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THE SPLIT OF HORIZONTAL SEMI-ANNULAR FLOW AT A LARGE DIAMETER T-JUNCTION

P. A ROBERTS[1], B. J. AZZOPARDI[2] and S. HIBBERD[1]

[1]Department of Theoretical Mechanics and [2]Department of Chemical Engineering,
University of Nottingham, University Park, Nottingham NG7 2RD, England

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Abstract—Experimental results are presented for the phase split which occurs at a T-junction made up of 0.125 m diameter pipes all on the same horizontal plane. Measurements were performed in the stratified and annular flow regimes and near the boundary of stratified-annular flow. A new phenomenological model is presented to determine the phase split of low liquid hold-up (<0.04) semi-annular flow and predictions compared with measurements from this present study, other sources of data and published phase separation models. Excellent agreement is found dependent upon the various correlations implemented in the model.

Key Words: junctions, flow split, data, models, gas–liquid

1. INTRODUCTION

Junctions, where two-phase flow is divided between the outlets, are common in the power generation, process and hydrocarbon production industries. The almost inevitable maldistribution of the phases can have a significant effect on the behaviour of equipment downstream of the junction far exceeding the size of the junction relative to the complete plant. For example, when steam injection is being used to effect enhanced recovery of viscous oils, the steam is usually generated at a central point and distributed to a number of wells. This can involve several junctions. In this process it is important to know where the water (either that coming from the boiler because of incomplete evaporation or that due to condensation of steam along the transmission lines) goes, as water having much lower enthalpy than steam is much less effective at lowering the viscosity of the oil.

In the past several decades, almost all measurements of the phase separation of two-phase flow have been performed in small-scale laboratory equipment, with pipe diameters generally not over 0.05 m. Exceptions to this are the recent experiments by Azzopardi (1994), who measured flow split at a tee with a vertical main pipe and a horizontal side arm of diameter 0.125 m, Mudde *et al.* (1993), who used a horizontal main pipe of diameter 0.23 m and a vertically upward side arm of diameter 0.1 m and Rubel *et al.* (1993) who used horizontal pipes of 0.0973 m. The scale of these pipelines is much closer to that used in industry and the measurements are therefore very useful in determining the effect on the phase separation of industrial-scale pipe diameters. In this paper phase separation measurements of stratified, semi-annular and annular flow in a large scale T-junction with all the arms of the tee lying in the horizontal plane are presented.

Models are available in the literature to predict the phase separation of annular flow and stratified flow at a horizontal T-junction. A review of these models is presented by Roberts (1994). There has, however, been little analysis of the phase separation of flows near the stratified–annular boundary referred to as semi-annular flows. At low liquid hold-up conditions this transitional flow regime consists of a crescent shaped liquid film at the bottom of the tube and, if the gas flow rate is high enough, liquid droplets travelling with the gas. Only the model by Hart *et al.* (1991) is applicable to such flows with liquid hold-up values less than 0.06. This model was based on the Bernoulli equations for each phase along the main pipe and from the main pipe to the side arm. Interaction between the phases is ignored and loss coefficients are described by single-phase correlations.

When annular flow approaches a tee, a sudden increase in the amount of liquid extracted for a small increase in the gas take off has been reported by Azzopardi (1989) when the main pipe was vertical and by Azzopardi & Smith (1992) with a horizontal main pipe. This trend was explained by the film reacting to the pressure increase along the main pipe and slowing down. When the pressure increase is high and the inlet film momentum low the film is brought to a complete halt and can be easily extracted. The phenomenon has thus been referred to as film-stop. Azzopardi (1989) determined an expression for the critical gas take off value at which the film was brought to a halt by formulating Bernoulli equations for each phase along the main pipe and imposing that the pressure increase was the same in both phases. Although single-phase correlations were used to describe loss coefficients for the gas, energy losses in the liquid were ignored. The quantities of liquid divided between the outlets after film-stop had occurred was assumed to be proportional to the shear of the gas flowing downstream in the main pipe and laterally into the side arm. This resulted in a simple expression for the extra amount of liquid taken off.

Azzopardi & Whalley (1982) proposed a method of determining phase separation based on observations of single-phase flow reported by McNown (1954). It was suggested that the fluid emerging through the branch outlet is taken from the segment of main pipe nearest the side arm. This approach has been shown by Azzopardi (1989) to yield good predictions of the split of annular flow at small diameter horizontal T-junctions if the occurrence of film-stop is accounted for. The model, however, has been applied to stratified flows with little success and Shoham *et al.* (1987) argued that better predictions can be obtained if the dividing streamlines are different for the gas and liquid phases. In this present study, the local segment model is applied to semi-annular flows by describing the flow configuration with the aid of correlations for the fraction of the tube wetted by the film and the liquid hold-up value. The film-stop analysis of Azzopardi (1989) is also assumed to hold for low liquid hold-up flows. The resulting model is compared against data taken at the large diameter T-junction and data from other sources with inlet flows of liquid hold-up less than 0.04. Comparisons with the model by Hart *et al.* (1991) are also presented to investigate which model yields the best agreement at different flow conditions.

2. THE MODEL

The methodology of Azzopardi & Whalley (1982) is applied to a low liquid hold-up semi-annular flow at a horizontal T-junction. The liquid film is assumed to be of uniform thickness and wet the wall over an angle α as shown in figure 1. An entrained fraction of liquid E is also assumed. If the fluids extracted into the side arm come from a segment of angle ϕ, then the mass fractions of the inlet gas and liquid flow which are taken off, G' and L'_{SEG}, are given by

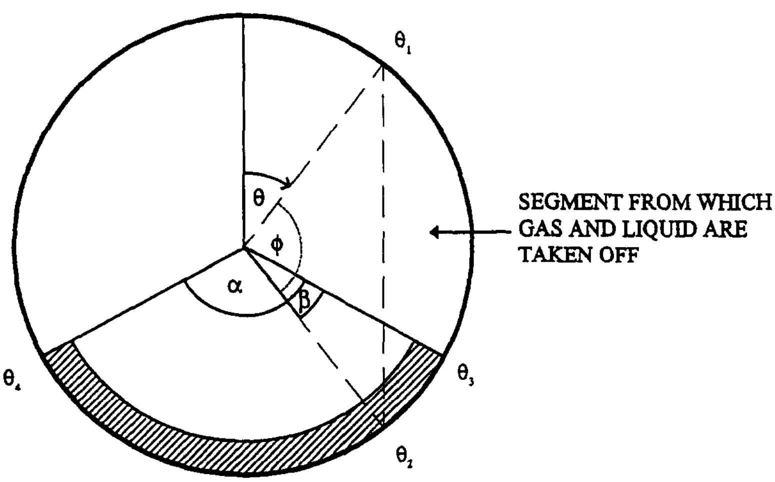

Figure 1. Schematic representation of gas–liquid flows with a small liquid hold-up.

$$G' = \frac{\phi - \sin\phi}{2\pi},$$

and

$$L'_{\mathrm{SEG}} = \frac{\beta}{\alpha}(1 - E),$$

where

$$\beta = \phi, \quad \text{if} \quad \theta_1 > \theta_3;$$
$$\beta = 0, \quad \text{if} \quad \theta_2 < \theta_3;$$
$$\beta = \theta_2 - \theta_3, \quad \text{if} \quad \theta_4 > \theta_2 > \theta_3 > \theta_1;$$
$$\beta = \alpha, \quad \text{if} \quad \theta_2 > \theta_4,$$

and

$$\theta_1 = (\pi - \phi)/2, \quad \theta_2 = (\pi + \phi)/2,$$
$$\theta_3 = \pi - \alpha/2, \quad \theta_4 = \pi + \alpha/2.$$

For given inlet flow conditions, the correlations by Hamersma & Hart (1987) or Hart *et al.* (1989) are used to calculate the fraction of the wall wetted by the liquid ($=\alpha/(2\pi)$), which determines the angles θ_3 and θ_4, and the correlation of Williams (1986) is used to predict the entrained liquid fraction. The segment angle ϕ is then varied from 0 to 2π and the corresponding fractions of gas and liquid taken off calculated by the above equations.

Film-stop is assumed to occur at a critical gas take off value, G'_c, given by

$$G'_c = 0.715 - \sqrt{0.493 - 0.633\frac{\rho_L u_{FI}^2}{\rho_G u_{GI}^2}},$$

where the gas and film velocities, u_{GI} and u_{FI}, are determined from the inlet flow rates using the liquid hold-up values predicted by the correlations of Lockhart & Martinelli (1949), Hamersma & Hart (1987) or Hart *et al.* (1989). After film-stop has occurred, the extra amount of liquid taken off, L'_S, is calculated by the following equation derived by Azzopardi (1989)

$$L'_S = (1 - L'_{\mathrm{SEG}} - E)\left(\frac{G'^2}{1 - 2G' + 2G'^2}\right).$$

3. EXPERIMENTAL ARRANGEMENT

The apparatus used in the experiments is illustrated schematically in figure 2 and is similar to that used by Azzopardi (1994). Air was drawn from the laboratory by a centrifugal blower through an intake section which contained an orifice plate to meter the flow rate and an iris valve to regulate the flow. Metal sieves were also stacked onto the inlet tube to reduce the air flow rate. Water was drawn from a storage tank by means of a centrifugal pump and correct water pressure obtained from bypassing part of the flow. The flow to the test section was monitored by one of a number of calibrated variable area rotameters before it entered the flow tube through a porous wall section. The junction was placed 3.5 m from the liquid entry point and was followed by a further 3.5 m of 0.125 m tube, a bend and another tube 0.5 m in length which contained a butterfly valve and led to a cyclone. The side arm consisted of 1.5 m of 0.125 m tubing and a similar arrangement leading to another cyclone. The T-junction used in the present study was machined from an acrylic resin block. The main bore and the side arm were both 0.125 m in diameter. The outside of the block had been machined to a square cross-section (0.2 × 0.2 m) to minimize refraction problems during observation. The junction block was provided with flanges at the three ends so as to mate with the rest of the test section pipework. The inside of the T-junction was carefully machined with sharp corners so as to eliminate the radius of curvature as a possible variable in the experiments.

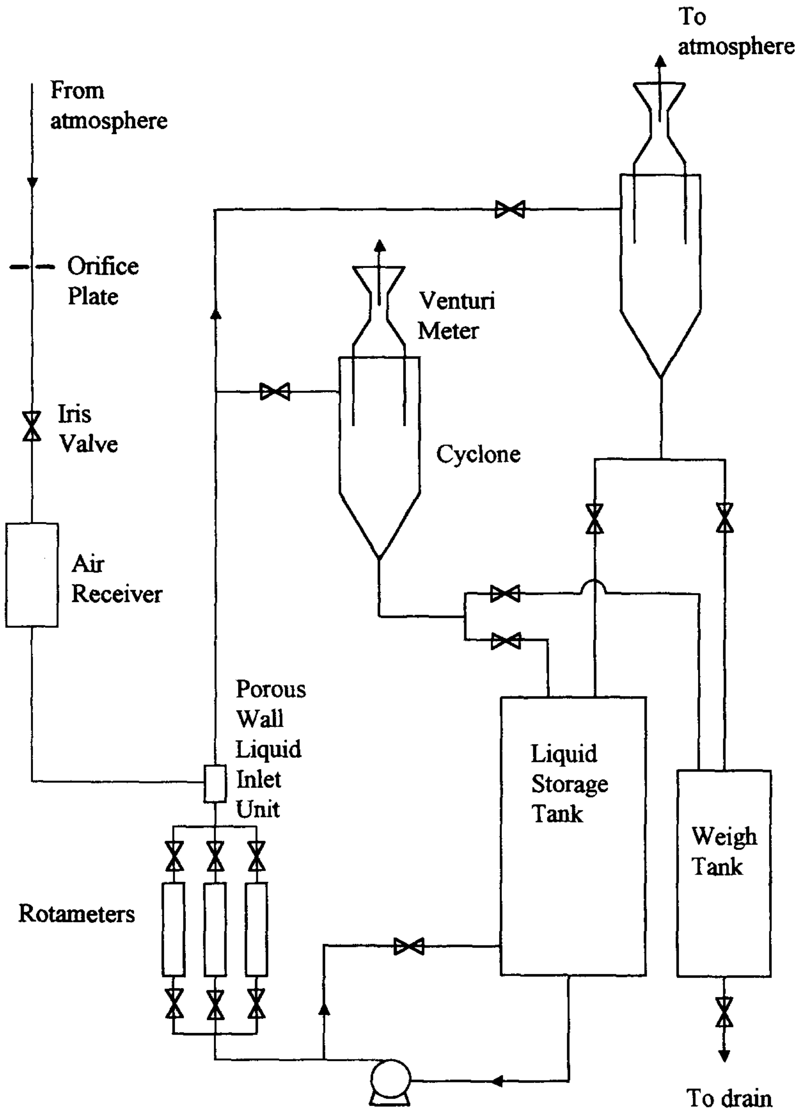

Figure 2. Experimental arrangement.

The air and water emerging from the outlets were separated in the cyclones and metered. The air flow was measured using a calibrated venturi meter and the water flow rate was determined from weighing a timed efflux after diverting the flow from either cyclone into a weigh tank placed on a calibrated load cell.

4. RESULTS

For each run the inlet flow rates were maintained constant and the division of the flow was controlled by the valves on the outlet tubes. The nominal inlet conditions at which measurements were taken and the flow split data are listed in the appendix. As, in most cases, the liquid and gas flow rates were measured for each of the two outlets as well as the inlet, mass balances could be carried out. These indicated that the sum of the outlet water flow rates differed by at most 5% from the inlet value. For the gas phase, the percentage difference was within $\pm 10\%$. Those runs where poorer mass balances were obtained were rejected. Figure 3 shows the inlet conditions together with the flow pattern boundaries suggested by Taitel & Dukler (1976). Visual observation of the inlet flows agreed with the predicted flow patterns.

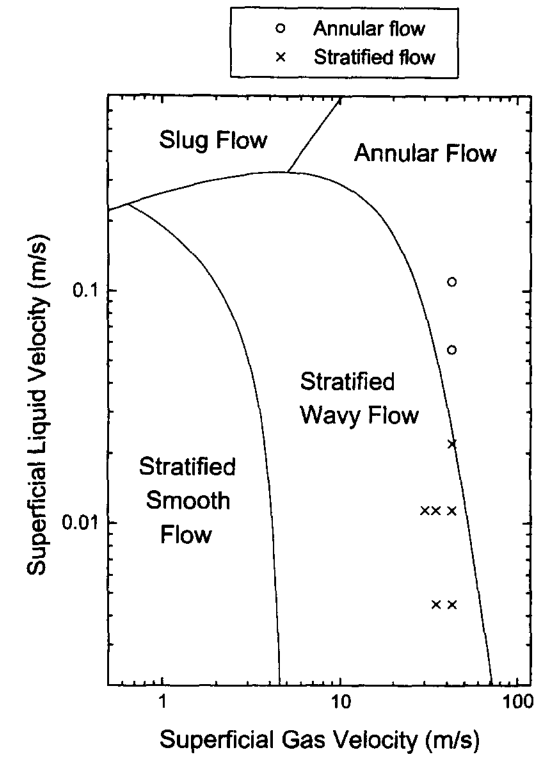

Figure 3. Flow pattern map as suggested by Taitel & Dukler (1976).

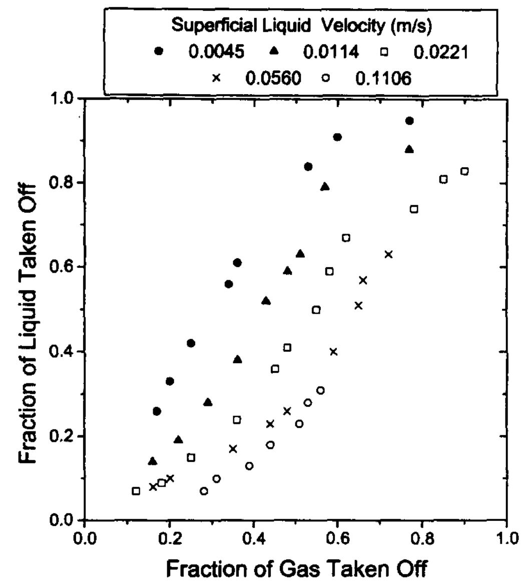

Figure 4. The effect of liquid velocity on the flow split—superficial gas velocity 42.8 m/s.

For the lowest liquid flow rate cases, the air–water boundary was observed to form a crescent shape as shown in figure 1. As the liquid flow rate was increased, the interface became more horizontal and droplets were observed to be travelling in the gas phase at the conditions of run 3. Further increases in the liquid flow rate produced annular flow.

Figure 4 illustrates the effect of increasing the liquid flow rate at the inlet to the junction on the phase separation. A decrease in the fraction of liquid taken off is found as the flow rate is increased for measurements in the annular and stratified flow regimes. This trend also appears in the data by Shoham *et al.* (1987), Azzopardi *et al.* (1988) and Hart *et al.* (1991). Since the range of inlet gas flow rate covered is very limited, it is tentatively concluded that the opposite trend occurs with increasing gas velocity, i.e. the fraction of liquid taken off increases as illustrated in figure 5.

It has been shown by Azzopardi *et al.* (1988) that the phase separation of stratified flows at a horizontal T-junction are similar if the momentum of their phases calculated with the superficial velocities are the same. This result was also shown to hold in vertical annular flow by Azzopardi (1994) if the momentum of the droplets was taken into account. In figure 6 data from the present study has been compared with available data from Azzopardi *et al.* (1988) for which the momentum flows are similar. Values of the momentum are given in table 1.

The entrained fraction was calculated by the correlation of Williams (1986) and the local mean velocity used to calculate the film momentum was determined using the correlation by Laurinat *et al.* (1984) for the mean film thickness. It can be seen that although the data in figure 6 are similar, there appears to be opposite trends in the slope at low and high gas take off. This is presumably due to differences in the inlet flows. Whilst the data by Azzopardi *et al.* (1988) was taken at conditions well into the annular flow regime, the data from the present study was measured at the boundary of stratified–annular flow. The asymmetry of the liquid is thus much more pronounced in the latter case with almost all the liquid film flowing along the bottom of the tube. One would thus expect the fraction of liquid taken off to be comparatively less at low gas taken off and more at high gas take off by the visual observations reported by McNown (1954). It should be noted that the correlation for the mean liquid height by Laurinat *et al.* (1984) has not been compared

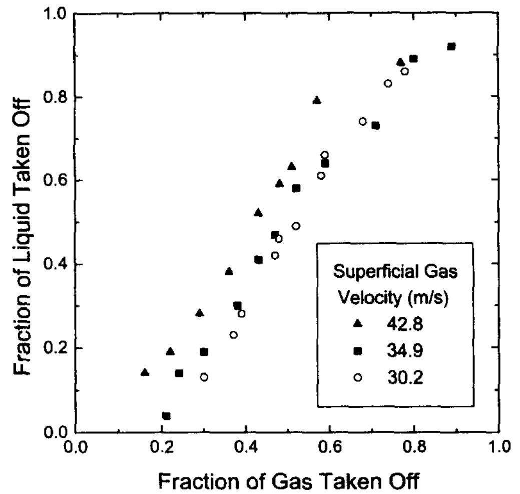

Figure 5. The effect of gas velocity on the flow split—superficial liquid velocity 0.0114 m/s.

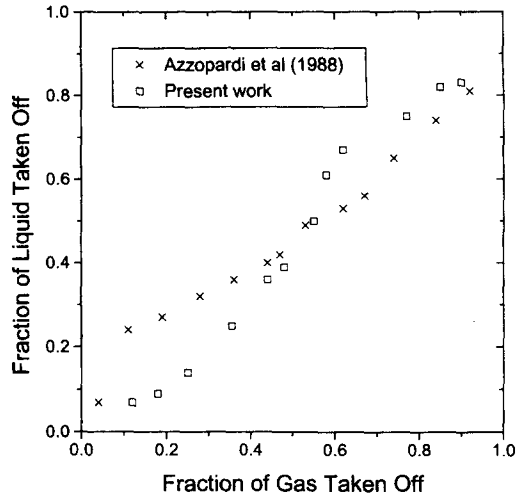

Figure 6. The effect of pipe diameter on the flow split [superficial values of gas and liquid velocity are 24.7 and 0.056 m/s for the data by Azzopardi *et al.* (1988) and 42.8 and 0.0221 m/s for the present work].

with film thickness measurements in large diameter tubes. Predictions of the mean liquid height are thus likely to be poor for flows at the annular–stratified boundary. Nonetheless, the correlation is used here to yield approximate values of the film momentum for comparative purposes, and figure 6 is consistent with the previous findings of Azzopardi if the effect of the flow pattern is taken into account.

5. COMPARISON OF THE MODEL WITH AVAILABLE DATA

Figure 7(a) shows a comparison of the model presented in section 2 with data taken at the large diameter T-junction for the lowest liquid and gas flow rate conditions. The correlation for the fraction of the wetted perimeter by Hamersma & Hart (1987) was implemented in the calculations and the void fraction is given by Hamersma's own correlation or that by Lockhart & Martinelli (1949). On this figure, the results with and without the additional take off due to film-stop are also illustrated. Although an abrupt increase in the data is not observed, the predictions which include film-stop are in excellent agreement. The difference in the results produced by using the different correlations for the liquid hold-up is noted to be small with the one by Lockhart & Martinelli (1949) yielding slightly better predictions for these flow conditions. In figure 7(b) a comparison has been made with data at a higher gas flow rate using the models by Hamersma & Hart (1987) or Hart *et al.* (1989) for the fraction of the wetted perimeter. The latter model yields much lower liquid hold-up values than that of Hamersma & Hart (1987) and consequently higher values of liquid momentum are calculated. This results in higher critical gas take off values, and for these flow conditions, film-stop is not found to occur and the data are significantly underpredicted. Excellent agreement is obtained with the correlation by Hamersma & Hart (1987) since film-stop is correctly accounted for.

Table 1. Comparison of the momentum flows for the small and large diameter cases

Pipe diameter (m)	0.038	0.125
Gas flow rate (kg/s)	0.101	0.65
Liquid flow rate (kg/s)	0.063	0.28
Gas momentum based on superficial velocity (kg/m s^2)	2203	2338
Liquid momentum based on superficial velocity (kg/m s^2)	3.09	0.52
Film momentum (kg/m s^2)	5335	5086
Entrained fraction	0.154	0.352

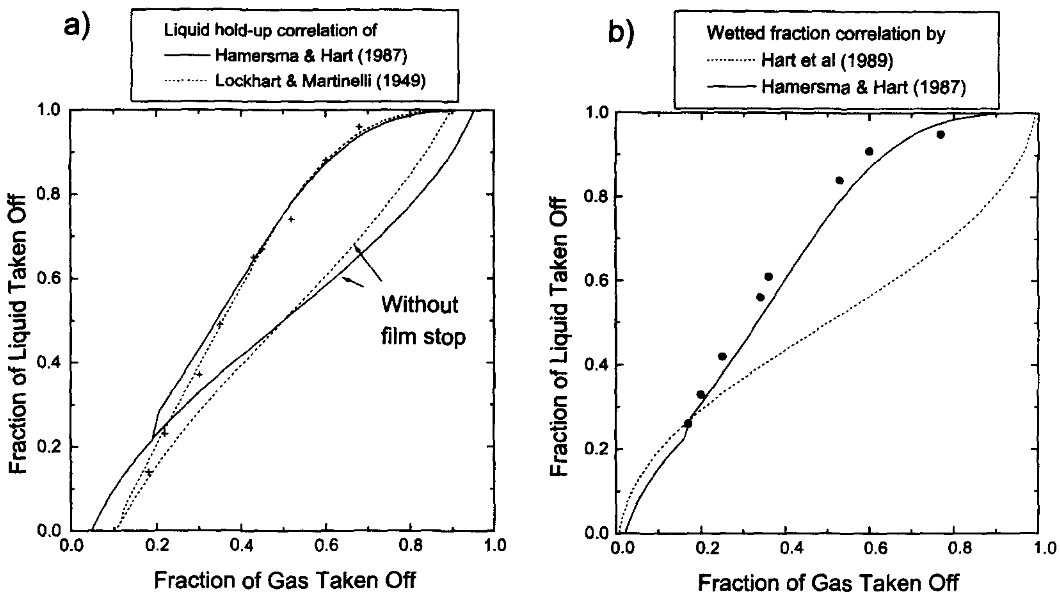

Figure 7. Comparisons between the segment model and data taken at the large diameter T-junction—superficial liquid velocity 0.0045 m/s; superficial gas velocity (a) 34.9 m/s and (b) 42.8 m/s.

Comparisons with data at a higher liquid flow rate are shown in figure 8 using the correlation by Hamersma & Hart (1987) for the fraction of the wetted perimeter. Although the correct trends are predicted, absolute comparison reveals that the fraction of liquid taken off is too high. Droplets are observed to be travelling with the gas at these flow conditions and the correlation by Williams (1986) predicts a small amount of entrainment ($E = 0.05$). If higher values of the entrained fraction were used, calculations would yield less liquid taken off bringing the curves closer to the data.

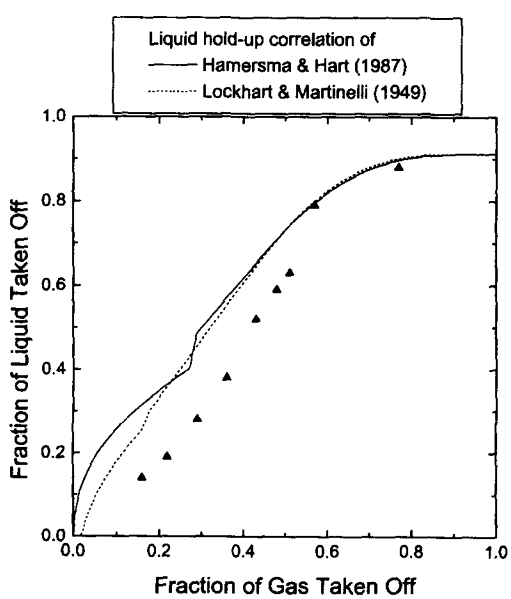

Figure 8. Comparison between the segment model and data taken at the large diameter T-junction—superficial liquid velocity 0.0114 m/s and superficial gas velocity 42.8 m/s.

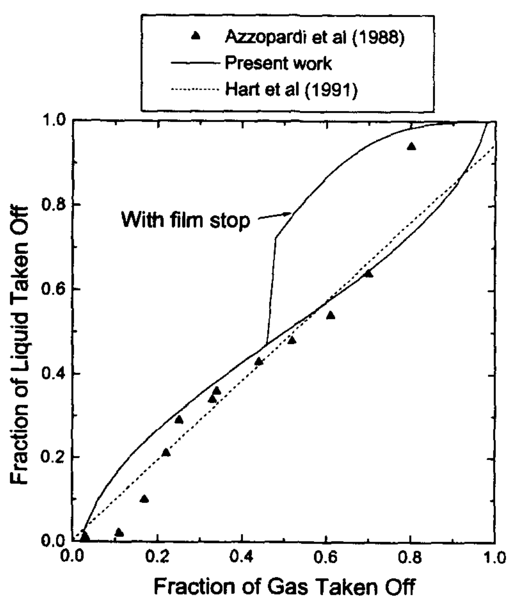

Figure 9. Comparison between models and data of Azzopardi *et al.* (1988) taken near the stratified–annular boundary—gas flow rate 0.044 kg/s, liquid flow rate 0.013 kg/s, pressure 3 bar, main pipe diameter = side arm diameter = 0.038 m.

Discrepancies in the results are thus probably due to inaccuracies in the calculated value of entrained fraction.

Phase separation data has been presented by Azzopardi *et al.* (1988) with inlet flows of low liquid hold-up. Figure 9 shows a comparison of data taken near the stratified–annular flow boundary with the new model and that of Hart *et al.* (1991), where the fraction of the wetted perimeter has been calculated with the correlation by Hart *et al.* (1989). There is good agreement with both models, but the new model predicts the trends in the data which are not picked up by the model of Hart. The film-stop analysis predicts a critical gas take off value much lower than the observed sudden increase in data which occurs at a gas take off value of about 0.75. This is presumably due to inaccuracies in the calculation of the liquid hold-up.

Predictions of the models have also been compared in figure 10 with data by Azzopardi *et al.* (1988) at a lower gas flow rate. The inlet flow in this case is well into the stratified flow regime according to Taitel & Dukler (1976). Excellent agreement is obtained with the new model when the correlation by Hamersma & Hart (1987) is used for the wetted fraction and the correlation by Lockhart & Martinelli (1949) is used for the liquid hold-up. The sudden increase in the data due to film-stop is correctly predicted, a phenomenon which is not picked up by the model of Hart.

The model by Hart has been shown by the authors to yield good agreement with data of Shoham *et al.* (1987). In figure 11 predictions are compared with those of the new model at the lowest liquid flow rate condition. Although absolute comparison is not as good as was obtained for previous flow conditions, the new model again predicts the *trends* in the data which are not obtained with the model by Hart.

6. DISCUSSION AND CONCLUSIONS

The phase separation of stratified and annular flow at a large diameter T-junction has been measured to extend the limited data bank on flow split at junctions made up of pipes of industrial-scale. The trends in the data are found to be very similar to those observed in pipes of smaller diameter with any differences being due to variation in the flow pattern and not the effect of scale.

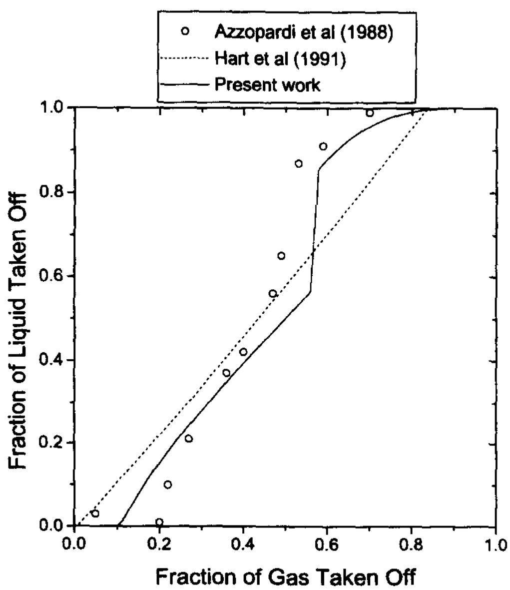

Figure 10. Comparison between models and data of Azzopardi *et al.* (1988)—gas flow rate 0.024 kg/s, liquid flow rate 0.009 kg/s, pressure 3 bar, main pipe diameter = side arm diameter = 0.038 m.

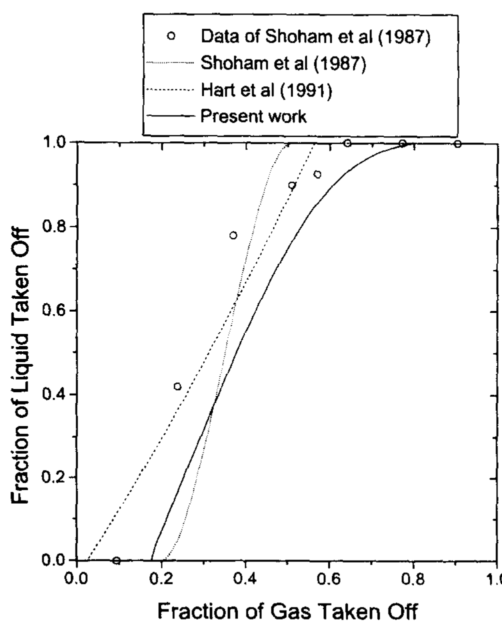

Figure 11. Comparison between models and data of Shoham *et al.* (1987)—superficial liquid velocity 0.00285 m/s, superficial gas velocity 6.1 m/s, pressure 3 bar, main pipe diameter = side arm diameter = 0.051 m.

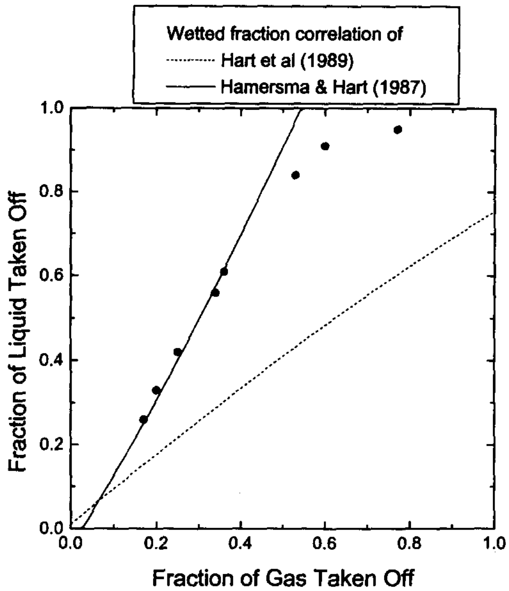

Figure 12. Comparison between data taken at the large diameter T-junction and the model by Hart *et al.* (1991) with different correlations for the wetted fraction—superficial liquid velocity 0.0045 m/s and superficial gas velocity 42.8 m/s.

It has been shown that the local segment model suggested by Azzopardi & Whalley (1982) and the film-stop analysis of Azzopardi (1989) can be applied to low liquid hold-up (<0.04) semi-annular flows with excellent prediction of data. The consideration of the extra amount of liquid taken off due to the occurrence of film-stop is found to be extremely important in the prediction of data from the present study and data by Azzopardi *et al.* (1988). The energy equations which are used in the film-stop analysis are as equally well applicable to semi-annular flow with a low liquid hold-up as for annular flow, but this has not been demonstrated until now. The film-stop phenomenon, however, was not observed in the experiments, presumably due to visual observation of film-stop being very difficult with only small amounts of liquid being present at the junction.

The calculation of the critical gas take off value is found to be sensitive to the correlations used to predict the fraction of the tube wetted by the film and the value of the liquid hold-up. The implementation of the correlation by Hamersma & Hart (1987) yielded better predictions than that by Hart *et al.* (1989) at very low values of liquid hold-up and the opposite result was found at higher values.

A similar result is also found with the model by Hart *et al.* (1991). Figure 12 shows a comparison between the predictions of the model calculated with the different correlations and data from the present study. The results using the correlation by Hamersma & Hart (1987) can be seen to yield significantly better agreement with the data.

There are thus two different approaches which can be used to predict the phase separation of stratified flows with a low liquid hold-up; that by Hart *et al.* (1991) based on the energy equations and the new model presented here implementing the local segment approach and film-stop. The latter model, however, predicts trends in the data which are not picked up by the model of Hart. As the liquid flow rate is increased, the agreement of the models with data deteriorates as expected since the description of the inlet flow breaks down. The film-stop model will also not hold with large amounts of liquid present since the effect of hydrostatic pressure and energy losses in the liquid are not taken into account. The extension of the analysis to higher liquid flow rates is currently underway.

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APPENDIX

Table A1. Nominal inlet conditions at which flow split was measured

	Inlet flow rates (kg/s)		Superficial velocities (m/s)	
Run No.	Gas	Liquid	Gas	Liquid
1	0.65	0.057	42.8	0.0045
2	0.65	0.710	42.8	0.0560
3	0.65	0.280	42.8	0.0221
4	0.65	0.145	42.8	0.0114
5	0.53	0.145	34.9	0.0114
6	0.46	0.145	30.0	0.0114
7	0.53	0.057	34.9	0.0045
8	0.65	1.400	42.8	0.1106

Inlet pressure = 1.0/1.05 bar.

Table A2. Flow split data

Run No.	Inlet flow rate (kg/s)		Outlet flow rate (kg/s) Side arm		Run		Fractional take off	
	Gas	Liquid	Gas	Liquid	Gas	Liquid	Gas	Liquid
1	0.65	0.057	0.109	0.015	0.542	0.038	0.17	0.26
	0.65		0.133	0.019	0.530	0.039	0.20	0.33
	0.65		0.165	0.024	0.496	0.034	0.25	0.42
	0.65		0.223	0.032	0.450	0.026	0.34	0.56
	0.65		0.237	0.035	0.423	0.024	0.36	0.61
	0.65		0.347	0.048	0.326	0.008	0.53	0.84
	0.65		0.390	0.052	0.264	0.005†	0.60	0.91
	0.65		0.500	0.054	0.153	0.003†	0.77	0.95
2	0.62	0.71	0.102	0.055	0.474	0.618	0.16	0.08
	0.65		0.130	0.070	0.474	0.608	0.20	0.10
	0.66		0.230	0.121	0.400	0.588	0.35	0.17
	0.65		0.283	0.161	0.351	0.526	0.44	0.23
	0.65		0.311	0.187	0.332	0.524	0.48	0.26
	0.66		0.386	0.282	0.246	0.455	0.59	0.40
	0.65		0.423	0.365	0.183	0.374	0.65	0.51
	0.65		0.356	0.408	0.220	0.309	0.66	0.57
	0.65		0.383	0.447	0.184	0.279	0.72	0.63
3	0.63	0.28	00.76	0.019	0.541	0.256	0.12	0.07
	0.65		0.119	0.024	0.531†	0.256†	0.18	0.09
	0.65		0.163	0.042	0.474	0.229	0.25	0.15
	0.65		0.231	0.066	0.415	0.208	0.36	0.24
	0.65		0.290	0.102	0.366	0.177	0.45	0.36
	0.65		0.314	0.114	0.344	0.154	0.48	0.41
	0.65		0.360	0.141	0.300	0.124	0.55	0.50
	0.65		0.380	0.165	0.258	0.108	0.58	0.59
	0.66		0.411	0.187	0.228	0.093	0.62	0.67
	0.65		0.504†	0.206	0.146	0.065	0.78	0.74
	0.66		0.559†	0.203	0.101	0.053	0.85	0.81
	0.64		0.578	0.233†	0.062	0.047	0.90	0.83
4	0.65	0.145	0.101	0.021	0.545	0.141	0.16	0.14
	0.65		0.144	0.028	0.505	0.112	0.22	0.19
	0.65		0.188	0.041	0.473	0.107	0.29	0.28
	0.65		0.235	0.055	0.424	0.093	0.36	0.38
	0.65		0.281	0.076	0.385	0.077	0.43	0.52
	0.67		0.319	0.086	0.359	0.059	0.48	0.59
	0.66		0.335	0.091	0.329	0.054	0.51	0.63
	0.66		0.378	0.115	0.264	0.037	0.57	0.79
	0.65		0.500†	0.127	0.150	0.021	0.77	0.88
5	0.53	0.145	0.072	0.007†	0.419	0.138	0.21	0.04
			0.100	0.020	0.401	0.130	0.24	0.14
			0.130	0.027	0.371	0.120	0.30	0.19
			0.183	0.044	0.331	0.105	0.38	0.30
			0.220	0.060	0.304	0.088	0.43	0.41
			0.261	0.068	0.283	0.075	0.47	0.47
			0.274	0.084	0.259	0.069	0.52	0.58
			0.312	0.093	0.205	0.052	0.59	0.64
			0.374	0.114	0.115	0.033	0.71	0.73
			0.423	0.129	0.034	0.016†	0.80	0.89
			0.470	0.133	0.060†	0.012†	0.89	0.92
6	0.46	0.145	0.086	0.019	0.322	0.130	0.30	0.13
			0.142	0.034	0.289	0.114	0.37	0.23
			0.162	0.040	0.280	0.110	0.39	0.28
			0.214	0.061	0.243	0.091	0.47	0.42
			0.230	0.066	0.238	0.082	0.48	0.46
			0.238	0.071	0.220	0.077	0.52	0.49
			0.266	0.088	0.172	0.062	0.58	0.61
			0.311	0.108	0.095	0.042	0.68	0.74
			0.341	0.120	0.043†	0.025†	0.74	0.83
			0.537	0.125	0.103†	0.020†	0.78	0.86

continued overleaf

Table A2—continued

	Inlet flow rate (kg/s)		Outlet flow rate (kg/s)					
			Side arm		Run		Fractional take off	
Run No.	Gas	Liquid	Gas	Liquid	Gas	Liquid	Gas	Liquid
7	0.53	0.057	0.066	0.008†	0.433	0.049	0.18	0.14
			0.091	0.013	0.414	0.047	0.22	0.23
			0.142	0.021	0.372	0.038	0.30	0.37
			0.188	0.028	0.346	0.029	0.35	0.49
			0.230	0.037	0.304	0.022	0.43	0.65
			0.246	0.038	0.291	0.020	0.45	0.67
			0.319	0.050	0.203	0.007†	0.60	0.88
			0.363	0.055	0.135	0.002†	0.68	0.96
8	0.57	1.40	0.159	0.091	0.365	1.316	0.28	0.07
	0.62		0.190	0.136	0.368	1.232	0.31	0.10
	0.63		0.242	0.179	0.350	1.192	0.39	0.13
	0.65		0.285	0.246	0.307	1.118	0.44	0.18
	0.65		0.330	0.323	0.247	1.091	0.51	0.23
	0.65		0.342	0.388	0.235	0.992	0.53	0.28
	0.65		0.365	0.436	0.186	0.935	0.56	0.31

†Deduced by difference.