Program Management Office
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Cranberry Township, PA 16066

Project Number 694

May 28, 2014

OG-14-196

US Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Attention: Mr. Jonathan Rowley, Project Manager
Mail Stop O-12D20

Subject: PWR Owners Group
Draft Information Regarding the PWROG Approach to Particulate-To-Fiber Ratio in Further Subscale Testing (PWROG PA-SEE-1090)

Dear Mr. Rowley,

During the April 16, 2014 meeting between the PWROG and NRC staff, the PWROG took the action to forward information regarding its plan for determination of limiting particulate-to-fiber ratio in the subscale testing performed for the ongoing PWROG GSI-191 deterministic program. Enclosed – for information only – are four (4) copies of said information for staff's consideration.

If you have any questions regarding this information, please contact John Maruschak (412) 374-3512 or maruscjt@westinghouse.com).

Sincerely,

Norman J. Stringfellow

Jack Stringfellow, Chairman
PWR Owners Group

NJS:jtm:rfn

D048
NRR

Enclosures (1): 1. "P:F Ratio for Subscale Testing – Draft, 5/27/2014" (Non-Proprietary).

cc: PWROG Management Committee
PWROG SEE Subcommittee
PWROG Licensing Subcommittee
PWROG PMO
J. D. Andrachek – Westinghouse
T. S. Andreychek - Westinghouse
T. D. Croyle - Westinghouse
J. A. Gresham – Westinghouse
J. K. McKinley - Westinghouse
J. P. Spring – Westinghouse
K. Greenwood – AREVA, Inc.
R. Schomaker – AREVA, Inc.
G. Wissinger – AREVA Inc.

P:F Ratio for Subscale Testing – DRAFT, 5/27/2014

Background

In the WCAP-16793-NP Fuel Assembly (FA) Test Program, a range of particulate to fiber (p:f) ratios was examined. The limiting p:f ratio for a large hot leg break (HLB) was found to be 1, while the limiting p:f ratio for a large cold leg break (CLB) was found to be 45. A couple of items on this result are noted:

1. The limiting p:f ratio was determined after the chemical surrogate AlOOH was added to the system.
2. Review of the pressure drop trends before chemical addition indicate that the bed pressure drop increases as p:f ratio increases for the conditions tested.
3. A few tests were run at HLB conditions using the AREVA FA at two different fiber loads with various p:f ratios. These results are summarized as follows:

Test	Flow (gpm)	Fiber (g)	Final p:f ratio	Assy dP before chem (psid)	Assy dP after chem (psid)
7-FG-FPC	45	60	1	6.26	>limit
8-FG-FPC	45	60	2.5	7.86	>limit
11-FG-FPC	45	60	2.5	5.65	>limit
12-FG-FPC	45	15	1	0.61	2.7
13-FG-FPC	45	15	2	0.67	2.56

   During these tests a single debris bed was formed near the FA inlet. With 60g of fiber, it is difficult to tell if the pressure drop increases or decreases with increasing p:f ratio because of the variation in the assembly pressure drop before chemical addition for tests run at a p:f ratio of 2.5. If an average pressure drop is calculated from the two tests, the average (6.76 psid) is higher than the pressure drop obtained when the p:f ratio equals 1. With 15g of fiber, the pressure drop increases with p:f ratio before the chemical surrogate was added.

4. Tests were also run using the Westinghouse FA at different fiber loads representative of large CLB conditions with various p:f ratio. These results are summarized as follows:

Test	Flow (gpm)	Fiber (g)	Final p:f ratio	Assy dP before chem (psid)	Assy dP after chem (psid)
CIB22	3	75	0	0.29	3.30
CIB23	3	75	1	0.49	5.10
CIB21	3	75	4.84	1.10	6.10
CIB29	3	18	5	0.16	0.64
CIB30	3	18	15	0.32	1.03
CIB32	3	18	45	0.70	1.74
CIB33	3	18	60	0.61	0.92

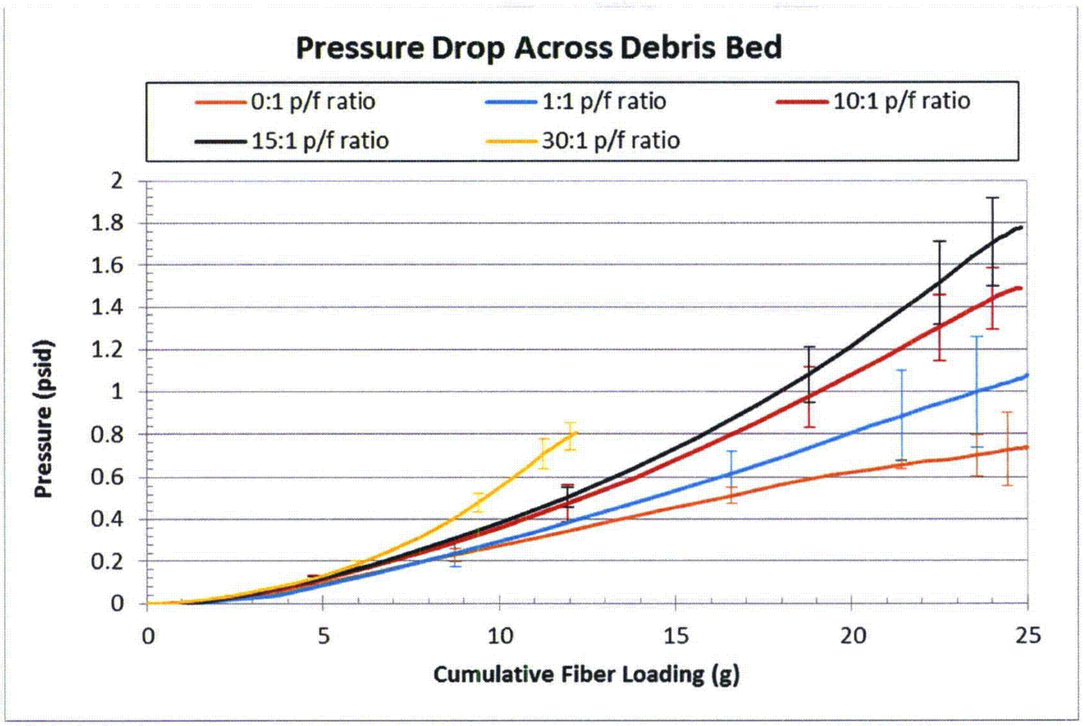
   During these tests a single debris bed was formed near the FA inlet. With 75g of fiber, increasing p:f ratio from 0 up to 4.84 results in an increased pressure drop both before and after

chemical addition. With 18 g of fiber, a similar trend is observed for p:f ratios of 5 up to 45. The pressure drop decreases when p:f ratio is further increased from 45 to 60 at this condition both before and after chemical addition.

5. The p:f ratio results obtained in theWCAP-16793-NP FA Test Program show trends that are consistent with those obtained in the Subscale Test Program to date: increasing p:f ratio results in higher bed pressure drops prior to the addition of chemical products. This is true for the entire range of conditions tested at HLB flows and is true for p:f ratios up to 45 for tests conducted at CLB flows. Given the narrow range of p:f ratios studied under the WCAP-16793 test program, it is difficult to fully understand the influence of p:f ratio on bed pressure drop without additional experimental data.

In the subscale testing to date, a p:f ratio study was undertaken to examine the effect of p:f ratio on a debris bed with only fiber and particulates. The subscale test results demonstrate that the pressure drop increases with increasing p:f ratio as shown in Figure 1. This behavior is consistent with trends observed in the WCAP-16793 Test Program prior to chemical addition. It should be noted that at the higher p:f ratio tests, the fiber load was reduced from 25g to 12.5g in order to keep the particulate concentration in the mixing tank reasonable.

Figure 1. Pressure Drop Across Debris Bed w/ p:f Ratio



These results lead to the following question for the PA-SEE-1090 Program: Is there a maximum particulate load that should be tested, which would set a particulate debris limit? This position paper develops the approach for answering this question in the PA-SEE-1090 Subscale Test Program.

In-Bed p:f ratio

Before a detailed analysis is presented, the in-bed p:f ratio is calculated. The following items are relevant to this discussion:

- In all testing, the p:f ratio identified in the test matrix and in test discussions is
  - mass based and
  - represents the <u>starting</u> ratio between particulate mass and fiber mass introduced into the test loop.
- In the WCAP-16793-NP FA Test Program, debris was allowed to circulate in the loop continuously. For the limiting HLB tests, visual observations indicated that most (if not all) of the particulate had been captured by the fiber bed (i.e. the water was basically clear) before the chemical surrogate was introduced to the test loop. This observation implies that the p:f ratio in the debris bed was very close to the p:f ratio that was started in the testing.
- In the subscale test loop, the particulates and fiber are introduced simultaneously and not allowed to continually recirculate. Therefore, the p:f ratio in the final debris bed will not be the same as the initial p:f ratio.

This last point bears further discussion and investigation. The actual p:f ratio in the beds of the subscale tests has to be determined. This can be done by using the results of the filter bag analysis from the tests.

There are two filter bags used in each test. Bag #1 captured the debris that was not captured at the capture grid during the test; this is called the penetration mass. Bag #2 captured the debris that was captured on the grid; this is called the capture mass. Both the capture mass and the penetration mass data will be used to determine the mass of particulate captured in the debris bed.

The fiber only test series (T.S. 9) indicated that approximately 2.5 g of fiber passed through the fuel grid (i.e. was not a part of the debris bed on the grid)[1]. A more detailed analysis is required to refine the total penetration fiber mass from the subscale tests; however, subsequent calculations will assume 2.5g of fiber penetration. Therefore, the calculations of mass on the capture grid assume that the fiber load on the fuel is 22.5g for tests that started with 25g of fiber and 10g for tests that started with 12.5g of fiber. Calculations of the average particulate mass in the debris bed were done for all tests. A summary of the results is presented in the following section for tests conducted with 25 and 12.5g of fiber and Type A particulate. The data is binned assuming that the bed p:f ratio is only dependent on the initial

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[1] Although the fiber amount that passes through the sub-scale fuel assembly can't be measured easily when particulate is included in the tests, visual comparison of the fiber in the bags and the water after the fiber bed were similar for all tests. Based on visual observation, it appears most of the fiber that gets past the fiber bed does so before a bed is developed on the spacer grid. Therefore, it is appropriate to use the same value for both the 25gm and 12.5 g/FA tests.

fiber loading, initial p:f ratio, and the particulate size. Experimental trends confirm the acceptability of these assumptions. The final debris bed p:f ratio can be calculated by dividing the average of the particulate mass in the debris bed by the mass of fiber in the debris bed, either 22.5g or 10g depending on the starting mass of fiber for the test.

Analysis

There are two possibilities for particulate loading:

1. Some p:f ratio less than the maximum amount of particulate loading results in the maximum bed pressure drop. In this case, a particulate limit is not needed, because all particulate loads above the limiting p:f ratio would be bounded. This trend was observed in the WCAP-16793-NP FA Test Program under CLB conditions at p:f ratios greater than 45.
2. The pressure drop across a particulate and fiber bed continues to increase with particulate load. In this case, a maximum particulate load would need to be defined through testing that is likely a function of fiber loading.

In order to examine these possibilities further, the results from the subscale testing that varied the initial p:f ratio is examined further. First, the bed p:f ratio is calculated.

The results from subscale tests conducted with 25g of fiber at the medium flow rate and particulate Type A (10 μm mean diameter) are used to provide a comparison of the bed p:f ratio to the starting p:f ratio:

Initial p:f Ratio	0	1	10	15
Bed Particulate Mass (g)	0	2.48	14.15	18.26
Bed p:f Ratio	0	0.11	0.63	0.81
Final Pressure Drop (psid)	0.86	1.08	1.56	1.78

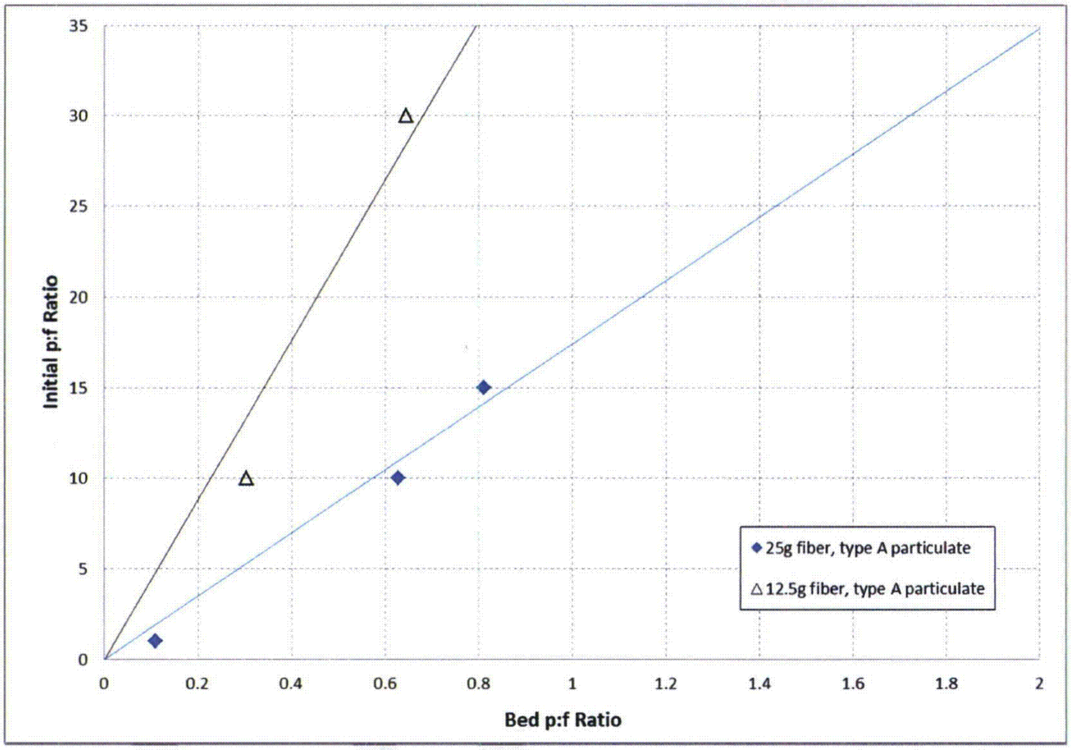
The results for 12.5 g of fiber at the medium flow rate and particulate Type A are also used to provide a comparison of the bed p:f ratio to the starting p:f ratio:

Initial p:f Ratio	10	30
Bed Particulate Mass (g)	3.04	6.45
Bed p:f Ratio	0.30	0.65
Final Pressure Drop (psid)	0.47	0.82

From both test sequences, it is noted that the bed p:f ratio is less than one. In fact, the only tests that showed a bed p:f ratio greater than one were the tests conducted with Type C (17 μm mean diameter) and Type D (mix of 6, 10, & 17 μm mean diameter) particulates. However, the Type C particulates are not expected exclusively in the plant, and there is only one test series with Type D particulates such that trends cannot be determined. Therefore, additional testing is needed to determine the relationship between initial p:f ratio and bed p:f ratio with particulates with larger diameters and broader size distributions.

To help inform future testing, the bed p:f ratio versus the initial p:f ratio from the subscale tests as summarized above are shown in Figure 2. This figure suggests that for a test with 25 g of fiber using particulate Type A, an initial p:f ratio of ~18 would provide a bed p:f ratio of 1 and an initial p:f ratio of ~35 would provide a bed p:f ratio of 2. The total mass of particulates would then be 450 g and 875 g respectively. Figure 2 also suggests that for a test with 12.5g of fiber using particulate Type A, an initial p:f ratio of ~50 would provide a bed p:f ratio of 1 and an initial p:f ratio of 88 would provide a bed p:f ratio of 2. The total mass of particulates would then be 625g and 1100g respectively.

Figure 2. Bed p:f Ratio v. Initial p:f Ratio



The variation in predicted initial p:f ratio between the results from the 25g tests and the 12.5g tests is likely due to the bed morphology. A review of Figure 1 indicates that a certain fiber bed (threshold) is required to begin capturing particulates. In particular, the pressure drop among all of the cases is essentially the same until roughly 5g of fiber has been introduced to the system. It's at this threshold that it is surmised that particulates will start to be captured by the fiber bed causing variation in pressure drop across the debris bed. That is, below the threshold of 5g of fiber in the system, the capture efficiency of particulates is essentially zero. After this point, the capture efficiency increases to approximately 6 percent calculated using the filter bag data for tests using 10 μm mean diameter particulates (Type A particulate). Given that the particulates are only captured at this rate for approximately 7.5g of fiber in the 12.5g test versus 20g in the 25g test, the variation in initial p:f ratio needed to obtain a bed p:f ratio of 1 makes sense.

Recommendation:

A position on particulate size distribution was previously presented. The recommendation therein was to develop a size distribution using the maximum size particulate determined from testing. To recap, up to nine tests would be done to

1. Establish the maximum particulate size that would result in high capture efficiency.
2. Based on the results of this test series, run additional test series with a larger particulate size to verify that the pressure drop was the same or decreased.

Once these tests are complete, the particulate size distribution should be developed. Included in this process should be the quantification of an average particulate diameter based on relative mass of the particulate distribution.

The following tests are then recommended to further explore the p:f ratio effect on the debris bed at the fuel. All tests should be run with 25g of fiber using the particulate size distribution and the mid-flow rate.

3. Three tests, one each at:
    a. p:f = 10
    b. p:f = 15
    c. p:f = 35
    - Given the established reproducibility of the subscale test loop, single tests are suggested to provide additional data from which to work and identify additional tests. Repeat tests can be done as needed based on the results from the 3 individual tests.
    - Once the trend of in-bed p:f ratio with initial p:f ratio is determined for the distributed debris size, additional p:f ratio tests will be recommended to determine the limiting p:f ratio. This limiting p:f ratio will be defined as the point where the overall bed pressure drop stabilizes (or even reduces) or the point where the resultant bed pressure drop is at the limit determined by the thermal hydraulic analysis. The later scenario will result in a specific, maximum particulate debris limit.

P:F Ratio for Subscale Testing – DRAFT, 5/27/2014

Background

In the WCAP-16793-NP Fuel Assembly (FA) Test Program, a range of particulate to fiber (p:f) ratios was examined. The limiting p:f ratio for a large hot leg break (HLB) was found to be 1, while the limiting p:f ratio for a large cold leg break (CLB) was found to be 45. A couple of items on this result are noted:

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3. A few tests were run at HLB conditions using the AREVA FA at two different fiber loads with various p:f ratios. These results are summarized as follows:

Test	Flow (gpm)	Fiber (g)	Final p:f ratio	Assy dP before chem (psid)	Assy dP after chem (psid)
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   During these tests a single debris bed was formed near the FA inlet. With 60g of fiber, it is difficult to tell if the pressure drop increases or decreases with increasing p:f ratio because of the variation in the assembly pressure drop before chemical addition for tests run at a p:f ratio of 2.5. If an average pressure drop is calculated from the two tests, the average (6.76 psid) is higher than the pressure drop obtained when the p:f ratio equals 1. With 15g of fiber, the pressure drop increases with p:f ratio before the chemical surrogate was added.

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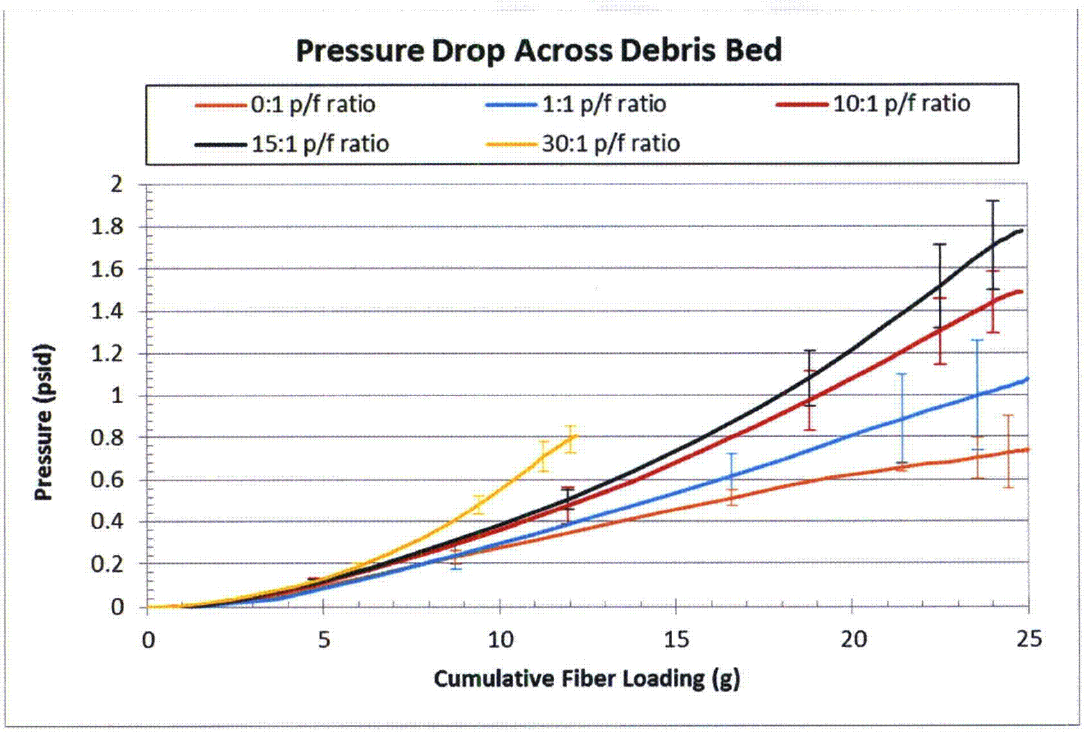
Figure 1. Pressure Drop Across Debris Bed w/ p:f Ratio



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Before a detailed analysis is presented, the in-bed p:f ratio is calculated. The following items are relevant to this discussion:

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Initial p:f Ratio	0	1	10	15
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The results for 12.5 g of fiber at the medium flow rate and particulate Type A are also used to provide a comparison of the bed p:f ratio to the starting p:f ratio:

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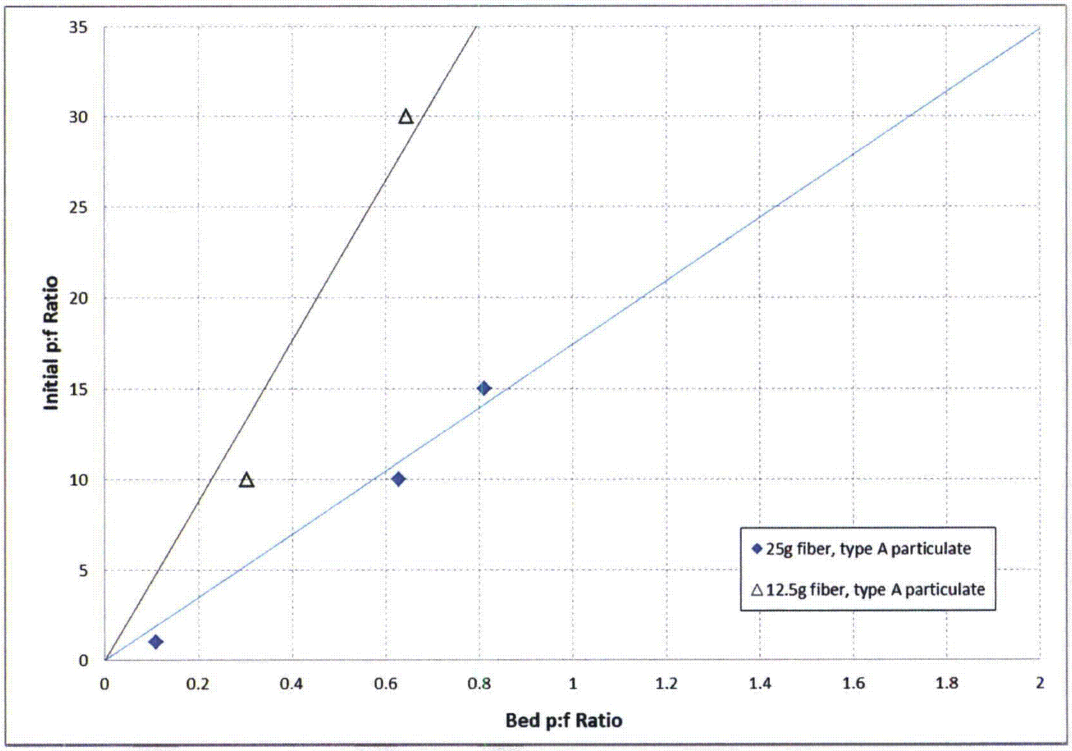
Figure 2. Bed p:f Ratio v. Initial p:f Ratio



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Recommendation:

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Once these tests are complete, the particulate size distribution should be developed. Included in this process should be the quantification of an average particulate diameter based on relative mass of the particulate distribution.

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    - Given the established reproducibility of the subscale test loop, single tests are suggested to provide additional data from which to work and identify additional tests. Repeat tests can be done as needed based on the results from the 3 individual tests.
    - Once the trend of in-bed p:f ratio with initial p:f ratio is determined for the distributed debris size, additional p:f ratio tests will be recommended to determine the limiting p:f ratio. This limiting p:f ratio will be defined as the point where the overall bed pressure drop stabilizes (or even reduces) or the point where the resultant bed pressure drop is at the limit determined by the thermal hydraulic analysis. The later scenario will result in a specific, maximum particulate debris limit.

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CIB33	3	18	60	0.61	0.92

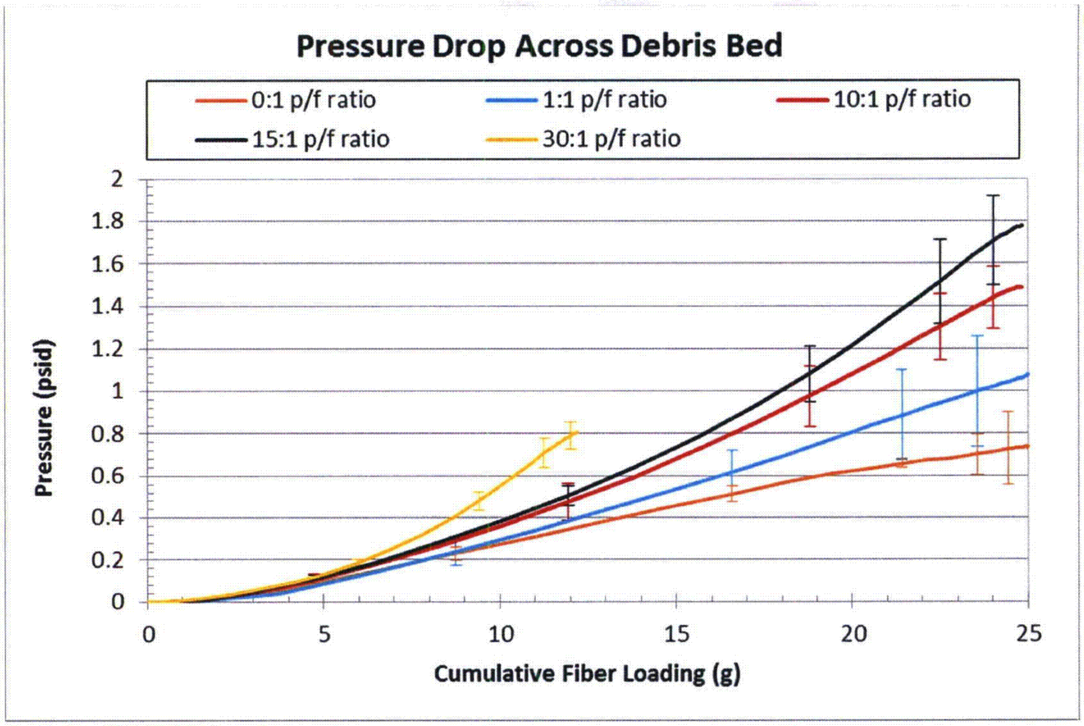
   During these tests a single debris bed was formed near the FA inlet. With 75g of fiber, increasing p:f ratio from 0 up to 4.84 results in an increased pressure drop both before and after

chemical addition. With 18 g of fiber, a similar trend is observed for p:f ratios of 5 up to 45. The pressure drop decreases when p:f ratio is further increased from 45 to 60 at this condition both before and after chemical addition.

5. The p:f ratio results obtained in theWCAP-16793-NP FA Test Program show trends that are consistent with those obtained in the Subscale Test Program to date: increasing p:f ratio results in higher bed pressure drops prior to the addition of chemical products. This is true for the entire range of conditions tested at HLB flows and is true for p:f ratios up to 45 for tests conducted at CLB flows. Given the narrow range of p:f ratios studied under the WCAP-16793 test program, it is difficult to fully understand the influence of p:f ratio on bed pressure drop without additional experimental data.

In the subscale testing to date, a p:f ratio study was undertaken to examine the effect of p:f ratio on a debris bed with only fiber and particulates. The subscale test results demonstrate that the pressure drop increases with increasing p:f ratio as shown in Figure 1. This behavior is consistent with trends observed in the WCAP-16793 Test Program prior to chemical addition. It should be noted that at the higher p:f ratio tests, the fiber load was reduced from 25g to 12.5g in order to keep the particulate concentration in the mixing tank reasonable.

Figure 1. Pressure Drop Across Debris Bed w/ p:f Ratio



These results lead to the following question for the PA-SEE-1090 Program: Is there a maximum particulate load that should be tested, which would set a particulate debris limit? This position paper develops the approach for answering this question in the PA-SEE-1090 Subscale Test Program.

In-Bed p:f ratio

Before a detailed analysis is presented, the in-bed p:f ratio is calculated. The following items are relevant to this discussion:

- In all testing, the p:f ratio identified in the test matrix and in test discussions is
  - mass based and
  - represents the starting ratio between particulate mass and fiber mass introduced into the test loop.
- In the WCAP-16793-NP FA Test Program, debris was allowed to circulate in the loop continuously. For the limiting HLB tests, visual observations indicated that most (if not all) of the particulate had been captured by the fiber bed (i.e. the water was basically clear) before the chemical surrogate was introduced to the test loop. This observation implies that the p:f ratio in the debris bed was very close to the p:f ratio that was started in the testing.
- In the subscale test loop, the particulates and fiber are introduced simultaneously and not allowed to continually recirculate. Therefore, the p:f ratio in the final debris bed will not be the same as the initial p:f ratio.

This last point bears further discussion and investigation. The actual p:f ratio in the beds of the subscale tests has to be determined. This can be done by using the results of the filter bag analysis from the tests.

There are two filter bags used in each test. Bag #1 captured the debris that was not captured at the capture grid during the test; this is called the penetration mass. Bag #2 captured the debris that was captured on the grid; this is called the capture mass. Both the capture mass and the penetration mass data will be used to determine the mass of particulate captured in the debris bed.

The fiber only test series (T.S. 9) indicated that approximately 2.5 g of fiber passed through the fuel grid (i.e. was not a part of the debris bed on the grid)[1]. A more detailed analysis is required to refine the total penetration fiber mass from the subscale tests; however, subsequent calculations will assume 2.5g of fiber penetration. Therefore, the calculations of mass on the capture grid assume that the fiber load on the fuel is 22.5g for tests that started with 25g of fiber and 10g for tests that started with 12.5g of fiber. Calculations of the average particulate mass in the debris bed were done for all tests. A summary of the results is presented in the following section for tests conducted with 25 and 12.5g of fiber and Type A particulate. The data is binned assuming that the bed p:f ratio is only dependent on the initial

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[1] Although the fiber amount that passes through the sub-scale fuel assembly can't be measured easily when particulate is included in the tests, visual comparison of the fiber in the bags and the water after the fiber bed were similar for all tests. Based on visual observation, it appears most of the fiber that gets past the fiber bed does so before a bed is developed on the spacer grid. Therefore, it is appropriate to use the same value for both the 25gm and 12.5 g/FA tests.

fiber loading, initial p:f ratio, and the particulate size. Experimental trends confirm the acceptability of these assumptions. The final debris bed p:f ratio can be calculated by dividing the average of the particulate mass in the debris bed by the mass of fiber in the debris bed, either 22.5g or 10g depending on the starting mass of fiber for the test.

Analysis

There are two possibilities for particulate loading:

1. Some p:f ratio less than the maximum amount of particulate loading results in the maximum bed pressure drop. In this case, a particulate limit is not needed, because all particulate loads above the limiting p:f ratio would be bounded. This trend was observed in the WCAP-16793-NP FA Test Program under CLB conditions at p:f ratios greater than 45.
2. The pressure drop across a particulate and fiber bed continues to increase with particulate load. In this case, a maximum particulate load would need to be defined through testing that is likely a function of fiber loading.

In order to examine these possibilities further, the results from the subscale testing that varied the initial p:f ratio is examined further. First, the bed p:f ratio is calculated.

The results from subscale tests conducted with 25g of fiber at the medium flow rate and particulate Type A (10 μm mean diameter) are used to provide a comparison of the bed p:f ratio to the starting p:f ratio:

Initial p:f Ratio	0	1	10	15
Bed Particulate Mass (g)	0	2.48	14.15	18.26
Bed p:f Ratio	0	0.11	0.63	0.81
Final Pressure Drop (psid)	0.86	1.08	1.56	1.78

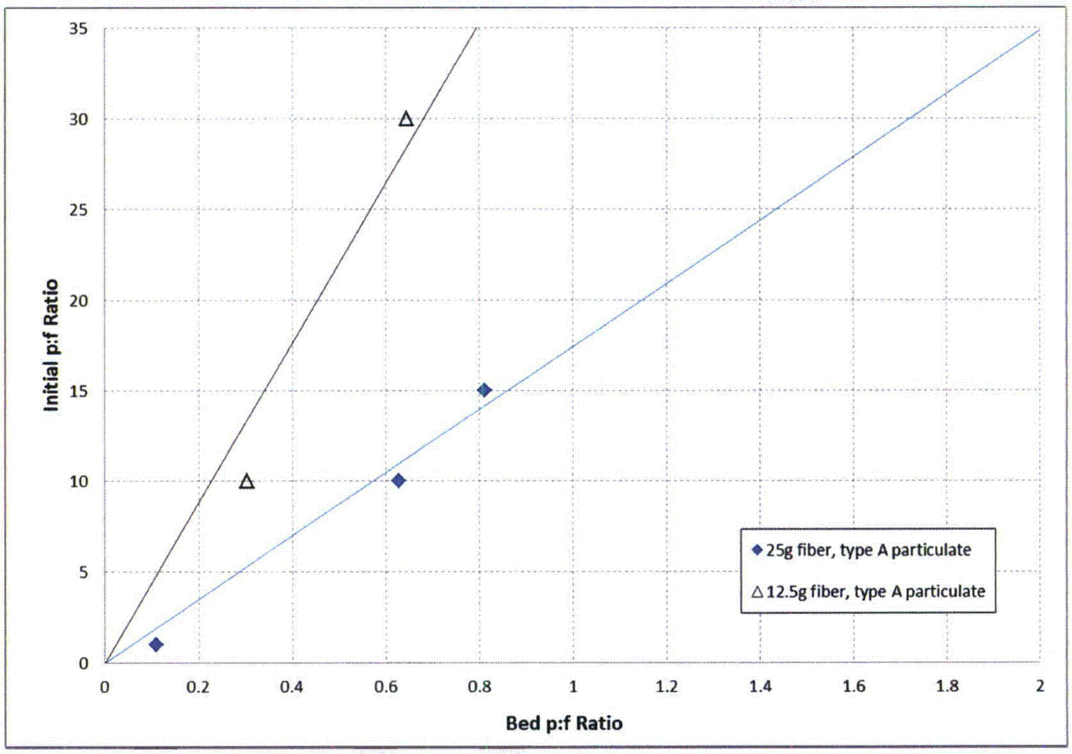
The results for 12.5 g of fiber at the medium flow rate and particulate Type A are also used to provide a comparison of the bed p:f ratio to the starting p:f ratio:

Initial p:f Ratio	10	30
Bed Particulate Mass (g)	3.04	6.45
Bed p:f Ratio	0.30	0.65
Final Pressure Drop (psid)	0.47	0.82

From both test sequences, it is noted that the bed p:f ratio is less than one. In fact, the only tests that showed a bed p:f ratio greater than one were the tests conducted with Type C (17 μm mean diameter) and Type D (mix of 6, 10, & 17 μm mean diameter) particulates. However, the Type C particulates are not expected exclusively in the plant, and there is only one test series with Type D particulates such that trends cannot be determined. Therefore, additional testing is needed to determine the relationship between initial p:f ratio and bed p:f ratio with particulates with larger diameters and broader size distributions.

To help inform future testing, the bed p:f ratio versus the initial p:f ratio from the subscale tests as summarized above are shown in Figure 2. This figure suggests that for a test with 25 g of fiber using particulate Type A, an initial p:f ratio of ~18 would provide a bed p:f ratio of 1 and an initial p:f ratio of ~35 would provide a bed p:f ratio of 2. The total mass of particulates would then be 450 g and 875 g respectively. Figure 2 also suggests that for a test with 12.5g of fiber using particulate Type A, an initial p:f ratio of ~50 would provide a bed p:f ratio of 1 and an initial p:f ratio of 88 would provide a bed p:f ratio of 2. The total mass of particulates would then be 625g and 1100g respectively.

Figure 2. Bed p:f Ratio v. Initial p:f Ratio



The variation in predicted initial p:f ratio between the results from the 25g tests and the 12.5g tests is likely due to the bed morphology. A review of Figure 1 indicates that a certain fiber bed (threshold) is required to begin capturing particulates. In particular, the pressure drop among all of the cases is essentially the same until roughly 5g of fiber has been introduced to the system. It's at this threshold that it is surmised that particulates will start to be captured by the fiber bed causing variation in pressure drop across the debris bed. That is, below the threshold of 5g of fiber in the system, the capture efficiency of particulates is essentially zero. After this point, the capture efficiency increases to approximately 6 percent calculated using the filter bag data for tests using 10 μm mean diameter particulates (Type A particulate). Given that the particulates are only captured at this rate for approximately 7.5g of fiber in the 12.5g test versus 20g in the 25g test, the variation in initial p:f ratio needed to obtain a bed p:f ratio of 1 makes sense.

Recommendation:

A position on particulate size distribution was previously presented. The recommendation therein was to develop a size distribution using the maximum size particulate determined from testing. To recap, up to nine tests would be done to

1. Establish the maximum particulate size that would result in high capture efficiency.
2. Based on the results of this test series, run additional test series with a larger particulate size to verify that the pressure drop was the same or decreased.

Once these tests are complete, the particulate size distribution should be developed. Included in this process should be the quantification of an average particulate diameter based on relative mass of the particulate distribution.

The following tests are then recommended to further explore the p:f ratio effect on the debris bed at the fuel. All tests should be run with 25g of fiber using the particulate size distribution and the mid-flow rate.

3. Three tests, one each at:
    a. p:f = 10
    b. p:f = 15
    c. p:f = 35
    - Given the established reproducibility of the subscale test loop, single tests are suggested to provide additional data from which to work and identify additional tests. Repeat tests can be done as needed based on the results from the 3 individual tests.
    - Once the trend of in-bed p:f ratio with initial p:f ratio is determined for the distributed debris size, additional p:f ratio tests will be recommended to determine the limiting p:f ratio. This limiting p:f ratio will be defined as the point where the overall bed pressure drop stabilizes (or even reduces) or the point where the resultant bed pressure drop is at the limit determined by the thermal hydraulic analysis. The later scenario will result in a specific, maximum particulate debris limit.

P:F Ratio for Subscale Testing – DRAFT, 5/27/2014

Background

In the WCAP-16793-NP Fuel Assembly (FA) Test Program, a range of particulate to fiber (p:f) ratios was examined. The limiting p:f ratio for a large hot leg break (HLB) was found to be 1, while the limiting p:f ratio for a large cold leg break (CLB) was found to be 45. A couple of items on this result are noted:

1. The limiting p:f ratio was determined after the chemical surrogate AlOOH was added to the system.
2. Review of the pressure drop trends before chemical addition indicate that the bed pressure drop increases as p:f ratio increases for the conditions tested.
3. A few tests were run at HLB conditions using the AREVA FA at two different fiber loads with various p:f ratios. These results are summarized as follows:

Test	Flow (gpm)	Fiber (g)	Final p:f ratio	Assy dP before chem (psid)	Assy dP after chem (psid)
7-FG-FPC	45	60	1	6.26	>limit
8-FG-FPC	45	60	2.5	7.86	>limit
11-FG-FPC	45	60	2.5	5.65	>limit
12-FG-FPC	45	15	1	0.61	2.7
13-FG-FPC	45	15	2	0.67	2.56

   During these tests a single debris bed was formed near the FA inlet. With 60g of fiber, it is difficult to tell if the pressure drop increases or decreases with increasing p:f ratio because of the variation in the assembly pressure drop before chemical addition for tests run at a p:f ratio of 2.5. If an average pressure drop is calculated from the two tests, the average (6.76 psid) is higher than the pressure drop obtained when the p:f ratio equals 1. With 15g of fiber, the pressure drop increases with p:f ratio before the chemical surrogate was added.

4. Tests were also run using the Westinghouse FA at different fiber loads representative of large CLB conditions with various p:f ratio. These results are summarized as follows:

Test	Flow (gpm)	Fiber (g)	Final p:f ratio	Assy dP before chem (psid)	Assy dP after chem (psid)
CIB22	3	75	0	0.29	3.30
CIB23	3	75	1	0.49	5.10
CIB21	3	75	4.84	1.10	6.10
CIB29	3	18	5	0.16	0.64
CIB30	3	18	15	0.32	1.03
CIB32	3	18	45	0.70	1.74
CIB33	3	18	60	0.61	0.92

   During these tests a single debris bed was formed near the FA inlet. With 75g of fiber, increasing p:f ratio from 0 up to 4.84 results in an increased pressure drop both before and after

chemical addition. With 18 g of fiber, a similar trend is observed for p:f ratios of 5 up to 45. The pressure drop decreases when p:f ratio is further increased from 45 to 60 at this condition both before and after chemical addition.

5. The p:f ratio results obtained in theWCAP-16793-NP FA Test Program show trends that are consistent with those obtained in the Subscale Test Program to date: increasing p:f ratio results in higher bed pressure drops prior to the addition of chemical products. This is true for the entire range of conditions tested at HLB flows and is true for p:f ratios up to 45 for tests conducted at CLB flows. Given the narrow range of p:f ratios studied under the WCAP-16793 test program, it is difficult to fully understand the influence of p:f ratio on bed pressure drop without additional experimental data.

In the subscale testing to date, a p:f ratio study was undertaken to examine the effect of p:f ratio on a debris bed with only fiber and particulates. The subscale test results demonstrate that the pressure drop increases with increasing p:f ratio as shown in Figure 1. This behavior is consistent with trends observed in the WCAP-16793 Test Program prior to chemical addition. It should be noted that at the higher p:f ratio tests, the fiber load was reduced from 25g to 12.5g in order to keep the particulate concentration in the mixing tank reasonable.

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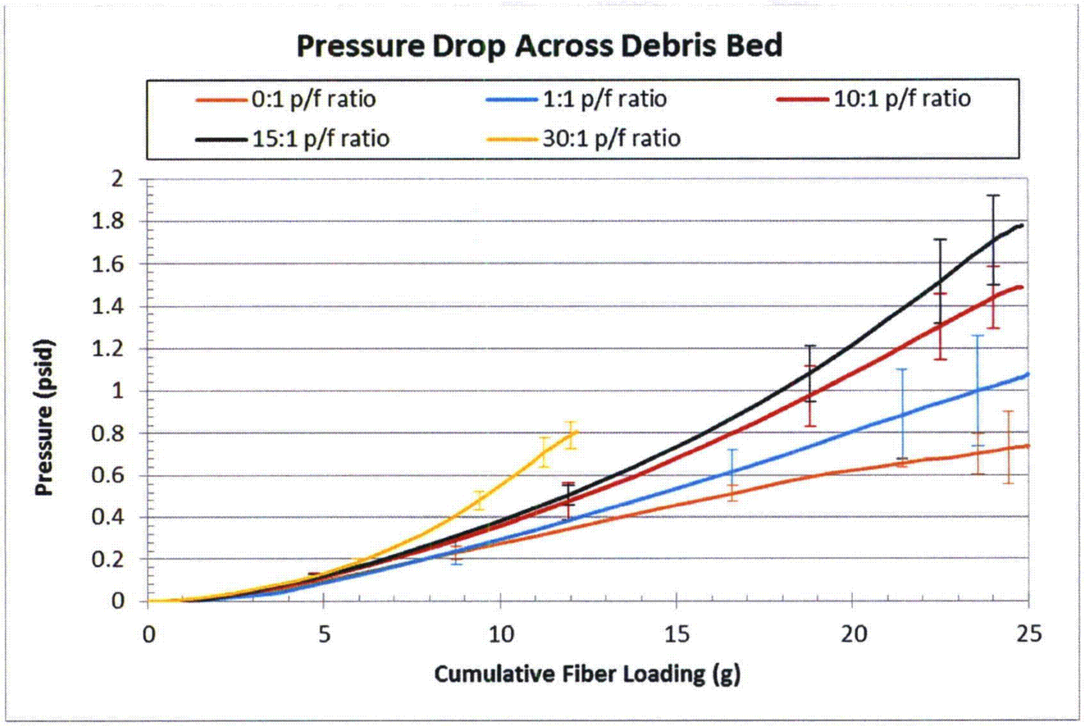

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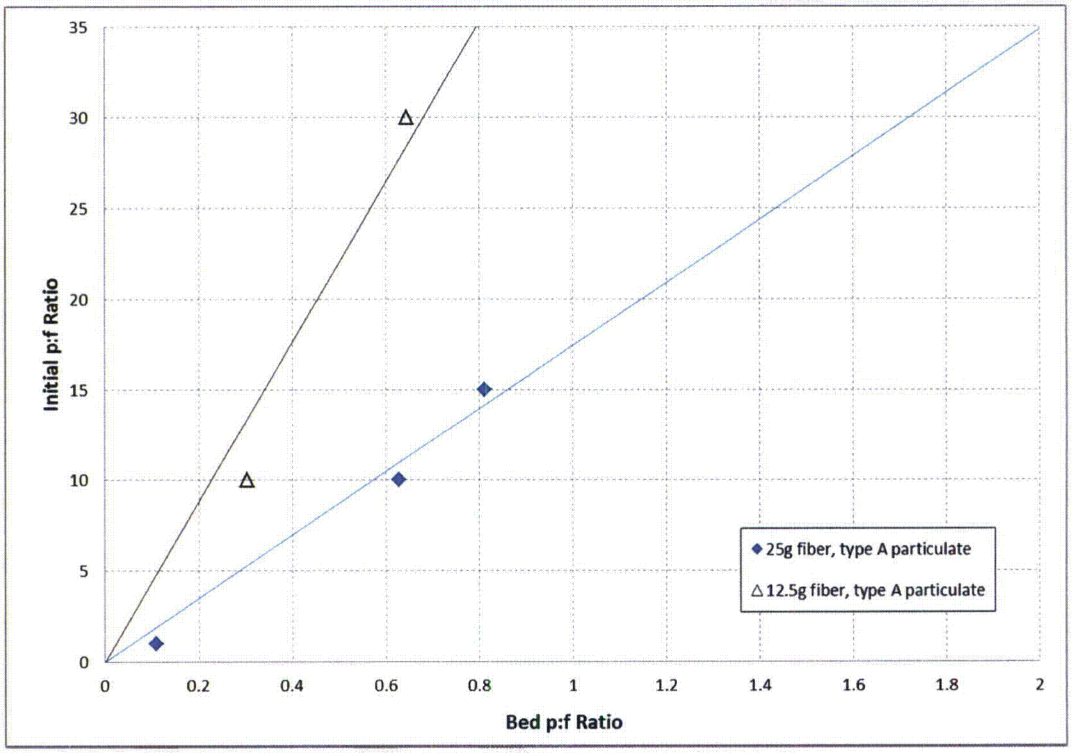

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Recommendation:

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