distilled water (i.e. a liquid of known density). The rotameters, on the purge lines, were then adjusted to obtain a zero reading across all possible combinations of pressure tap pairs (one high side and low side port) when the column was empty. However, the purge flow through any given rotameter was maintained below 45 cc/min.

After adjusting the DP cell, the column was filled with wax up to the desired height and measurements commenced. The pressure drop across all possible combinations of the pressure taps was measured approximately 45 minutes to one hour after achieving the desired column temperature and gas flow rate. It was necessary to wait at least 45 minutes to ensure that steady state was achieved, particularly when foam was present. For all experiments, the liquid static height was approximately 2.0 to 2.4 m with the exception of the experiment in the small column with the SMP distributor (H_s = 1.0 m). Periodically, the HPSL and the LPSL were cleared by using the secondary nitrogen purge system (i.e. by closing valves V15 and V16 and opening valves V13 and V14).

C.3. Experimental Results

The differential pressure measurements obtained from the experiments were converted to axial and average hold-up values using the data reduction procedure outlined in APPENDIX B.

C.3a. 1.85 mm Single Hole Orifice Plate Distributor

Axial gas hold up profiles obtained from the experiments conducted in increasing and decreasing order of gas velocities (0.051 m ID column) are shown in Figures V-40 and V-41 respectively. In the experiments conducted from low to high gas flow rates (Figure V-40), three zones of gas hold-up can be noted at the higher gas velocities: (1) low hold-ups are obtained

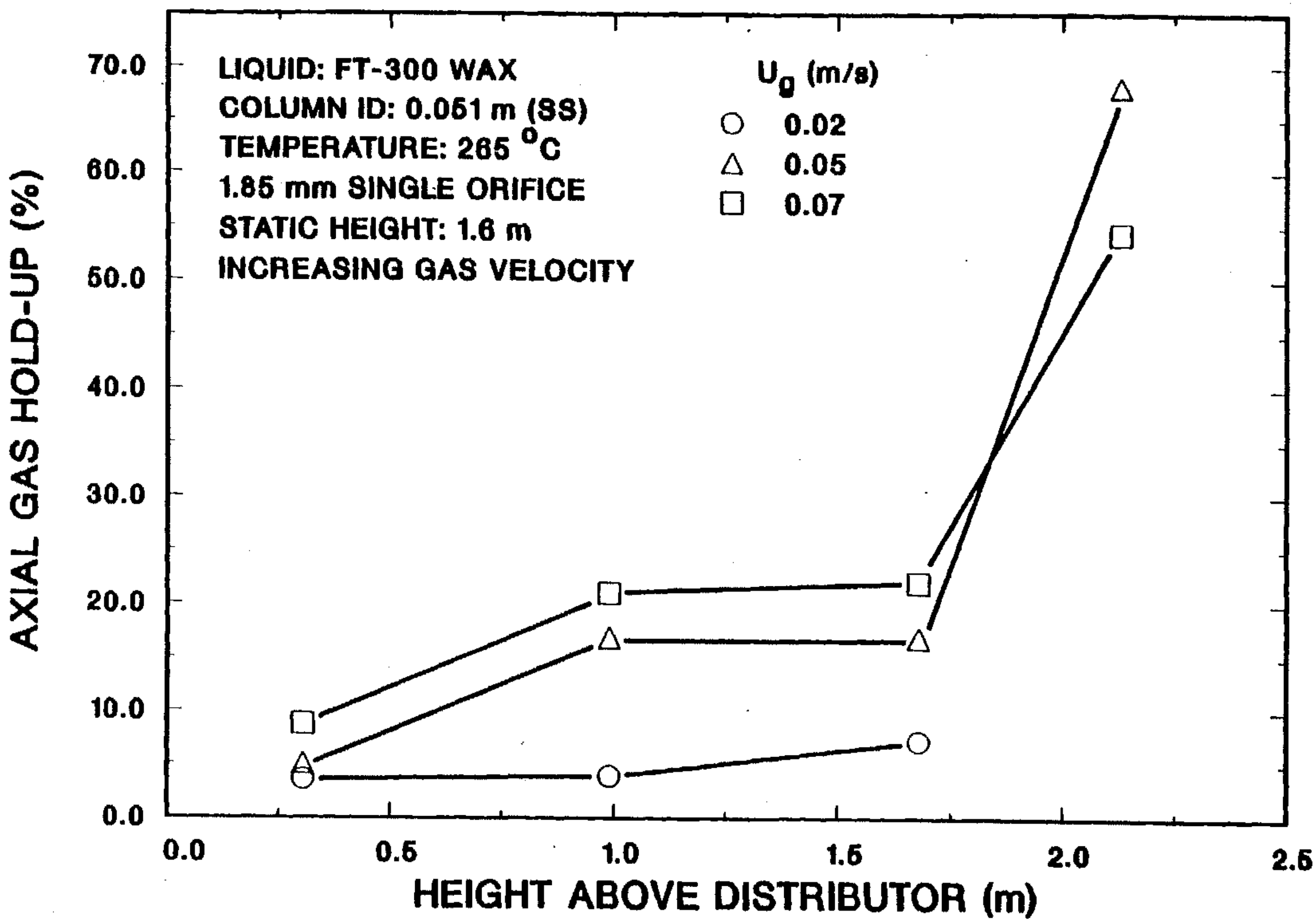

Figure V-40. Effect of superficial gas velocity and height above the distributor on axial gas hold-up (Run 3-4 - increasing order of velocities) near the distributor; (2) higher hold-ups in the middle of the column; and (3) very high hold-ups (foam) near the top of the expanded bed. In this experiment, the transition from the "foamy" regime to the "slug flow" regime was not complete (as shown in Figure V-42). This is reflected in Figure V-40 by almost similar axial hold-up at the top of the column as velocity was increased from 0.05 to 0.07 m/s. In general, the axial gas hold-up increased with height and gas velocity. The axial gas hold-up profiles follow patterns that were expected based on visual observations. Larger bubbles produced with the 1.85 mm orifice plate distributor break into smaller bubbles as they rise within the column, and consequently the increase of gas hold-up with column height is expected. Further up in the column, the presence of foam causes the higher axial hold-up. The same type of behavior was observed in a 0.051 m ID by 9 m tall bubble column equipped with a 1 mm single hole orifice plate distributor by Mobil workers (Kuo et al., 1985) who used the FT-200 wax as the liquid medium. Towell et al. (1965) and Ueyama et al. (1980) have reported a similar increase in axial hold-up with height for experiments conducted with the air-water system. In both of these studies, froth was present at the top of the dispersion.

For the run conducted in decreasing order of gas velocities (Figure V-41), a start-up velocity of 0.07 m/s was employed. This prevented the formation of foam, and consequently much lower hold-up values were obtained than in the experiment conducted in increasing order of velocities. The axial gas hold-ups were qualitatively the same for both experiments, i.e. the gas hold-up increases with velocity and height. However, the increase of hold-up with height, at a constant superficial gas velocity,

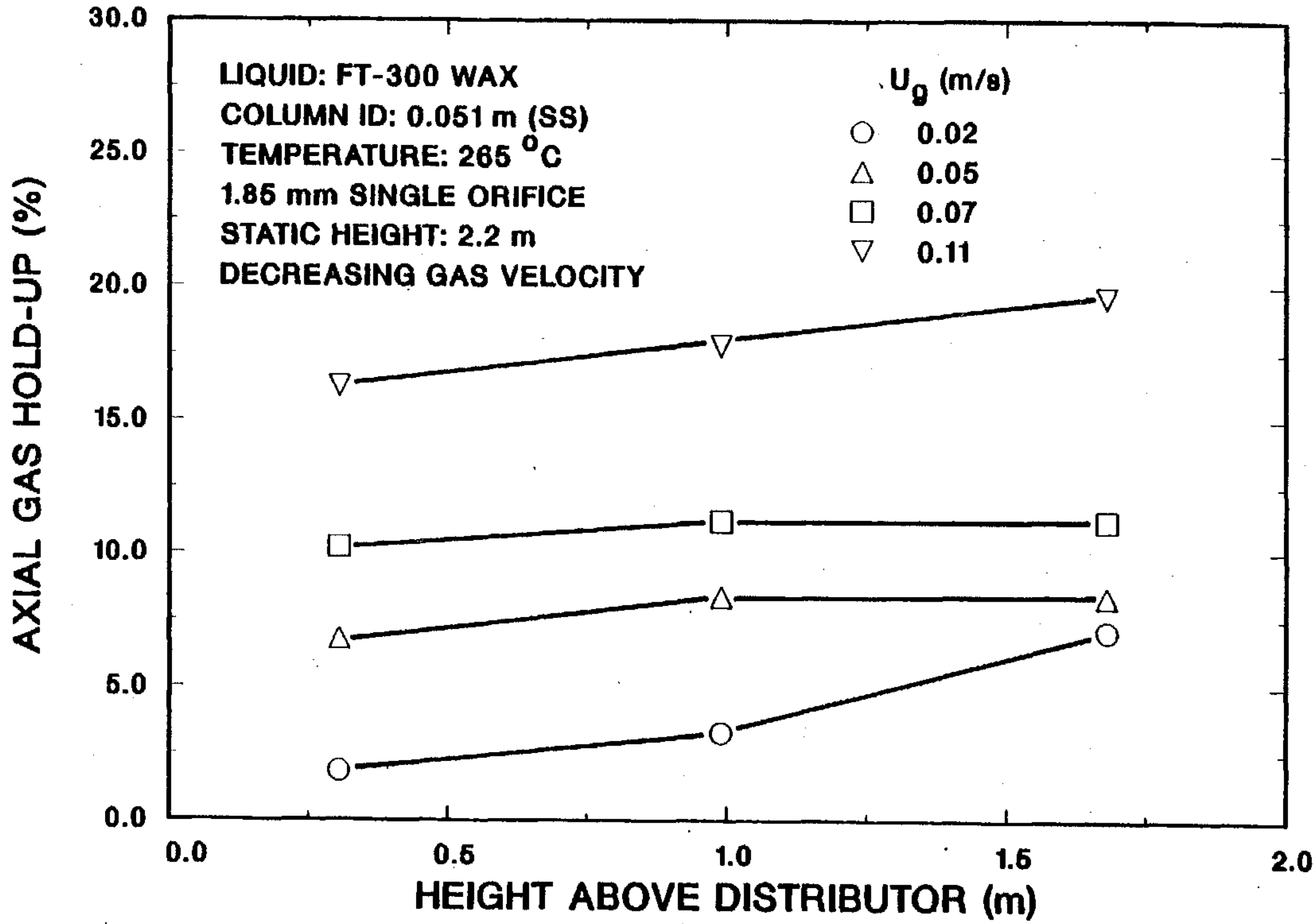

Figure V-41. Effect of superficial gas velocity and height above the distributor on axial gas hold-up (Run 3-5 - decreasing order of velocities) is fairly small in the "slug flow" regime (Figure V-41). This is in agreement with the findings of Zahradnik and Kastanek (1979) for air-water system.

Figure V-42 shows a comparison of average gas hold-up values obtained from the 0.051 m ID SS column (using DP measurements) with those obtained from the 0.051 m ID glass column (from visual observations of the static and expanded heights). In view of the fact that the experiments were conducted in two different columns (wall surface roughness effect) under somewhat different conditions (e.g. purge flow in the SS column but not in the glass columns) and that different techniques were used to obtain the average gas hold-ups, the agreement in results is quite satisfactory. The main differences in the results are as follows. The foam breakup did not occur to a significant extent in the SS column at velocities greater than 0.05 m/s using an increasing order of gas velocities (open circles); whereas, it did occur in the glass column (open squares). A transition from the "slug flow" regime (where slugs dominate and foam is absent) to the "foamy" regime (where a stable layer of foam persists at the top of the dispersion) took place in the glass column when the velocity was decreased from 0.05 m/s to 0.03 m/s; while, for the experiment conducted in the steel column using decreasing order of gas velocities, the transition to the "foamy" regime did not occur.

C.3b. 40 μm Sintered Metal Plate Distributor.

The axial gas hold-up profiles obtained with the 40 μm SMP distributor are shown in Figure V-43. The same general trends were observed as with the 1.85 mm orifice plate distributor. At higher gas velocities, a significant amount of foam is present even in the

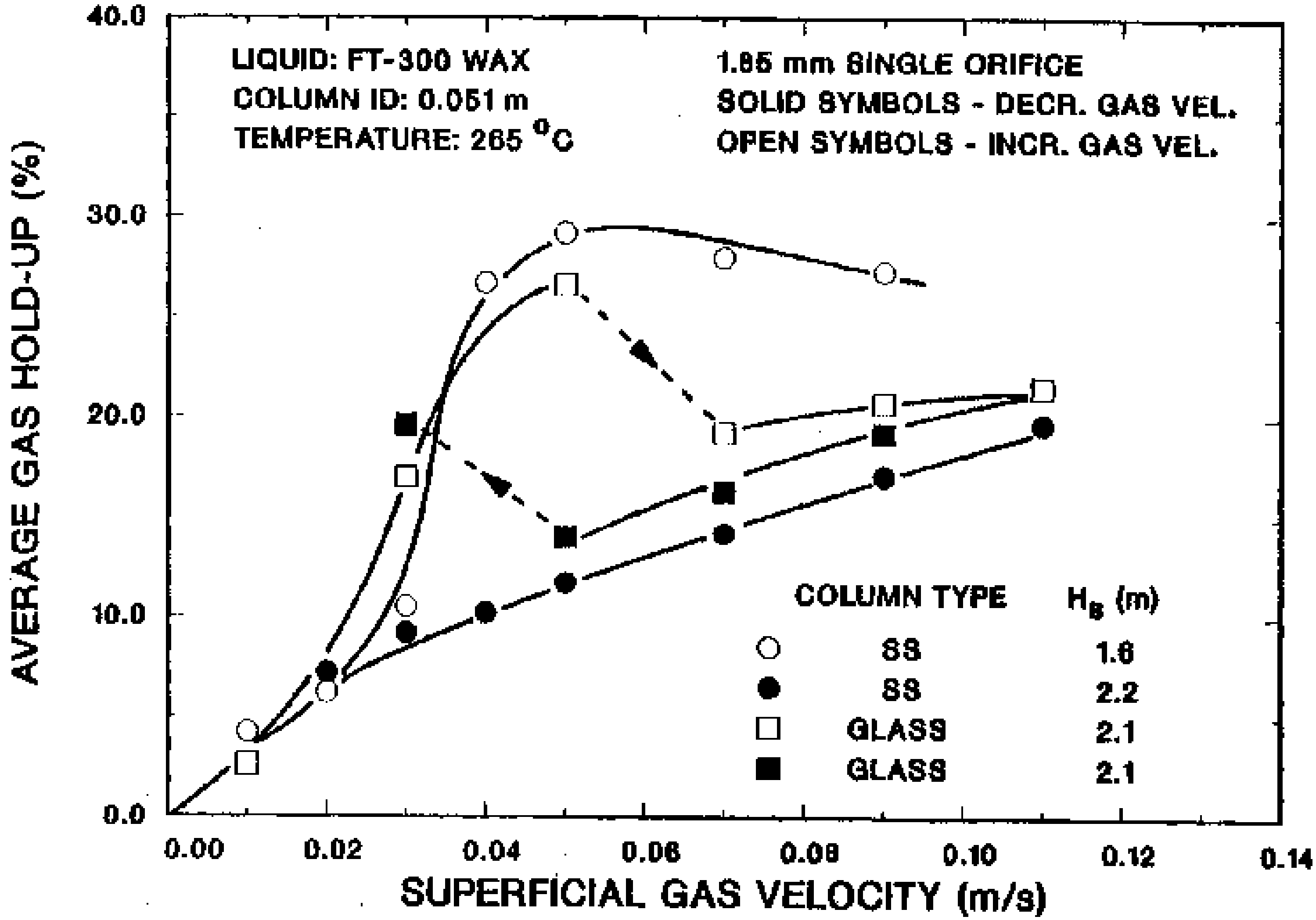

Figure V-42. Effect of superficial gas velocity on gas hold-up (○ - Run 3-4; ● - Run 3-5; □,■ Run 3-1)

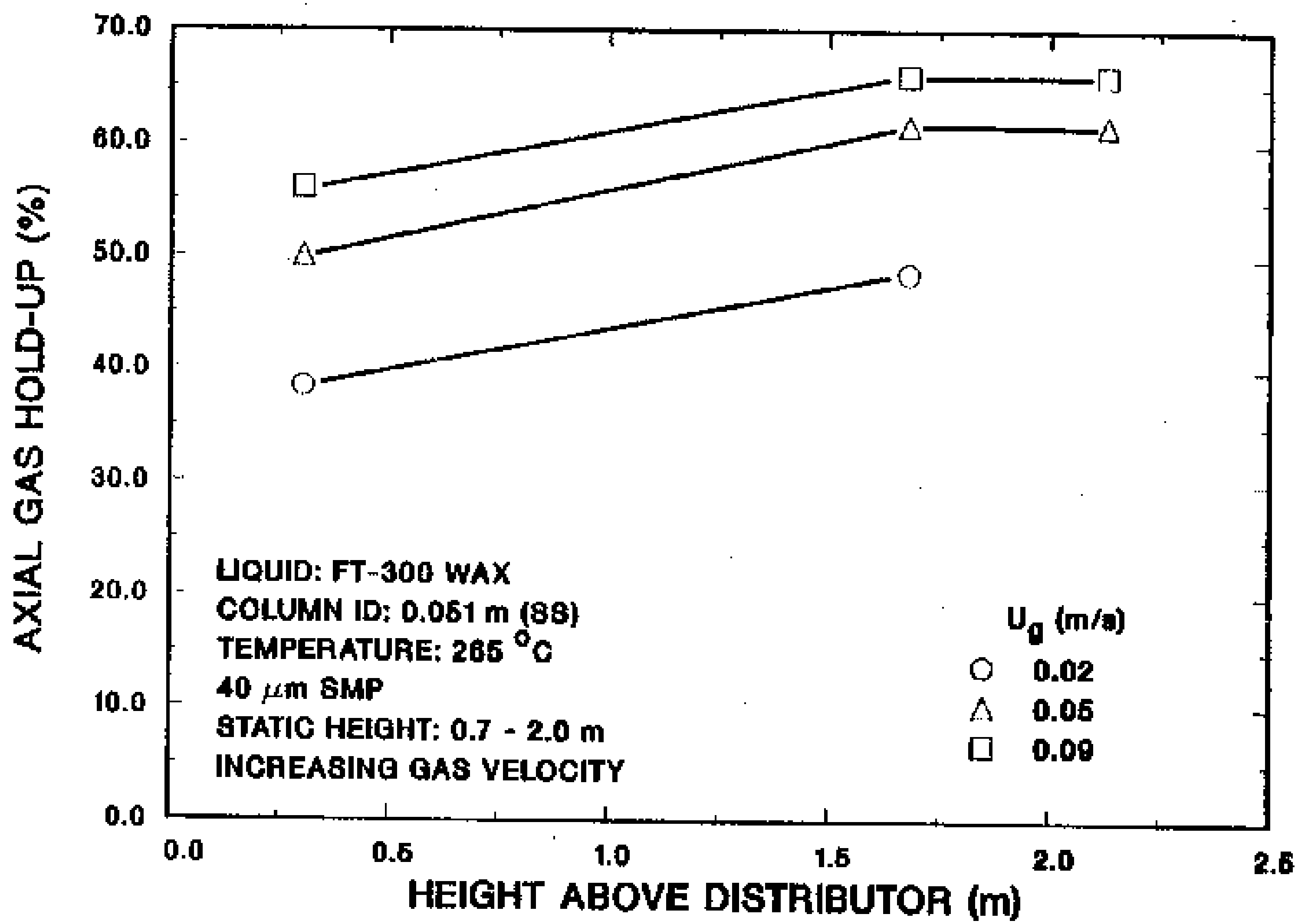

Figure V-43. Effect of superficial gas velocity and height above the distributor on axial gas hold-up (Run 3-7)

lower part of the column, which is in agreement with visual observations.

C.3c. 19 x 1.85 mm Perforated Plate Distributor

Axial gas hold-up profiles obtained in the large column with the 19 x 1.85 mm PP distributor using FT-300 as the liquid medium are shown in Figure V-44. In general, the same behavior was observed as with the axial gas hold-up measurements in the smaller diameter column (see Figure V-41). Namely, in the absence of foam, axial gas hold-up increases with gas velocity, however, it increases only slightly with an increase in column height. The average gas hold-ups at a given velocity were higher in the large SS column as opposed to the large glass column (see Figure V-45). This, along with the constant hold-up profile, indicates that smaller bubbles were present in the 0.241 m ID stainless steel column and they were uniformly dispersed (i.e. the higher average gas hold-ups were not caused by a layer of foam on top of the dispersion but rather by a higher concentration of smaller bubbles dispersed throughout the liquid medium). One possible explanation for this could be the aging of wax. Studies have shown that hold-up tends to be higher in runs conducted with wax that has been on stream for an extended period of time (see Section V-B.2.) The wax used to conduct runs in the stainless steel column was on stream longer than the wax used for the run conducted in the glass column. Therefore, it is expected that smaller bubbles would be produced in the stainless steel column, resulting in higher hold-ups.

Average gas hold-ups obtained using FT-300 as the liquid medium at 200 and 265°C in the 0.241 m ID stainless steel column are shown in Figure V-45; also shown are the average gas hold-ups obtained in the 0.229 m ID glass column. All experiments were conducted using increasing order of

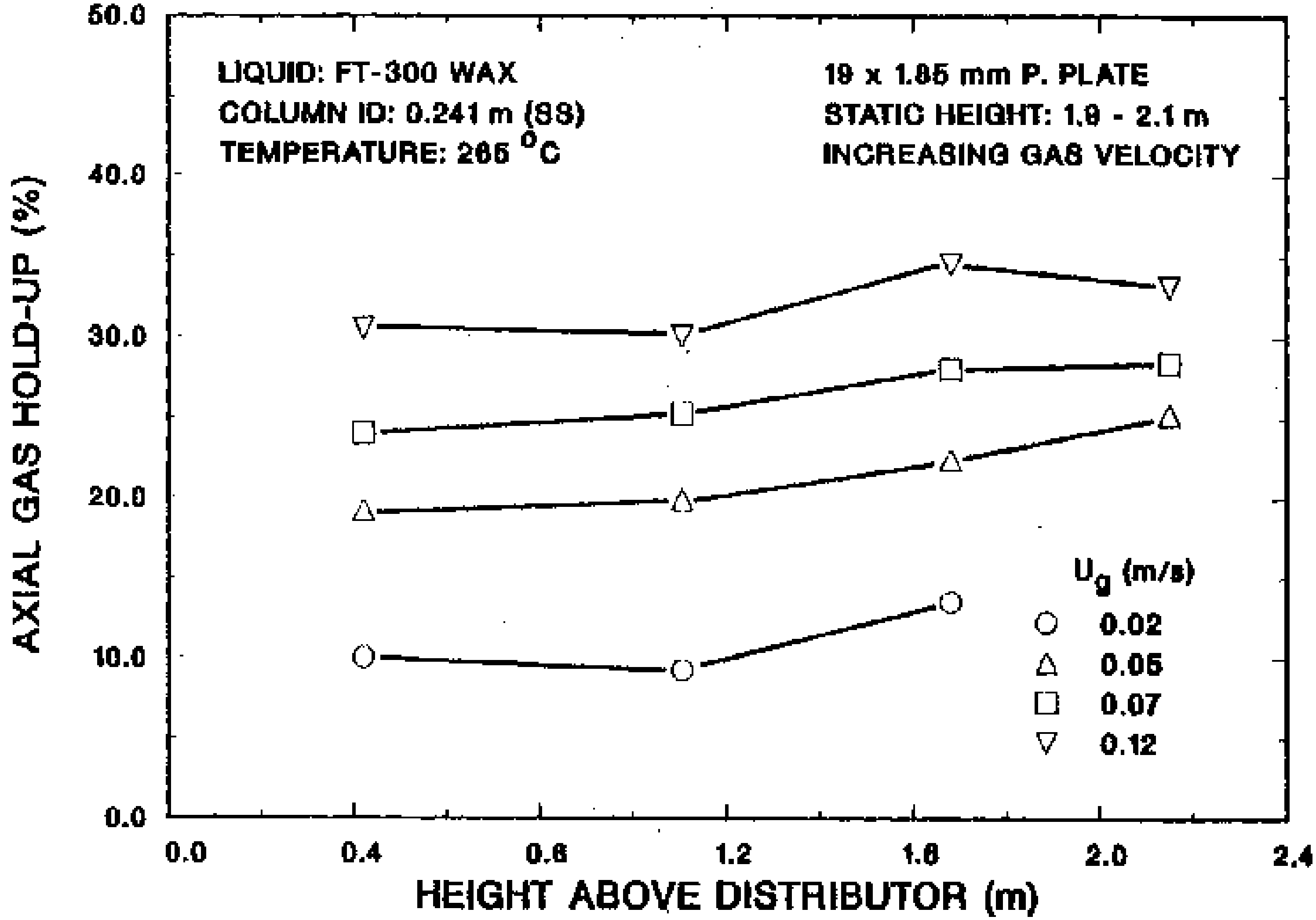

Figure V-44. Effect of superficial gas velocity and height above the distributor on axial gas hold-up (Run 2-7)

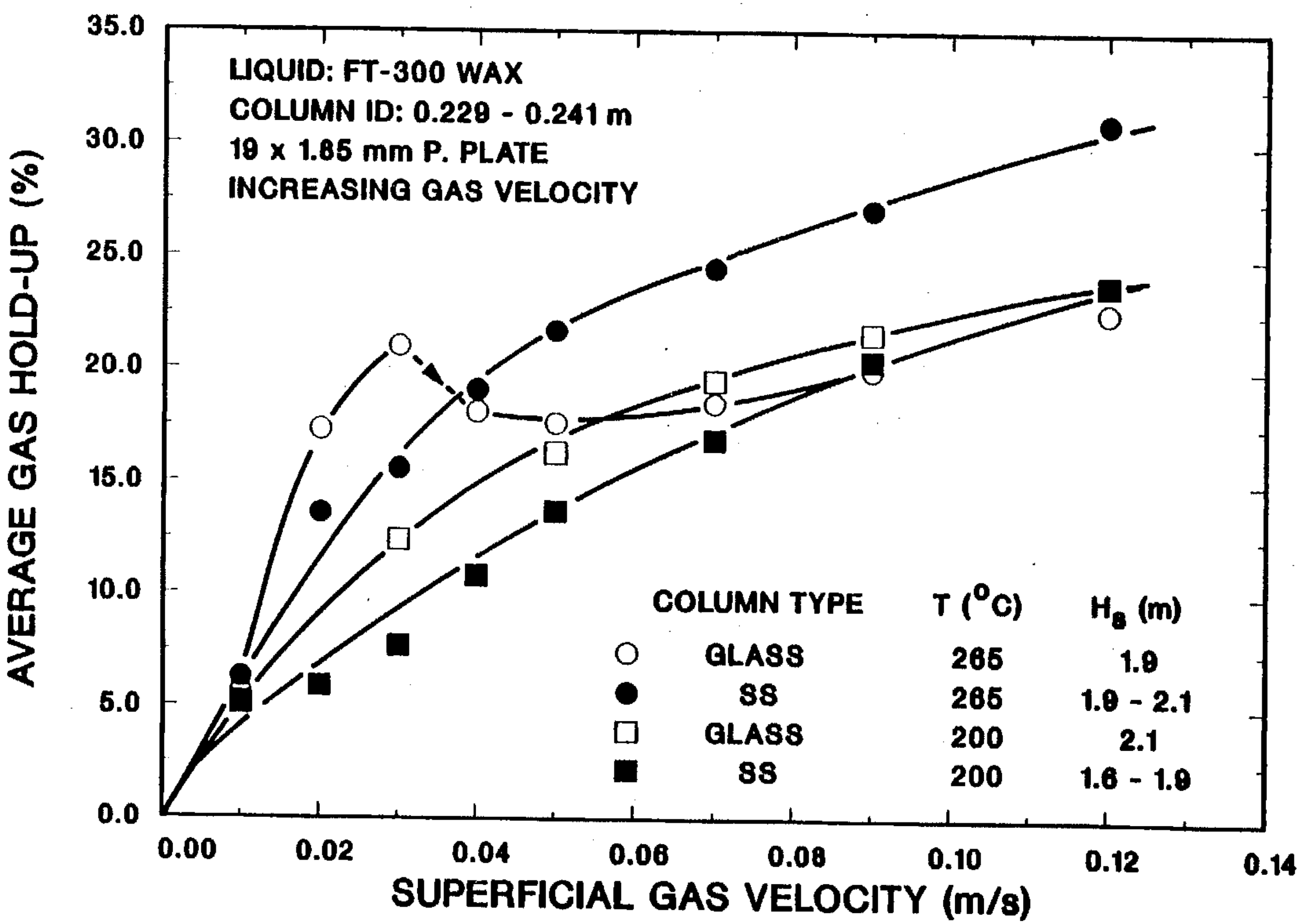

Figure V-45. Effect of superficial gas velocity on gas hold-up (○ - Run 2-8; ● - Run 2-7; □ - Run 1-1; ■ - Run 2-6) velocities. There is good agreement between the data obtained in the stainless steel column and the glass column especially at 200°C. Average gas hold-ups obtained from the experiment conducted at 265°C in the 0.241 m ID stainless steel column were larger than the values obtained in the "churn-turbulent" regime in the glass column; yet, lower than the values obtained in the "foamy" regime at 0.02 and 0.03 m/s. On the other hand, the gas hold-ups obtained at 200°C in the stainless steel column were slightly lower than those obtained in the glass column at 200°C. A similar trend was observed with Sasol wax in the large column (see Figure V-47) and in the small column with FT-300 wax (see Figure V-42, decreasing order of velocities). This is probably due to overestimating the slurry density in the uppermost section of the column.

Figure V-46 shows the axial gas hold-ups for Sasol wax in the 0.241 m ID stainless steel column. The profiles are different from those obtained with FT-300 wax. Our results with Sasol wax indicate a minimum axial gas hold-up midway along the column height. Sasol wax has a greater tendency to coalesce than does FT-300. For this type of medium, it is possible to reach a maximum stable bubble size along the column height. Above this point, the bubbles may remain unchanged or disperse. This is a possible explanation for the type of behavior we saw with Sasol wax. Kuo et al. (1985) conducted axial hold-up measurements with reactor wax produced in their bench scale unit (Run CT-256-7 wax). Their results indicate a gradual decrease in the axial gas hold-up as column height is increased (for u_g > 0.025 m/s). Since their runs were conducted in a 0.051 m ID column, the presence of slugs would have a significant effect on axial hold-up. It has been shown that in a column of this size, slugs are present for this

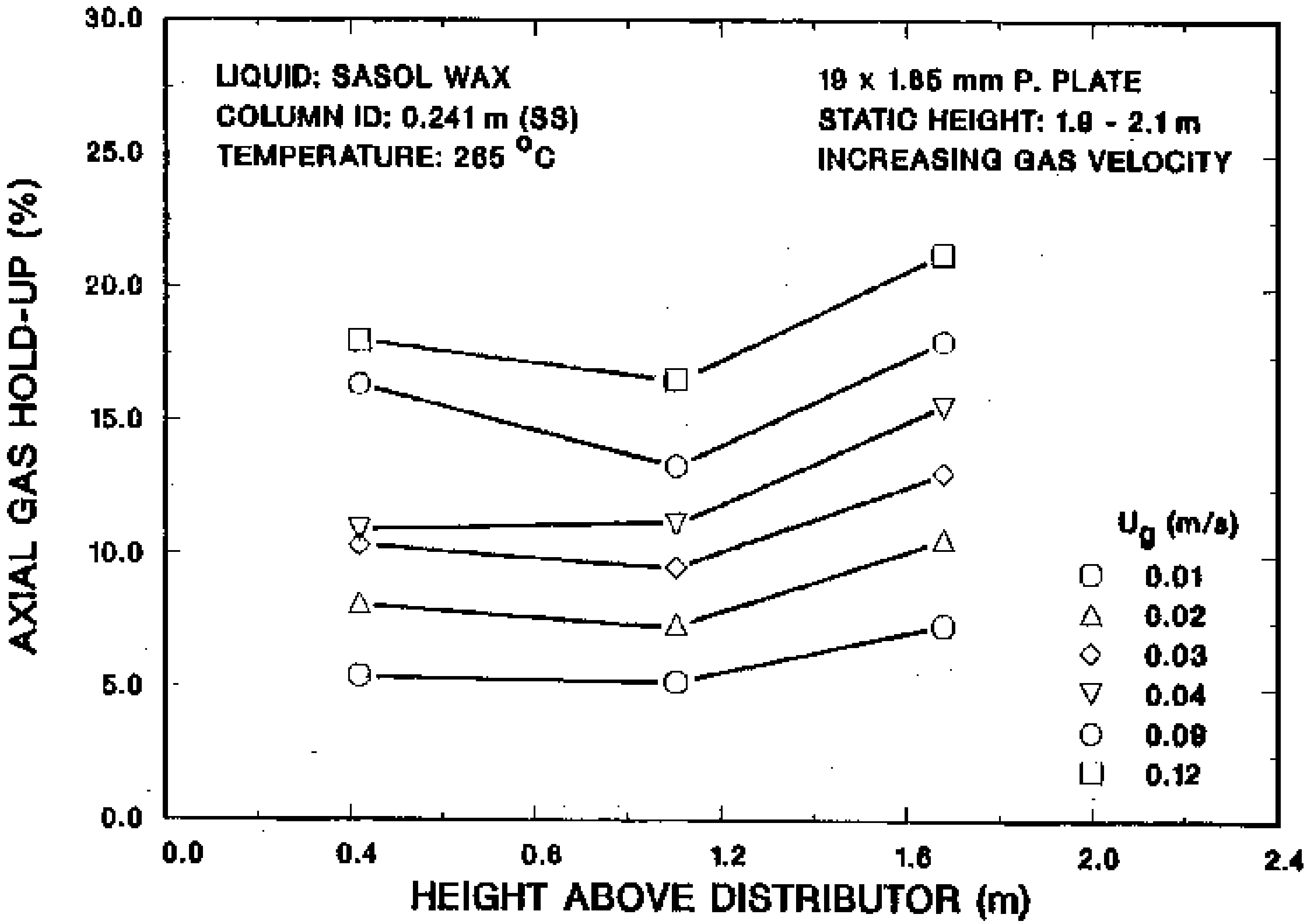

Figure V-46. Effect of superficial gas velocity and height above the distributor on axial gas hold-up (Run 3-1)

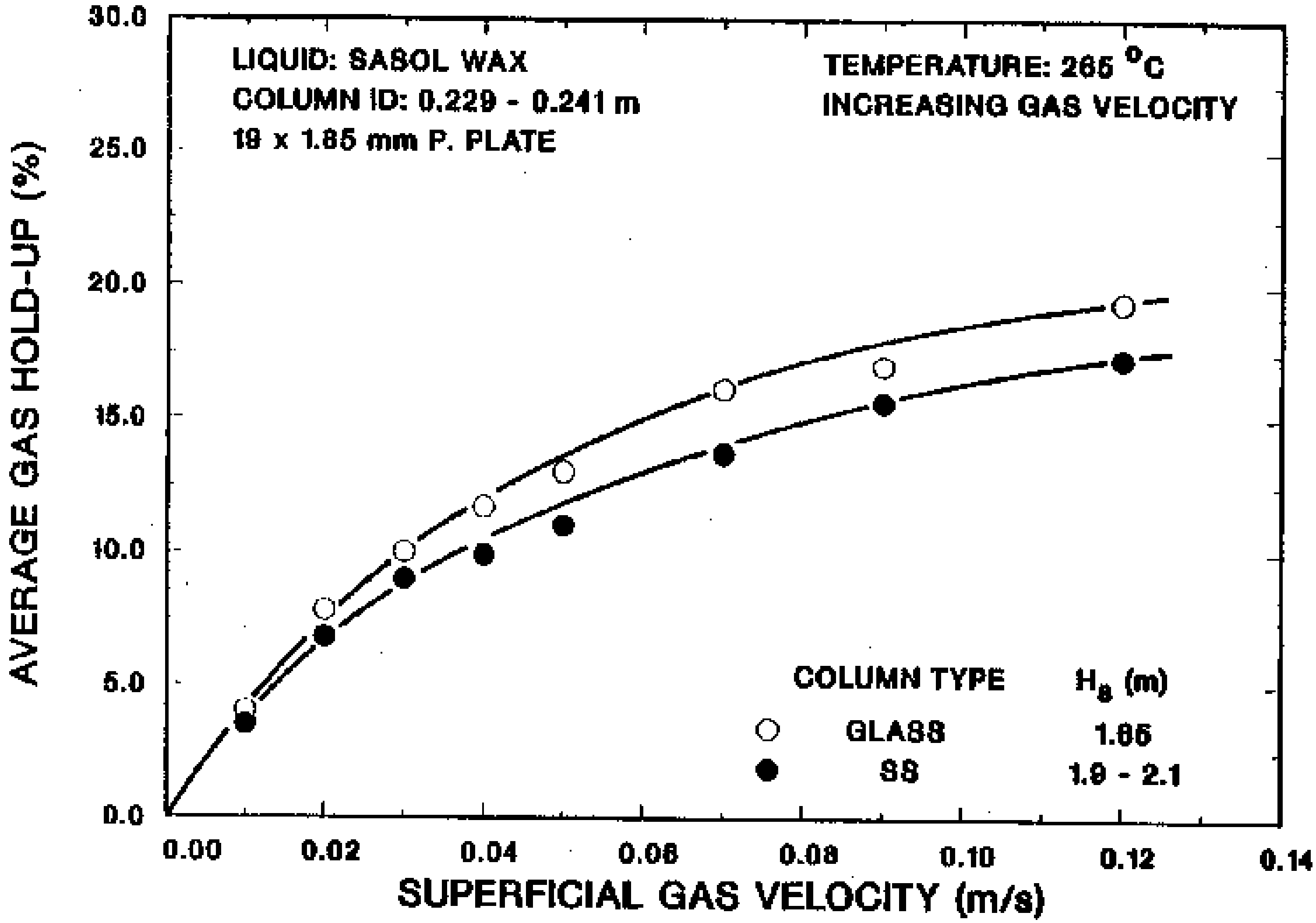

Figure V-47. Effect of superficial gas velocity on gas hold-up (○ - Run 3-2; ● - Run 3-1) velocity range, and therefore, the axial hold-up is expected to decrease with an increase in column height. Whereas, in the present study, where a larger column was used (0.241 m ID), flow is mostly in the "churn-turbulent" regime, where large bubbles are more uniformly mixed with a lot of fine bubbles, therefore, axial hold-up tends to remain constant or increase slightly with column height.

Axial hold-up measurements show that hold-up profiles along the length of the column are dependent on the flow regime. In the presence of foam the gas hold-ups near the top of the dispersion are significantly higher than those in the lower portion of the column. However, in the absence of foam and for systems with a high coalescence rate, the increase in hold-up with column height is only marginal. An increase in gas velocity shifts the axial gas hold-up profile upwards (towards higher values) irrespective of whether the foam is present or not.