REPORT PP

THE US D-96: AN ISOKINETIC
SUSPENDED-SEDIMENT/WATER-QUALITY
COLLAPSIBLE-BAG SAMPLER

ADDENDUM – I

PERFLUOROALKOXY – POLYETHYLENE
COLLAPSIBLE BAG COMPARISON

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FEDERAL INTERAGENCY SEDIMENTATION PROJECT
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199
(601) 634-2721
http://fisp.wes.army.mil

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Introduction

The Federal Interagency Sedimentation Project (FISP) designed, tested, and currently supplies a collapsible-bag depth-integrating isokinetic sampler for the collection of suspended-sediment/water-quality samples. The sampler is designated the US D-96 (patent number 6,216,549 B1) and a report (FISP Report PP) describing the development and testing of the sampler is available on the FISP internet site (http://fisp.wes.army.mil). Instructions for use of the sampler are also available on the site. All tests were conducted using a perfluoroalkoxy (PFA) bag. The PFA bag is required for water-quality sampling. For sediment sampling only, a PFA bag would not be required. FISP has tested a commercially available polyethylene bag for use in the US D-96. This addendum to Report PP summarizes the results of a comparison between PFA and polyethylene bags and shows that the commercially available polyethylene bag is acceptable for use in the US D-96.

Collapsible Bags Description

The PFA bag currently in use is a custom designed bag fabricated to FISP specifications. It is a fin-seam bag that is made from sheet material. It is seamed at the bottom and longitudinally. It is a lay-flat bag 7 in. wide by 22 in. long and 0.002 in. thick. The PFA bag can be acid rinsed and is autoclavable. The unit cost of a PFA bag is currently $9.00.

The polyethylene bag tested is commercially available. It is fabricated from tube material and has a seam only at the bottom. It is a lay-flat bag that is 7 in. wide by 22 in. long and 0.002 in. thickness. The polyethylene bag is acid resistant but is not autoclavable. The unit cost of a polyethylene bag is currently $0.10.

Test Procedure

The results of hydraulic efficiency tests conducted during the development and testing of the US D-96 showed that acceptable hydraulic efficiencies (1.0 +/- 0.1) could be obtained using a PFA bag in flow velocities from 2 ft/sec to over 10 ft/sec. Extensive testing was required to obtain the results. The approach to determine if the polyethylene bag could be used with the US D-96 was to conduct a direct comparison between the hydraulic efficiencies using the PFA and polyethylene bags. A test series was designed such that all conditions were constant for each specific comparison test, with the composition of the bag the only variable. The tests included four flow velocities and three different internal diameter nozzles. Tests at flow velocities of 2 and 4.3 ft/sec were conducted in a flume, and simulated velocities of 5.5 to 6.0 ft/sec and 9 to 10 ft/sec were accomplished by towing the sampler with a boat in a lake. Nozzle intake diameters were 3/16 in., 1/4 in., and 5/16 in. A minimum of three replications was conducted at each velocity-nozzle-bag combination.

Test Results

Figures 1-3 show graphical results of the hydraulic efficiency versus flow velocity for the PFA and polyethylene bags for each of the three internal diameter nozzles. Data curves plotted using an Excel chart routine for the two bags were very similar for the 3/16 in. and 1/4 in. internal diameter nozzles (Figures 1 and 2 respectively). The data curves for the two bags using the 5/16 in. internal diameter nozzle (Figure 3) were less similar, with the polyethylene bag having a higher hydraulic efficiency at 2 ft/sec flow velocity and the PFA bag higher efficiencies in the 5 to 6 ft/sec velocity range and the 9 to 10 ft/sec range. The efficiencies using the two bags were almost identical at 4.3 ft/sec velocity. With the exception of some of the data points at 2 ft/sec, the hydraulic efficiencies using both bags were between 0.9 and 1.1 with all three nozzles.

A simple and straightforward way to determine if there was a statistical difference between the hydraulic efficiencies using the two different bags was to run an F-test of the variances. In an F-test, the F-value is calculated by dividing var_1/var_2 where $var_1 > var_2$. The null hypothesis is that $var_1/var_2 = 1$ and the variance in the data set is due to randomness, or in the case of bag comparisons, experimental error. In practice, the observed F-value is compared to an F-distribution table value determined by the number of degrees of freedom for error. If the observed F-value is less than the table value (critical F-value), there is no statistically significant difference between the observations. Observed F-values for the data were calculated using the Data Analysis routine in an Excel spreadsheet. The program also finds the critical F-value for the number of degrees of freedom of the data set. Data was analyzed at the 95 pct confidence level.

F-tests for statistical difference were conducted for all velocities for the two bags for each of the three nozzles, and also for each velocity for the three nozzles. Table 1 presents the results for the 3/16 in. internal diameter nozzle. The mean hydraulic efficiency for all velocities using the polyethylene bag was 0.94 and 0.93 for the PFA bag. The observed F-value was less than critical F-value indicating that there was no statistical difference in the hydraulic efficiencies between the two bags for all velocities. F-tests of the data at 2 ft/sec, 4.3 ft/sec and 9-10 ft/sec velocities also showed that the observed F-value was less than critical F-value, indicating that there was no statistical difference between the hydraulic efficiencies of the two bags. F-test results at 5.5-6.0 ft/sec showed that there was a slight statistical difference (9.727 observed F-value, 9.277 critical F-value). However, the mean for the polyethylene bag (0.96) was closer to 1.0 than the mean for the PFA bag (0.92).

Table 2 shows the F-test results for the 1/4 in. internal diameter nozzle. The mean hydraulic efficiency for all velocities using the polyethylene bag was 0.98 and 0.96 for the PFA bag. The observed F-value was less than the critical F-value indicating that there was no statistical difference in the hydraulic efficiencies between the two bags for all velocities. F-tests of the data at each of the velocities also showed that the observed F-value was less than critical F-value, indicating that there was no statistical difference between the hydraulic efficiencies of the two bags.

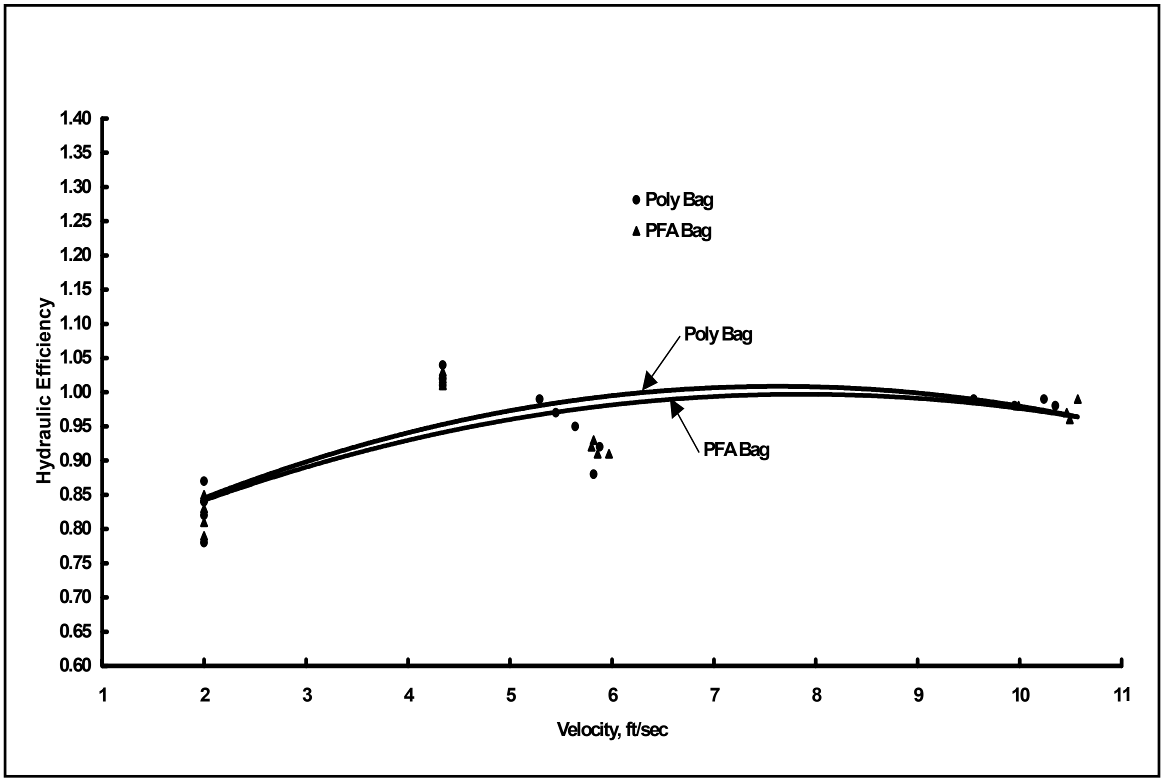

Figure 1-- Hydraulic efficiency results using a 3/16 in. internal diameter nozzle

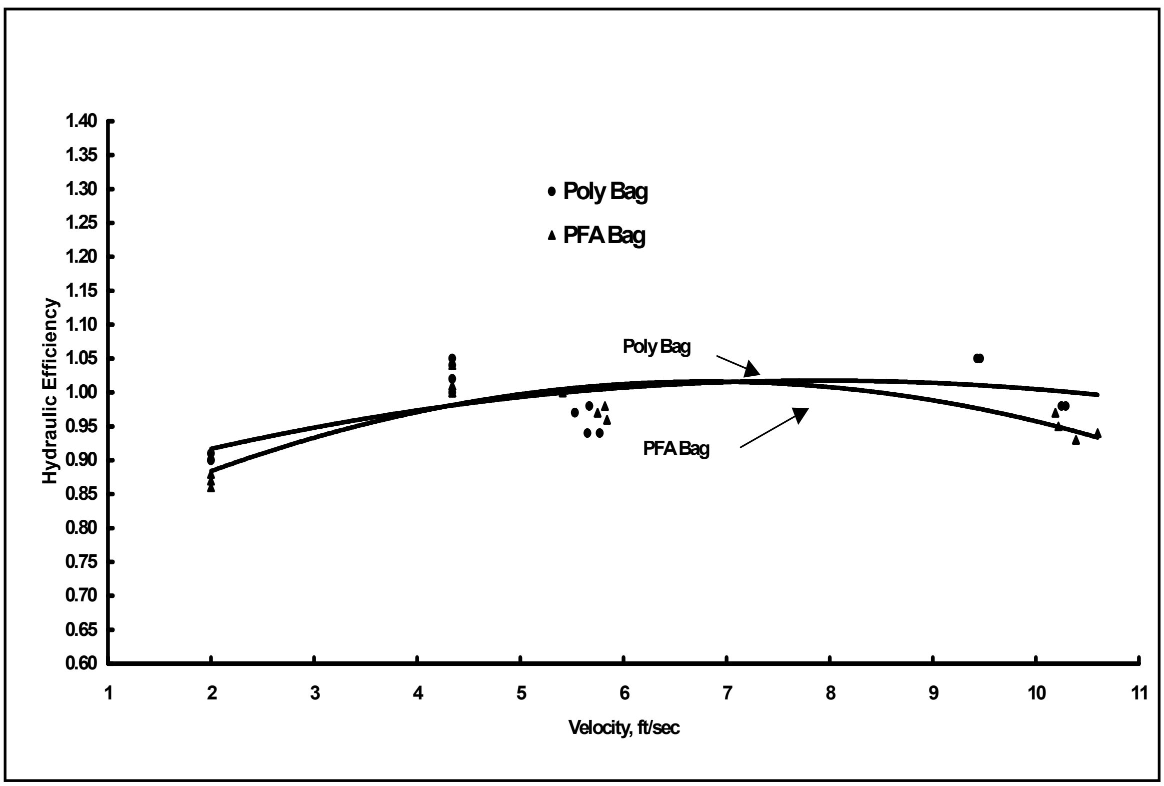

Figure 2-- Hydraulic efficiency results using a 1/4 in. internal diameter nozzle

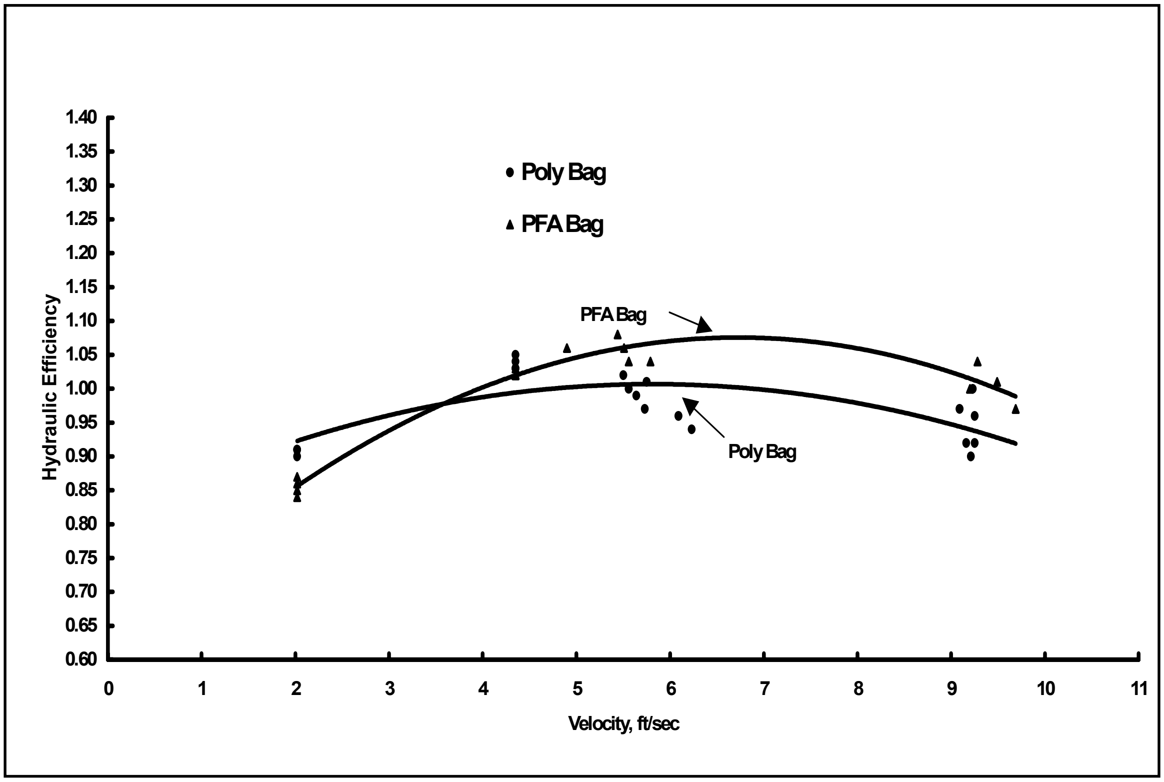

Figure 3-- Hydraulic efficiency results using a 5/16 in. internal diameter nozzle

Table 1-- F-test results using a 3/16 in. internal diameter nozzle

Velocity ft/sec	Mean Hydraulic Efficiency		Variance		Observed $F_{0.05}$	Critical $F_{0.05}$
	Poly Bag	PFA Bag	Poly Bag	PFA Bag		
All	0.94	0.93	0.006368	0.006047	1.053	2.368
2.0	0.83	0.82	0.001100	0.000667	1.650	9.117
4.3	1.03	1.02	0.000133	0.0000917	1.455	9.277
5.5 – 6.0	0.96	0.92	0.000892	0.0000917	9.727	9.277
9.0 – 10.0	0.99	0.98	0.000167	0.0000333	5.000	9.277

Table 2-- F-test results using a 1/4 in. internal diameter nozzle

Velocity ft/sec	Mean Hydraulic Efficiency		Variance		Observed $F_{0.05}$	Critical $F_{0.05}$
	Poly Bag	PFA Bag	Poly Bag	PFA Bag		
All	0.98	0.96	0.00295	0.002846	1.036	2.424
2.0	0.90	0.87	0.0000333	0.000100	3.000	19.000
4.3	1.03	1.01	0.000492	0.00027	1.821	6.591
5.5 – 6.0	0.96	0.98	0.000425	0.000292	1.457	9.277
9.0 – 10.0	1.02	0.95	0.001633	0.000292	5.600	9.277

Table 3-- F-test results using a 5/16 in. internal diameter nozzle

Velocity ft/sec	Mean Hydraulic Efficiency		Variance		Observed $F_{0.05}$	Critical $F_{0.05}$
	Poly Bag	PFA Bag	Poly Bag	PFA Bag		
All	0.97	0.99	0.002519	0.006499	2.580	2.215
2.0	0.91	0.86	0.0000333	0.000167	5.000	19.164
4.3	1.04	1.02	0.0000917	0.000025	3.667	9.277
5.5 – 6.0	0.98	1.06	0.001227	0.000280	4.381	6.094
9.0 – 10.0	0.95	1.01	0.00143	0.000833	1.716	9.013

Table 3 presents the F-test results for the 5/16 in. internal diameter nozzle. The mean hydraulic efficiency for all velocities using the polyethylene bag was 0.97 and 0.99 for the PFA bag. The observed F-value (2.58) was close to the critical F-value (2.215) indicating there may have been a statistical difference in the hydraulic efficiencies between the two bags for all velocities tested. However, F-test results of the individual velocities showed that there was no statistically significant difference between the hydraulic efficiencies between the two bags for the individual velocities. The probable reason for the statistical difference between the two bags using all the data was the difference in hydraulic efficiency at 2 ft/sec flow velocity. At 2 ft/sec flow velocity, the mean for the polyethylene bag was 0.91 and 0.86 for the PFA bag resulting in a high F-value of 5. However, due to the low number of degrees of freedom for error, the critical F-value was very high (19.194). Including the other data, the observed F-value only drops to 2.58, but the critical F-value drops to 2.215 due to the increased number of degrees of freedom for error. An F-test performed on all the 5/16 in. internal diameter nozzle data except the 2 ft/sec flow velocity data indicated no statistically significance difference between the hydraulic efficiencies of the two bags.

An examination of the mean hydraulic efficiencies using the two different bags in the 12 flow velocity-nozzle combinations shows that the bags produce similar results. In seven instances, the polyethylene bag had a mean hydraulic efficiency closer to 1.0, and in five instances, the PFA bag had a mean hydraulic efficiency closer to 1.0.

Conclusions

The only collapsible bag currently used in the US D-96 is an expensive custom designed PFA bag. A much less expensive polyethylene bag is commercially available. An examination of the test results of a comparison between the hydraulic efficiencies using the two bags in the sampler under identical conditions showed that the bags have comparable efficiencies. F-tests indicate that there is no statistically significant difference in the hydraulic efficiencies using the two bags under all conditions tested except two. In one case, the polyethylene bag had a mean hydraulic efficiency closer to 1.0, and in the other case, the PFA had a mean hydraulic efficiency closer to 1.0. With the exception of some of the data points at 2 ft/sec flow velocity, the hydraulic efficiencies using both bags were 1.0 +/- 0.1.