Section 8

Attachments

Appendix 8.1
Theoretical flow rates for siphons: head–discharge charts

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This appendix includes 3 charts of theoretical flow rate (in litres per second) for a given combination of operating head (in mm) and siphon internal diameter (ID, in mm). Each chart has been designed for a particular siphon length, representative of the most common lengths provided by manufacturers. The lengths specified are 3.6 m, 4.0 m and 4.3 m.

All charts have a range of operating heads specified in 20 mm increments up to a maximum of 1 m. The siphon sizes specified represent a selection of those widely used. Imperial siphon sizes are specified according to their internal diameter (ID). Different manufacturers should provide a siphon of similar ID, taking account of manufacturing tolerances.

Metric siphon sizes are specified according to outside diameter (OD) and hence the corresponding ID (which is the figure essential for determining flow) varies according to the variation in pipe wall thickness used for different pipe classes. For this reason, the charts may have more than one value of ID for a corresponding metric OD. It is imperative that siphon ID is measured to determine the appropriate corresponding chart ID. Measure the ID in more than one direction, and average the readings to account for any ovalness.

As can be seen on the charts, even a very small increase in ID (3 mm) can have a dramatic increase in the rate of discharge, particularly as head increases.

Because the level of water in the head ditch may vary and the discharge point of the siphon may not be consistent, it is suggested that head is measured for numerous siphons along the length of the head ditch and over a number of irrigations to see the possible variation.

Discharge is also affected by

- non-circular siphon pipes
- siphon inlet orientation (towards, perpendicular to, or away from the direction of flow in the head ditch)
- trash (blocking the siphons):

and even small factors such as water temperature and quality, and so the chart is only a guide to the actual flow rate.

For more detail on how the charts were constructed, see the discussion of **Theoretical flow** after the charts.

Flow rate in litres/seconds (L/s), siphon Length = 3.6 metres

Operating head (mm)	Nominal siphon size, internal diameter (mm)							
	1 ¼", 31.75	1 ½", 38.1	2", 50.85	50 mm, 44.0	50 mm, 47.0	63 mm, 55.5	63 mm, 59.0	75 mm, 65.1
100	0.55	0.83	1.58	1.15	1.33	1.91	2.19	2.71
120	0.60	0.91	1.73	1.26	1.45	2.10	2.40	2.97
140	0.65	0.98	1.87	1.36	1.57	2.27	2.59	3.21
160	0.70	1.05	2.00	1.45	1.68	2.42	2.77	3.43
180	0.74	1.11	2.12	1.54	1.78	2.57	2.94	3.64
200	0.78	1.17	2.23	1.62	1.88	2.71	3.10	3.84
220	0.82	1.23	2.34	1.70	1.97	2.84	3.25	4.03
240	0.85	1.29	2.45	1.78	2.06	2.97	3.39	4.20
260	0.89	1.34	2.55	1.85	2.14	3.09	3.53	4.38
280	0.92	1.39	2.64	1.92	2.22	3.20	3.66	4.54
300	0.95	1.44	2.74	1.98	2.30	3.32	3.79	4.70
320	0.99	1.49	2.82	2.05	2.37	3.42	3.92	4.86
340	1.02	1.53	2.91	2.11	2.45	3.53	4.04	5.00
360	1.05	1.58	3.00	2.17	2.52	3.63	4.15	5.15
380	1.07	1.62	3.08	2.23	2.59	3.73	4.27	5.29
400	1.10	1.66	3.16	2.29	2.65	3.83	4.38	5.43
420	1.13	1.70	3.24	2.35	2.72	3.92	4.49	5.56
440	1.16	1.74	3.31	2.40	2.78	4.02	4.59	5.69
460	1.18	1.78	3.39	2.46	2.85	4.11	4.70	5.82
480	1.21	1.82	3.46	2.51	2.91	4.19	4.80	5.95
500	1.23	1.86	3.53	2.56	2.97	4.28	4.90	6.07
520	1.26	1.89	3.60	2.61	3.03	4.37	4.99	6.19
540	1.28	1.93	3.67	2.66	3.08	4.45	5.09	6.31
560	1.30	1.97	3.74	2.71	3.14	4.53	5.18	6.42
580	1.33	2.00	3.80	2.76	3.20	4.61	5.27	6.54
600	1.35	2.03	3.87	2.81	3.25	4.69	5.36	6.65
620	1.37	2.07	3.93	2.85	3.30	4.77	5.45	6.76
640	1.39	2.10	3.99	2.90	3.36	4.84	5.54	6.87
660	1.41	2.13	4.06	2.94	3.41	4.92	5.62	6.97
680	1.44	2.17	4.12	2.99	3.46	4.99	5.71	7.08
700	1.46	2.20	4.18	3.03	3.51	5.07	5.79	7.18
720	1.48	2.23	4.24	3.07	3.56	5.14	5.87	7.28
740	1.50	2.26	4.30	3.12	3.61	5.21	5.96	7.38
760	1.52	2.29	4.35	3.16	3.66	5.28	6.04	7.48
780	1.54	2.32	4.41	3.20	3.71	5.35	6.11	7.58
800	1.56	2.35	4.47	3.24	3.75	5.42	6.19	7.68
820	1.58	2.38	4.52	3.28	3.80	5.48	6.27	7.77
840	1.60	2.41	4.58	3.32	3.85	5.55	6.35	7.87
860	1.62	2.44	4.63	3.36	3.89	5.61	6.42	7.96
880	1.63	2.46	4.68	3.40	3.94	5.68	6.49	8.05
900	1.65	2.49	4.74	3.44	3.98	5.74	6.57	8.14
920	1.67	2.52	4.79	3.48	4.02	5.81	6.64	8.23
940	1.69	2.55	4.84	3.51	4.07	5.87	6.71	8.32
960	1.71	2.57	4.89	3.55	4.11	5.93	6.78	8.41
980	1.72	2.60	4.94	3.59	4.15	5.99	6.85	8.50
1000	1.74	2.63	4.99	3.62	4.20	6.05	6.92	8.58

Flow rate in litres/seconds (L/s), siphon Length = 4.0 metres

Operating head (mm)	Nominal siphon size, internal diameter (mm)							
	1 ¼", 31.75	1 ½", 38.1	2", 50.85	50 mm, 44.0	50 mm, 47.0	63 mm, 55.5	63 mm, 59.0	75 mm, 65.1
100	0.54	0.81	1.54	1.12	1.30	1.87	2.14	2.66
120	0.59	0.89	1.69	1.23	1.42	2.05	2.35	2.92
140	0.63	0.96	1.83	1.32	1.53	2.22	2.54	3.15
160	0.68	1.02	1.95	1.41	1.64	2.37	2.71	3.37
180	0.72	1.09	2.07	1.50	1.74	2.51	2.88	3.57
200	0.76	1.14	2.18	1.58	1.83	2.65	3.03	3.76
220	0.79	1.20	2.29	1.66	1.92	2.78	3.18	3.95
240	0.83	1.25	2.39	1.73	2.01	2.90	3.32	4.12
260	0.86	1.30	2.49	1.80	2.09	3.02	3.46	4.29
280	0.90	1.35	2.58	1.87	2.17	3.14	3.59	4.45
300	0.93	1.40	2.67	1.94	2.24	3.25	3.71	4.61
320	0.96	1.45	2.76	2.00	2.32	3.35	3.84	4.76
340	0.99	1.49	2.85	2.06	2.39	3.46	3.95	4.91
360	1.02	1.54	2.93	2.12	2.46	3.56	4.07	5.05
380	1.04	1.58	3.01	2.18	2.53	3.65	4.18	5.19
400	1.07	1.62	3.09	2.24	2.59	3.75	4.29	5.32
420	1.10	1.66	3.16	2.29	2.66	3.84	4.40	5.46
440	1.12	1.70	3.24	2.35	2.72	3.93	4.50	5.58
460	1.15	1.74	3.31	2.40	2.78	4.02	4.60	5.71
480	1.17	1.77	3.38	2.45	2.84	4.11	4.70	5.83
500	1.20	1.81	3.45	2.50	2.90	4.19	4.80	5.95
520	1.22	1.85	3.52	2.55	2.95	4.27	4.89	6.07
540	1.24	1.88	3.59	2.60	3.01	4.36	4.98	6.19
560	1.27	1.91	3.65	2.65	3.07	4.43	5.08	6.30
580	1.29	1.95	3.72	2.69	3.12	4.51	5.17	6.41
600	1.31	1.98	3.78	2.74	3.17	4.59	5.25	6.52
620	1.33	2.01	3.84	2.78	3.23	4.67	5.34	6.63
640	1.35	2.05	3.91	2.83	3.28	4.74	5.43	6.73
660	1.37	2.08	3.97	2.87	3.33	4.81	5.51	6.84
680	1.40	2.11	4.03	2.92	3.38	4.89	5.59	6.94
700	1.42	2.14	4.08	2.96	3.43	4.96	5.67	7.04
720	1.44	2.17	4.14	3.00	3.48	5.03	5.75	7.14
740	1.46	2.20	4.20	3.04	3.53	5.10	5.83	7.24
760	1.48	2.23	4.26	3.08	3.57	5.17	5.91	7.34
780	1.49	2.26	4.31	3.12	3.62	5.23	5.99	7.43
800	1.51	2.29	4.37	3.16	3.67	5.30	6.07	7.53
820	1.53	2.32	4.42	3.20	3.71	5.37	6.14	7.62
840	1.55	2.35	4.47	3.24	3.76	5.43	6.22	7.72
860	1.57	2.37	4.53	3.28	3.80	5.50	6.29	7.81
880	1.59	2.40	4.58	3.32	3.84	5.56	6.36	7.90
900	1.61	2.43	4.63	3.35	3.89	5.62	6.43	7.99
920	1.62	2.45	4.68	3.39	3.93	5.68	6.51	8.07
940	1.64	2.48	4.73	3.43	3.97	5.75	6.58	8.16
960	1.66	2.51	4.78	3.46	4.01	5.81	6.65	8.25
980	1.68	2.53	4.83	3.50	4.06	5.87	6.71	8.33
1000	1.69	2.56	4.88	3.54	4.10	5.93	6.78	8.42

Flow rate in litres/seconds (L/s), siphon Length = 4.3 metres

Operating head (mm)	Nominal siphon size, internal diameter (mm)							
	1 ¼", 31.75	1 ½", 38.1	2", 50.85	50 mm, 44.0	50 mm, 47.0	63 mm, 55.5	63 mm, 59.0	75 mm, 65.1
100	0.52	0.79	1.52	1.10	1.27	1.85	2.11	2.62
120	0.57	0.87	1.66	1.20	1.40	2.02	2.31	2.88
140	0.62	0.94	1.80	1.30	1.51	2.18	2.50	3.11
160	0.66	1.00	1.92	1.39	1.61	2.33	2.67	3.32
180	0.70	1.07	2.04	1.47	1.71	2.48	2.83	3.52
200	0.74	1.12	2.15	1.55	1.80	2.61	2.99	3.71
220	0.78	1.18	2.25	1.63	1.89	2.74	3.13	3.89
240	0.81	1.23	2.35	1.70	1.97	2.86	3.27	4.07
260	0.85	1.28	2.45	1.77	2.05	2.98	3.41	4.23
280	0.88	1.33	2.54	1.84	2.13	3.09	3.54	4.39
300	0.91	1.38	2.63	1.90	2.21	3.20	3.66	4.55
320	0.94	1.42	2.72	1.97	2.28	3.30	3.78	4.70
340	0.97	1.46	2.80	2.03	2.35	3.40	3.90	4.84
360	0.99	1.51	2.88	2.08	2.42	3.50	4.01	4.98
380	1.02	1.55	2.96	2.14	2.48	3.60	4.12	5.12
400	1.05	1.59	3.04	2.20	2.55	3.69	4.23	5.25
420	1.07	1.63	3.11	2.25	2.61	3.78	4.33	5.38
440	1.10	1.67	3.19	2.30	2.67	3.87	4.43	5.51
460	1.12	1.70	3.26	2.36	2.73	3.96	4.53	5.63
480	1.15	1.74	3.33	2.41	2.79	4.04	4.63	5.75
500	1.17	1.78	3.40	2.46	2.85	4.13	4.72	5.87
520	1.20	1.81	3.46	2.51	2.91	4.21	4.82	5.99
540	1.22	1.85	3.53	2.55	2.96	4.29	4.91	6.10
560	1.24	1.88	3.59	2.60	3.01	4.37	5.00	6.21
580	1.26	1.91	3.66	2.65	3.07	4.44	5.09	6.32
600	1.28	1.95	3.72	2.69	3.12	4.52	5.18	6.43
620	1.31	1.98	3.78	2.74	3.17	4.59	5.26	6.54
640	1.33	2.01	3.84	2.78	3.22	4.67	5.35	6.64
660	1.35	2.04	3.90	2.82	3.27	4.74	5.43	6.74
680	1.37	2.07	3.96	2.87	3.32	4.81	5.51	6.84
700	1.39	2.10	4.02	2.91	3.37	4.88	5.59	6.94
720	1.41	2.13	4.08	2.95	3.42	4.95	5.67	7.04
740	1.43	2.16	4.13	2.99	3.47	5.02	5.75	7.14
760	1.45	2.19	4.19	3.03	3.51	5.09	5.83	7.24
780	1.46	2.22	4.24	3.07	3.56	5.15	5.90	7.33
800	1.48	2.25	4.30	3.11	3.60	5.22	5.98	7.42
820	1.50	2.27	4.35	3.15	3.65	5.28	6.05	7.52
840	1.52	2.30	4.40	3.18	3.69	5.35	6.12	7.61
860	1.54	2.33	4.45	3.22	3.74	5.41	6.20	7.70
880	1.56	2.36	4.51	3.26	3.78	5.47	6.27	7.79
900	1.57	2.38	4.56	3.30	3.82	5.54	6.34	7.87
920	1.59	2.41	4.61	3.33	3.86	5.60	6.41	7.96
940	1.61	2.43	4.66	3.37	3.91	5.66	6.48	8.05
960	1.62	2.46	4.71	3.40	3.95	5.72	6.55	8.13
980	1.64	2.49	4.76	3.44	3.99	5.78	6.61	8.22
1000	1.66	2.51	4.80	3.47	4.03	5.84	6.68	8.30

Theoretical flow

The equation used to calculate these charts is that proposed by Bos (1989) specifically for measuring theoretical flow through irrigation siphons. This differs from the more usually encountered equation based on Manning's outlet control, which is theoretically inappropriate (Queensland Water Resources Commission, 1984). Values used for entrance and exit loss coefficient (C) and friction factor (f) are 1.9 and 0.019 respectively. These values were decided upon following procedures outlined by Bos, and after careful analysis of available siphon discharge data.

This equation aims to provide the theoretical flow rate of siphons in the field and hence takes account of many in-field hydraulic issues. The charts do not provide a measure of theoretical flow of siphons operating under laboratory conditions.

Equations used

For those interested in calculating flows for siphon lengths or pipe internal diameters that are not specified in the following tables, the equation used is as follows.

$$Q = \frac{\pi D^2}{4}\left[\frac{2g\Delta h}{1.9 + \frac{fL}{D}}\right]^{0.5}$$

where:

Q – discharge (m^3/s)

D – siphon internal diameter (m)

g – acceleration due to gravity ($9.81\ m/s^2$)

Δh – operating head (m)

f – friction loss coefficient (0.019 in the charts)

L – siphon length (m)

More information regarding the theory and application of this equation is available in Bos (1989).

For reference

The theoretically incorrect Manning's equation that has been used in the past is as follows:

$$Q = 10^{-5}\sqrt{\frac{124g\Delta hD^{5}}{0.00015D + \frac{124n^2L}{D^{1/3}}}}$$

This equation, and charts based on this equation, should **not** be used, as they are likely to incorrectly estimate the siphon flow rate.

References

Bos, MG 1989, Discharge measurement structures, 3rd edn, ILRI Publication 20, International Institute for Land Reclamation and Improvement, The Netherlands.

Queensland Water Resources Commission 1984, Farm Water Supplies Design Manual vol. II: Irrigation Systems, 2nd edn, Queensland Water Resources Commission, Brisbane.