

Figure 8.1. Flow patterns for air-water mixtures flowing in a 1.025-inch pipe based on observations of Govier, Radford, and Dunn, 1957, and calculations.

TABLE 8.1
Flow Pattern Details for Air-Water Mixture Flowing in
1.025 Inch I.D. Vertical Pipe (See Figure 8.1)

Sketch Identi- fica- tion	Flow Pattern	Continuous Phase	Superficial Velocity		Volume Fraction Air, E_G	Holdup Ratio, H	Slip Velocity, S ft/sec
			Water, V_{SL} ft/sec	Air, V_{SG} ft/sec			
A	bubble	water	0.1	0.1	0.47	1.15	0.03
B	bubble	water	0.1	0.5	0.67	2.50	0.45
C	slug	water	0.1	1.0	0.70	4.30	1.10
D	slug	water	0.1	3.5	0.75	11.6	4.26
E	froth	neither	0.1	10.0	0.77	29.0	12.5
F	annular mist	air	0.1	50.0	0.96	20.5	49.5
G	annular mist	air	0.1	100.0	0.988	12.5	93.1
H	bubble	water	1.0	0.1	0.09	1.05	0.05
I	bubble	water	1.0	0.5	0.294	1.20	0.28
J	slug	water	1.0	1.0	0.43	1.35	0.61
K	slug	water	1.0	3.5	0.62	2.15	3.02
L	froth	neither	1.0	10.0	0.69	4.40	11.1
M	annular mist	air	1.0	50.0	0.877	7.0	48.9
N	annular mist	air	1.0	100.0	0.93	7.0	91.7
O	bubble	water	10.0	0.1	0.01	1.01	0.10
P	bubble	water	10.0	0.5	0.04	1.1	1.04
Q	bubble	water	10.0	1.0	0.08	1.13	1.41
R	slug	water	10.0	5.0	0.27	1.35	4.80

Sketch Identi- fica- tion	Flow Pattern	Approximate Only				
		Diameter of Bubbles or Droplets, d_s , in.	Number of Bubbles or Droplets, n_b^a	Average Film Thickness, δ_{av} , in.	Length of Liquid Slug, L_s , in.	Length of Taylor Bubble, L_b , in.
A	bubble	0.25	540	—	—	—
B	bubble	0.25	780	—	—	—
C	slug	0.25	350	—	—	—
D	slug	0.2–0.25	150	—	8	18
E	froth	0.2–0.5	30	—	8	32
F	annular mist	—	—	0.025	—	—
G	annular mist	0.027	2100	0.08	—	—
H	bubble	0.25	100	0.0025	—	—
I	bubble	0.25	350	—	—	—
J	slug	0.25	400	—	—	—
K	slug	0.2–0.25	70	—	3	0.6
L	froth	0.2–0.5	80	—	8	16
M	annular mist	—	—	0.035	—	—
N	annular mist	0.05	1300	0.015	—	—
O	bubble	0.25	12	—	—	—
P	bubble	0.25	50	—	—	—
Q	bubble	0.25	95	—	—	—
R	slug	0.25	45	—	8	3.7

^a Per foot of 1-inch pipe; in the slug flow pattern it refers to the small bubbles in the liquid slug only.

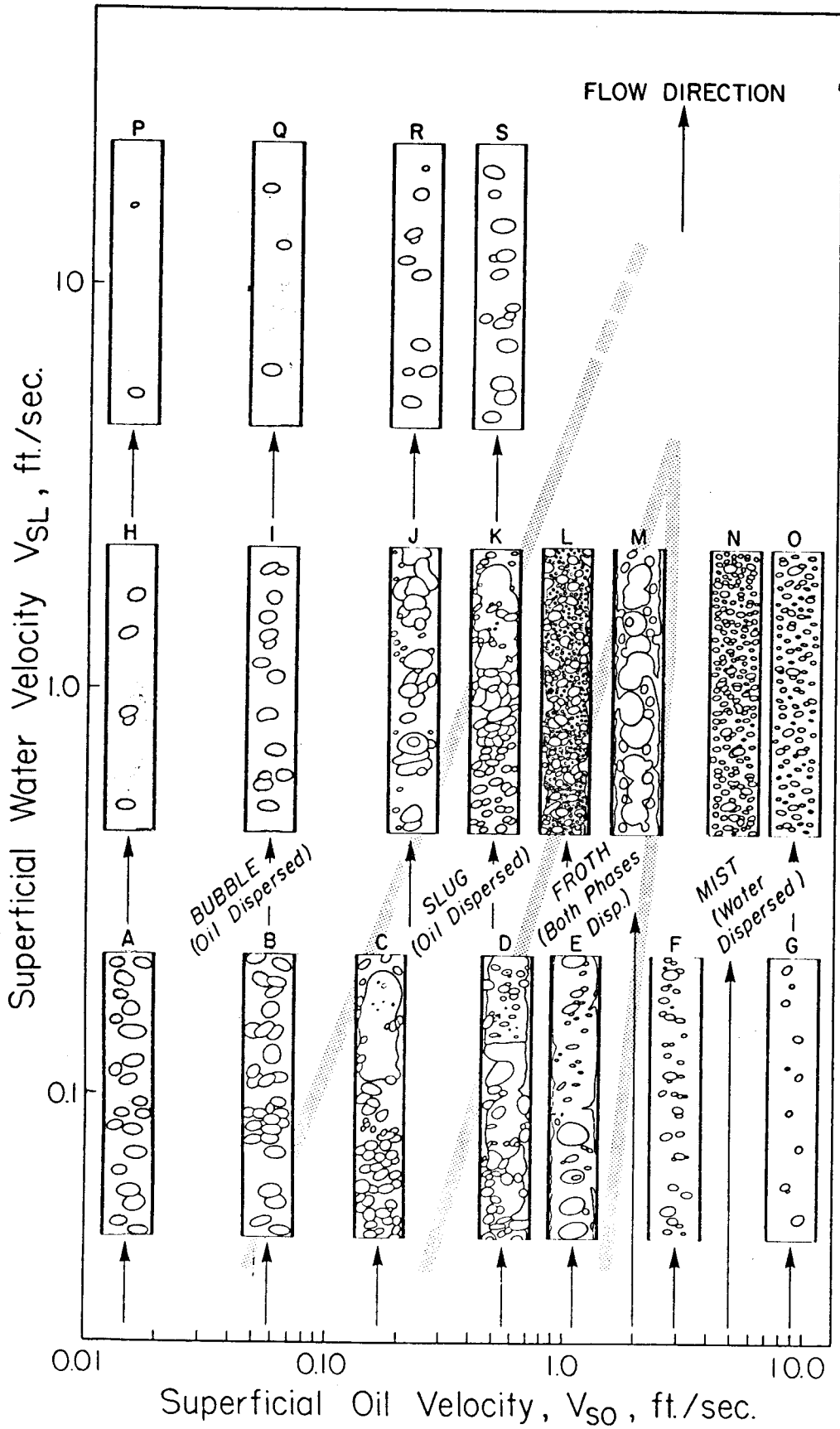


Figure 8.2. Flow patterns for 20.09-centipoise viscosity, 0.851-specific gravity oil, and water mixtures in a 1.04-inch pipe based on observations of Govier, Sullivan, and Wood, 1961.

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TABLE 8.2
Flow Pattern Details for 20.09-Centipoise Viscosity, 0.851-Specific Gravity
Oil Flowing with Water in 1.04-Inch I.D. Vertical Pipe (See Figure 8.2)

Sketch Identi- fica- tion	Flow Pattern	Continuous Phase	Superficial Velocity		Volume Fraction Oil, E_o	Holdup Ratio, H	Slip Velocity, S ft/sec
			Water, V_{SL} ft/sec	Oil, V_{SO} ft/sec			
A	bubble	water	0.1	0.015	0.08	1.70	0.08
B	bubble	water	0.1	0.058	0.17	2.85	0.22
C	slug	water	0.1	0.167	0.32	3.60	0.38
D	froth	neither	0.1	0.562	0.67	2.80	0.54
E	froth	neither	0.1	1.11	0.87	1.62	0.49
F	mist	oil	0.1	2.94	0.97	0.84	-0.58
G	mist	oil	0.1	9.0	0.99	0.72	-3.53
H	bubble	water	1.0	0.015	0.01	1.26	0.26
I	bubble	water	1.0	0.058	0.035	1.60	0.62
J	bubble	water	1.0	0.22	0.114	1.71	0.80
K	slug	water	1.0	0.49	0.24	1.52	0.69
L	froth	neither	1.0	1.61	0.58	1.17	0.40
M	froth	neither	1.0	2.0	0.65	1.10	0.28
N	mist	oil	1.0	5.0	0.85	0.92	-0.52
O	mist	oil	1.0	9.0	0.909	0.90	-1.10
P	bubble	water	10.0	0.015	0.0014	1.05	0.50
Q	bubble	water	10.0	0.058	0.005	1.10	1.00
R	bubble	water	10.0	0.22	0.02	1.10	1.02
S	bubble	water	10.0	0.49	0.04	1.10	1.04

Approximate Only

Sketch Identi- fica- tion	Flow Pattern	Diameter of Bubbles or Droplets, d_s , in.	Number of Bubbles or Droplets, n_b^a	Average Film Thickness, δ_{av} , in.	Length of Liquid Slug, L_s , in.	Length of Taylor Bubble, L_b , in.
B	bubble	0.37	60	—	—	—
C	slug	0.22	110	—	8.0	2.3
D	froth	—	—	0.082	—	—
E	froth	0.2-0.46	40	0.015	—	—
F	mist	0.20	65	—	—	—
G	mist	0.20	20	—	—	—
H	bubble	0.30	8	—	—	—
I	bubble	0.30	25	—	—	—
J	bubble	0.40	30	—	—	—
K	slug	0.20	140	—	8.0	1.8
L	froth	0.1-0.25	1500	0.06	—	—
M	froth	0.2-0.5	75	0.045	—	—
N	mist	0.20	365	—	—	—
O	mist	0.20	215	—	—	—
P	bubble	0.20	3	—	—	—
Q	bubble	0.25	6	—	—	—
R	bubble	0.30	15	—	—	—
S	bubble	0.35	20	—	—	—

^a Per foot of 1 inch pipe; in the slug flow pattern it refers to the small bubbles in the liquid slug only.

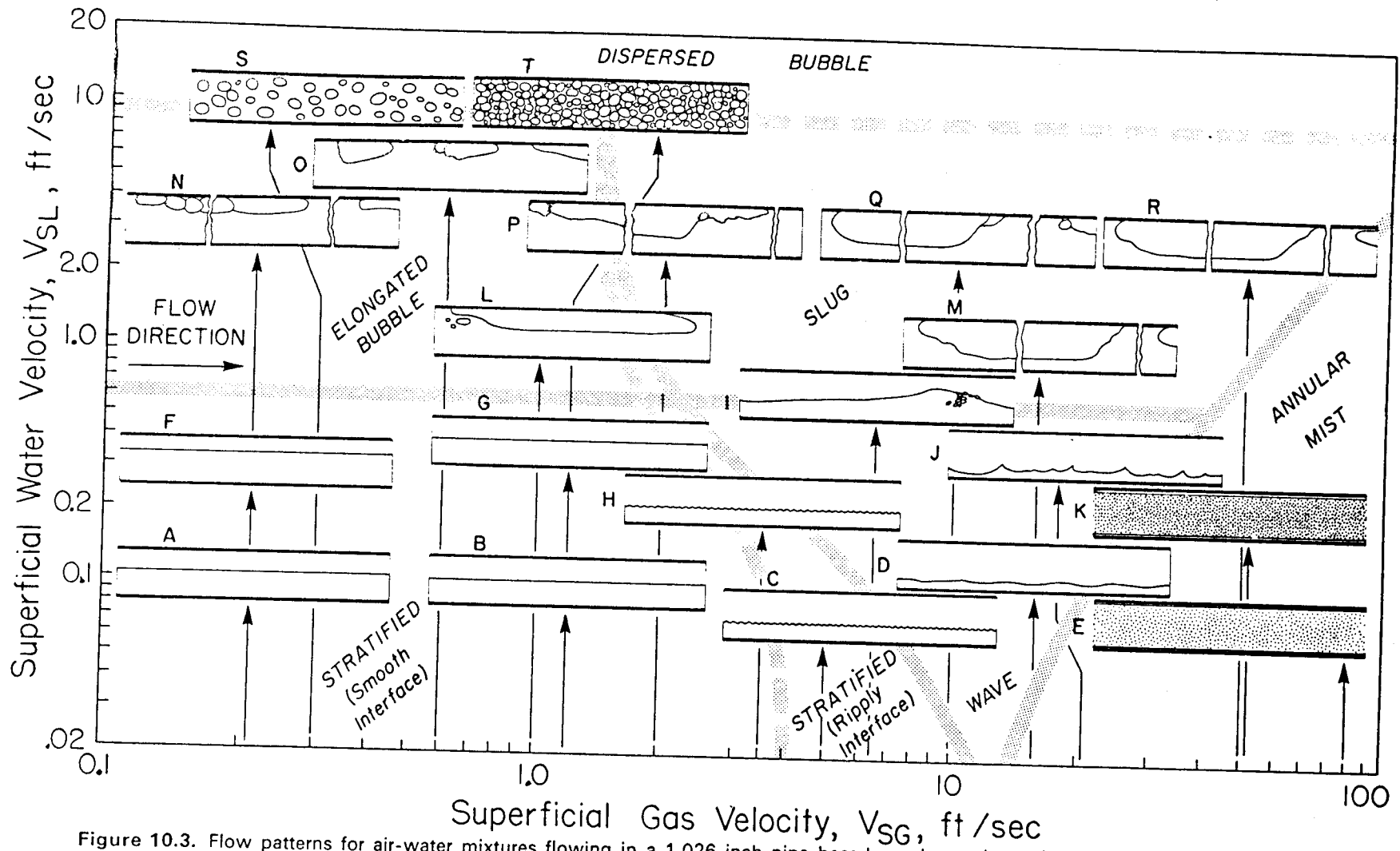


Figure 10.3. Flow patterns for air-water mixtures flowing in a 1.026-inch pipe based on observations of Govier and Omer (1962) and calculations.

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TABLE 10.3
Flow Pattern Details for Air-Water Mixture Flowing in 1.026-Inch I.D. Horizontal Pipe (See Figure 10.3)

Sketch Identi- fica- tion	Flow Pattern	Continuous Phase	Superficial Velocity		Volume Fraction Air, E_G	Holdup Ratio H	Slip Velocity S ft/sec	Approximate Only					
			Water, V_{SL} ft/sec	Air, V_{SG} ft/sec				Diameter of Bubbles or Droplets, d_p , in.	Number of Bubbles or Droplets, n_b^a	Average Height to Interface, h_{av} , in.	Average Film Thickness, δ_{av} , in.	Length of Liquid Slug, L_s , in.	Length of Taylor Bubble, L_b , in.
A	stratified	both	0.1	0.21	0.375	3.5	0.40	—	—	0.61	—	—	—
B	stratified	both	0.1	1.2	0.465	13.8	2.39	—	—	0.54	—	—	—
C	stratified	both	0.1	5.0	0.725	19.0	6.53	—	—	0.32	—	—	—
D	wave	both	0.1	15.9	0.90	18.0	16.7	—	—	0.16	—	—	—
E	annular mist	water	0.1	90	0.96	34.0	90.6	0.01+	60000	—	0.007	—	—
F	stratified	both	0.3	0.21	0.25	2.1	0.44	—	—	—	—	—	—
G	stratified	both	0.3	1.2	0.42	5.6	2.4	—	—	0.72	—	—	—
H	stratified	both	0.3	3.5	0.66	6.0	4.4	—	—	0.57	—	—	—
I	wave	both	0.4	6.5	0.75	5.5	7.1	—	—	0.37	—	—	—
J	wave	both	0.3	21	0.86	11.4	22.3	—	—	0.28	—	—	—
K	annular mist	air	0.3	52.2	0.92	16.0	53.4	—	—	0.20	—	—	—
L	elongated bubble	water	1.1	1.0	0.34	1.8	1.32	0.02	40000	—	0.016	—	—
M	slug	water	1.1	15.9	0.74	5.0	17.1	—	—	0.61	—	4-5	5
N	elongated bubble	water	3.02	0.21	0.061	1.07	0.22	—	—	0.20	—	3-5	25-39
O	elongated bubble	water	5.0	0.6	0.098	1.1	0.55	—	—	0.75	—	8-9	8-9
P	slug	water	3.02	2.0	0.32	1.4	1.78	—	6	0.75	—	1	1
Q	slug	water	3.02	10	0.60	2.2	9.1	—	—	0.64	—	3	7-8
R	slug	water	3.02	50	0.79	4.4	48.9	—	—	0.30	—	3-5	14-23
S	bubble	water	10	0.3	0.029	1.0	0	—	—	0.20	—	3-5	40-65
T	bubble	water	10	1.2	0.11	1.0	0	0.2	70	—	—	—	—
								0.2	300	—	—	—	—

^a Per foot of 1-inch pipe.

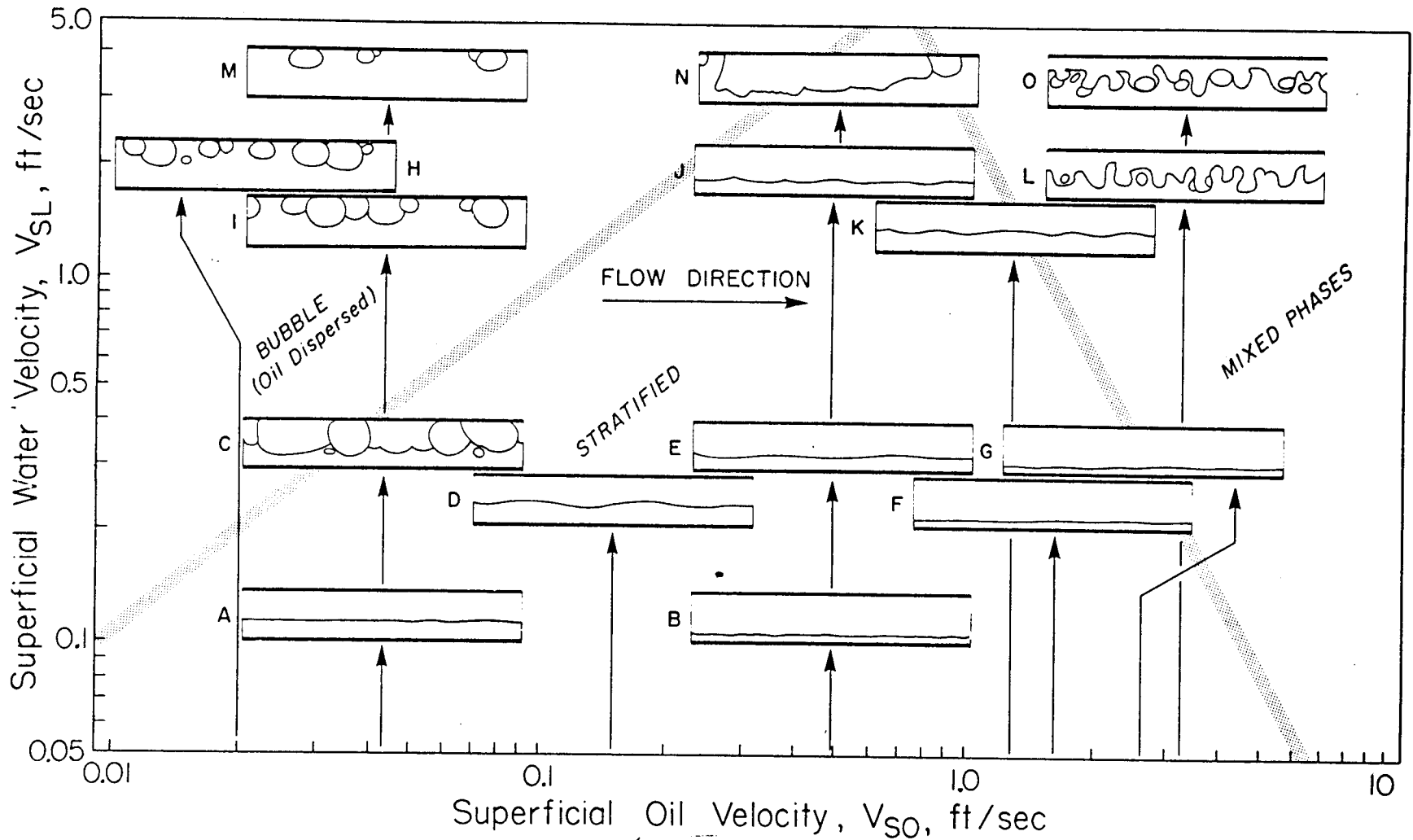


Figure 10.2. Flow patterns for 18.0-centipoise, 0.834-specific gravity oil and water mixtures in a 0.806-inch pipe based on observations of Russell, Hodgson, and Govier (1959) and calculations.

TABLE 10.2
Flow Pattern Details for 18.0-Centipoise Viscosity, 0.834-Specific Gravity Oil Flowing with Water in 0.806-Inch I.D. Horizontal Pipe (See Figure 10.2)

Sketch Identi- fica- tion	Flow Pattern	Continuous Phase	Superficial Velocity		Volume Fraction Oil, E_o	Holdup Ratio, H	Slip Velocity, S ft/sec	Approximate Only		
			Water, V_{SL} ft/sec	Oil, V_{SO} ft/sec				Diameter of Bubbles or Droplets, d_s , in.	Number of Bubbles or Droplets, n_b^a	Average Height to Interface, h_{av} , in.
A	stratified	both	0.116	0.043	0.63	0.22	-0.24	-	-	0.31
B	stratified	both	0.116	0.49	0.90	0.45	-0.66	-	-	0.13
C	bubble	water	0.287	0.043	0.36	0.27	-0.32	0.5	34	0.32
D	stratified	both	0.287	0.15	0.58	0.38	-0.42	-	-	0.36
E	stratified	both	0.287	0.49	0.75	0.58	-0.48	-	-	0.24
F	stratified	both	0.287	1.63	0.884	0.75	-0.62	-	-	0.14
G	stratified	both	0.287	2.61	0.92	0.80	-0.71	-	-	0.10
H	bubble	water	1.79	0.02	0.085	0.12	-1.72	0.3-0.5	14	-
I	bubble	water	1.79	0.043	0.094	0.23	-1.52	0.3-0.5	12	-
J	stratified	both	1.79	0.48	0.232	0.89	-0.26	-	-	0.23
K	stratified	both	1.79	1.29	0.376	1.20	+0.57	-	-	0.32
L ^b	mixed phases	neither	1.79	3.26	0.55	1.50	+1.98	-	-	-
M	bubble	water	3.55	0.043	0.14	0.85	-0.54	0.3	6	-
N	slug	water	3.55	0.50	0.10	~1.30	+1.18	-	-	-
O ^b	mixed phases	neither	3.55	3.27	0.34	~1.80	+4.29	-	-	-

^a Per foot of 0.806-inch pipe.

^b Largely schematic.

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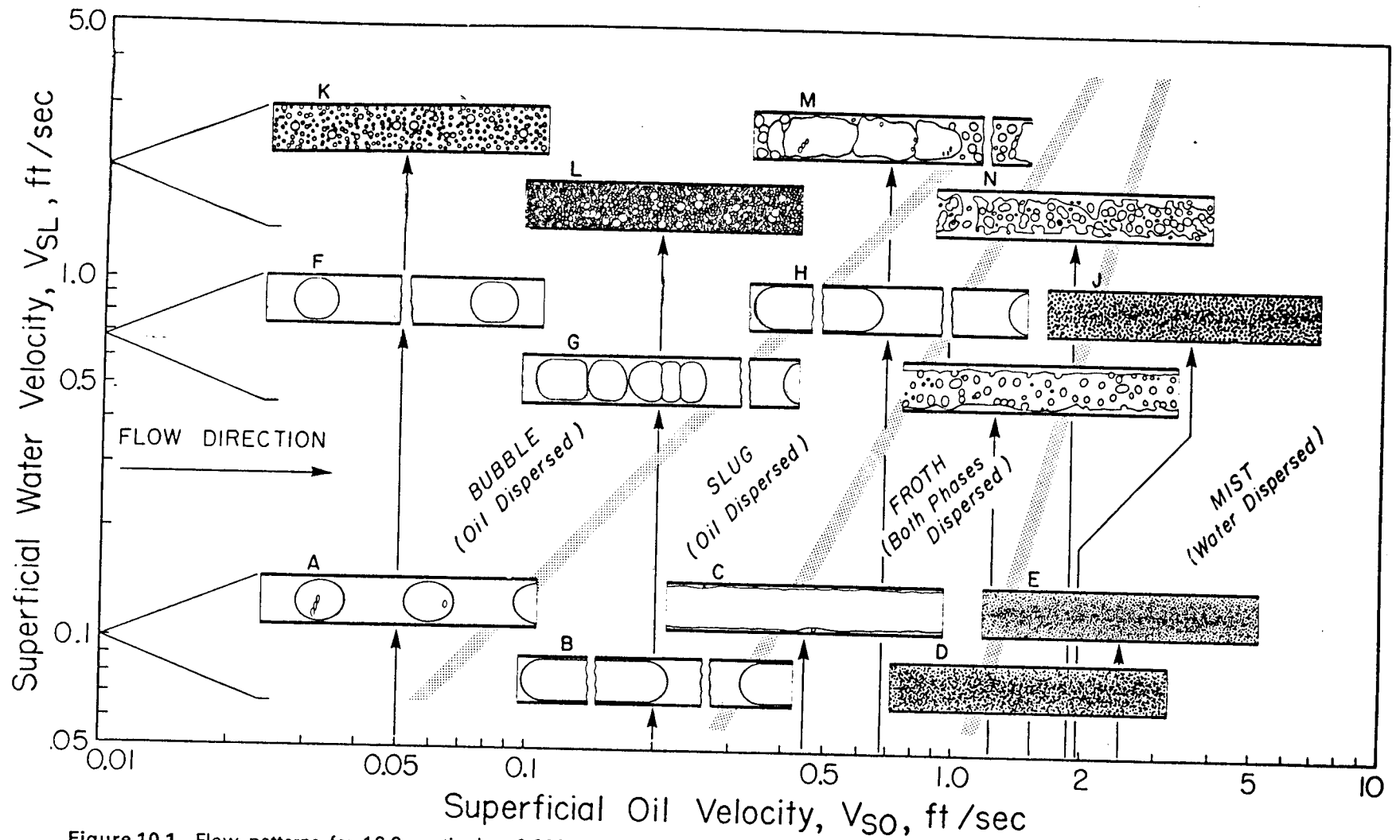


Figure 10.1. Flow patterns for 16.8-centipoise, 0.998-specific gravity oil and water mixtures in a 1.04-inch pipe based on observations of Charles, Govier, and Hodgson (1961) and calculations.

Figure 10.1 shows flow patterns for 16.8-centipoise, 0.998-specific gravity oil and water mixtures in a 1.04-inch pipe based on observations of Charles, Govier, and Hodgson (1961) and calculations.

mixtures

TABLE 10.1
Flow Pattern Details for 16.8-Centipoise Viscosity, 0.998-Specific Gravity Oil Flowing with Water in 1.04-Inch I.D. Horizontal Pipe (See Figure 10.1)

Sketch Identi- fica- tion	Flow Pattern	Continuous Phase	Superficial Velocity		Volume Fraction Oil, E_o	Holdup Ratio, H	Slip Velocity, S ft/sec	Approximate Only				
			Water, V_{SL} ft/sec	Oil, V_{SO} ft/sec				Diameter of Bubbles or Droplets, d_p , in.	Number of Bubbles or Droplets, n_b^a	Average Film Thickness, δ_{av} , in.	Length of Liquid Slug, L_s , in.	Length of Taylor Bubble, L_b , in.
A	bubble	water	0.1	0.05	0.32	1.05	0.007	1.0	5.2	—	1.2	1.0
B	slug	water	0.1	0.20	0.61	1.28	0.072	1.0	2.2	—	2.1	3.3
C	oil in film ^b	both	0.1	0.45	0.73	1.64	0.24	—	—	0.07	—	—
D	mist	oil	0.1	1.36	0.91	1.39	0.42	0.03–0.06	17000	—	—	—
E	mist	oil	0.1	2.27	0.96	1.01	0.023	0.03–0.06	7800	—	—	—
F	bubble	water	0.68	0.05	0.07	1.01	0.007	1.0	1.15	—	9.3	1.1
G	bubble	water	0.68	0.20	0.22	1.04	0.035	1.0	0.85 ^c	—	10.5	3.5 ^c
H	slug	water	0.68	0.68	0.47	1.12	0.15	1.0	0.73	—	8.6	7.7
I	froth	neither	0.68	1.11	0.56	1.26	0.41	0.12	90	0.11	—	—
J	mist	oil	0.68	1.95	0.67	1.41	0.85	0.06–0.12	7500	—	—	—
K	bubble	water	2.04	0.05	0.02	1.01	0.02	0.07–0.19	500	—	—	—
L	bubble	water	2.04	0.20	0.09	1.03	0.067	0.07–0.19	1800	—	—	—
M	bubble ^c	water	2.04	0.68	0.23	1.11	0.29	1.0 ^d	0.62	—	15.0	4.2 ^{c,d}
N	froth	neither	2.04	1.82	0.42	1.25	0.87	0.15	300	0.14	—	—

^a Per foot of 1-inch pipe.

^b Corresponds to froth flow in fluids with density contrast.

^c Bubble cluster.

^d Large bubble only.

^e Approaching transition to slug flow.