INSTALLATION AND USE
OF
POWLUS V FURROW FLUMES

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The 60 degree V-notch trapezoidal flume, originally developed and calibrated by Robinson and Chamberlain (1960), is a convenient flume for measuring small flows. One version of this long-throated flume with a side contraction is in common use in the western United States for measuring flows in irrigation furrows. The Powlus V furrow flume is made of fiberglass on a mold originally made by the USDA-ARS in Kimberly, Idaho. It was marketed by ACME Manufacturing Company until 1981 and is presently being made and sold by Honkers Supreme (previously Powlus Manufacturing Company)[1] of Twin Falls, Idaho. Over 1,000 of these flumes have been sold.

The Powlus V-notch flume is small and light weight and convenient for measuring furrow flows for irrigation design and evaluation work. It satisfies the hydraulic requirements for long-throated flumes (Bos, Replogle, and Clemmens, 1991) up to a flow depth of 90 mm (3.5 in) or a gauge reading of 100 mm (4 in) when it carries 95 L/m (25 gpm). It has a maximum capacity of 120 L/m (32 gpm).

Figure 1 shows the dimensions of the Powlus version of the flume. The flume is 50 cm (20 in) long, 10 cm (4 in) high, and 17 cm (7 in) wide. The actual side slope is 61°, slightly steeper than the originally designed 60° version and the 60.5° models sold before about 1981.

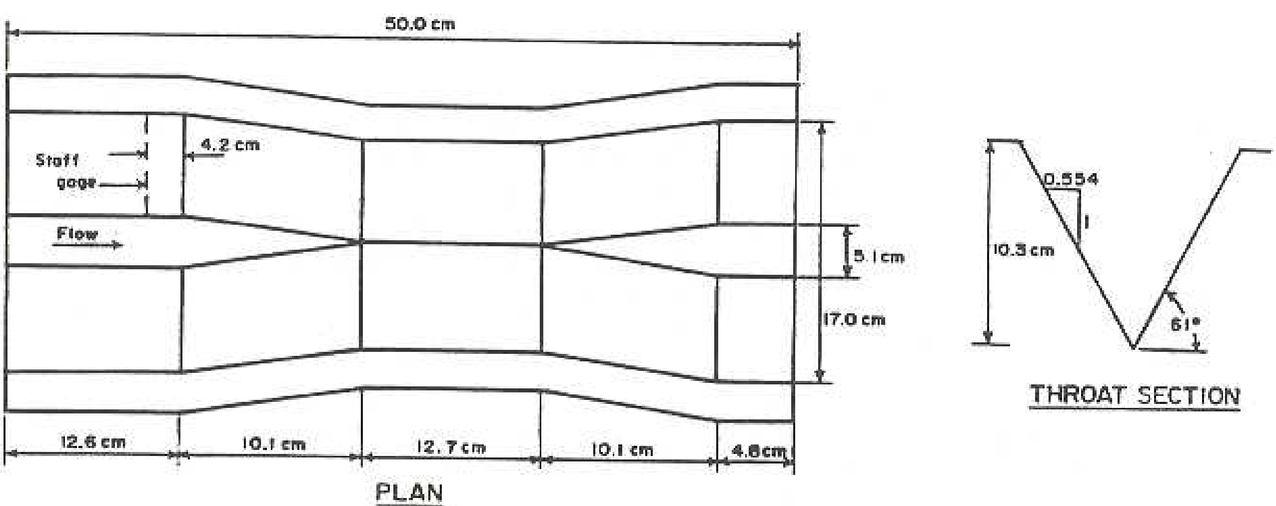

Figure 1. Dimensions of the Powlus V furrow flume.

[1]Honkers Supreme, 269 1/2 Addison Ave. West, Twin Falls, ID 83301, Tel. (208) 734-2060. Names of equipment manufacturers and suppliers are provided for the benefit of the reader and do not imply endorsement by the Department of Agriculture.

INSTALLATION

In loose, moist soils, the flumes can be pressed into the furrow to the proper position. In hard soil, a trough must be excavated, the flume put in place, and loose soil repacked around the flume. The flume must be installed high enough to ensure proper free flow conditions (critical flow in the throat). When the downstream water surface is too high, the flume will submerge and the upstream flow depth will increase, causing an overestimate of the flow. The long-throated flumes will operate properly at submergence levels below 80%. A hydraulic jump (curling wave) is evidence of free flow, although free flow can occur without a visible jump. Free flow is ensured if obstructing and raising the downstream flow depth slightly does not affect the gauge reading. A flume with free flow will sometimes later submerge if sediment deposits in the downstream furrow, so free flow conditions should be checked occasionally. Furrow flumes should not be installed too high, especially in flat furrows, or they will back up the water, increase the flow depth and infiltration rate upstream, and sometimes overtop the furrow. If the water is not backed more than a few feet up the furrow, the infiltration will not be significantly affected. In steep furrows, the water velocity entering the flume may be high enough to cause waves at the gauging point. If this is a problem, the inflow velocity should be reduced by raising the flume or excavating a larger furrow just upstream of the flume.

Sediment accumulation in the entrance section of the flume will decrease flow depth and thus cause an underestimation of flow. This effect becomes significant when the accumulation is more than about 10 mm deep. Clean sediment from the flume and ensure the throat is unobstructed before each reading. Installed flumes should also be periodically checked for leakage around the flume.

The most critical factor in accurate measurement is the levelness of the flume. Levelness should be checked with a torpedo level both longitudinally and across the flume. The level is placed on a side rail above the gauge for longitudinal leveling and across the sides above the gauges for side-to-side leveling. Levelness of an installed flume should be checked before each reading.

TAKING READINGS

Powlus flumes have a centimeter gauge and a gauge which reads directly in flow units (liters per minute (L/min)). Because the centimeter gauge has equal divisions, it can be read more precisely, but the flow unit gauge is adequate for many applications. The centimeter gauge, shown in Fig. 2, is set up like a survey staff gauge. Each mark is 2 mm thick and the extended point is at the even centimeter. The gauge can be read to the nearest 0.2 cm (2 mm) and estimated to the nearest millimeter. Gauge readings should be recorded in millimeter units to avoid the decimal point. The figure shows several readings from the gauge. The flow gauge reading can be converted to gallons per minute (gpm) by dividing by 3.79 or to L/s by dividing by 60.

Earlier Powlus flumes (before 1984) had side gauges in inches and tenths of inches and in centimeters. Adhesive vinyl gauges of the new style can be purchased from the manufacturer to install on the old flumes.

Experience has shown that, due to the meniscus formed by the water surface along the flume sides, most people read flume side gauges 1 to 3 mm too high. Estimating the actual water surface level with the side gauge is very difficult. Consequently, it is recommended that gauge readings be taken at the top of the meniscus and a reading correction adjustment be applied. A 1.5 mm (0.06") adjustment has been made to the discharge equations listed in Table 1 and the flume Discharge Table. The L/min side gauge has been adjusted upward to account for the meniscus.

Figure 2. Centimeter side gauge used on Powlus V furrow flumes showing several readings.

More precise head readings can be made with a small, portable point gauge such as that shown in Fig. 3. The gauge is a rod marked off in length units and pointed at the bottom end. The rod slides through a bar which is placed on the flume at the gauging point (over the side gauges). The rod gauge should read zero when the point touches the flume bottom. When the raised point is slid downward to touch the flowing water surface, the gauge directly reads the vertical flow depth.

Often, periodic measurements are required to determine flow hydrographs and volumes of water applied. An automatic flow logger for Powlus furrow flumes is described by Trout (1986).

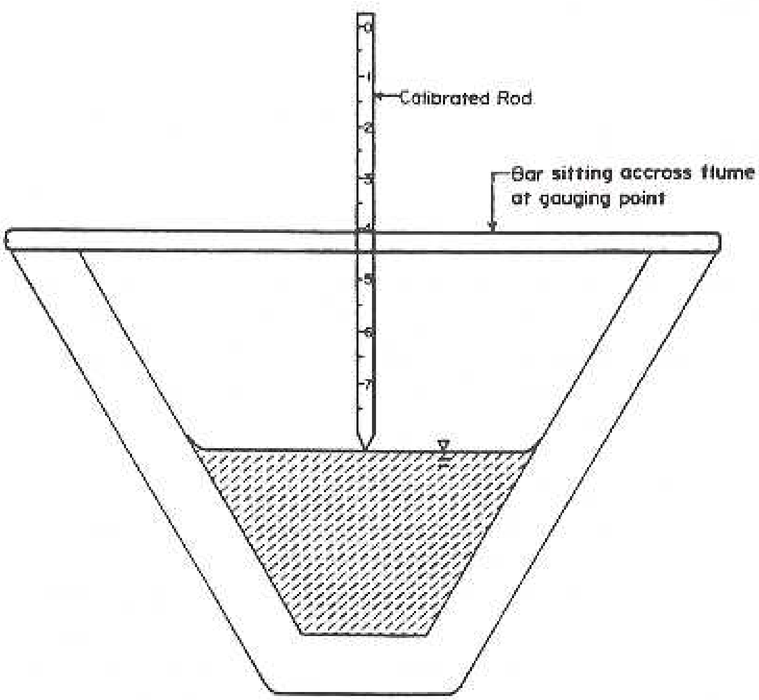

Figure 3. Point gauge for furrow flumes.

CALIBRATION

A discharge equation for the flume was developed with a theoretical computer calibration program developed for long-throated flumes by Replogle, Bos, and Clemmens (1991). This equation was verified by calibrating several flumes in the laboratory. The discharge equation for the flume is

$$Q = 0.000767\ h^{2.63} \tag{1}$$

where the head, h, is measured vertically in millimeters (mm) and the flow rate, Q, is given in liters per minute (L/min). Table 1 lists discharge equations for both sloping wall gauges and vertical point gauges in various units. Note the meniscus correction factor in the wall gauge equations. A discharge table for the centimeter sidewall gauges is attached.

As was noted earlier, the V furrow flumes manufactured before about 1981 have wider throat angles (59° vs the present 57 1/2°). The calibration equation for the earlier models is $Q(L/m) = .000857\ h\ (mm)^{2.63}$ which is about 12% higher than the calibration of the newer flumes. Gauge angle partially compensates for the throat differences so that gauge reading calibrations differ by 10%.

ACCURACY

The accuracy of furrow flow measurement with V flumes depends both upon having a correct installation and the precision of the gauge reading. The flumes, being made from precision molds, should be dimensional duplicates unless damaged. Assuming free flow conditions, little sediment accumulation, and no leakage, the major sources of error are unlevelness and gauge reading errors. A flume longitudinally out of level by only one-half degree will cause the equivalent to a 2-mm error in gauge reading. Levelness, both side-to-side and longitudinally, is critical. Sloping-sided flumes have a wide flow range but are very sensitive to reading errors. For these V flumes, the flow measurement error is 2.63 times larger than the relative gauge reading error.

$$\text{Flow Measurement Error (\%)} = \frac{\text{reading error}}{\text{reading}} \times 2.63 \times 100 \tag{2}$$

Gauge reading accuracy better than 2 mm is difficult to achieve in the field. A 2-mm reading error will result in a 6% flow measurement error at 60 L/min (gauge reading = 84 mm) and a 12% error at 10 L/min (gauge reading = 43 L/min). Trout and Mackey (1988a) discuss furrow flow measurement errors in detail and estimate normal and very good furrow flow measurement accuracy at ±10% and ±5%, respectively.

When the difference of two flow measurements are used to estimate soil infiltration (inflow-outflow method), the measurement errors become critical. Trout and Mackey (1988b) explain how inflow-outflow infiltration measurement errors increase as the furrow section length between the measurements decrease. For example, at ±8% flow measurement accuracy, the infiltration rate measurement is accurate to only ±50% if the flow decrease between the flumes is only 20%, but is ±10% if 80% of the water is infiltrated. Consequently, it is extremely important to measure infiltration in as long of furrow sections as possible to achieve reasonable accuracy.

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Table 1. **Discharge Equations for Powlus Furrow Flumes**

I. HEAD READ OFF SLOPING WALL GAUGE (With meniscus correction)

Gauge Units	Flow Units	Equation
mm	gallons/min (gpm)	$Q = .000143\ (h-1.5)^{2.63}$
	liters/min (L/min)	$Q = .000543\ (h-1.5)^{2.63}$
	liters/sec (L/s)	$Q = .0000091\ (h-1.5)^{2.63}$
cm	gpm	$Q = .0612(h-1.5)^{2.63}$ 0.15
	L/min	$Q = .232(h-1.5)^{2.63}$
	L/s	$Q = .00386(h-1.5)^{2.63}$
in	gpm	$Q = .710(h-.06)^{2.63}$
	L/min	$Q = 2.69\ (h-.06)^{2.63}$
	L/s	$Q = .0448(h-.06)^{2.63}$

II. HEAD READ FROM A VERTICAL POINT GAUGE ON THE WATER SURFACE

mm	gpm	$Q = .000203h^{2.63}$
	L/min	$Q = .000767h^{2.63}$
	L/s	$Q = .0000128h^{2.63}$
cm	gpm	$Q = .0866\ h^{2.63}$
	L/min	$Q = .327\ h^{2.63}$
	L/s	$Q = .00546\ h^{2.63}$
in	gpm	$Q = 1.01\ h^{2.63}$
	L/min	$Q = 3.80\ h^{2.63}$
	L/s	$Q = .0634\ h^{2.63}$
ft	gpm	$Q = 693\ h^{2.63}$
	L/min	$Q = 262\ h^{2.63}$
	L/s	$Q = 43.7\ h^{2.61}$

Powlus V Furrow Flume Discharge Table

(with 1.5 mm correction for meniscus)

Gage Reading	Flow Rate		
(mm)	(L/min)	(L/s)	(gpm)
20	**1.2**	**0.020**	**0.3**
22	1.5	0.026	0.4
24	2.0	0.033	0.5
26	2.4	0.041	0.6
28	3.0	0.050	0.8
30	**3.6**	**0.061**	**1.0**
32	4.4	0.073	1.1
34	5.1	0.086	1.4
36	6.0	0.101	1.6
38	7.0	0.117	1.8
40	**8.0**	**0.135**	**2.1**
41	8.6	0.144	2.3
42	9.2	0.154	2.4
43	9.8	0.164	2.6
44	10.4	0.174	2.7
45	11.1	0.185	2.9
46	11.7	0.197	3.1
47	12.5	0.209	3.3
48	13.2	0.221	3.5
49	13.9	0.234	3.7
50	**14.7**	**0.247**	**3.9**
51	15.5	0.261	4.1
52	16.4	0.275	4.3
53	17.3	0.289	4.5
54	18.1	0.304	4.8
55	19.1	0.320	5.0
56	20.0	0.336	5.3
57	21.0	0.352	5.5
58	22.0	0.369	5.8
59	23.1	0.386	6.1
60	**24.1**	**0.404**	**6.4**
61	25.2	0.423	6.6
62	26.4	0.442	6.9
63	27.5	0.461	7.2
64	28.7	0.481	7.6
65	29.9	0.502	7.9
66	31.2	0.523	8.2
67	32.5	0.544	8.6
68	33.8	0.566	8.9
69	35.1	0.589	9.3

Gage Reading	Flow Rate		
(mm)	(L/min)	(L/s)	(gpm)
70	**36.5**	**0.612**	**9.6**
71	38.0	0.636	10.0
72	39.4	0.660	10.4
73	40.9	0.685	10.8
74	42.4	0.711	11.2
75	44.0	0.737	11.6
76	45.6	0.764	12.0
77	47.2	0.791	12.4
78	48.8	0.819	12.9
79	50.5	0.847	13.3
80	**52.3**	**0.876**	**13.8**
81	54.0	0.906	14.2
82	55.9	0.936	14.7
83	57.7	0.967	15.2
84	59.6	0.998	15.7
85	61.5	1.031	16.2
86	63.5	1.063	16.7
87	65.4	1.097	17.2
88	67.5	1.131	17.8
89	69.5	1.166	18.3
90	**71.7**	**1.201**	**18.9**
91	73.8	1.237	19.4
92	76.0	1.274	20.0
93	78.2	1.311	20.6
94	80.5	1.349	21.2
95	82.8	1.388	21.8
96	85.2	1.427	22.4
97	87.5	1.467	23.1
98	90.0	1.508	23.7
99	92.4	1.549	24.3
100	**95.0**	**1.591**	**25.0**
101	97.5	1.634	25.7
102	100.1	1.678	26.4
103	102.8	1.722	27.1
104	105.4	1.767	27.8
105	108.2	1.813	28.5
106	110.9	1.859	29.2
107	113.8	1.906	30.0
108	116.6	1.954	30.7
109	119.5	2.003	31.5