HYDRAULICS DIVISION

Technical Note

DATE: May 1981 **REPORT NO:** 81-18

TITLE: "Comparison of Two Probes for the Measurement of Flow Velocities in Peat"

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REASON FOR REPORT: This report was prepared jointly with Lands Directorate of Environment Canada at their request to assist in the development of their flow meter.

CORRESPONDENCE FILE NO:

5690 (Study No. H80 3381)

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[1]Hydraulics Division

[2]Lands Directorate

1.0 INTRODUCTION

The Engineering Section of the Hydraulics Division (formerly of the Scientific Support Division) has developed a new flow meter for the Lands Directorate of Environment Canada to measure very low flow velocities in peat. Preliminary tests in a specially built test column were conducted by Engel and Pedrosa (1980) with the initial probe, hereafter referred to as probe no. 1, using commercial shredded and disturbed natural peat. It was concluded from these tests that some changes be made to the probe and that additional tests be conducted using undisturbed natural peat specimen. A new probe, hereafter referred to as probe no. 2, was fabricated and tested together with the original model in the test facility of the hydraulics laboratory at the National Water Research Institute. The two probes are described by Pedrosa (1980) and the test facility is described by Engel and Pedrosa (1980). During the summer of 1980, limited field testing of the probes, particularly probe no. 1, was carried out. Flow measurements were made in various peatland types in the Attawapiskat area of the Hudson Bay lowland, and in selected sites near Cochrane, Ontario. Following each field measurement, .5 m^2 samples of the peat were obtained and returned to Burlington for laboratory calibration and further testing. Results of the field tests, together with recommendations for further tests were reported by Wickware (1980). On this basis, further testing was carried out using the previously described test facility. This report represents the results of the new tests.

2.0 TEST PROCEDURE

Tests were conducted using two relatively undisturbed peat samples. One sample was a fibric sphagnum peat (Sphagnum fuscum), and the other a sedge peat. A third porous medium comprised of sawdust was also used in the hope of obtaining a more controllable test section. The peat samples were cut carefully so as to fit snuggly into the test cylinder used previously by Engel and Pedrosa (1980) and shown here in Figure 1. Each sample plug was cut so that the internal bedded structure of the peat was parallel to the direction of flow, thereby simulating the natural condition. Care was taken to ensure no undue leakage between the peat plug and the walls of the test cylinder. The test cylinder was then bolted to the vertical stand pipe (Figure 2). Water was allowed to rise slowly to a height of 1 meter and kept constant at this level for several hours before testing. Water temperature was maintained between 5^oC to 7^oC. Tests were then conducted on probe no. 1 for zero flow as well as velocities over the operating range of the probe in the manner described by Engel and Pedrosa (1980). Probe no. 2 was tested in a similar fashion. The sequence of tests was followed for each of the three media. The data obtained as meter output and flow rate (ml/min) are given in Tables 1, 2, 3 for probe no. 1 and Tables 4, 5, 6 for probe no. 2. In each table the meter output for zero flow, E_o, is also given.

3.0 DATA ANALYSIS

The calibration curve for each meter must be given in terms of flow velocity as a function of meter output.

It was found by Engel and Pedrosa (1980) that the values of E_o are of fundamental importance in determining a calibration curve for a meter, and this value appeared to depend on the nature of the porous material. Therefore, the indicator of flow velocity in each case must be the meter output in excess of E_o, say E_n. Values of E_n were therefore computed as $E_n=(E-E_o)$ (E=measured meter output), for all the data in Tables 1 through 6. Values of flow velocity in cm/s were determined by simply dividing the discharge through the test section by the cross-sectional area of the test section. These computed values of E_n and velocity are also given in Tables 1 to 6.

Values of E_n versus velocity for probe 1 and 2 in the sphagnum peat were plotted in Figure 3a and 3b respectively. Except for a few isolated values, the data all follow the same trend. A smooth average curve was fitted by eye through the data for relative comparison of the two probes. For values of velocity up to 0.01 cm/s, both probes behave similarly in the sphagnum peat. For velocities greater than 0.01 cm/s, the meter output E_n for a change in velocity is slightly more sensitive for probe no. 1 than for probe no. 2. For both probes, the rate of increase in E_n with velocity v progressively decreases as v increases. For probe no. 1, when $v \approx 0.03$ cm/s, the meter output becomes independent of velocity. For probe no 2, this point is reached when $v \approx 0.02$ cm/s. This indicates that there is a slight advantage to using probe no. 1 in the sphagnum peat but that it is useful only for flow velocities less than 0.03 cm/s.

Next values of E_n versus velocity were plotted in Figures 4a and 4b for probe no. 1 and 2 in the sedge peat. For probe no. 1, the data is quite scattered. However, there is still a noticable trend of E_n varying with velocity. An average curve was again fitted through the data to obtain an approximate relationship between E_n and v. The large scatter in comparison to the data obtained with the sphagnum peat may be a function of both the properties of the peat as well as the internal structural characteristics of the peat moss. Whereas the sphagnum peat sample was relatively homogeneous and uniformly structured, the sedge peat sample tended to be more heterogeneous, often with undecomposed stem and wood fragments. As a result, micro flows significantly different from the mass flow occur and are reflected in the large scatter. This suggests that a number of points should be sampled in the field to ensure that a valid measurement of mass flow is in fact obtained. Once again, it appears that the meter becomes insensitive when $v \approx .03$ cm/s. Examination of the results obtained with probe no. 2 in the same sedge peat test shows no clearly defined trend. Because all test conditions were the same as those obtained with probe no. 1, one can only ascribe this difference to the performance of probe no. 2 in this type of peat. It is felt that, in the case of probe no. 2, the heterogeneity of the peat and its sensitivity to localized or micro flow conditions within the peat results in its poorer performance.

Finally, the values of E_n versus v obtained for probes no. 1 and 2 in the sawdust were plotted in Figures 5a and 5b. The data for each probe exhibit more scatter than was observed for similar tests for the sphagnum peat. Nevertheless, there is a clearly definable trend for both probes, and an average smooth curve was manually drawn through the data in each case. It is clear from these curves that the two probes behave quite differently in this medium, with probe no. 2 providing a more sensitive curve over the range of data shown. This is contrary to the relative behaviour of the two probes in the sphagnum peat, where they exhibited a great similarity for the same conditions. Furthermore, a comparison of the curves for probe no. 1 obtained in the sawdust and sedge peat also show a great similarity, although such a comparison is only approximate because of the scatter in the plotted data. On the other hand, a comparison of the data for probe no. 2 in sawdust and sedge peat, in spite of the inconsistency demonstrated for the latter medium, indicates a large difference in the performance of the probe in these two media. This implies that probe no. 2 is not as consistent in its performance as is probe no. 1.

In summary, it appears that, based on the limited testing conducted on probes 1 and 2, probe 1 provides better and more consistent results and thus appears to be more suitable for use in peat and obtaining data in the coming field season. The values of E_o for probe no. 1 were -78, -57 and -130 for sphagnum peat, sedge peat and sawdust respectively. This confirms findings by Engel and Pedrosa (1980), that values of E_o are unique to the type of material in which the flow is measured. Therefore, care must be taken that consistent values of E_o for each peat in the field are obtained. In addition, the results from the present tests indicate that there is a different shape of calibration curve for each peat material. This was also observed by Engel and Pedrosa (1980). Therefore, it is necessary to obtain representative, undisturbed samples of the peat in which the probe is used in the field. These samples can then be used to obtain a calibration curve for the probe in a particular peat which can then be applied to the field measurements. Once sufficient data for the different materials have been obtained, it may be possible to draw further conclusions regarding the performance of the probe in different peat media.

4.0 CONCLUSIONS

4.1 The tests have shown that probe no. 1 (i.e. the original probe tested by Engel and Pedrosa (1980)) performs better than the modified probe identified as probe no. 2. Therefore, this probe should be used in the upcoming field season.

4.2 Probe no. 1 is sufficiently sensitive only for flow velocities equal to or less than about 0.03 cm/s in the sphagnum and sedge peats tested.

4.3 The consistency of flow measurements appears to be dependent on the type of peat in which the probe is placed. This is indicated by the fact that there was less scatter in the measured data for sphagnum peat than sedge peat.

4.4 The test results have confirmed the need to obtain values of E_o (meter output at zero flow velocity) for each type of peat encountered.

4.5 At present, because of the importance of peat properties on meter performance, it is necessary to obtain an undisturbed representative sample of each peat material in which the probe is used. A calibration curve for reach material must then be obtained in the existing calibration facility of the hydraulics laboratory.

REFERENCES

1. Pedrosa, M., 1980. "Peat, Water Mass (Velocity) Flow Meter". Handbook Notes, ES-1098, Engineering and Computing Support Group, National Water Research Institute, Burlington, Ontario.

2. Engel, P., Pedrosa, M., 1980. "Evaluation of an Experimental Meter to Measure Lateral Flow Velocities in Peat". Hydraulics Division Technical Note No. 80-19, National Water Research Institute, Burlington, Ontario.

3. Wickware, G. M., 1980. "Results of Preliminary Field Testing of an Experimental Meter to Measure Lateral Flow Velocities in Wetlands". Lands Directorate, Burlington, Ontario, Open File Report.

TABLE 1 TEST DATA FOR PROBE NO. 1 IN SPHAGNUM PEAT

E_o = -78 mV

Meter Reading E mV	E_n mV	Flow ml/min	V cm/sec
-68.5	9.5	55	0.0028
-68.5	9.5	44	0.0023
-58.0	20.0	94	0.0048
-59.0	19.0	74	0.0038
-48.5	29.5	177	0.0091
-50.0	28.0	147	0.0076
-55.0	23.0	127	0.0065
-56.0	22.0	117	0.0060
-28.5	49.5	572	0.0294
-29.0	49.0	556	0.0286
-73.5	4.5	15	0.0008
-74.5	3.5	14	0.0007
-69.0	9.0	52	0.0027
-69.0	9.0	45	0.0023
-56.0	22.0	124	0.0064
-56.5	21.5	96	0.0049
-67.0	11.0	56	0.0029
-67.5	10.5	50	0.0026
-28.0	50.0	449	0.0231
-28.5	49.5	448	0.0230
-33.5	44.5	351	0.0180
-35.5	42.5	325	0.0167
-43.5	34.5	232	0.0119
-46.0	31.0	183	0.0094
-63.5	14.5	61	0.0031
-73.0	5.0	22	0.0011
-74.0	4.0	20	0.0010
-43.0	35.0	300	0.0154
-44.5	33.5	269	0.0138
-21.0	57.0	620	0.0319
-21.0	57.0	613	0.0315
- 4.0	74.0	940	0.0483
- 3.0	75.0	922	0.0474
- 9.0	69.0	592	0.0304
- 9.0	69.0	586	0.0301

TABLE 2 TEST DATA FOR PROBE NO. 1 IN SEDGE PEAT

E_o = 57.0 mV

Meter Reading E mV	E_n mV	Flow ml/min	V cm/sec
-18.5	38.5	202	0.0104
-19.0	38.0	202	0.0104
-35.0	22.0	74	0.0038
-35.0	22.0	74	0.0038
-37.5	19.5	73	0.0038
-38.0	19.0	73	0.0038
-45.0	12.0	26	0.0013
-46.0	11.0	26	0.0013
+ 2.0	59.0	884	0.0455
+ 1.0	58.0	882	0.0454
-13.0	44.0	516	0.0265
-12.0	45.0	520	0.0267
-32.0	25.0	198	0.0102
-33.0	24.0	199	0.0102
-43.0	14.0	92	0.0047
-43.0	14.0	92	0.0047
-43.5	13.5	92	0.0047
-43.0	14.0	92	0.0047
-52.0	5.0	28	0.0014
-52.5	4.5	28	0.0014
-44.0	13.0	94	0.0048
-44.0	13.0	94	0.0048
-37.0	20.0	195	0.0100
-37.0	20.0	195	0.0100
-10.0	47.0	818	0.0421
-10.0	47.0	818	0.0421
-28.5	28.5	343	0.0176
-28.0	29.0	342	0.0176
-47.0	10.0	106	0.0055
-47.0	10.0	106	0.0055
-60.0	-3.0	22	0.011
-61.0	-4.0	20	0.0010
-26.0	31.0	453	0.0233
-26.0	31.0	454	0.0233
-37.0	20.0	266	0.0137
-38.0	19.0	265	0.0136
-47.0	10.0	153	0.0079
-47.0	10.0	153	0.0079
-57.0	0	60	0.0031
-57.0	0	61	0.0031

TABLE 3 TEST DATA FOR PROBE NO. 1 IN SAWDUST

E_o = -130 mV

Meter Reading E mV	E_n mV	Flow ml/min	V cm/sec
-121.0	9.0	98	0.0050
-121.5	8.5	91	0.0047
-118.0	12.0	157	0.0081
-119.0	11.0	156	0.0080
-112.0	18.0	304	0.0156
-112.5	17.5	281	0.0145
-103.0	27.0	722	0.0371
-103.0	27.0	707	0.0364
- 99.0	31.0	1212	0.0623
- 99.5	30.5	1212	0.0623
-103.0	27.0	953	0.0490
-103.0	27.0	943	0.0485
-108.0	22.0	647	0.0333
-108.5	21.5	603	0.0310
-119.0	11.0	205	0.0105
-119.5	10.5	197	0.0101
-127.0	3.0	104	0.0054
-127.0	3.0	102	0.0053
-129.5	0.5	81	0.0042
-129.5	0.5	80	0.0041
-119.5	10.5	98	0.0050
-120.5	9.5	87	0.0045
-111.5	18.5	197	0.0101
-111.0	19.0	191	0.0098
-102.0	28.0	339	0.0174
-103.0	27.0	315	0.0162
- 93.0	37.0	711	0.0366
- 93.0	37.0	707	0.0364
- 90.0	40.0	860	0.0442
- 90.0	40.0	864	0.0444
- 96.0	34.0	551	0.0283
- 96.0	34.0	550	0.0283
-105.5	24.5	250	0.0129
-107.5	22.5	222	0.0114
-113.5	16.5	146	0.0075
-112.0	18.0	135	0.0069
-120.5	9.5	59	0.0030
-121.0	9.0	58	0.0030
-122.0	8.0	75	0.0039
-121.0	9.0	73	0.0038
-106.5	23.5	213	0.0110
-107.0	23.0	206	0.0106
- 99.0	31.0	361	0.0186

TABLE 3 cont'd.

- 99.5	30.5	368	0.0189
- 86.0	44.0	784	0.0403
-117.0	13.0	77	0.0040
-116.0	14.0	77	0.0040
- 97.0	33.0	280	0.0144
- 97.5	32.5	270	0.0139
- 91.0	39.0	592	0.0304
- 91.0	39.0	587	0.0302
- 98.0	32.0	279	0.0143
- 98.0	32.0	277	0.0142
-114.5	15.5	68	0.0035
-115.5	14.5	65	0.0033
-120.0	10.0	38	0.0020
-120.5	9.5	38	0.0020
-125.0	5.0	37	0.0019
-120.0	10.0	73	0.0038
-119.5	10.5	71	0.0037
-115.0	15.0	100	0.0051
-114.5	15.5	99	0.0051
-105.0	25.0	184	0.0095
-105.0	25.0	176	0.0090
- 91.0	39.0	438	0.0225
- 91.0	39.0	437	0.0225
-111.0	19.0	113	0.0058
-112.0	18.0	110	0.0057
-122.5	7.5	37	0.0019
-123.0	7.0	37	0.0019

TABLE 4 TEST DATA FOR PROBE NO. 2 IN SPHAGNUM PEAT

E_o = 540 mV

Meter Reading E mV	E_n mV	Flow ml/min	V cm/sec
551.5	11.5	29	0.0015
550.0	10.0	20	0.0010
586.0	46.0	232	0.0119
585.5	45.5	220	0.0113
595.0	55.0	436	0.0224
594.5	54.5	432	0.0222
585.0	45.0	570	0.0293
586.0	46.0	565	0.0291
581.5	41.5	342	0.0176
581.0	41.0	306	0.0157
562.5	22.5	92	0.0047
561.5	21.5	88	0.0045
560.5	20.5	82	0.0042
555.5	15.5	61	0.0031
553.5	13.5	49	0.0025
551.5	11.5	43	0.0022
542.0	2.0	22	0.0011
541.5	1.5	17	0.0009
554.5	14.5	84	0.0043
556.0	16.0	83	0.0043
575.5	35.5	223	0.0115
574.5	34.5	212	0.0109
555.0	15.0	83	0.0043
554.5	14.5	83	0.0043
549.5	9.5	51	0.0026
548.5	8.5	49	0.0025
570.0	30.0	174	0.0089
570.0	30.0	168	0.0086
568.0	28.0	157	0.0081
569.0	29.0	166	0.0085
581.0	41.0	361	0.0186
581.0	41.0	357	0.0184
586.0	46.0	566	0.0291
585.0	45.0	562	0.0289
557.5	17.5	109	0.0056
556.5	16.5	99	0.0051
578.5	38.5	285	0.0147
578.0	38.0	277	0.0142
594.0	54.0	788	0.0405
593.5	53.5	776	0.0399
578.0	38.0	374	0.0192
577.5	37.5	369	0.0190

TABLE 5 TEST DATA FOR PROBE NO. 2 IN SEDGE PEAT

E_o = 534 mV

Meter Reading E mV	E_n mV	Flow ml/min	V cm/sec
536.0	2.0	71	0.0037
536.0	2.0	71	0.0037
540.0	4.0	129	0.0066
540.5	4.5	129	0.0066
551.0	17.0	296	0.0152
551.0	17.0	296	0.0152
541.0	7.0	118	0.0061
541.0	7.0	119	0.0061
540.0	6.0	121	0.0062
540.0	6.0	122	0.0063
532.0	-4.0	29	0.0015
531.5	-4.5	121	0.0015
542.0	8.0	121	0.0062
541.0	7.0	121	0.0062
548.0	14.0	213	0.0110
548.0	14.0	216	0.0111
552.0	18.0	217	0.0112
552.0	18.0	230	0.0118
571.0	37.0	700	0.0360
571.0	37.0	696	0.0358
545.0	11.0	106	0.0055
545.0	11.0	106	0.0055
563.0	29.0	388	0.0200
563.0	29.0	394	0.0203
567.5	32.5	474	0.0244
567.0	33.0	473	0.0243
558.0	24.0	105	0.0054
558.0	24.0	106	0.0055
588.0	54.0	685	0.0352
588.0	54.0	685	0.0352
595.0	61.0	692	0.0356
595.0	61.0	690	0.0355
569.0	35.0	98	0.0050
568.5	34.5	98	0.0050
557.0	23.0	35	0.0018
557.0	23.0	35	0.0018
559.5	25.5	40	0.0021
560.0	26.0	46	0.0024
561.5	27.5	48	0.0025
560.0	26.0	46	0.0024
561.5	27.5	48	0.0025
560.0	26.0	48	0.0025
577.0	43.0	138	0.0071
576.5	42.5	143	0.0074

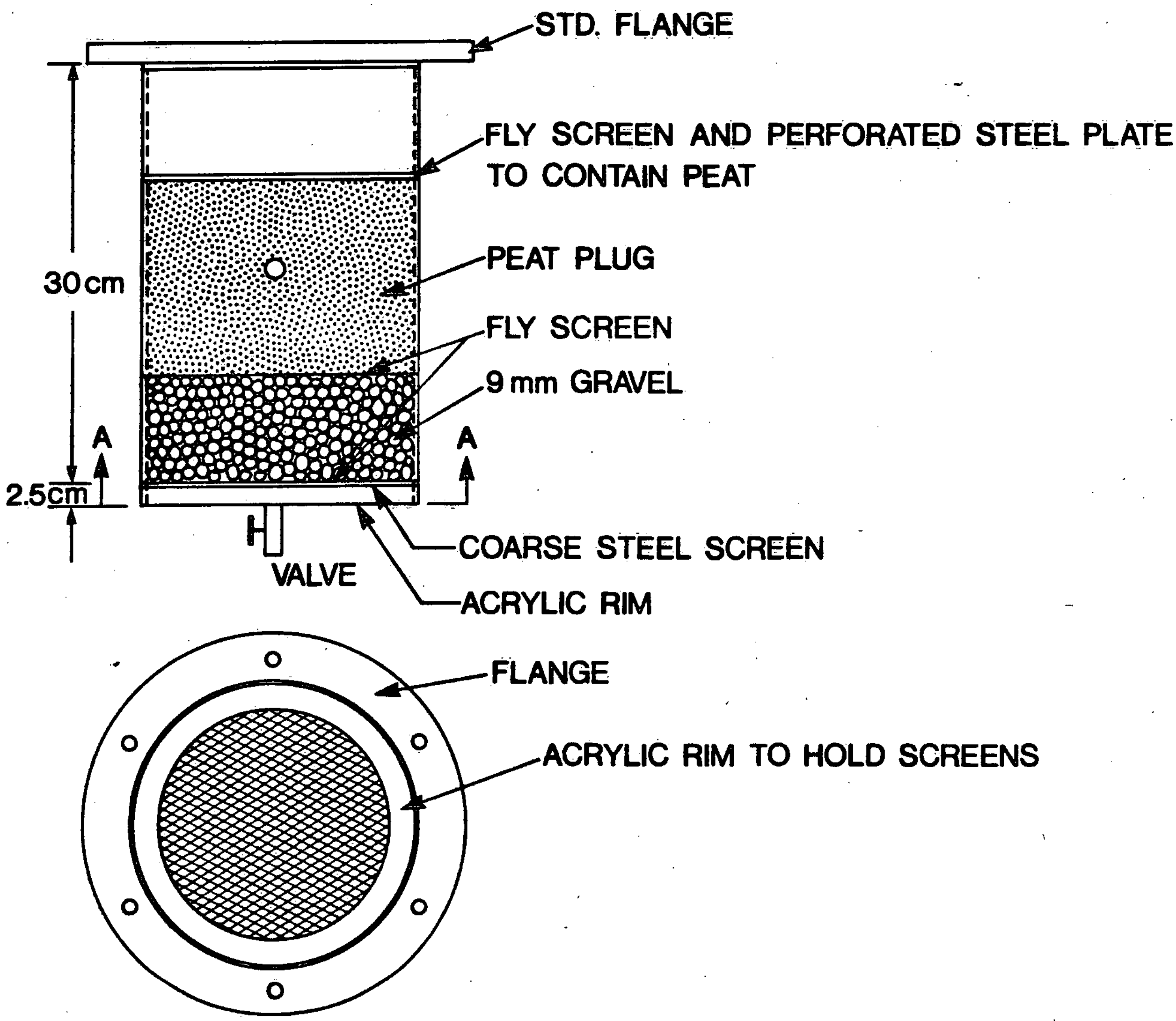
TABLE 6 TEST DATA FOR PROBE NO. 2 IN SAWDUST

E_o = 532 mV

Meter Reading E mV	E_n mV	Flow ml/min	V cm/sec
+617.0	85.0	950	0.0488
+616.0	84.0	932	0.0479
+625.0	99.0	846	0.0435
+624.0	100.0	812	0.0418
+613.0	81.0	450	0.0231
+610.0	78.0	355	0.0183
+602.0	70.0	291	0.0150
+585.0	53.0	169	0.0087
+577.0	45.0	102	0.0052
+564.0	32.0	78	0.0040
+542.0	10.0	51	0.0026
+541.0	9.5	41	0.0021
+562.0	30.0	122	0.0063
+584.0	52.0	81	0.0042
+581.0	49.0	79	0.0041
+598.0	66.0	154	0.0079
+590.0	58.0	127	0.0065
+616.5	84.5	512	0.0263
+617.5	85.5	510	0.0262
+625.5	93.5	602	0.0310
+625.0	93.0	600	0.0309
+596.0	64.0	153	0.0079
+592.0	60.0	133	0.0068
+569.0	37.0	74	0.0038
+565.0	33.0	69	0.0035
+549.5	17.5	51	0.0026
+550.0	17.0	49	0.0025
+590.0	58.0	203	0.0104
+587.5	55.5	187	0.0096
+608.0	76.0	465	0.0239
+604.5	72.5	448	0.0230
+610.5	78.5	340	0.0175
+600.0	68.0	205	0.0105
+554.5	23.0	35	0.0018
+544.5	12.5	30	0.0015
+564.0	32.0	112	0.0058
+561.0	29.0	96	0.0049
+577.0	45.0	181	0.0093
+575.5	43.5	176	0.0090
+606.0	74.0	576	0.0296
+606.0	74.0	565	0.0291
+616.5	84.5	888	0.0457
+616.0	84.0	886	0.0456

TABLE 6 cont'd.

+621.0	89.0	1158	0.0595
+621.5	89.5	1152	0.0592
+604.5	72.5	272	0.0140
+572.0	39.5	103	0.0053
+568.5	36.5	101	0.0052
+558.5	26.5	82	0.0042
+557.0	25.0	82	0.0042



SECTION A-A

FIGURE 1 DETAILS OF TEST SECTION

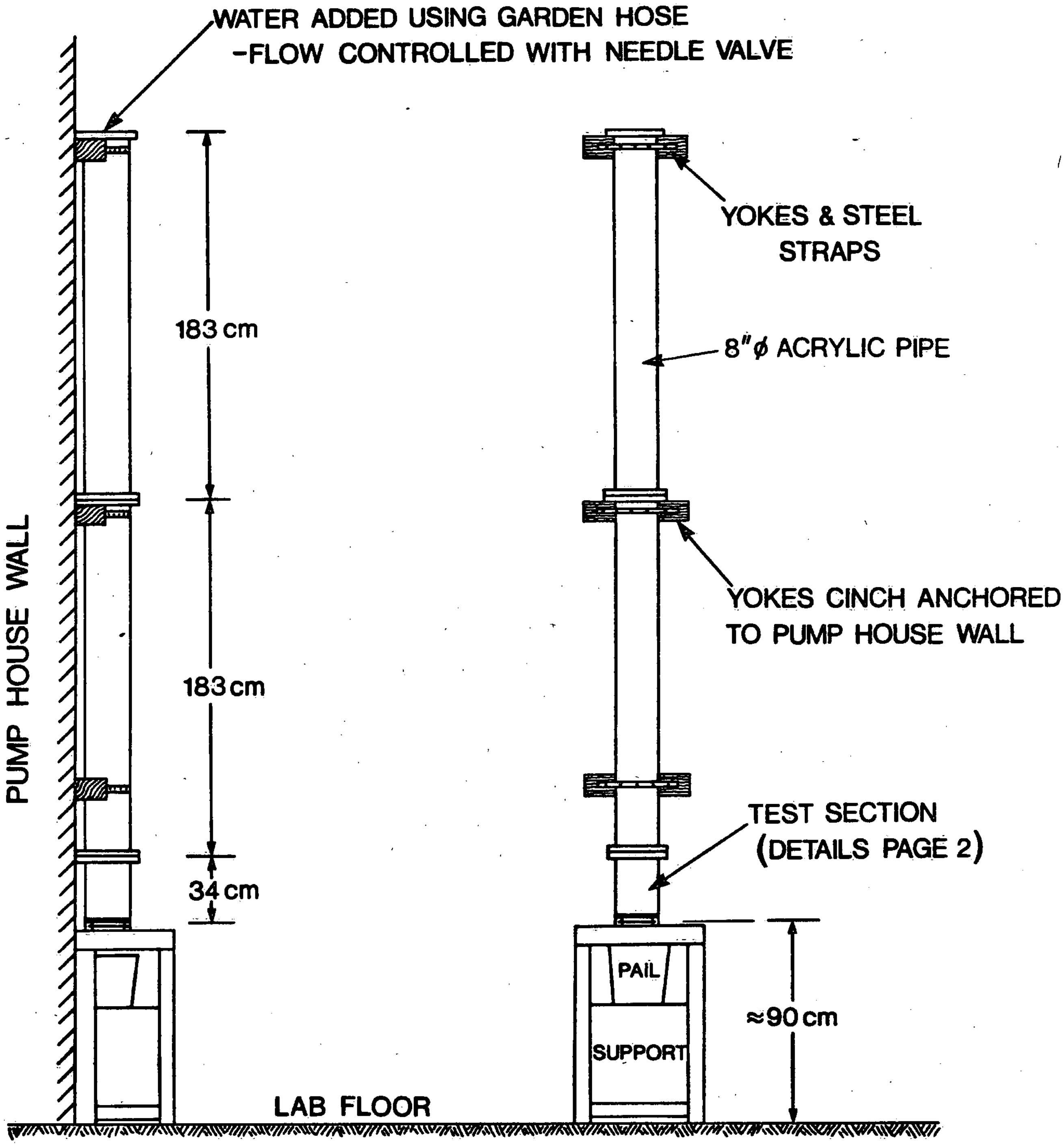
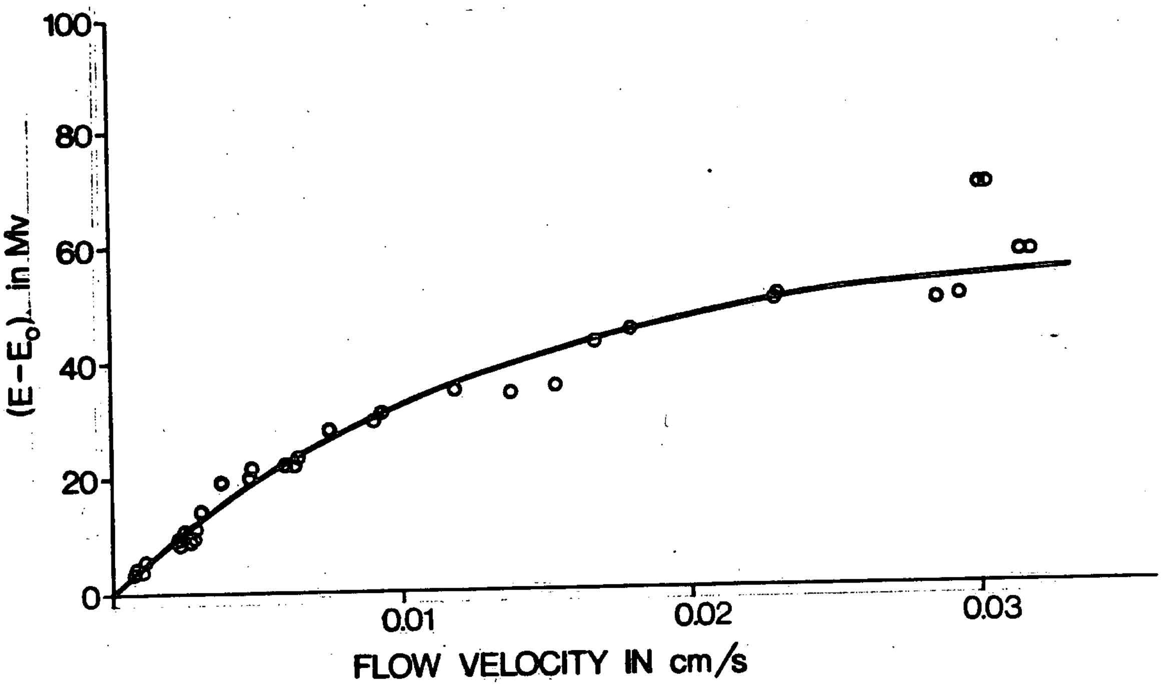
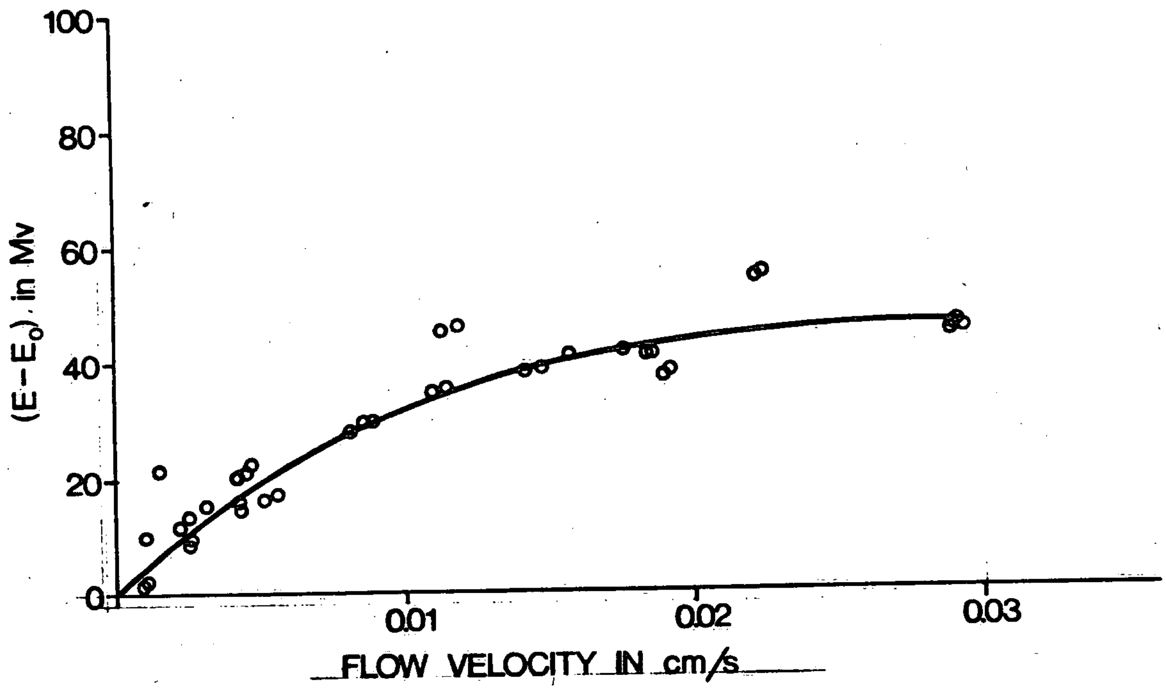


FIGURE 2 GENERAL LAYOUT OF TEST FACILITY

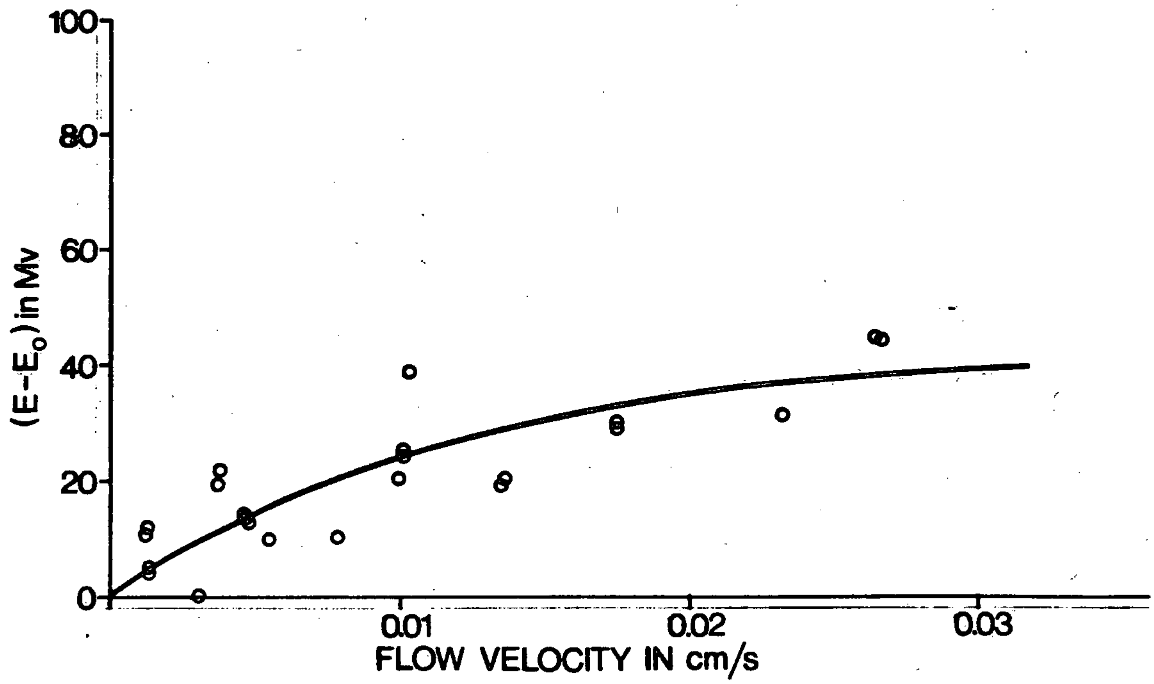


3(a) TEST RESULTS FOR PROBE No. 1

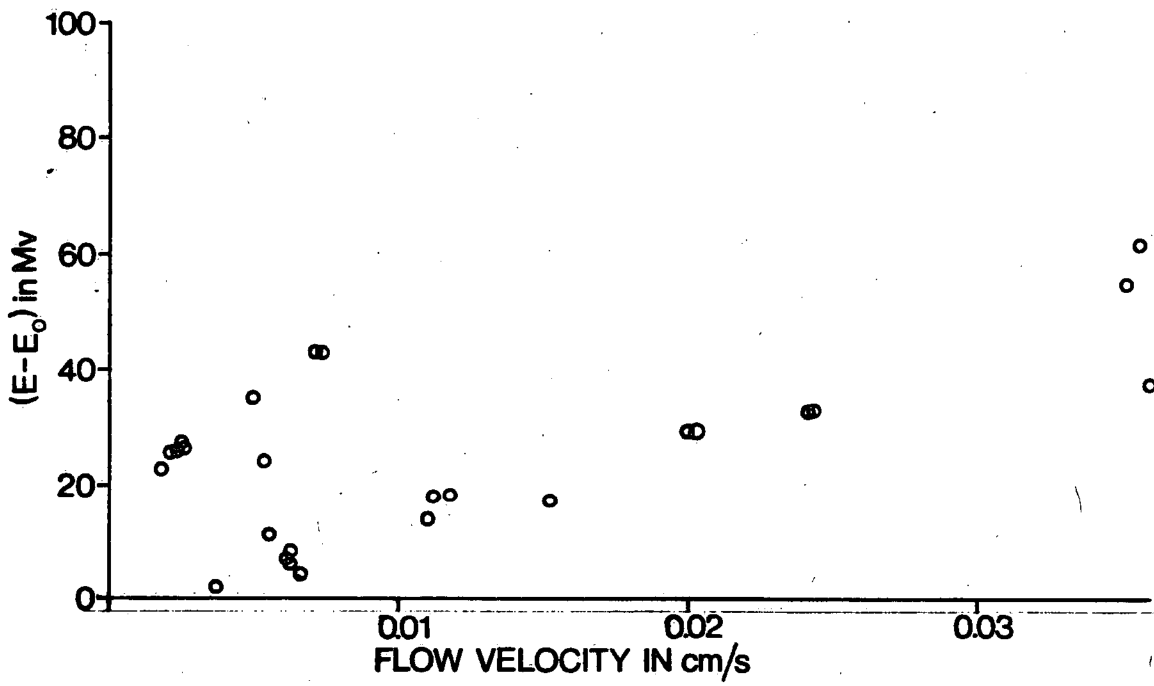


3(b) TEST RESULTS FOR PROBE No. 2

Figure 3 COMPARISON OF PROBES IN SPHAGNUM PEAT SAMPLE



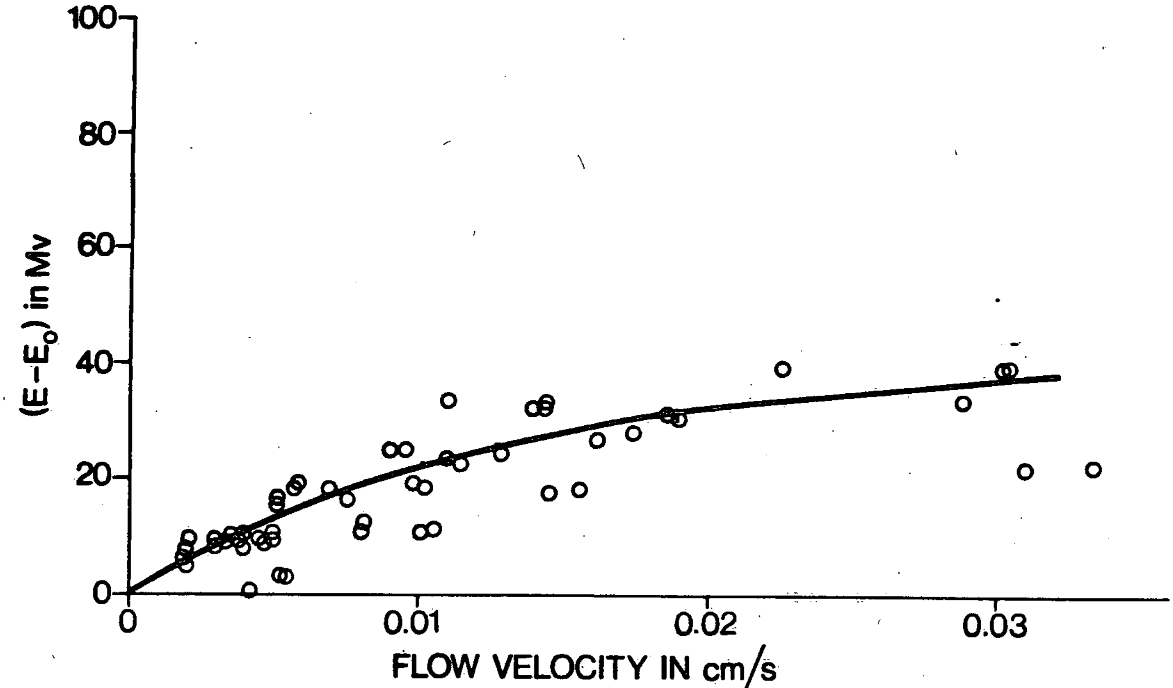
4(a) TEST RESULTS FOR PROBE No.1



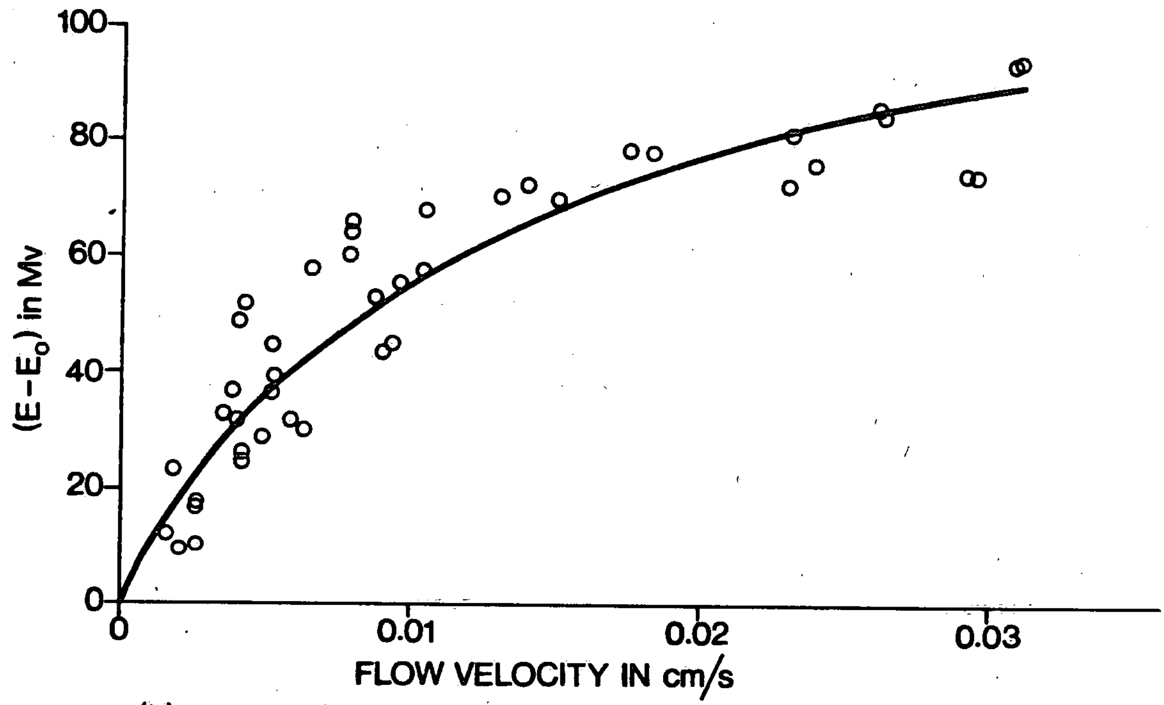
4(b) TEST RESULTS FOR PROBE No. 2

Figure 4 COMPARISON OF PROBES IN SEDGE PEAT SAMPLE

23699



5(a) TEST RESULTS FOR PROBE No.1



5(b) TEST RESULTS FOR PRODE No.2

Figure 5 COMPARISON OF PROBES IN SAWDUST SAMPLE