in the section on experimental procedure. Briefly, the experiments consisted of three parts. In the first part, only 140 mesh minus sand was allowed to circulate through the column. In the second part a mixture of 60/80 mesh and 140 mesh minus sand was used to determine the effect of large but suspended particles on the accumulation of the fines. In the third part 20/30 mesh particles were placed in the column to simulate settled solids and a slurry containing a mixture of 60/80 mesh and 140 mesh minus sand was allowed to recycle through the column. Samples from parts II & III were screened to obtain a particle size distribution.

The results show that the presence of large suspended particles has no influence on the accumulation or distribution of fine particles. The settled particles also have no effect on solids distribution of both the large suspended and fine particles. The results from all three parts of the experiment are summarized in Figure 17. Samples from parts II & III were screened to 100 mesh minus, 60/100 or 40/100 and 40 mesh plus particles. This procedure was adapted so that the samples can be screened more efficiently. Figure 17 shows the solids concentration as a function of column height for the three groups of particles. For simplicity, the following distinction for particle size is used. 40 mesh plus particles are considered as large, 60/100 or 40/100 mesh particles are considered as medium and 100 mesh

FIGURE 17.
PARTICLE–PARTICLE INTERACTION



minus particles are considered as small particles. Figure 17 clearly indicates that the presence of large particles does not affect the distribution of medium and small particles as the concentration profiles for these particles from part II and III are quite close to each other. For small particles the results from part I of the experiment do not fall in the range of those from parts II and III. Parts II and III show more fines than part I. This small difference could possibly be due to particle attrition from the medium particles which have been heavily used in this research program. Also note that the experiments in parts II & III classified 100 mesh minus particles as small while 140 mesh minus particles were classified as small in part I. Some of the 60/80 mesh particles used in parts II & III could have contained smaller particles, resulting in an increase in concentration of small particles as shown in Figure 17. In spite of the small difference mentioned above, our results have shown negligible influence of large particles on the accumulation of the fines. This finding also implies the validity of superimposing previous results obtained from individual particle size to simulate the solids concentration profile consisting of a wide range of particle size.

5.5 Screening Experiments and Column Enclosure Construction

During this quarter the construction of the column enclosure was completed. A detailed description of the enclosure along with the safety features will be presented in the next quarterly report. During the construction phase, screening experiments were conducted in the 5-inch column to identify the organic liquid/liquids to be used in the 12-inch diameter column. The viscosity and surface tension of these liquids were also determined so that the selected liquid could closely resemble the fluid in the dissolver under SRC-I demonstration plant operating conditions. At the end of the quarter, work was still in progress on the screening experiments; results and conclusions will be presented in the next report.

6.0 FUTURE WORK

Data anlaysis will be completed to investigate the effect of different distributor configurations on solids distribution and accumulation. Based on the screening tests one or two organic fluids will be identified and Task 5 will be started. Before the start of Task 5, the column enclosure will be tested for safe operation.

7.0 REFERENCES

1. "Gas/Slurry Flow in Coal Liquefaction Processes", Quarterly Technical Progress Report for period 1 July 1980-30 September 1980, FE-14801-12, December 1980.

2. "Gas/Slurry Flow in Coal Liquefaction Processes", Quarterly Technical Progress Report for period 1 October 1979-31 December 1979, FE-14801-3, January 1980.

3. "Gas/Slurry Flow in Coal Liquefaction Processes", Quarterly Technical Progress Report for period 1 January 1980-31 March 1980, FE-14801-6, May 1980.

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