UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: May 12, 2005

TO : Dale Ray, Project Manager, Upholstered Furniture
Directorate for Economic Analysis

THROUGH: Andrew G. Stadnik, P.E. Andrew Stadnik
Associate Executive Director, Directorate for Laboratory Sciences
Edward W. Krawiec, P.E.
Director, Division of Electrical and Flammability Engineering, Laboratory Sciences
Edward Krawiec

FROM : Weiying Tao, Ph.D. WT
Textile Technologist, Division of Electrical and Flammability Engineering

SUBJECT : Evaluation of Test Method and Performance Criteria for Cigarette Ignition (Smoldering) Resistance of Upholstered Furniture Materials*

Summary

The U.S. Consumer Product Safety Commission (CPSC) staff is developing a draft flammability standard addressing both the smoldering and small open flame ignition hazards for upholstered furniture products. This memorandum reports on the development of the test method and performance criteria for smoldering ignition resistance of upholstered furniture materials for incorporation into a draft flammability standard.

A review of the available literature and the experience of the CPSC staff suggested that the test fixtures and protocols described in the Upholstered Furniture Action Council (UFAC) Voluntary Program could provide the basis for the evaluation of the cigarette ignition resistance of materials of upholstered furniture. From May 2004 through April 2005, CPSC staff conducted over 1000 mockup smoldering ignition tests. The test program used 38 fabrics, 11 foams, and 14 interlining materials (barrier or batting) in various combinations. The fabrics, foams, and interlining materials were selected to provide a broad range of performance when exposed to a smoldering ignition source, the standard cigarette as specified in 16 CFR 1632 and the UFAC standard.

The interlining materials used in this test program, most of which could properly be called fire-blocking barriers, were developed principally for use in other products such as mattresses. Some of them effectively improved the smoldering resistance of the mockups, and some did not. Although the fire dynamics of burning upholstered furniture and mattresses are similar in many respects, materials such as fire-blocking barriers are expected to differ in some characteristics between those two applications. Consequently, the performance of mockups tested with early

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generation fire-blocking barriers designed for use in mattresses may not represent the performance that can reasonably be expected once barriers specifically designed for use in upholstered furniture become available.

Thirty-eight upholstery fabrics were tested. It is not practical to evaluate the fire-performance of the universe of fabrics – particularly when upholstery fabrics include designs and patterns produced by methods ranging from printing to weaving special threads into the base fabric. The CPSC staff selected fabrics on the basis of the known fire-performance of generic fabric compositions and included the "standard" fabrics specified in existing or draft proposed standards. Fabrics with weights and patterns typical of upholstered furniture were also selected.

Eleven commercially available foam compositions were selected. These foams included foams with no flame retardant (FR) treatment, lower level FR treatment, and higher level FR treatment. They also included visco-elastic foams and a polyester foam. The two higher level FR treated foams are designed to provide significantly greater resistance to open-flame sources and are used in commercial furniture and transportation vehicle applications.

Test results suggest that:

1) A 100% cotton velvet fabric, the standard test fabric specified in the California Bureau of Home Furnishings and Thermal Insulation Technical Bulletin 117, Requirements, Test Procedure and Apparatus for testing the Flame and Smolder Resistance of Upholstered Furniture, Draft 2/2002 ("TB117+") (1), seems to be a reasonable choice for standard cover fabric for smoldering ignition tests. It is a smolder-prone fabric and presents a challenge to the underlying materials.
2) Certain small amounts of FR formulations of foams can cause foams to be more prone to smoldering, which suggests these foams may be good substrates for evaluations of fabrics, fillings, and barriers with regard to smoldering ignition because they present a greater challenge than untreated foams.
3) Heavily FR treated foams improve smoldering resistance for fabrics that performed poorly over untreated and lightly FR treated foams.
4) Using 3-inch thick foam geometry at a 30 minute test duration avoids potential mockup wooden frame involvement for more consistent comparisons between materials.
5) Foams treated with small amounts of FR chemicals that exhibit an average foam weight loss between 10 and 15% when tested in 3 inch thickness under the proposed standard cotton velvet test fabric for a test duration of 30 minutes may be a good choice as the standard foam substrate.
6) The UFAC standard polyester batting/barrier is quite effective for a limited period of time in preventing smoldering ignition when used directly underneath the cover fabric.
7) Fire barriers may improve open flame ignition resistance and some also improve smoldering ignition resistance, but some currently available fire-blocking barriers can degrade smoldering ignition resistance. This supports the need to evaluate fire-barriers for both open flame and smoldering ignition performance.
8) An average foam weight loss of not more than 10% at a 30 minute test duration may be a reasonable choice as a pass/fail criterion to evaluate the smolder resistance of other upholstered furniture materials.

Test Program Development Overview

The American Furniture Manufacturers Association (AFMA) submitted a proposal to CPSC in May 2004, recommending CPSC adopt various test methods for an upholstered furniture flammability standard. The AFMA proposal suggested the following tests to evaluate materials with respect to smoldering ignition:

- All foam (any type) used in upholstered furniture should comply with the cigarette ignition requirements contained in the February, 2002 draft revision to the California Bureau of Home Furnishings and Thermal Insulation Technical Bulletin 117, Requirements, Test Procedure and Apparatus for testing the Flame and Smolder Resistance of Upholstered Furniture (“TB117+”) (1).

- All non-foam cushion core materials used in upholstered furniture should comply with the cigarette ignition requirements of TB117+ or a comparable test method.

- Any cotton batting used in upholstered furniture should comply with the ASTM International E 1353 (2) with maximum smolder length criteria specified by the Upholstered Furniture Action Council (UFAC) (3).

- All non-foam materials used in arm constructions should comply with the filling and padding test of ASTM International E 1353 with the maximum smolder length criteria specified by UFAC.

CPSC staff reviewed the smoldering ignition standards recommended by AFMA. Table 1(a) summarizes and compares relevant elements of the test methods and Table 1(b) presents their performance criteria. Table 1 shows that the ASTM International E 1353 and UFAC test methods and performance criteria are similar. Both require tests to run to their ultimate conclusion, e.g., until combustion ceases or a performance criterion is exceeded. Both use the same type of performance criteria: limited development of char in the vertical direction and cessation of combustion prior to “obvious ignition.” There is no clear definition of “obvious ignition” in these or other related standards, nor is there any guidance provided. It is likely that some observers would accept the appearance of open flames as evidence of an obvious ignition. Others may use a different criterion such as increased smoke density in the test box. Given the limited dimensions of the mockup assemblies, the increasing intensity of smoldering combustion leading to open-flaming can be affected by interaction of the furniture components with the wood mockup frame. Obvious ignition might also be interpreted as involvement of the mockup frame as possibly indicated by a change in color, density, or volume of smoke. Similarly, cessation of combustion may be interpreted as a decrease in color, density, or volume of smoke even though an exothermic reaction continues. These are subjective observations and can lead to differences between laboratories or even between personnel in the same laboratory in determining the acceptability of furniture materials. Thus, a more definitive set of performance criteria needs to be considered.

The TB117+ draft standard specifies a different standard cover fabric than the ASTM International and UFAC standards. TB117+ calls for a 100% cotton velvet fabric for foam testing, and the performance criteria are based on weight loss of the foam panels. To test fiber battings and loose fill materials, TB117+ uses a “sandwich” test (similar to ASTM International D 5238, Standard Test Method for Smoldering Combustion Potential of Cotton-Based Batting) by placing the sample completely around the lit cigarette to form a sandwich. The performance criteria are based on a maximum char length limit in any direction. The smoldering resistance of furniture cover fabrics is not evaluated by TB117+.

After reviewing the smoldering test methods in ASTM International E 1353, UFAC, and TB117+, the CPSC staff developed a test program to evaluate appropriate smoldering ignition test methods and performance criteria for an upholstered furniture standard. The CPSC staff test protocol uses the fundamental test geometry requirements of the UFAC Voluntary Program for testing and evaluating the cigarette ignition resistance of fabric, filling, and barrier materials. This protocol geometry was selected because it is recognized in many existing standards to evaluate the smoldering ignition resistance of upholstery materials. Measurements of char length in any direction and foam weight loss were recorded in the CPSC test protocol in order to evaluate other performance criteria in addition to the upward vertical char or “obvious ignition” criteria specified in the UFAC methodology.

LS staff experience conducting UFAC type smoldering tests suggested that, for most cover fabrics, the standard cigarette will be completely consumed in approximately 25 minutes. Failure to comply with the UFAC vertical char length or “obvious ignition” criteria is usually evident while the cigarette is still smoldering or shortly thereafter. In order to ensure observing all aspects of the smoldering performance of the broad range of materials evaluated under this exploratory program, it was necessary to permit the tests to continue beyond the time required for the cigarette to be consumed. A test duration of 45 minutes was considered sufficient to detect subtle differences in performance while still permitting a very large number of smoldering tests to be conducted in a limited period of time. The data collected and observations made during the early stages of this exploratory program suggested that the performance of materials under evaluation could be compromised by involvement of the UFAC wood mockup frame in the combustion process. In order to minimize that possibility, several modifications to the smoldering test procedure and apparatus were explored. Limiting the test duration to 30 minutes while also increasing the thickness of the materials under evaluation from 2 inches to 3 inches reduced possible interactions with the UFAC mockup frame and improved the accuracy and repeatability of the smoldering test when using weight loss as a performance measure.

Table 1(a). Comparison of Smoldering Ignition Resistance Test Methods for Upholstered Furniture Materials

	UFAC	ASTM E 1353	TB117+
Mockup Configuration	UFAC mockup	UFAC mockup	Small mockup like UFAC
Sheeting	Unlaundered	Laundered	Laundered
Conditioning	At least 4 hours	At least 24 hours	At least 24 hours
Replicates	3	3	3
Cover Fabric Test	Fabric over UFAC foam	Fabric over UFAC foam	None
Foam Test	Foam under UFAC type I fabric	Foam under UFAC type I fabric	Foam under 100% cotton velvet standard test fabric
Barrier Test	Barrier under UFAC type II cover fabric, over UFAC foam	Barrier under UFAC type II cover fabric, over UFAC foam	None
Loose Fill Test	Vertical panel: sew bags, pack materials in; Horizontal panel: UFAC foam, UFAC type I cover fabric	Sew bags for vertical and horizontal panels, pack materials in UFAC type I cover fabric	Sandwich test - place the sample around the cigarette to form a sandwich
Measurement	Upward vertical char	Upward vertical char	Foam weight loss, maximum char for loose fill

Table 1(b). Comparison of Smoldering Ignition Resistance Performance Criteria for Upholstered Furniture Material Testing

		UFAC	ASTM E 1353	TB117+
Pass/Fail Criteria	**Fabric**	Class I: upward vertical char < 1.75in., or no ignition Class II: upward vertical char ≥ 1.75in., or obvious ignition	Class I: upward vertical char < 1.8in., or no ignition Class II: upward vertical char ≥ 1.8in., or obvious ignition	NA
	Foam	Class I: upward vertical char < 1.5in., or no ignition Class II: upward vertical char ≥ 1.5in.	Class A: upward vertical char < 1.5in., or no ignition Class B: upward vertical char ≥ 1.5in. or obvious ignition	Fail: Foam weight loss ≥ 20%
	Barrier	Class I: upward vertical char < 1.5in., or no ignition Class II: upward vertical char ≥ 1.5in.	Class A: upward vertical char < 2.0in., or no ignition Class B: upward vertical char ≥ 2.0in. or obvious ignition	NA
	Loose Fill	Class I: upward vertical char<1.5in., or no ignition Class II: upward vertical char ≥ 1.5in.	Class A: upward vertical char < 1.5in., or no ignition Class B: upward vertical char ≥ 1.5in. or obvious ignition	Fail: Maximum char > 1in. in any direction, or obvious ignition

Goal

The goal of this test program was to determine an appropriate smoldering ignition resistance test method and performance criteria for fabrics, foams, barrier and/or batting materials, while taking into account recent industry proposals and existing standards. An effort to develop a test protocol and performance criteria to evaluate smoldering ignition resistance of loose fill materials is discussed in a separate report (4).

Objectives

The objectives of this test program were to:

1) Evaluate the smoldering performance of different upholstery fabric, filling, and barrier and/or batting materials and their combinations.
2) Identify standard test materials (fabric and foam substrate) and geometries (foam thickness) to be used in a smoldering ignition resistant test standard.
3) Determine which parameters should be used as performance criteria, such as char length, weight loss, smoldering combustion time limit, or a combination of these.

Materials, Experimental Design, and Test Procedures

This section describes the types of fabric, foam, barriers, and batting materials used in this evaluation, the experimental design, and specific test procedures used.

Upholstery Fabrics

A total of 41 upholstery fabrics were selected for testing for the development of the flammability standard for upholstered furniture. These fabrics included the TB117+ standard upholstery test fabric (100% cotton velvet), UFAC type I (100% cotton mattress ticking) and type II (100% bright regular rayon) fabrics, and others ranging from 100% cellulose to 100% synthetic (thermoplastic) fabrics and cellulose-synthetic blends. It also included flame retardant (FR) treated, naturally inherent flame resistant, and FR backcoated fabrics. These fabrics are listed below:

1. 60% acetate/40% cotton, 3.5 oz/yd^2
2. 100% Cotton print, 6.0 oz/yd^2
3. 57% acrylic/31% polyester/12% olefin, 8.0 oz/yd^2
4. 100% cotton corduroy, 9.0 oz/yd^2
5. 56% rayon/34% polyester/10% cotton, 10.0 oz/yd^2
6. 100% cotton twill, 11.5 oz/yd^2
7. 92% cotton/8% rayon chenille, 20.0 oz/yd^2
8. 90% cotton/10% rayon chenille, FR backcoated, 24.0 oz/yd^2
9. 100% cotton twill, FR backcoated, 14.0 oz/yd^2
10. 50% cotton/50% polyester, ½ FR backcoated, 9.0 oz/yd^2
11. 100% cotton, FR (Pyrovatex), 7.5 oz/yd^2
12. 57% cotton/36% polyester/7% rayon, FR backcoated, 12.0 oz/yd^2
13. 88% cotton/12% nylon sateen, FR treated (Proban), 10.0 oz/yd^2

14. 100% wool, 11.0 oz/yd^2
15. 100% silk, 3.7 oz/yd^2
16. 100% standard FR polyester, 6.5 oz/yd^2
17. 100% nylon, 12.3 oz/yd^2, FR backcoated
18. 50% rayon/50% nylon, 14.5 oz/yd^2, FR backcoated
19. 100% cotton, 10.0 oz/yd^2
20. 54% acrylic/24% polyester/22% olefin, 8.2 oz/yd^2
21. 100% olefin, 18.7 oz/yd^2
22. 100% olefin, 5.7 oz/yd^2
23. 100% cotton twill, 9.5 oz/yd^2
24. 100% cotton velvet, TB117+ test fabric, 10.0 oz/yd^2
25. 100% cotton, UFAC type I, 9.0 oz/yd^2
26. 100% rayon, UFAC type II, 8.0 oz/yd^2
27. 100% cotton, 7.5 oz/yd^2
28. 56% rayon/34% polyester/10% cotton, 9.7 oz/yd^2
29. 41% olefin/33% acrylic/26% polyester, 7.9 oz/yd^2
30. 52% rayon/48% polyester, 9.4 oz/yd^2
31. 100% wool, 12.5 oz/yd^2
32. leather 1, 7.3 oz/yd^2
33. leather 2, 12.0 oz/yd^2
34. vinyl, 21.5 oz/yd^2
35. 100% olefin, 10.0 oz/yd^2
36. 100% olefin, 10.0 oz/yd^2
37. 100% polypropylene, 11.5 oz/yd^2
38. 56% cotton/44% polyester, 10.0 oz/yd^2
39. 58% polyester/42% cotton/, 8.3 oz/yd^2
40. 67% cotton/33% polyester, 11.0 oz/yd^2
41. 60% rayon/40% polyester, 13.8 oz/yd^2

Thirty-eight of the above fabrics were tested in this smoldering ignition study. Fabrics 28-30 were not tested in this study because there were not enough of these fabric materials available, but they were evaluated in a 45 degree fabric open flame flammability test evaluation (5). Fabrics 31-41 were purchased after tests on fabrics 1-27 were completed and are discussed in the Phase IV results and discussion section. They were purchased to allow evaluation of additional varieties of upholstery fabrics, such as leather, vinyl, polypropylene, and cotton/polyester blends.

Foams

Eleven different foams were used for testing. They included a non-flame retardant polyurethane foam and foams treated with different levels of FR chemicals. Table 2 lists these foams and their FR chemical contents provided by the manufacturers and analyzed by the CPSC Laboratory Sciences Chemistry Division (LSC) (6).

Table 2. Chemical Content of Foams Used for Testing

Foam	Type	Melamine %		TDCP*%	
		Manufacturer Claim	CPSC Staff Analysis	Manufacturer Claim	CPSC Staff Analysis
1. U	Polyurethane untreated	0	Avg=1.2 Range=1.1-1.5	0	0
2. T	Polyurethane FR treated	2	Avg=2.2 Range=1.2-4.2	6	Avg=8.2 Range=6.6-9.2
3. Y	Polyurethane high level FR treated	12	Avg=11.1 Range=10.3-12.4	3	Avg=3.5 Range=3.1-4.6
4. P	Polyurethane higher level FR treated	30	Avg=28.4 Range=23.2-34.1	3	Avg=2.9 Range=2.6-3.4
5. S	Polyurethane FR treated	0	0	7.8	Avg=6.6 Range=6.3-6.9
		Melamine %		**FM-550**%**	
6. Z	Polyurethane FR treated	3.63	Avg=2.8 Range=2.2-3.3	6.96	Avg=6.0 Range=5.5-6.2
		PBDE* %**		**FM-550%**	
7. R	Polyurethane FR treated	NA	Avg=3.0% Range 2.9-3.2	4.1	Avg=3.3 Range=3.1-3.5
		Chemical Content			
8. J	Visco-elastic	No chemical treatment claimed or detected			
9. K	Visco-elastic	No chemical treatment claimed or detected			
10. L	Visco-elastic	No chemical treatment claimed or detected			
11. N	Polyester	No chemical treatment claimed or detected			

*TDCP = tris (1,3-dichloro-2-propyl) phosphate
**FM-550 is a flame retardant chemical containing a mixture of halogenated aryl esters and aromatic phosphates
*** PBDE = polybrominated diphenyl ethers.

Interliners

Fourteen different interliner (barrier or batting) materials were also evaluated. These interliner materials are listed below:

1) Interliner P, UFAC standard garneted polyester barrier/batting
2) Interliner S, nonwoven barrier
3) Interliner M, nonwoven barrier
4) Interliner V, nonwoven barrier
5) Interliner L, nonwoven barrier

6) Interliner O, nonwoven barrier
7) Interliner D, nonwoven barrier
8) Interliner T, nonwoven barrier
9) Interliner C, organic cotton batting
10) Interliner G, nonwoven barrier
11) Interliner W, nonwoven barrier
12) Interliner $, woven barrier
13) Interliner ¢, woven barrier
14) Interliner K, nonwoven barrier

The term "interliner" as used in this report means a material that is used under the cover fabric and above the foam. "Interliner" includes the commonly used terms "batting" and "fire blocking barrier" or simply "barrier". Interliners are used to improve one or more characteristics of upholstered furniture, for example, to provide additional comfort padding (batting), to provide improved fire performance (fire blocking barrier), or as a moisture barrier. Some interlining materials can serve multiple purposes, e.g., a high-loft, fire-blocking barrier.

The interlining materials evaluated in this test program included some based on applications as standard test materials, likely use in upholstered furniture, or their availability in various stages of development as potential fire-blocking barriers for use in other applications.

Test Method Description:

The test method was based loosely on the UFAC Voluntary Program test protocols to evaluate the smoldering ignition resistance of upholstery fabric, filling, and batting or barrier materials. The test used the UFAC mockup frame. It consists of two pieces of wood, nominally 8 inches by 8 inches by 0.75 inches thick and joined at one edge. The fabric specimen size is 8 in.x15 in. for vertical panels and 8 in.x10 in. for horizontal panels. The foam size is 8 in.x8 in.x2 in. for the vertical panels and 5 in.x8 in.x2 in. for the horizontal panels. The barrier specimen is 8 in.x12 in. for vertical panels and 8 in.x8 in. for horizontal panels. To assess the UFAC geometry, LS staff also conducted tests using 3 inch thick foam with slightly larger fabric specimens.

The fabric specimen is placed over the foam (Figure 1a). When interlining material is used, it is placed between the cover fabric and the foam. The lit cigarette is placed in the crevice created by the intersection of the horizontal and vertical panels. A 5x5 inch square of unlaundered cotton sheeting material is then used to cover the cigarettes as specified by UFAC (Figure 1b). Smoldering tests conducted by LS staff indicated that the effect of laundering or thread count density of the sheeting fabric was too small to be recognized in these smoldering tests. LS staff believe that either laundered or unlaundered sheets can be used in this type of smoldering test (7) and that the added cost of laundering the sheeting material can be avoided.

The ignition source used for all the tests was the standard cigarette specified in 16 CFR 1632 – Standard for the Flammability of Mattresses and Mattress Pads (8). A draft-preventive enclosure is used to restrict airflow. The enclosure is designed to permit simultaneous testing of up to three mockup assemblies.

All testing materials were conditioned at a temperature of 21±3°C and between 50% and 66% relative humidity for at least 4 hours before testing according to UFAC test protocol. The weight of each piece of foam was recorded before each test after conditioning. The cigarettes were allowed to burn their entire length and all tests were terminated at either 30 or 45 minutes.

(a) (b)

Figure 1. UFAC Mockup

After the tests were terminated at the time limit, the sheeting materials were removed and the char length was measured in six different directions from the cigarette residue: vertical up and down, horizontal in (into the foam) and out, and side left and right. The UFAC test protocol only measures upward vertical char length. However, prior observations from many UFAC mockup smoldering tests suggest that when smoldering occurs, the char tends to go downward inside the crevice and the upward vertical char length in most cases is not the longest char on the mockup. The downward char progression observed during tests supports that upward vertical char measurement alone does not adequately characterize smoldering behavior. CPSC staff had hypothesized that the smoldering ignition hazard might be better evaluated by measuring char length in any direction versus only vertically. Also, while char length has been identified as a measure of smoldering performance, TB117+ uses weight loss of the foam as a performance parameter for evaluation of resilient filling materials. This may be a more useful parameter as the concern with the smoldering hazard ultimately lies in the accumulated foam damage that could result in production of toxic smoke and progression to open flaming. Since weight loss may be a more useful measure of materials performance, foam weight loss data were also recorded.

After the char length measurement, the foam was removed from the test panel and the smoldered portion of the foam was removed. The weight of the non-burned portion of the foam was then recorded within 15 minutes of the end of the test. If water was used to extinguish the smoldering combustion, the foam was dried out under a hood, reconditioned for 24 hours and then weighed (9). The foam weight loss is calculated as follows:

Weight loss (%) = (pre-weight – post-weight)/pre-weight x 100%

Test Matrices

Test matrices are shown in Appendices 1(a), 1(b). and 1(c). The Appendix 1(b) test matrix covers the materials added to the test program after it began. The Appendix 1(c) test matrix covers tests conducted using 2 inch vs. 3 inch thick foams at 30 and 45 minute test durations. The Appendix 1 test matrix includes more than 2,000 possible mockup tests. In order to reduce the total number of tests, the tests were conducted in phases. The data from one phase were used to select the tests for the next phase as detailed in the Results and Discussions section. The shaded matrix cells in Appendix 1 represent the combinations selected for testing.

Results and Discussion

The tests were conducted in five phases. Phase I tests consisted of 27 fabrics with foam U and repeated with foam T. Based on the results of Phase I testing, Phase II was focused on testing selected fabrics with a higher propensity to smolder and with two higher level FR treated foams, foams Y and P. Phase III tested combinations of fabrics, foams and interlining materials (batting or barrier) based on the results of Phases I and II, in order to determine the effect of batting or barrier materials on smoldering ignition. Phase IV tested the new materials added to the program. These new materials were added to the test program after all planned tests listed in Appendix 1(a) were completed. They were only tested on foam T (a potential standard test foam formulation) and/or with the TB117+ standard test fabric (100% cotton velvet) with only foam weight loss recorded. Phase V investigated the effects of the test duration and the foam thickness on the cigarette ignition test results. Tests were done using 2 inch and 3 inch thick foams at 30 and 45 minute test durations.

All phase I through phase V test results are attached in Appendices 2 through 42. The maximum char lengths of three mockups tested for each combination are listed in Appendix 2. The average foam weight losses are listed in Appendix 3 (a), Appendix 3 (b), and Appendix 3 (c). In Appendices 2 and 3, the matrix cells with bold numbers identify mockup assemblies that were still smoldering when the tests were terminated. Appendices 4 through 42 show the results of maximum char length on each mockup and the average foam weight loss of the three repeated tests for that mockup configuration.

<u>Phase I – All Fabrics with Foam U and Foam T</u>

As seen from Appendices 2, 3(a), and 4, when tested over foam U, fabrics 7, 8, 9, and 27 had a maximum char length equal to or greater than 2 inches. These fabric mockups were still smoldering when the tests were terminated at 45 minutes. However, only the foam tested with fabric 27 had more than 10% weight loss. The foam weight losses at 45 minutes were less than 5% when tested with fabrics 7, 8, and 9. Mockups of fabric 24 (TB117+ cotton velvet test fabric) self-extinguished with a char length of 1 ¾ in. and a foam weight loss of about 1%. All other fabric mockups had a char length less than 1 ¾ in. with less than 1% foam weight losses and self-extinguished. It was expected that fabrics 7, 8, 9, 24, and 27 had poorer smoldering behavior than the other fabrics tested because they are all 100% cellulosic fabrics.

As shown in Appendices 2, 3(a) and 5, most fabrics performed similarly when they were tested with foam T. However, fabrics 6, 19, 23, and 24, which are all 100% cotton fabrics, had char lengths of 2 in. or greater and had higher foam weight losses compared to the same test with foam U. Fabric 27, which is also 100% cotton, exhibited a reversal in performance between foam U (>10% foam weight loss) and foam T (1.5% foam weight loss). Fabrics 6, 23, and 24 mockups were still smoldering at 45 minutes. When tested with foam U, the char lengths of the mockups for fabrics 6 and 19 were less than 1 in. and the mockups self-extinguished. Fabric 21, a 100% olefin fabric, had a char length of 1 5/8 in. and was still smoldering at 45 minutes when tested with foam T. This same fabric self-extinguished when tested with foam U and the char length was only ¾ in. (Appendix 2). Figure 2 shows that the char of the fabric 24 mockup reached the side edge of the mockup when tested with foam T.

Figure 2. Post Test Mockup of Fabric 24 with Foam T

Figures 3-4 show the comparisons of average maximum char length and average foam weight loss from the three mockup tests of foam U vs. foam T for all 27 fabrics. These two charts indicate that mockups tested with foam T generally had higher char lengths and foam weight losses than the same fabric mockups tested with foam U.

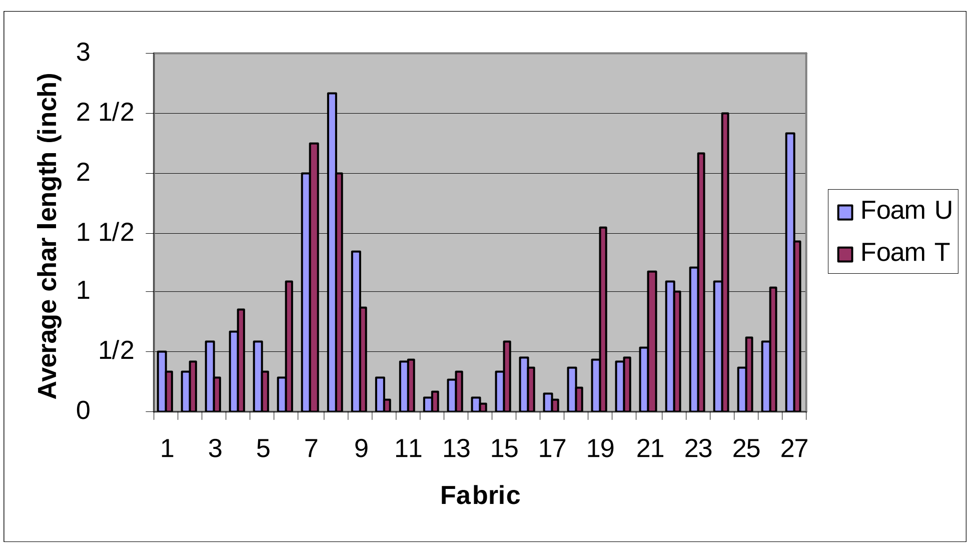

Figure 3. Char Length – Foam U vs. Foam T (No Interliner)

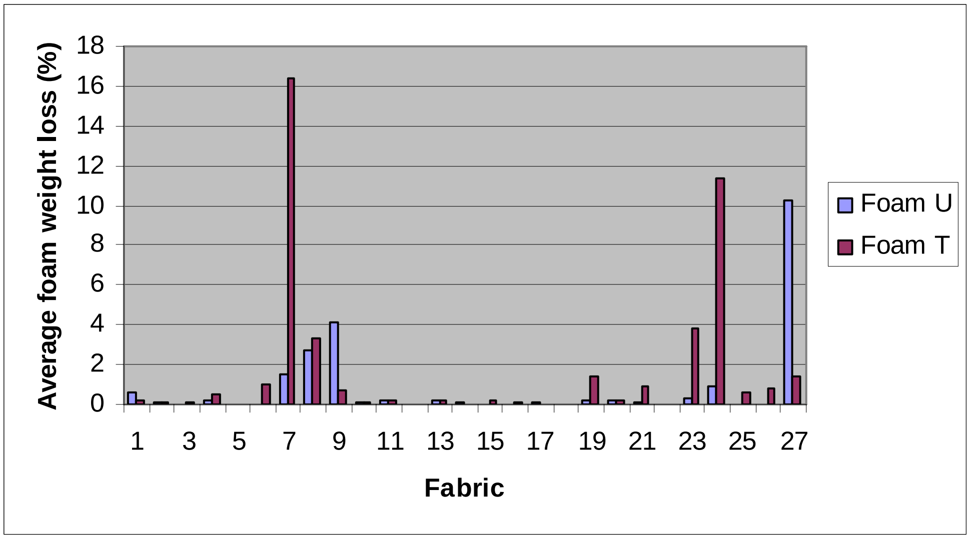

Figure 4. Foam Weight Loss – Foam U vs. Foam T (No Interliner)

The data suggest that the small amount of FR treatment in foam T resulted in lower smoldering ignition resistance. The data also appear to confirm the statement made in TB117+ that certain FR formulations of the foams can cause foams to be more prone to smoldering (1). The results suggest that foams treated with relatively small amounts of FR chemicals may provide a good standard substrate for the evaluation of fabric, filling, and fire barrier materials with respect to smoldering ignition, because they present a greater challenge than untreated foam.

Phase II – Selected Fabrics with Foams Having Higher Levels of FR Treatment (Foams Y and P)

Fabrics that exhibited poor smoldering ignition resistance performance in Phase I testing were selected for use in Phase II. Fabrics 6, 7, 8, 9, 19, 21, 23, 24, and 27 were selected because they had char lengths of 2 in. or more, or were still smoldering at 45 minutes when tested with foam U or foam T, or exhibited high foam weight losses from the phase I tests. Except for fabric 21, a 100% olefin fabric, these were primarily cellulosic fabrics. A rayon/polyester/cotton blend (fabric 5) , and UFAC type I and II fabrics were also included to compare results of the poor performing Phase I fabrics, standard test fabrics and potential standard test fabrics. These fabrics were tested over the two higher level FR treated foams, foams Y and P, to determine if they could better resist smoldering ignition than when tested over foam U or foam T.

Appendices 2, 3(a), 6, and 7 show the results when the fabrics were tested with foam Y and foam P. From the combinations tested in this phase, fabric 7 tested over foam Y had a maximum char length of 1 ¾ in. and maximum weight loss 2.1%. In addition, this was the only combination that continued to smolder after 45 minutes. All other fabrics self-extinguished and had char lengths less than 1 ¾ in. and foam weight losses less than 2%.

Fabric 7 is a heavy weight 100% cellulosic fabric and smoldered progressively in most of the smoldering tests. When fabric 7 was tested with foam T, the mockup had an average 16% foam weight loss with heavy smoke when the test was terminated at 45 minutes. This fabric is the worst smoldering fabric in the group. The next worst smoldering fabric in the group appears to be fabric 24, 100% cotton velvet. When fabric 24 was tested with foam T, the mockup was also still smoldering at 45 minutes, with an average 11% foam weight loss. These results indicate that fabric 24 seems to be a reasonable choice to be considered as a standard cover fabric for smoldering ignition tests because it presents a challenge to the underlying materials less than a very poor performing fabric such as fabric 7. Fabric 24 is also consistent with the TB117+ standard upholstery test fabric.

All fabrics tested with foam P self-extinguished. All char lengths were less than 1 in. and most of the foam weight losses were less than 1%. Figures 5 and 6 compare the average maximum char length for the three mockups tested and average foam weight loss of foam Y vs. foam P. These two figures clearly show that the char lengths and foam weight losses of the mockups tested with foams Y and P were all minimal, and in most cases mockups tested with foam P had lower char lengths and foam weight losses compared with the mockups tested with foam Y. These results indicate that the higher level FR treatment in foams Y and P improved the smoldering resistance for the fabrics that performed poorly over foam U and foam T.

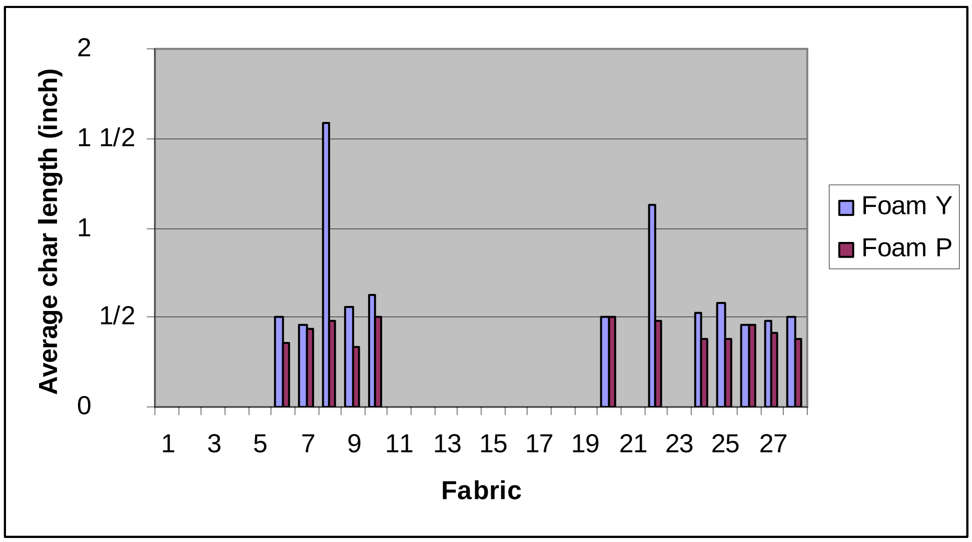

Figure 5. Average Char Length – Foam Y vs. Foam P (No Interliner)

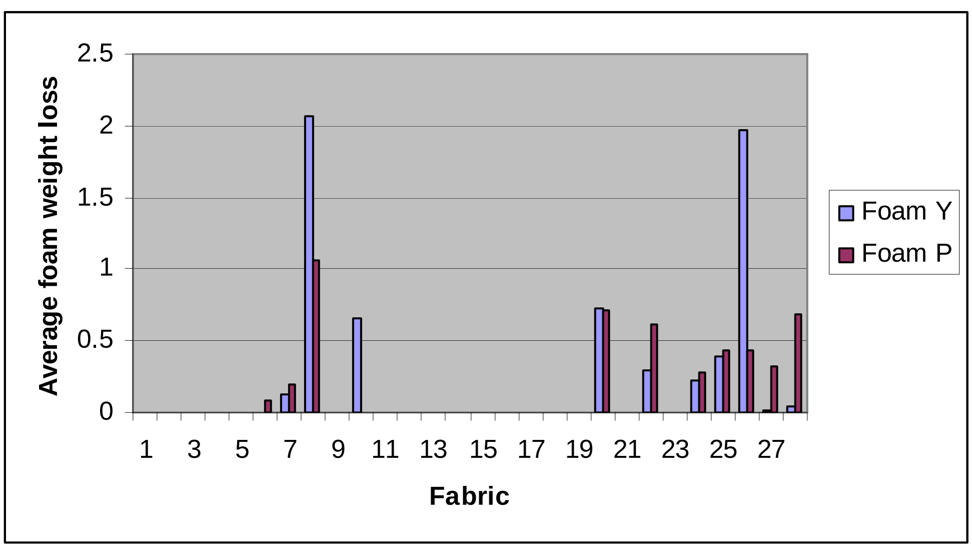

Figure 6. Average Foam Weight Loss – Foam Y vs. Foam P (No Interliner)

Phase III – Fabric, Foam, and Interliner Combination Test

Phase III of test program explored the effects of varieties of interliner materials between the fabric and foam. Phases I and II results indicated that fabrics 7, 8, 23, 24 and 27 smoldered strongly and would challenge the performance of other materials. Fabrics 5, 6, 21, 25, and 26 were selected to include fabrics with non-cellulosic materials and existing standard test fabrics. Battings and fire blocking barriers were added to the mockup assemblies to determine if their use would affect the smoldering resistance of the selected upholstery fabrics. Not all selected fabrics were tested with every combination due to limitations of materials. Selections were made based on matching several challenging fabrics with available quantities of each of the various interliner materials to determine their behavior in a smoldering condition.

Test results are shown in Appendices 8 through 42. Appendix 8 shows the test results using the UFAC standard polyester batting with foam U. The UFAC standard batting is a thick, high loft polyester material. None of the fabrics tested produced smoldering sufficient to penetrate the batting during the 45 minute test period. All foam weight losses were essentially zero. The char lengths measured on fabric surfaces were less than 1 in., except for fabric 7 which had a char length of 1 ½ in. and the fabric itself was still smoldering at 45 minutes.

Because fabric 7 was still smoldering at 45 minutes, three more mockups of the same configuration were tested for 1 hour duration. All three mockups smoldered progressively and smoldering penetrated the batting to involve the foam and penetrated to the wooden support assembly as shown in Figure 7. These results indicated that the UFAC polyester batting was only effective in preventing foam smoldering for a certain period of time depending on the smoldering properties of the fabric.

Figure 7. Post Test Mockup of Fabric 7 with UFAC Foam and UFAC Polyester Batting Still Smoldering

Test results using fire blocking barrier materials S, M, V, L, and O are shown in Appendices 2, 3, and 9 through 28. Figures 8 through 15 compare the average maximum char lengths and average foam weight losses of the three mockups for the four different foams tested with and without the interlining materials. As shown in Figures 8 through 15, most of the mockups tested with the fire blocking barriers had larger char lengths and larger foam weight losses as compared with the mockups tested without the barriers, except for barrier M which improved smoldering resistance of foam T. For example, when foam T was tested with fabric 24, 100% cotton velvet, without barrier M, the mockup was still smoldering at 45 minutes and reached a maximum char length of 2 ¾ inches and 11% foam weight loss. When barrier M was added to the same assembly, the mockup self-extinguished and the maximum char length was only 1 1/8 inches and the foam weight loss was less than 0.5%, as shown in Appendices 2 and 3(a).

Appendix 2 shows that when fabrics 7 and 8 were tested with foam P, they self-extinguished and had char lengths of ½ in. or less. However, when these two fabrics were tested with barrier materials S, M, V, L, and O over foam P, the mockups were still smoldering after 45 minutes and the fabrics had char lengths that approached or exceeded 4 inches. When fabric 24 was tested with foam U without the interlining materials, the mockup self-extinguished. However, when this same fabric was tested with foam U and interlining materials S, M, V, L, or O, the mockup assemblies were still smoldering at 45 minutes and reached fabric char lengths of 2 inches. The results indicate in most cases these barriers did not improve the smoldering resistance of the poor performing fabrics, and may have negatively affected the performance of some fabrics. This is probably because these barriers were designed for different applications or to provide resistance to open flame sources.

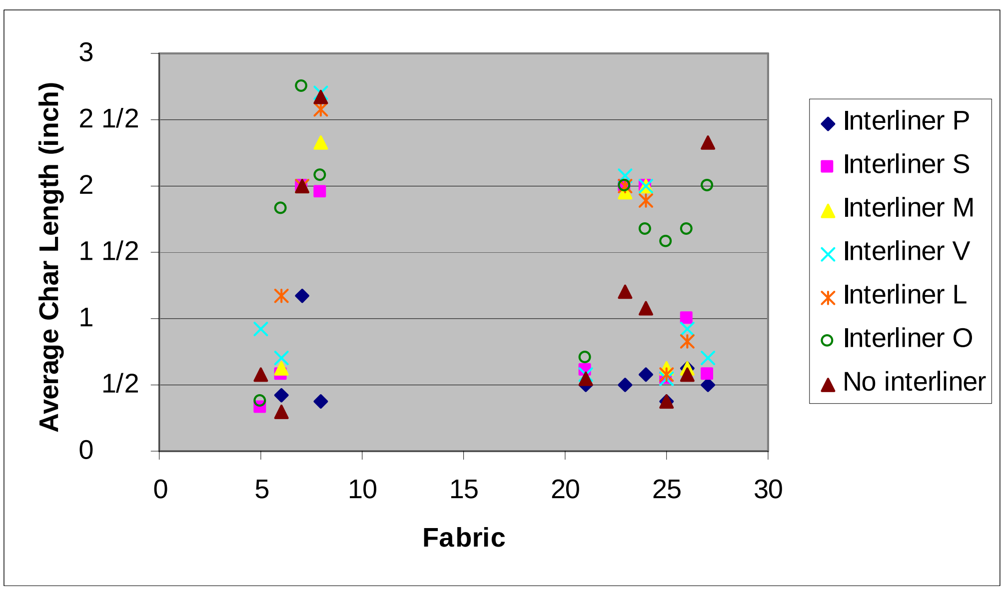

Figure 8. Char Length – Foam U with and without Interliner

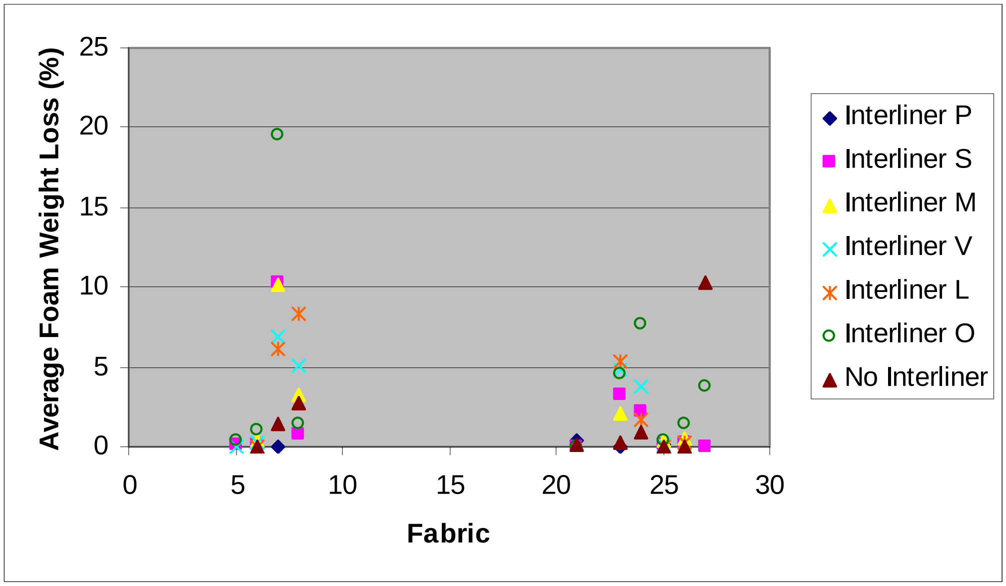

Figure 9. Foam Weight Loss – Foam U with and without Interliner

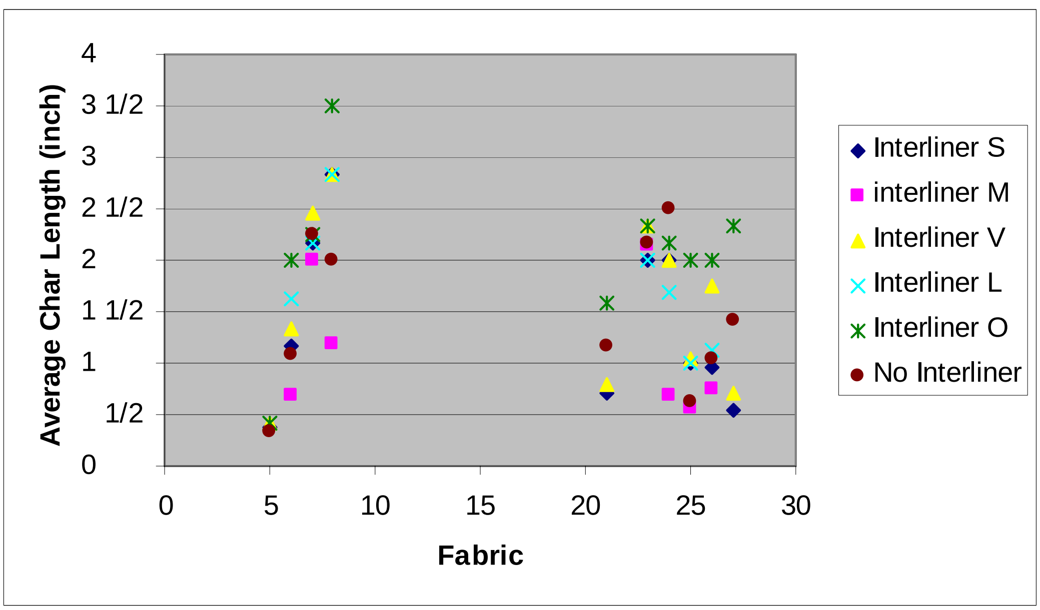

Figure 10. Char Length – Foam T with and without Interliner

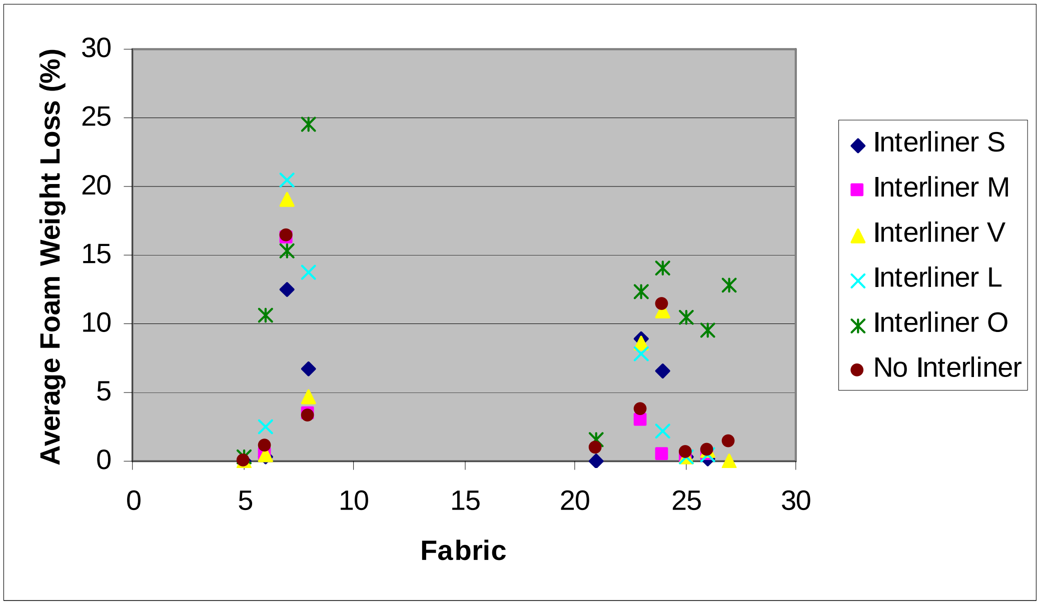

Figure 11. Foam Weight Loss – Foam T with and without Interliner

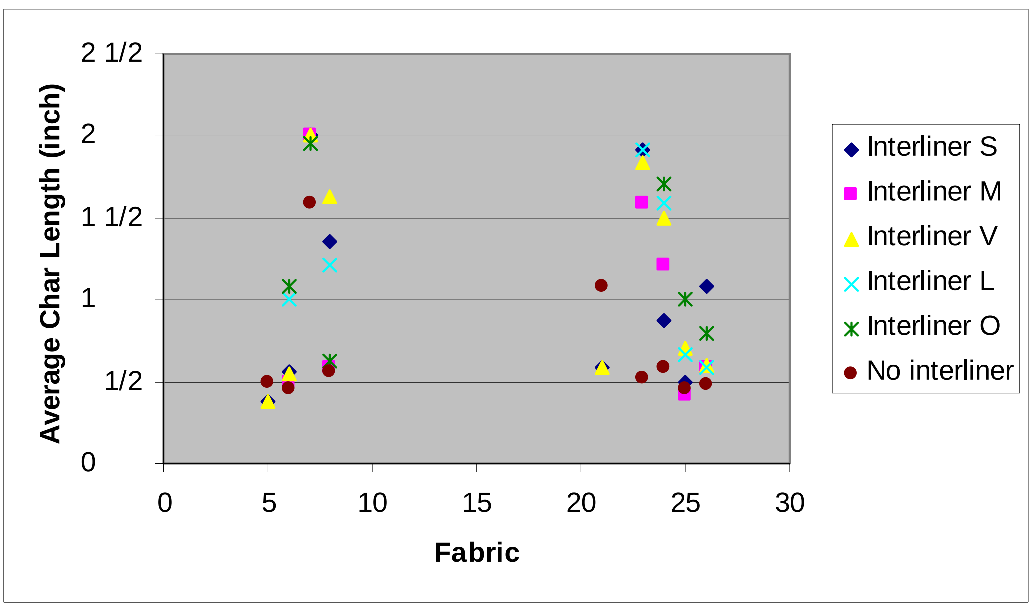

Figure 12. Char Length – Foam Y with and without Interliner

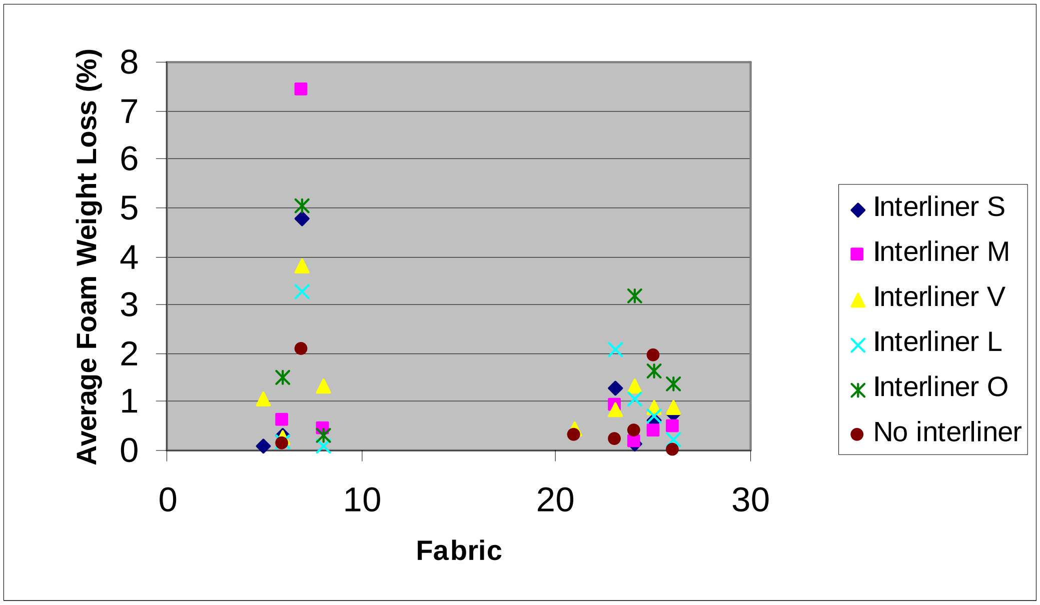

Figure 13. Foam Weight Loss – Foam Y with and without Interliner

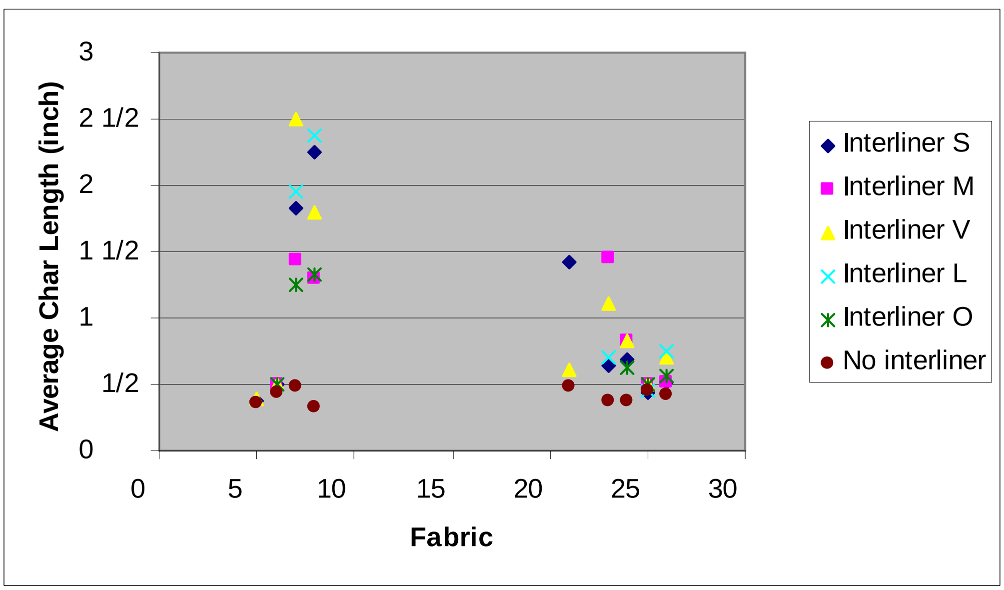

Figure 14. Char Length – Foam P with and without Interliner

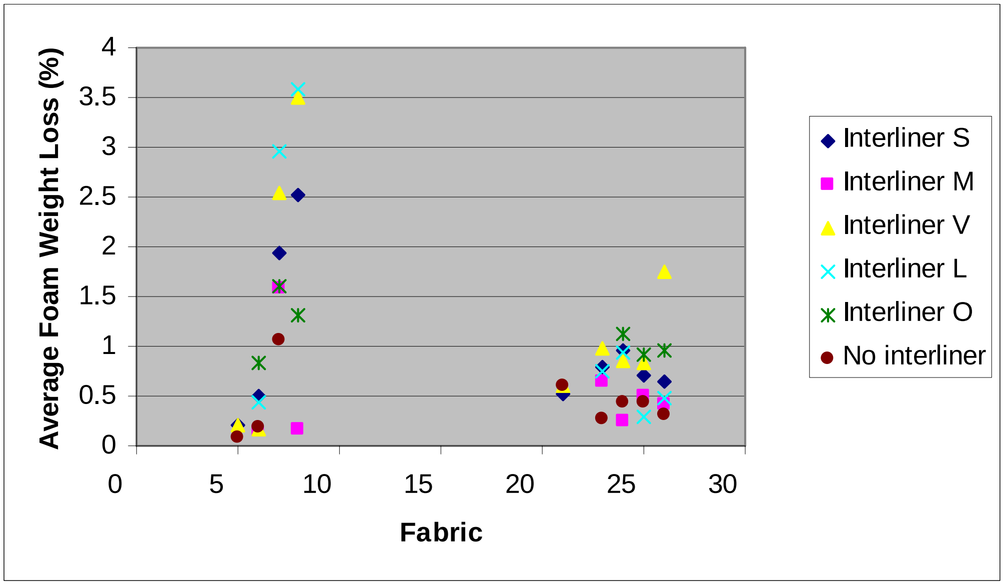

Figure 15. Foam Weight Loss – Foam P with and without Interliner

The test results showed that UFAC standard polyester batting was quite effective in preventing smoldering ignition for a limited period of time depending on the cover fabric when used alone. The results also showed that some currently available fire-blocking materials could have a negative effect when used alone.

A series of interliner combination tests was also conducted. Fabrics 6 and 24 were tested using both UFAC polyester batting and barrier V together over foam U. Appendix 29 shows that the char lengths were less than 1 in. when the polyester batting was placed on top of barrier V. The smoldering did not progress to the foam, and the assemblies self-extinguished. However, when fabric 24 was tested with barrier V on top of the polyester batting, all three mockups continued to smolder at 45 minutes and the foam was badly charred. The maximum char length reached 5 inches. The average foam weight loss reached 20%. Figures 16(a) and 16(b) show the results from these two mockup configurations.

Fabric 6 had one mockup continue to smolder with foam involvement at the end of 45 minutes when tested with barrier V on top of the polyester batting. The maximum char length reached 4 inches. These results suggest that some currently available fire barriers may degrade smoldering ignition resistance. Testing results on open flame performance of interliner materials, reported in a separate memorandum (10), suggest that these same fire barriers may improve open flame ignition resistance. This supports the need to evaluate fire-barriers for both open flame and smoldering ignition performance.

Figure 16 (a). Post Test Mockups of Fabric 24 with Foam U and UFAC Polyester Batting (top)/Interliner V (under)

Figure 16 (b). Post Test Mockups of Fabric 24 with Foam U and Interliner V (top)/UFAC Polyester Batting (under)

Barrier materials D and T were tested with fabric 24 using the 4 different foams. Test results are reported in Appendices 2, 3(a), and 31 through 38. Appendices 2 and 3(a) show that when barrier D was added to the mockup assemblies, only the foam T mockup was still smoldering at 45 minutes, and had a char length of 1 7/8 inches. All other foam mockup assemblies self-extinguished. When barrier T was added to the mockup assemblies, both foam U and foam T mockups were still smoldering at 45 minutes, had char lengths of 2 ½ inches, and had more than 5% foam weight loss.

Because the mockups using fabric 24 and foam T both smoldered excessively when tested with barriers D and T, UFAC polyester batting was added to the mockup assemblies, underneath barriers D and T. Appendices 2 and 3(a) show that the mockup with barrier D and UFAC polyester batting self-extinguished and had a char length less than 1 inch. The measurement was on the fabric surface only because the foam was only slightly discolored. However, the mockup with barrier T and UFAC polyester batting was still smoldering at 45 minutes and had a fabric surface char length of 3 ½ inches. However, the foam weight loss was less than 1%.

A non-FR treated organic cotton batting was also tested over the polyester batting with fabric 24 and foam T. The results are listed in Appendices 2, 3(a), 41, and 42. Appendices 2 and 3(a) show that both mockups were still smoldering at 45 minutes and had char lengths exceeding 2 inches and foam weight losses exceeding 7%.

<u>Phase IV – Testing on Materials Added to the Test Program</u>

Additional fabric materials such as leather, wool, vinyl, 50/50 cotton/polyester blended fabrics, and 100% polypropylene fabrics (fabrics 31-41), and additional foam types (foams S, Z, R, J, K, L, N), both FR and non FR treated were tested to cover more varieties of materials. Additional interliner materials (interliners G, W, $, ¢, K) also became available and tested. Test results are shown in Appendix 3 (b) and Appendix 5. The additional fabrics were only tested with foam T. The additional foams were only tested with TB117+ standard test fabric, fabric 24, 100% cotton velvet. The new interliner materials were only tested with fabric 24 and foam T. Foam weight losses were determined.

The test results in Appendix 3(b) show that when the two leather fabrics were tested on foam T, the mockups were still smoldering at 45 minutes with one set of mockups having an average foam weight loss of 3.4% and the other set having an average foam weight loss of 5.2%. These are light weight leather fabrics and they are not furniture grade leathers. The other additional fabrics self-extinguished with very low foam weight losses, most of them below 1%, when tested on foam T without interliners.

Figure 17 presents the foam weight losses of all upholstery fabrics tested with foam T without interlining materials (Fabrics 28-30 were not tested due to shortage of the fabric supply). It is seen from this figure that most of the mockups made from smolder prone fabrics and foam T had more than 10% foam weight losses and most of the mockups made from smolder resistant fabrics and foam T had weight losses less than 5%. This result suggests that either a 5% or 10% foam weight loss may be a reasonable pass/fail criterion.

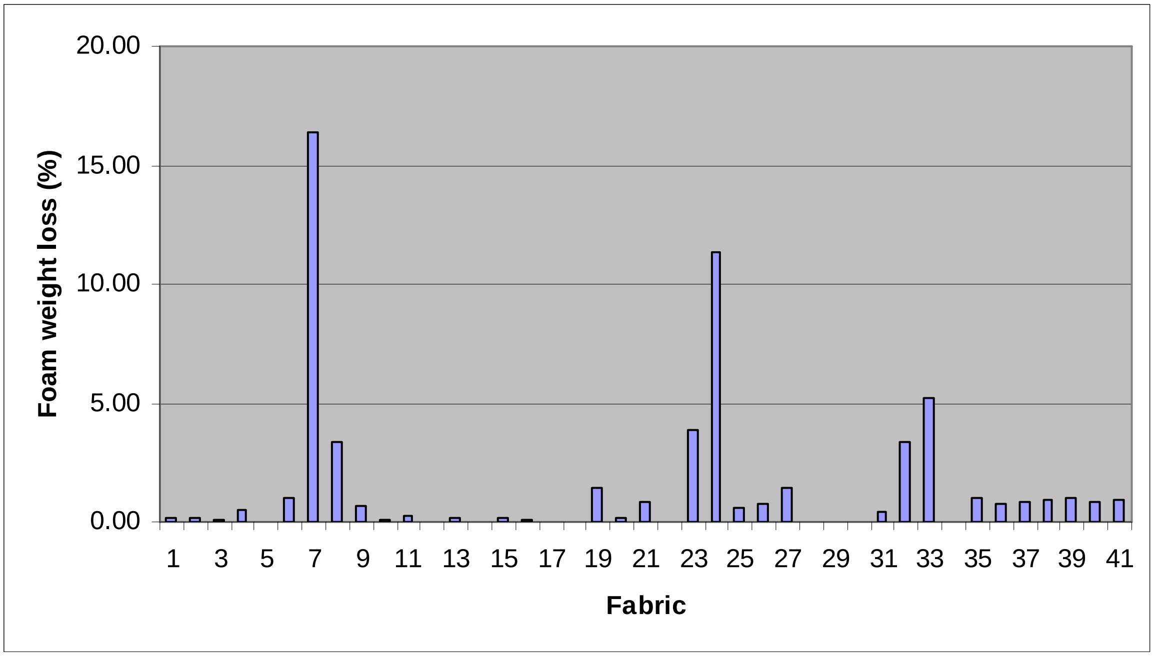

Figure 17. Foam Weight Losses of Mockups made from Foam T and all Fabrics

Appendix 3(b) shows that when interliners W and K were placed over foam T and covered by fabric 24 (100% cotton velvet), the mockups were still smoldering at 45 minutes with foam weight losses well above 10%. These two interliners did not improve the smoldering resistance of the mockup made with foam T and fabric 24. Appendix 3(b) also shows that when interliners G, $, and ¢ were placed over foam T and covered with fabric 24, the mockups self-extinguished with only about 1% average foam weight losses. These results indicate that these three barriers greatly improve the smoldering resistance of the foam T/fabric 24 mockup. When fabric 24 was tested over foam T without fire barriers, the mockup was still smoldering at 45 minutes with an average foam weight loss above 11% as shown above in Figure 17 and in Appendix 3(a).

Foams J, K and L are visco-elastic foams. Foam N is a polyester foam. Appendix 3(b) shows that when foams J, K, L and N were tested with fabric 24, the mockups self-extinguished with very low foam weight losses. Foams T, Z, R, and S are all treated with lower level of FR chemicals. In order to compare the smoldering performance of foams T, Z, R, and S, more than three smoldering mockup tests were performed on these foams with fabric 24. Figure 18 shows the foam weight loss data for all foams tested with fabric 24, and the average foam weight losses and their standard deviations are listed in Table 3. Foams T, Z, R, and S mockups were still smoldering at 45 minutes and had average foam weight losses ranging from 8% to 12%. All other foam mockups self-extinguished and had very little foam weight loss (below 1.5%) when they were tested with fabric 24.

Figure 18 and Table 3 show that when foams T, Z, R, and S were tested with fabric 24, their foam weight losses varied greatly, ranging from about 4% to 20%. This is probably caused by the interaction of the smoldering foams with the wooden support frames. The smoldering front penetrated through the 2 inch foams and charred the wooden frames in many cases (as noticed when the tests were terminated).

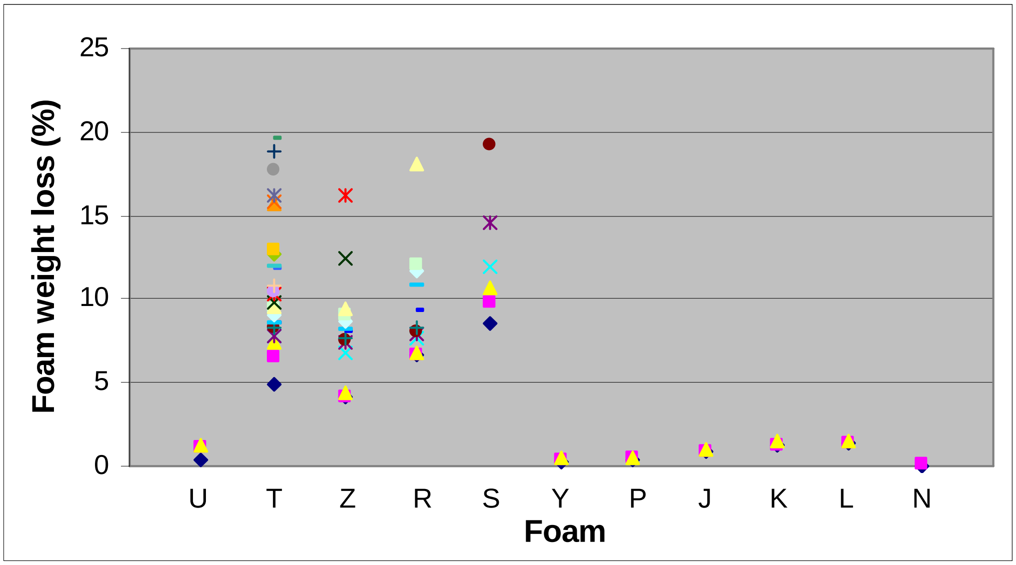

Figure 18. Foam Weight Loss of Mockups Tested with Fabric 24

Table 3. Foam Weight Loss Data (Mockups Tested with Fabric 24)

Foam	Number of Replicates	Weight loss (%) (low)	Weight loss (%) (high)	Weight loss (%) (range)	Weight loss (%) (average)	Weight loss (%) (Standard deviation)
U	3	0.38	1.25	0.87	0.90	0.46
T	26*	4.88	19.55	14.67	11.18	3.94
Y	3	0.30	0.44	0.14	0.39	0.08
P	3	0.41	0.46	0.05	0.44	0.03
S	6	8.57	19.25	10.68	12.47	3.90
Z	14	4.17	16.17	12.00	8.14	3.21
R	12	6.62	18.06	11.44	9.48	3.30
J	3	0.85	0.97	0.12	0.92	0.06
K	3	1.25	1.47	0.22	1.33	0.12
L	3	1.37	1.50	0.13	1.43	0.07
N	3	0.05	0.07	0.02	0.06	0.01

*One outlier removed

To assess the date of test and tester variability, Figure 19 shows the foam T weight loss data of each of the three mockups tested with fabric 24 at different times by 3 to 4 different test personnel. As shown in this figure, foam T weight loss generally falls between 5% and 20%, except one outlier (37%). The pattern in the data tends to indicate little effect of tester or day to day variability. However, as noted above, there is a wide range of variability in the results on 2 inch thick foam and 45 minute test duration.

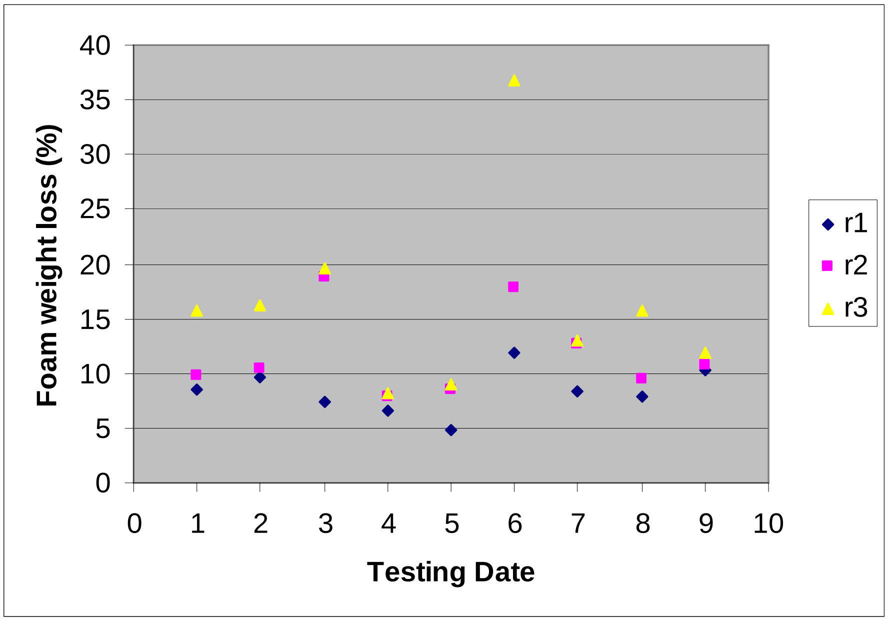

Figure 19. Fabric 24 Mockup Foam T Weight Loss Tested at Different Times

<u>Effect of Interliners (Fire-Blocking Barriers) on Foam U and Foam T Tested with Fabric 24 Cotton Velvet Fabric</u>

Figures 20 and 21 compare the average maximum char length and average foam weight loss of foam U and foam T tested with different fire-blocking barriers and without barriers. These figures show that adding fire-blocking barriers to foam U tested with fabric 24, cotton velvet fabric, increased the char length and foam weight loss. Adding barriers M, $, ¢, and G to foam T tested with cotton velvet fabric reduced the foam weight loss to equal or below 1%, comparing to the average of 11% foam weight loss of the mockups tested without barriers . However, other barriers tested with foam T and cotton velvet fabric were not as effective as barriers M, $, ¢, and G at reducing smoldering.

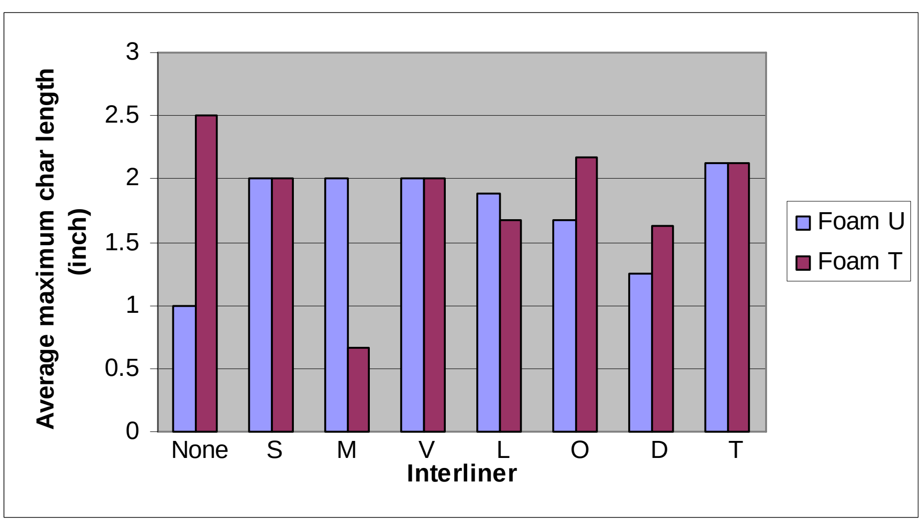

Figure 20. Comparison of Char Length of TB117+ Cotton Velvet Fabric Tested with Different Interliners and without Interliners

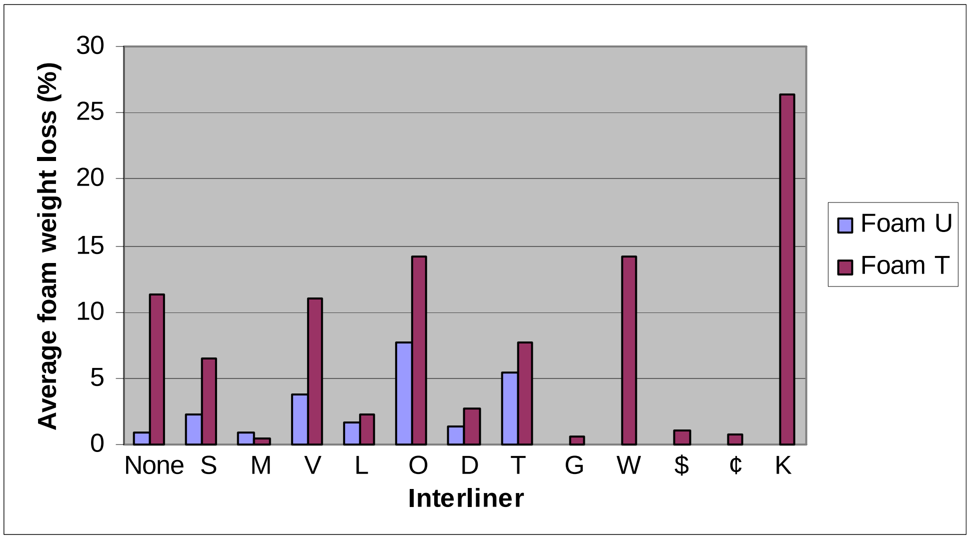

Figure 21. Comparison of Foam Weight Loss of TB117+ Cotton Velvet Fabric Tested with Different Interliners and without Interliners

Foam U vs. Foam T

The average maximum char length and average foam weight loss for the three mockups of foam U vs. foam T when tested with interlining materials are shown in Figures 22 through 31 and without interlining materials in Figures 3 and 4. These figures show that, in general, mockups tested with foam T had a larger char length and a higher foam weight loss compared with the mockups tested with foam U. These results indicate that adding a small amount of FR chemicals to the foam appears to reduce resistance to smoldering ignition consistent with the statement in Section 2 of TB117+ (1). Those data suggest that foams treated with small amounts of FR chemicals are better choices for use as standard test foams because they present a greater challenge than untreated foam.

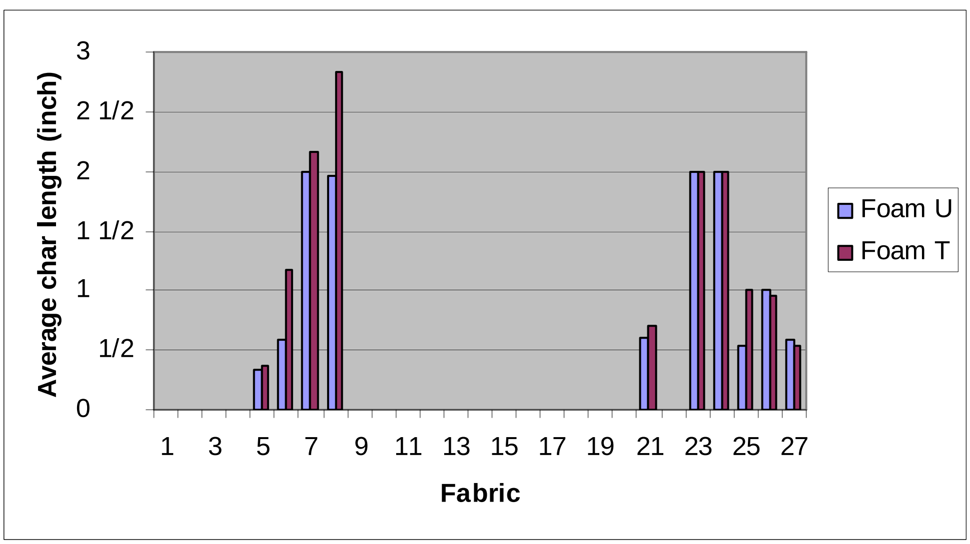

Figure 22. Char Length: Foam U vs. Foam T with Interliner S

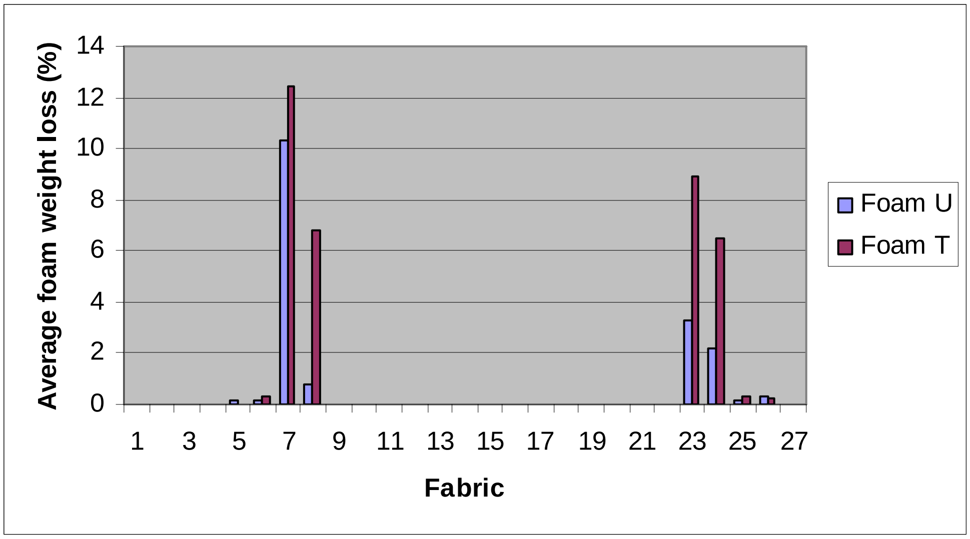

Figure 23. Weight Loss: Foam U vs. Foam T with Interliner S

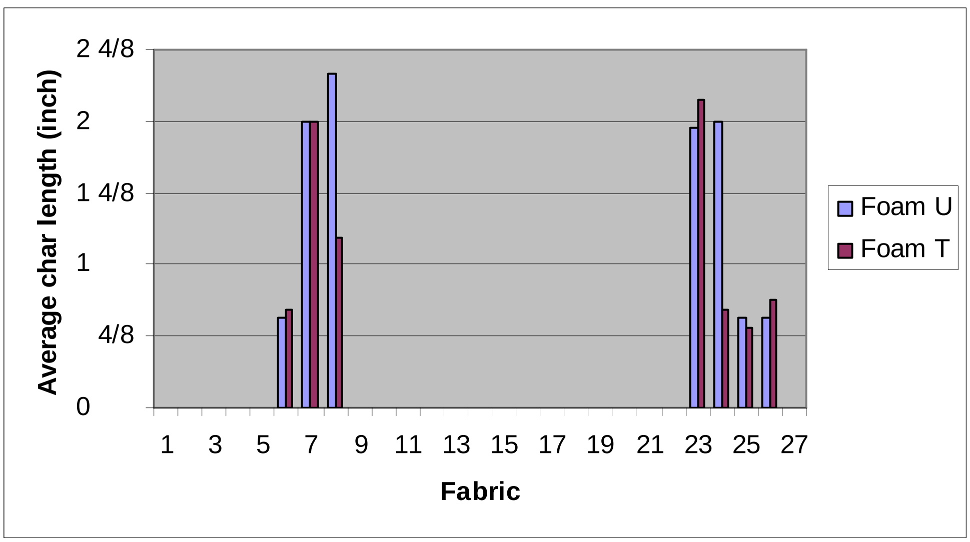

Figure 24. Char Length: Foam U vs. Foam T with Interliner M

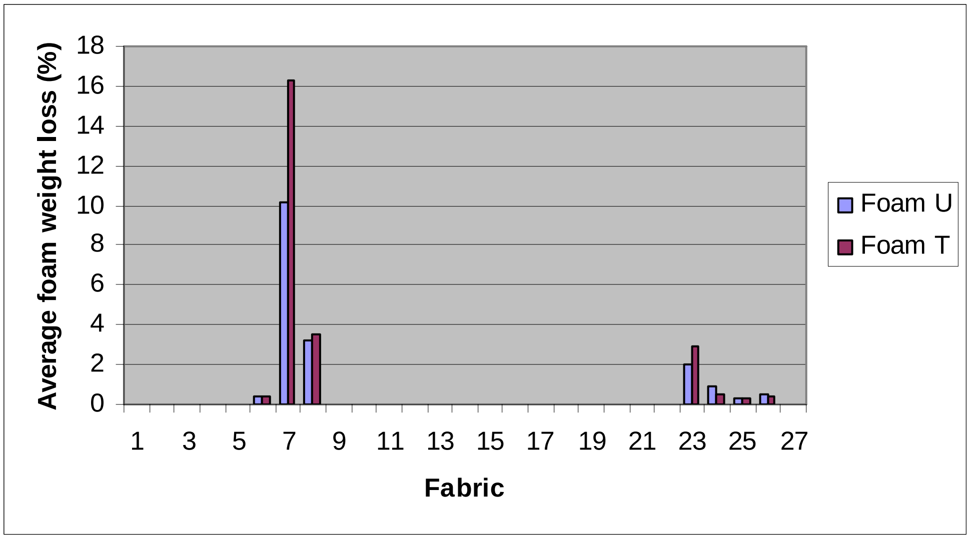

Figure 25. Weight Loss: Foam U vs. Foam T with Interliner M

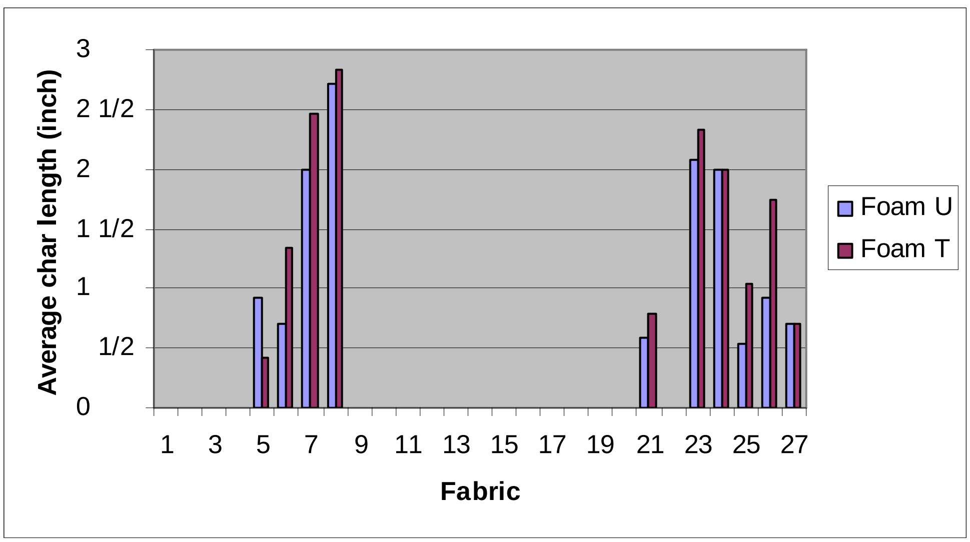

Figure 26. Char Length: Foam U vs. Foam T with Interliner V

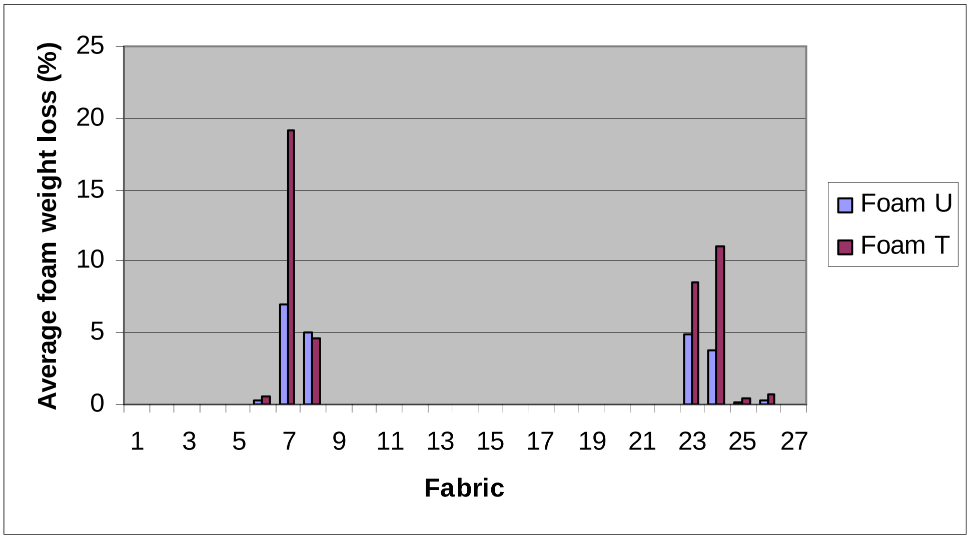

Figure 27. Weight Loss: Foam U vs. foam T with Interliner V

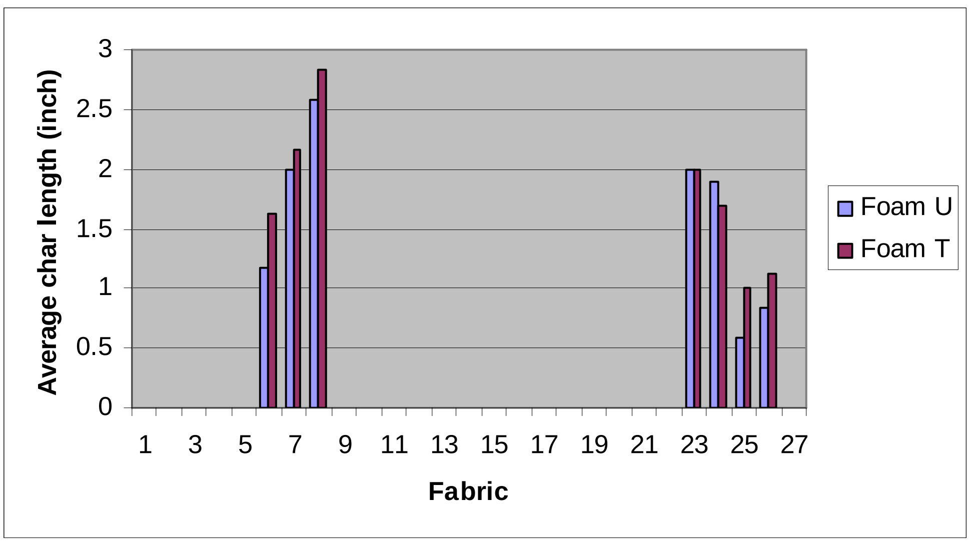

Figure 28. Char Length: Foam U vs. Foam T with Interliner L

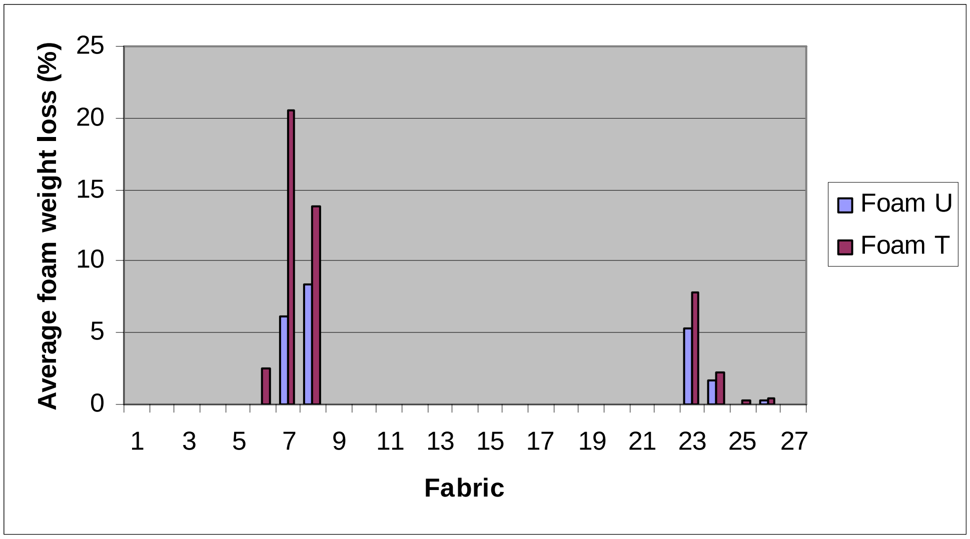

Figure 29. Weight Loss: Foam U vs. Foam T with Interliner L

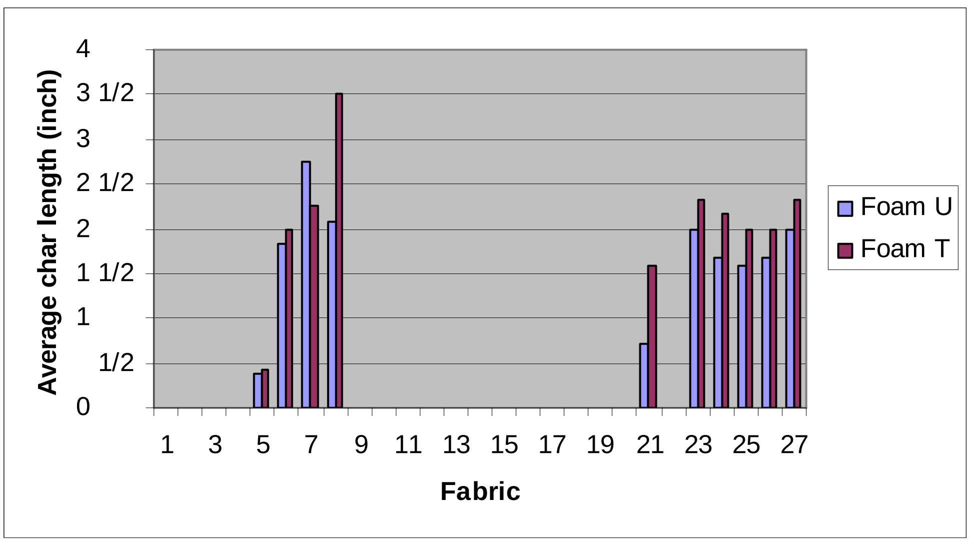

Figure 30. Char Length: Foam U vs. Foam T with Interliner O

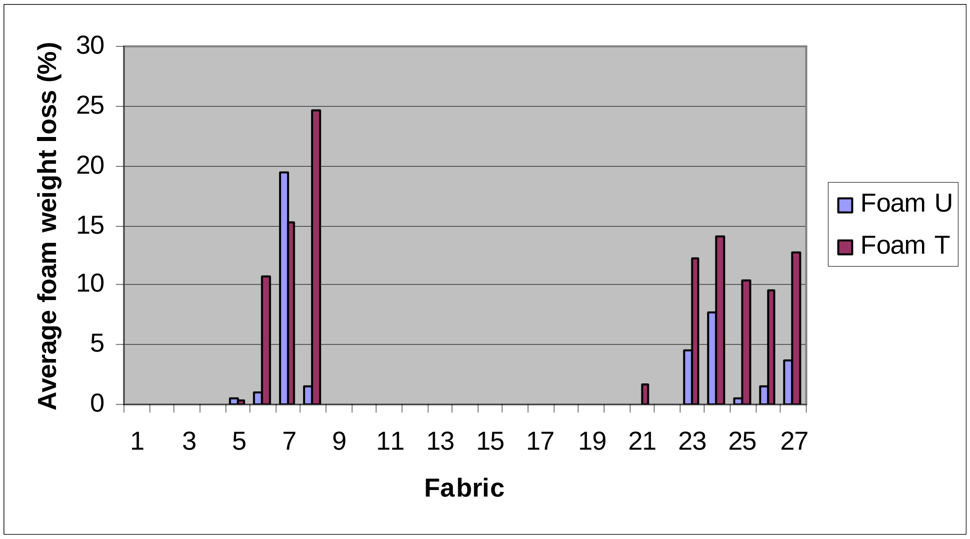

Figure 31. Weight Loss: Foam U vs. Foam T with Interliner O

<u>Comparison of Char Length and Foam Weight Loss of Fabric 24 Cotton Velvet Fabric Tested with Different Foams and Interliners (Fire-Blocking Barriers)</u>

Figures 32 and 33 show the average maximum char length and average foam weight loss of the cotton velvet fabric tested with different foams and different fire-blocking barriers. As shown in these figures, foam T tested with cotton velvet fabric produced higher char length and foam weight loss than foams U, Y, and P. Foams Z, R, and S tested with cotton velvet fabrics also generated higher foam weight losses than foam U, Y, and P as seen from Figure 33. This result also supports the use of foams treated with small amounts of FR chemicals as the standard test foam.

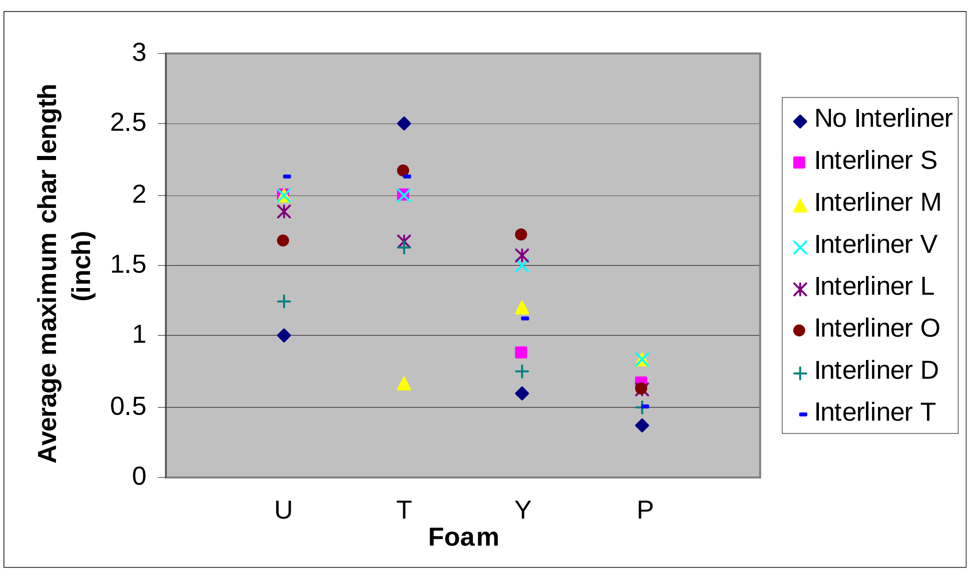

Figure 32. Comparison of Char Length of TB117+ Cotton Velvet Fabric Tested with Different Foams and Interliners

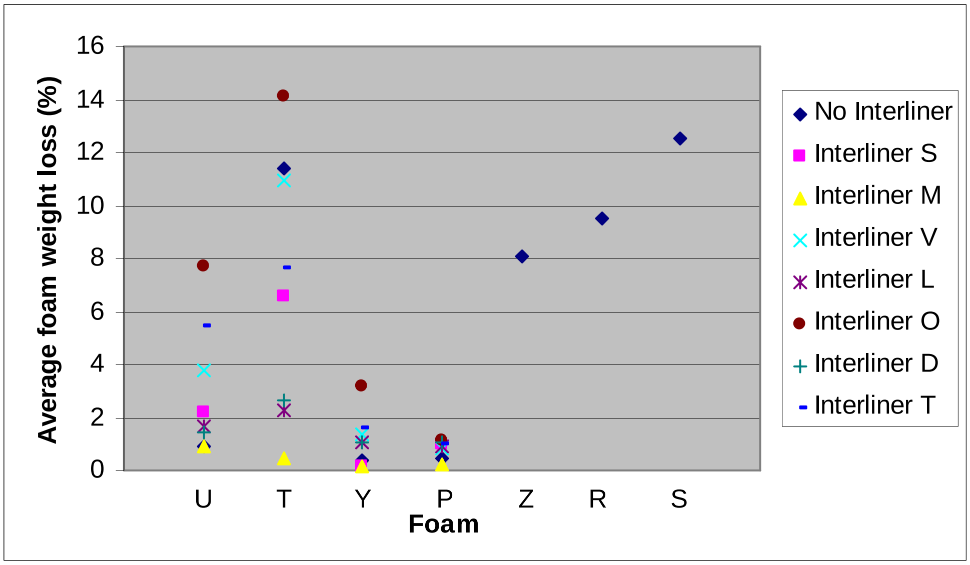

Figure 33. Comparison of Foam Weight Loss of TB117+ Cotton Velvet Fabric Tested with Different Foams and Interliners

Foams T, Z, R, and S are all treated with small amounts of FR chemicals, but with different chemicals at different levels. Given the lower smoldering resistance of foams T, Z, R, and S and compared with the FR contents listed in Table 2 for foams Y and P, it appears that higher levels of Melamine and lower levels of TDCP in the foam improve the smoldering performance for foams Y and P.

Discussion of Possible Performance Criteria – Char Length and Foam Weight Loss

The UFAC Voluntary Program uses the length of char upwards on the vertical panel to classify the upholstery fabric. However, the smoldering combustion front can proceed in any direction. In many cases, the greatest extent of char developed downward into the crevice between the horizontal and vertical panels. Figure 34 shows the post test mockups of fabric 24 tested with foam U and barrier V. The disassembled mockup shows that the char progressed down into the crevice and reached the bottom edge of the horizontal foam. Disassembly of the other two mockups in the picture revealed that the chars also reached the bottom edge of the horizontal foam. This result indicates that the char length in the vertical upward direction may not adequately evaluate the smoldering resistance of the mockup. Also, it appears that when the smoldering front reached the bottom edge the plywood mockup frame may have also begun to smolder.

Figure 34. Post Test Mockups of Fabric 24 with Foam U and Interliner V

These observations suggest that the UFAC requirement limiting only the vertical char length may not be a sufficient measure for characterizing the smoldering ignition of materials. Travel of the smoldering combustion front along or down into the crevice results in a configuration where multiple burning surfaces can reinforce the strength and duration of the combustion of either surface. Also, involvement of the plywood mockup materials may not provide a true measure of the upholstery material performance. Close-fitting gaps between cushions and/or the vertical and horizontal surfaces of actual upholstered furniture are mimicked by the crevice in the UFAC mockup.

Measurements of either the maximum char length or weight loss are presently used by voluntary and state government standards as the performance criteria for the evaluation of materials used in upholstered furniture. However, both types of measurements have limitations and are subject to technician-induced errors. Char length can be influenced by intimacy of the sheeting with the cigarette and the fabric, and intimacy of the fabric with the underlying materials or foam. Foam weight loss can be influenced by intimacy of the fabric or interliners with the foam, the relative humidity, absorbed moisture when water is needed as an extinguishing agent, the technique used to remove the residue from the unburned portion of the foam block prior to post-test weighing, and the mockup frame/foam interaction when the mockup frames become involved. Figures 35 through 40 show the average maximum char length vs. average foam weight loss of the three mockups for foam U and foam T with and without interlining materials. Although some CPSC staff tests demonstrated reasonable agreement between average maximum char length and average foam weight loss, the data do not show a consistently high degree of correlation between these two measurements.

The discrepancies are at least partially due to the fact that foam weight loss is volumetric but maximum char length is a one-dimension measurement from a two-dimensional effect (the surface area of the thin fabric that is consumed by the combustion). As noted above and considering the assessment of the data, the CPSC staff believes that weight loss is a better measure to use in the evaluation of smoldering ignition resistance of upholstered furniture materials.

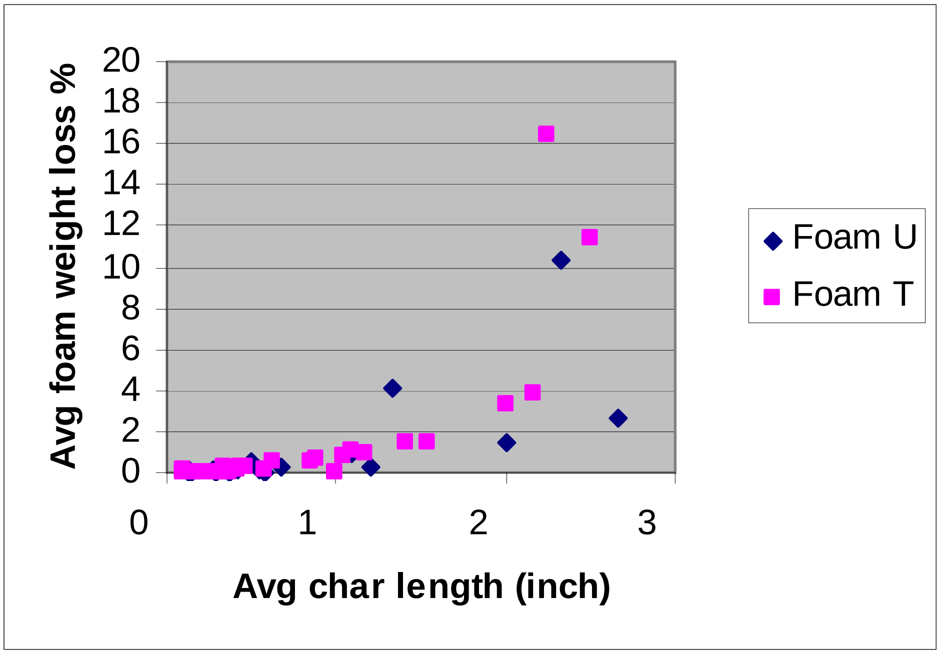

Figure 35. Char Length vs. Weight Loss – No Interliner

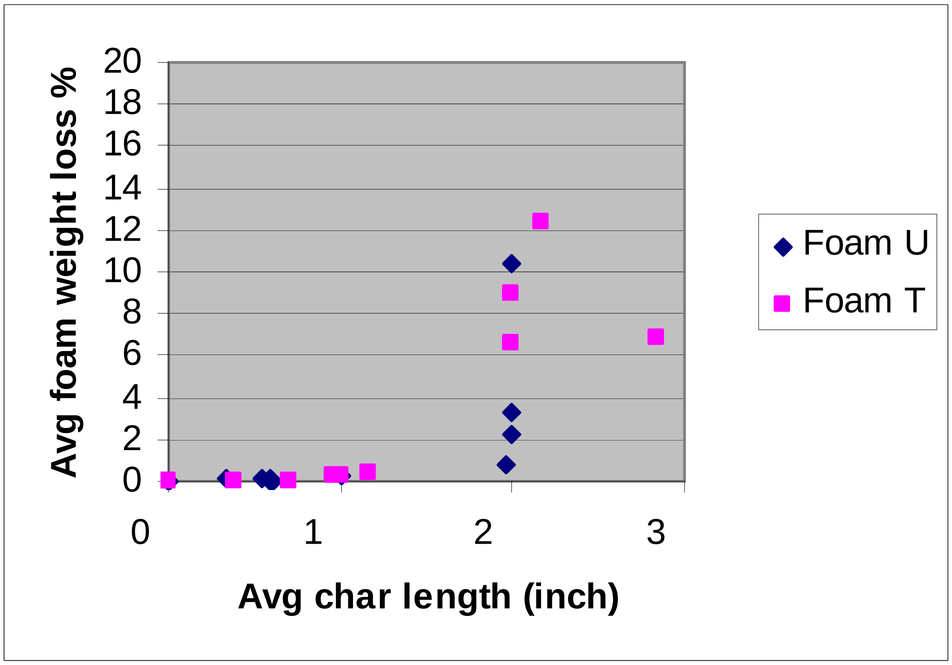

Figure 36. Char Length vs. Weight Loss – Interliner S

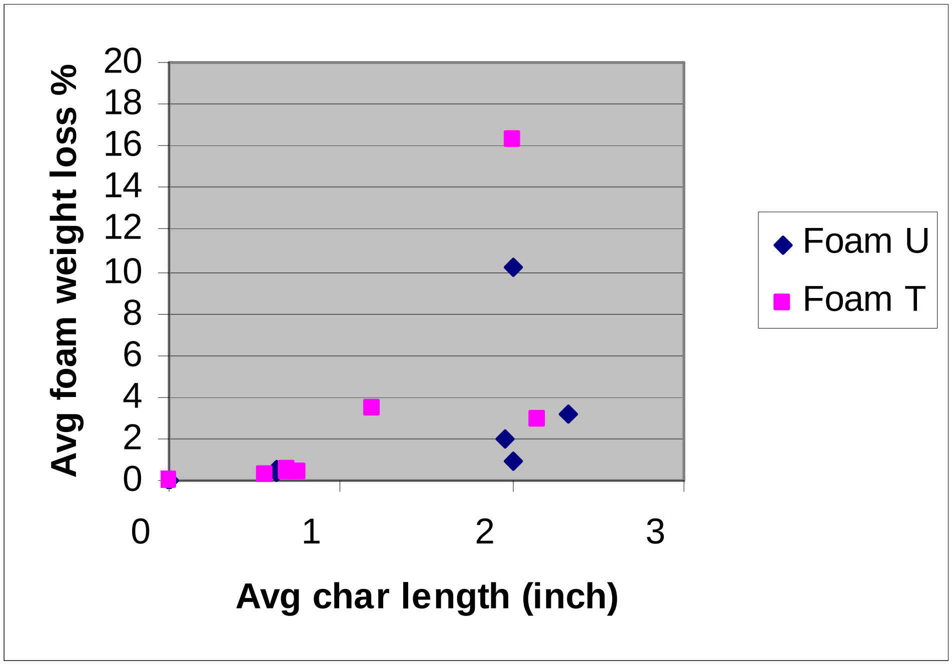

Figure 37. Char Length vs. Weight Loss – Interliner M

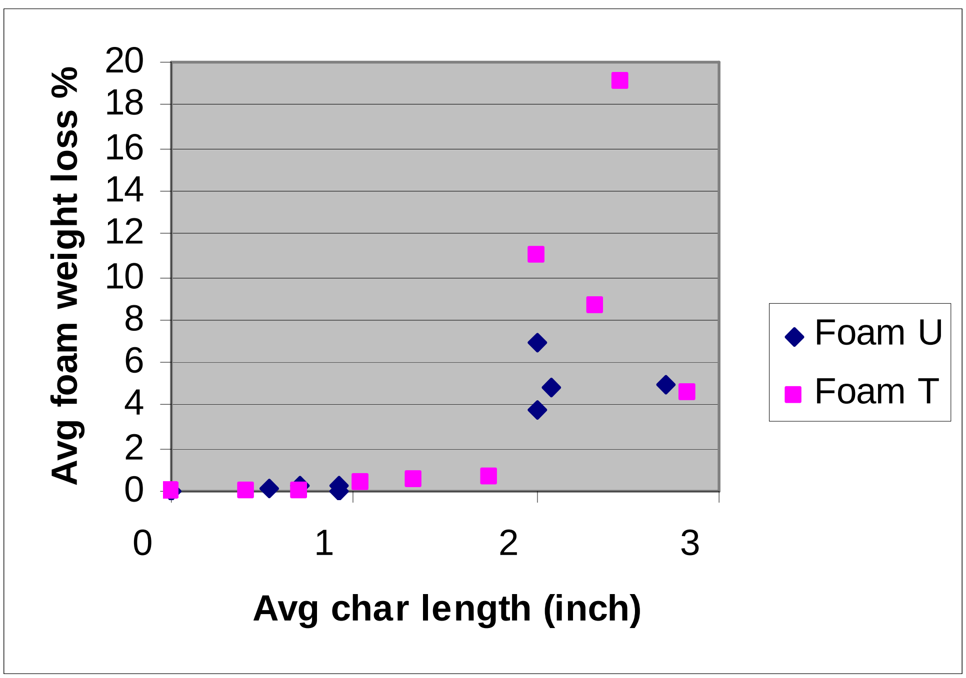

Figure 38. Char Length vs. Weight Loss – Interliner V

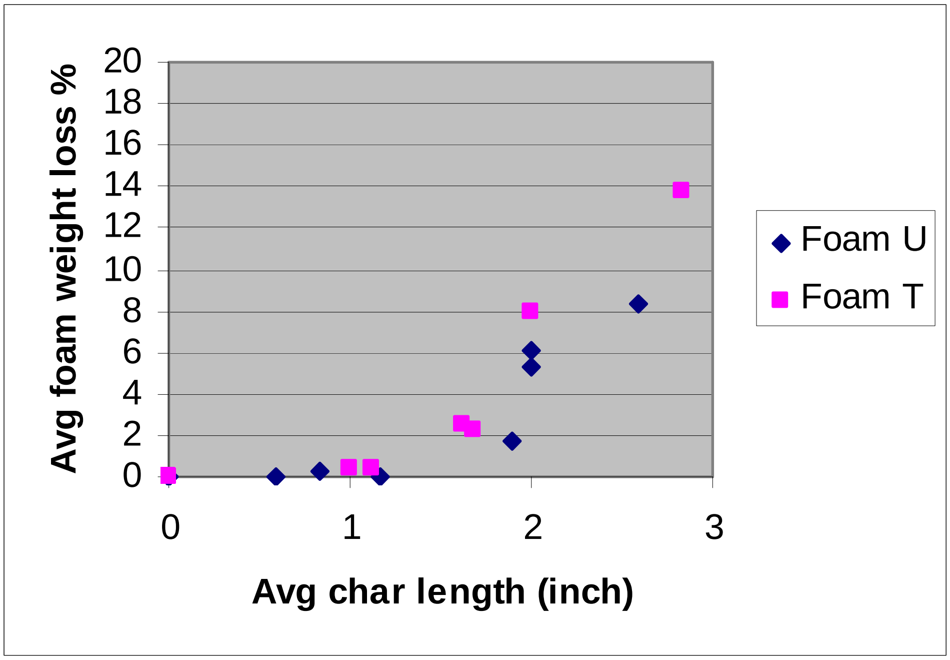

Figure 39. Char Length vs. Weight Loss – Interliner L

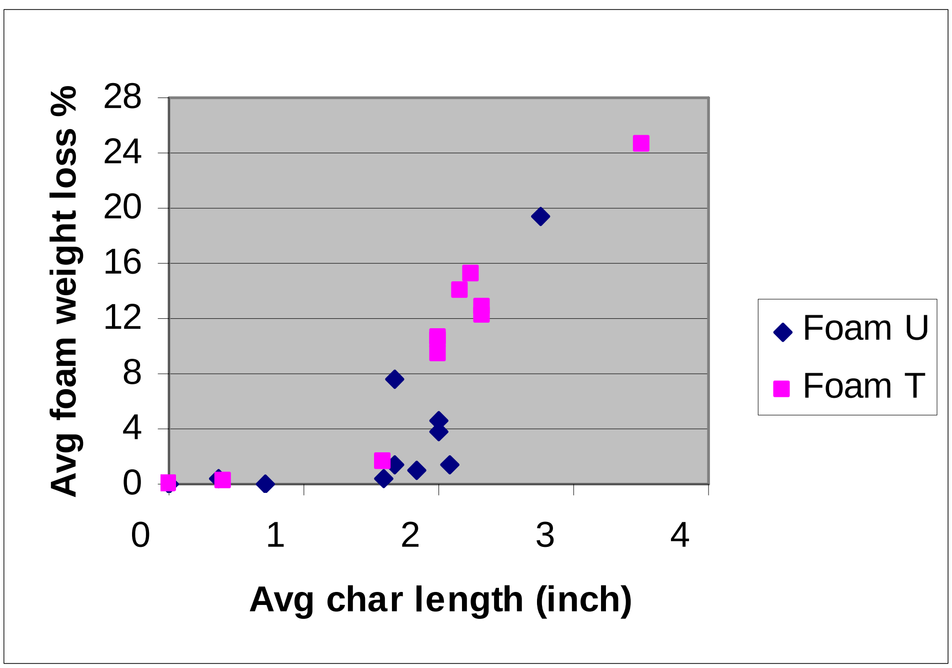

Figure 40. Char Length vs. Weight Loss – Interliner O

TB117+ uses weight loss of the foam to evaluate the performance of upholstered furniture materials. At present, the proposed revision requires the weight loss of the foam to not exceed 20% when tested to the TB 117+ protocol. The TB117+ protocol does not have a time limit. Without a time limit, CPSC staff notes that smoldering of the wooden mockup can begin to occur during the test. Once the wooden mockup begins to smolder, CPSC staff believes the test method becomes compromised. From the CPSC test data, it appears that most of the aggressive smoldering fabrics will exceed 2 inches of char in less than 45 minutes. Therefore, CPSC staff believes that the test duration should be limited to less than 45 minutes to minimize the potential effect of the mockup support materials becoming involved. In doing so, the key performance parameter to consider would be the damage to the foam substrate as measured by weight loss from the charred foam material.

CPSC staff also notes that there was quite a large range of weight loss data for foams T, Z, R, and S when tested with fabric 24 for 45 minutes. This large range in the data raised an issue with respect to the test method. In reviewing the data, one thing that was noted was that often when foam weight losses exceeded 5 to 10%, the smoldering front had penetrated to the wooden support assembly used. The wooden assembly in several tests charred and these may have led to some cases where the smoldering performance of the materials under test was not truly being measured. In order to avoid the potential of the wooden frame becoming involved, and further investigate the effects of the test duration and the foam thickness on the cigarette ignition test results, Phase V tests were added to the program to assess thicker foam geometry and shorter test time duration.

Phase V – Evaluation of Test Time Duration and Foam Thickness (2 inch Foam vs. 3 inch Foam at 30 and 45 minute Test Durations)

CPSC staff observed that charring of the wooden frame can occur during the cigarette ignition test using the 2 inch foams and the 45 minute test duration for the mockups made from smolder prone upholstery fabrics and foams. CPSC staff also noted that the foam weight loss data using a 45 minute test duration and the 2 inch foams varied greatly. The foam weight losses of mockups made from fabric 24 and foam T ranged from about 5% to 20% as shown in Table 3. In order to assess the foam weight loss variation being observed, avoid potential involvement of the wooden frame, and further investigate the effects of the test duration and the foam thickness on the cigarette ignition test results, over 180 mockup tests were done using 2 inch and 3 inch foams at both 30 and 45 minute test durations. The 30 minute test duration was chosen because a cigarette usually burns its entire length in about 25 minutes, except on very heavy fabrics where a cigarette may take more than 30 minutes to complete burning. The tests were conducted using fabric 24, a cotton velvet fabric, fabric 7, a very heavy cotton/rayon chenille fabric, and foams T, R, Z, and U. Limited tests were done using foam Z due to a limited amount of material. Test results are shown in Table 4 and Figures 41-43. Table 4 reports the highest, lowest, and average foam weight loss for each mockup configuration and test duration time. Figure 41 shows the individual foam weight loss data points and Figure 42 shows the average foam weight loss and data range for each mockup configuration and test duration time. Figure 43 presents foam char depth of these smoldering mockup tests.

Table 4 and Figure 42 show that increasing the test duration from 30 minutes to 45 minutes generally increases the percent weight loss seen in the foam pieces, as expected, regardless of the foam thickness. The data also show that for a given test duration, the percent weight loss is greater for the thicker foam pieces. This is not intuitive. Lab staff attribute this trend to the fact that for a 2-inch foam specimen, the smoldering front had progressed through the thickness of the foam at a time less than 30 minutes, and the smoldering front had reached the wooden mockup holder. This is indicated by the depth of the char measurement shown in Figure 43. In the 3 inch mockups, the smolder front had not gone through the thickness of the foam. For the 30 minute period more foam smoldering was occurring with the 3 inch geometry. This supports the need to use a shorter test time and thicker foam so that the test is measuring the smoldering performance of the furniture materials, not the mockup support frames. A noteworthy exception is for foam U, the untreated foam. Because this foam self-extinguishes with minimal weight loss, testing with a thicker foam piece minimizes the proportion of the smoldered portion of the foam, resulting in a comparative reduction in the percent weight loss.

Figures 41 and 42 indicate that the variation in the results increases when the test duration is increased. This may also be an effect of the smoldering front reaching the wooden mockup frame and thus measuring wood smoldering versus the materials of interest. The contribution of the wooden frame to the combustion will vary depending on the initial condition of the frame prior to testing and the natural variation of the wood as it interacts with the smoldering front. This interaction cannot easily be quantified or assessed in this test program and does not provide a measure of the smoldering performance of the materials under test. Consequently, the test method must select parameters that prevent the smoldering front from progressing completely through the foam to the interface with the wooden frame. These data suggest that is best accomplished by limiting the test duration to 30 minutes and using a 3-inch thick geometry for the foam.

As noted earlier in this Results and Discussion section, a 5% or 10% foam weight loss may be a reasonable choice for a pass/fail criterion based on the test results using 2 inch foam pieces. This was based on the performance of the smolder prone fabrics 7 and 24. These additional data show that for a given test duration using the 3 inch thick foam results in a greater percent weight loss than using the 2 inch thick foam. Considering the findings in this section, it would appear that a larger foam weight loss (10%) may be a better choice as a pass/fail criterion then a smaller foam weight loss (5%) when using 3 inch foam as the test foam.

Test data using 3 inch thick foam at 30 minute test duration shown in this section also indicate that at a 30 minute test duration using 3 inch foams tested with fabrics 7 and 24, the average foam T weight loss is less than 10% and lower than the average foam weight loss of foam R (13%). This result suggests that foam R is a greater challenge than foam T. Foams with similar smoldering performance to foam R would be good candidates as standard test foam formulations. From this result, it appears that a standard test foam used to evaluate the smoldering combustion performance of cover fabrics should experience an average foam weight loss between 10 and 15% when tested in 3 inch thickness under fabric 24 for a test duration of 30 minutes.

Table 4. Smoldering Test Foam Weight Loss Comparison Data
(2” vs. 3” at 30 and 45 minutes)

	High	Low	Average
2"T-30/F24	6.5	1.7	4.13
2"T-30/F7	5.26	2.13	3.93
2"T-45/F24	19.55	4.88	11.18
2"T-45/F7*	20.02	13.99	16.40
3"T-30/F24	9.03	3.06	6.78
3"T-30/F7	12.35	4.06	7.20
3"T-45/F24	30	6.92	16.63
3"T-45/F7	32.27	14.75	21.40
2"R-30/F24	9.29	4.4	6.83
2"R-45/F24	18.06	6.62	9.48
3"R-30/F24	17.38	9.34	13.24
3"R-30/F7	21.23	8.35	13.11
3"R-45/F24	48.81	23.07	40.12
2"Z-30/F24	14.58	13.37	13.98
2"Z-45/F24	16.17	4.17	8.14
3"Z-30/F24	19.55	19.55	19.55
3"Z-45/F24	41.39	36.43	39.42
2"U-30/F24	4.65	1.19	2.51
2"U-45/F24	1.25	0.38	0.90
2"U-45/F7	2.09	1	1.47
3"U-30/F24	1.97	0.84	1.25
3"U-45/F24	0.76	0.64	0.70

*One outlier (foam weight loss 36.82%) removed.

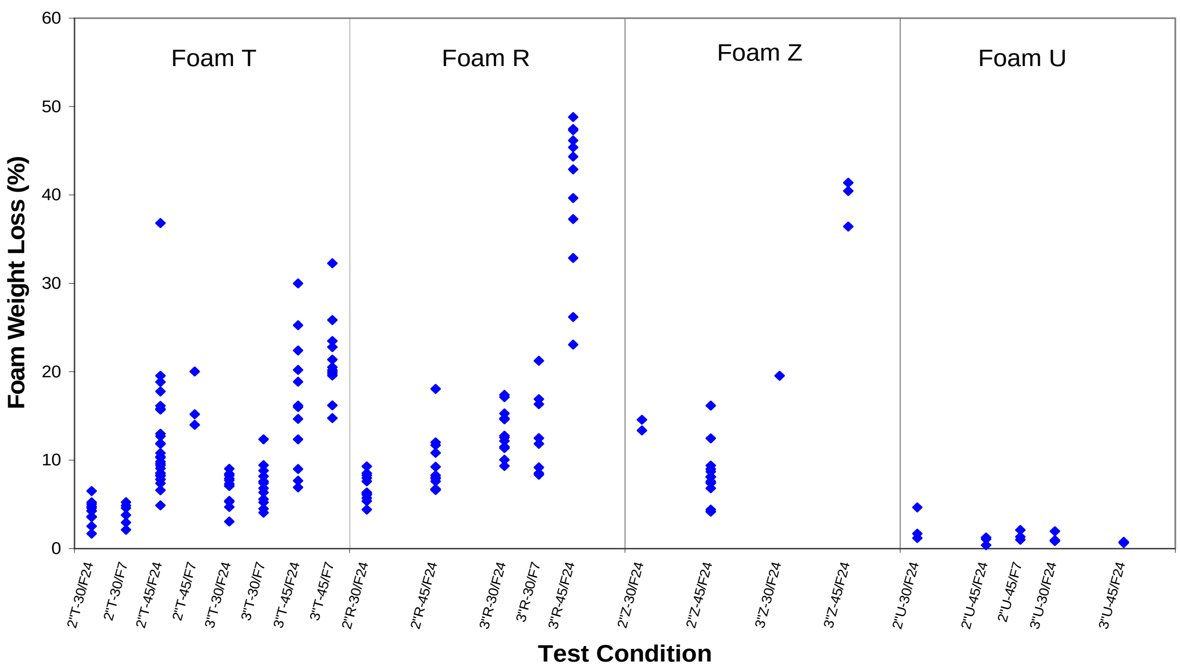

Figure 41. Smoldering Test Foam Weight Loss Data (2” vs. 3” at 30 and 45 minutes)

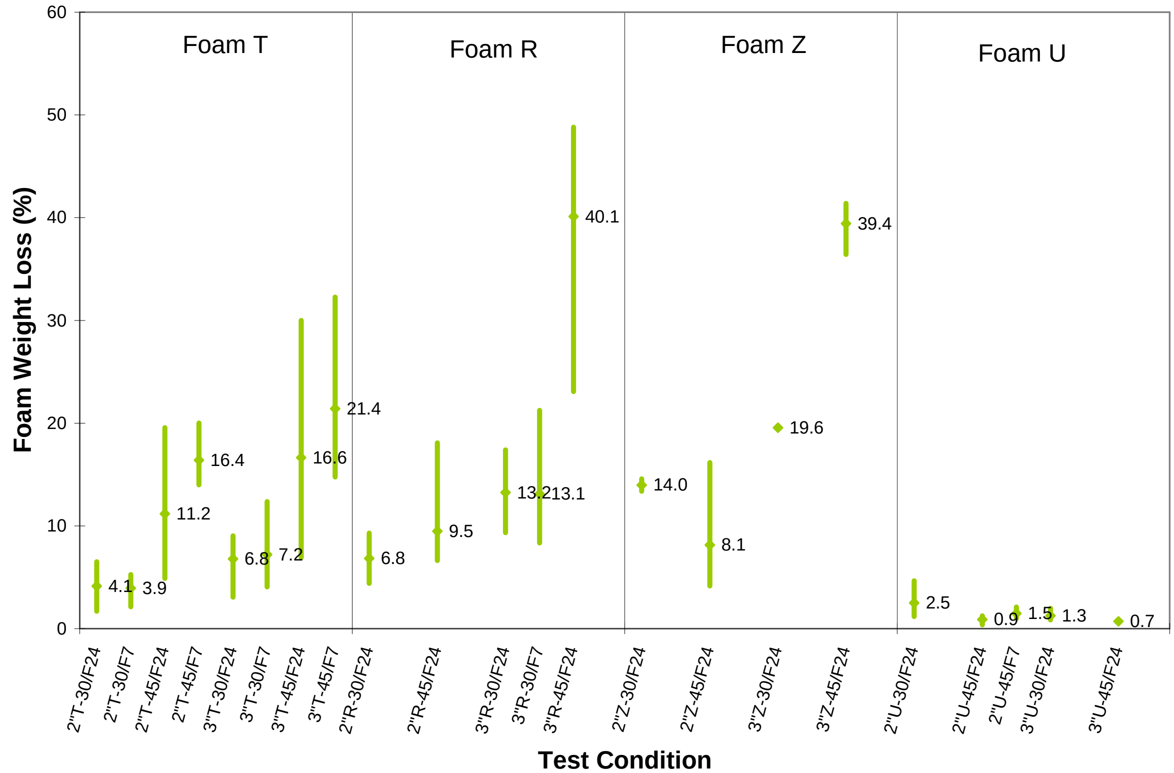

Figure 42. Smoldering Test Foam Weight Loss (High, Low, Average, 2” vs. 3” at 30 and 45 minutes)

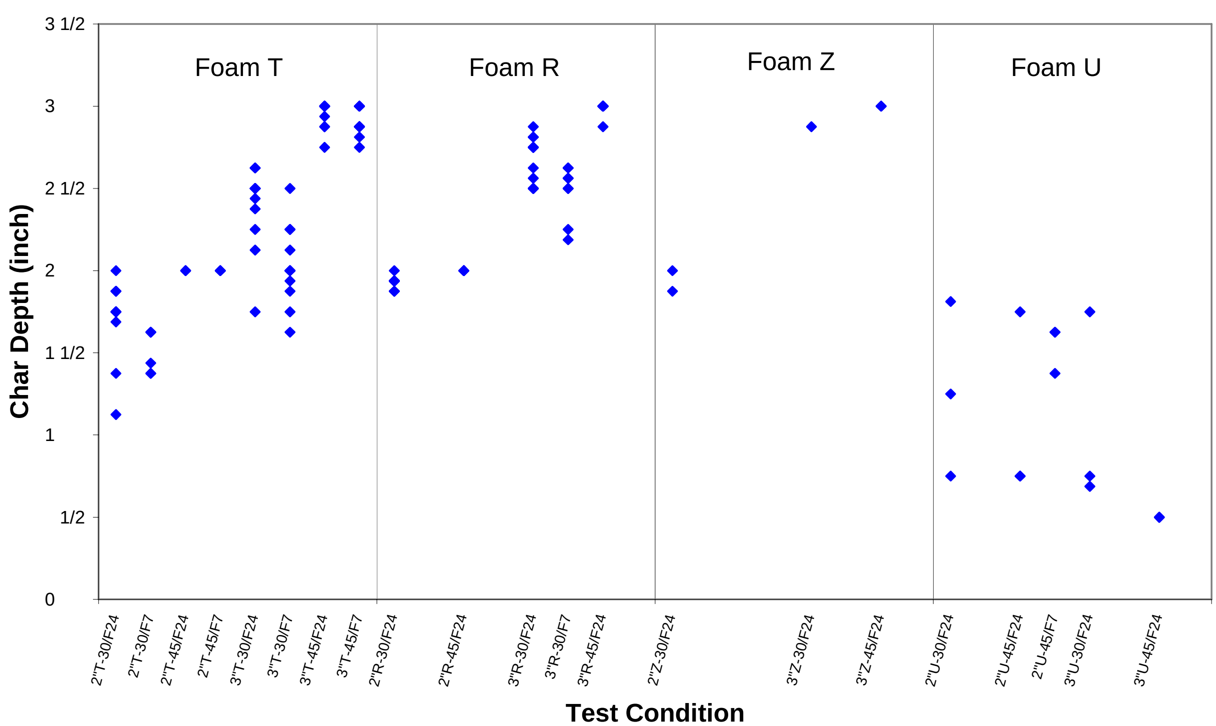

Figure 43. Smoldering Test Foam Char Depth Data

Conclusions

1) A 100% cotton velvet fabric, the standard test fabric specified in the California Bureau of Home Furnishings and Thermal Insulation Technical Bulletin 117, Requirements, Test Procedure and Apparatus for testing the Flame and Smolder Resistance of Upholstered Furniture, Draft 2/2002 ("TB117+"), seems to be a reasonable choice for a standard cover fabric for smoldering ignition tests. It is a smolder-prone fabric and presents a challenge to the underlying materials.
2) Certain small amounts of FR formulations of foams can cause foams to be more prone to smoldering, which suggests these foams may be good substrates for evaluations of fabrics, fillings, and barriers with regarding to smoldering ignition because they present a greater challenge than untreated foams.
3) Heavily FR treated foams improve smoldering resistance for fabrics that performed poorly over untreated and lightly FR treated foams.
4) Using 3-inch thick foam geometry at a 30 minute test duration avoids potential mockup wooden frame involvement for more consistent comparisons between materials.
5) Foams treated with small amounts of FR chemicals that exhibit an average foam weight loss between 10 and 15% when tested in 3 inch thickness under the proposed standard cotton velvet test fabric for a test duration of 30 minutes may be a good choice as the standard foam substrate.
6) The UFAC standard polyester batting/barrier is quite effective for a limited period of time in preventing smoldering ignition when used directly underneath the cover fabric.
7) Fire barriers may improve open flame ignition resistance and some also improve smoldering ignition resistance, but some currently available fire-blocking barriers can degrade smoldering ignition resistance. This supports the need to evaluate fire-barriers for both open flame and smoldering ignition performance.
8) An average foam weight loss of not more than 10% at a 30 minute test duration may be a reasonable choice as a pass/fail criterion to evaluate the smolder resistance of other upholstered furniture materials.

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Gail Stafford
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9. Memorandum to Dale Ray from Edward Krawiec and Weiying Tao, LS, Review of Proposed Requirement for Reconditioning Cigarette Ignition Mockup Foam for Post-Test Weight Loss Measurement, May 2005.
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Appendix 1(a)
Smoldering Test Plan

Fabric		Smoldering Test (3 replicates, measure char length and weight loss)																											
Type	Weight (oz/yd^2)	Foam U	Foam T	foam Y	foam P	UFAC std. PET batting + foam				Interliner S + foam				Interliner M + foam				Interliner V+ foam				Interliner L + foam				Interliner O + foam			
						U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P
1.Acetate/cotton	3.5																												
2.Cotton print	6.0																												
3.Acrylic/PET/ olefin	8																												
4.Cotton corduroy	9																												
5.Rayon/PET/ cotton	10																												
6.Cotton twill	11.5																												
7.Cotton/rayon chenille	20																												
8.Cotton/rayon chenille (FR backcoated)	24																												
9.Cotton twill (FR backcoated)	14																												
10.cotton/PET (1/2 FR backcoated)	9																												
11.Cotton, FR (pyrovatex)	7.5																												
12.Rayon/PET/ cotton (FR backcoated)	12																												
13.Cotton/nylon sateen, FR treated (proban)	10																												
14. 100% wool	11																												
15. 100% silk	3.7																												
16.Std. FR polyester	6.5																												
17.100% nylon (FR backcoated)	12.3																												
18.Rayon/nylon (FR backcoated)	14.5																												
19.100% cotton	10.0																												
20.Acrylic/PET/ olefin	8.2																												
21.100% olefin	18.7																												
22.100% olefin	9.1																												
23.Cotton twill	9.5																												
24.Cotton velvet (TB117+)	10																												
25.UFAC type I	9.0																												
26.UFAC type II	8.0																												
27.100% cotton	7.5																												

		UFAC batting (top)/ Interliner V under + foam				Interliner V (top)/ UFAC batting under +foam				Interliner D + foam				Interliner T + foam				Interliner D + UFAC batting + foam				Interliner T + UFAC batting + foam				Cotton batting	Cotton+Poly batting
		U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P	T	T
6.Cotton twill	11.5																										
24.Cotton velvet (TB117+)	10																										

Appendix 1(b)
Smoldering Test Plan

Fabric		Foam								Foam T				
										Interliner				
Type	Weight (oz/yd^2)	T	Z	J	K	L	N	R	S	G	W	$	¢	K
24. 100% cotton velvet	10.0													
31. Leather1	7.0													
32. Leather2	12.0													
33. 100% wool	12.5													
34. Vinyl	21.5													
35. 100% olefin	10.0													
36. 100% olefin	10.0													
37. 100% polypropylene	11.5													
38. Cotton/polyester	10.0													
39. Cotton/polyester	8.3													
40. Cotton/polyester	11.0													
41. Rayon/polyester	13.8													

Appendix 1(c)
Smoldering Test Plan

Fabric	Test Duration (minutes)	2" Foam				3" Foam			
		T	R	Z	U	T	R	Z	U
7. cotton/rayon chenille	30								
	45								
24. cotton velvet	30								
	45								

Appendix 2. Mockup Smoldering Test Maximum Char Length (inch)

Fabric	Foam U	Foam T	foam Y	foam P	UFAC batting	Interliner S + foam				Interliner M + foam				Interliner V+ foam				Interliner L + foam				Interliner O + foam			
					U	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P
1.Acetate/cotton	½ (124)	3/8 (12)																							
2.Cotton print	3/8 (234)	1/2 (2)																							
3.Acrylic/PET/ olefin	1 (1)	3/8 (1)																							
4.Cotton corduroy	¾ (2)	1 1/8 (2)																							
5.Rayon/PET/ cotton	1 (1)	3/8 (13)	1/2 (13)	3/8 (4)		3/8 (1)	1/2 (2)	7/16 (1)	3/8 (15)					3/4 (1)	7/16 (1)	7/16 (3)	7/16 (1)					3/8(1 245)	1/2 (2)		
6.Cotton twill	3/8(1 234)	**2 (2)**	1/2 (4)	1/2 (4)	1/2 (1)	5/8 (2)	1 3/8 (2)	5/8 (2)	9/16 (2)	5/8 (2)	7/8 (2)	5/8 (2)	½ (2)	7/8 (1)	2 (2)	5/8 (2)	1/2 (24)	1 1/2 (1)	**2 (2)**	1 1/2 (1)	1/2 (123)	**2 (2)**	**2 (2)**	1 1/2 (2)	1/2 (4)
7.Cotton/rayon chenille	**2 (24)**	**2 ½ (1)**	**1 3/4 (2)**	1/2 (4)	**1 1/2 (2)**	**2 (2)**	**2 1/2 (5)**	**2 (2)**	**1 7/8 (2)**	**2 (2)**	**2 (2)**	**2 (2)**	**1 9/16 (2)**	**2 (2)**	**2 1/2 (3)**	**2 (2)**	**3 3/4 (3)**	**2 (2)**	**2 1/2 (5)**	**2 (2)**	**2 (2)**	**4 1/4 (1)**	**2 1/2 (5)**	**2 (2)**	**1 3/8 (2)**
8.Cotton/rayon chenille (FR backcoated)	**4 (1)**	**2 1/2 (1)**	7/8 (2)	3/8 (124)	1/2 (3)	**2 (23)**	**4 1/2 (1)**	**2 1/8 (3)**	**4 (1)**	**4 1/2 (1)**	**2 1/4 (5)**	7/8 (2)	**2 1/4 (3)**	**4 1/2 (2)**	**4 1/2 (1)**	**2 (2)**	**4 (1)**	**4 1/2 (1)**	**4 1/2 (1)**	**1 5/8 (3)**	**4 1/2 (1)**	**2 3/4 (3)**	**4 1/2 (1)**	7/8 (3)	**1 7/8 (2)**
9.Cotton twill (FR backcoated)	**2 (2)**	**1 1/4 (2)**	11/16 (2)	1/2 (2)																					
10.cotton/PET (FR backcoated)	3/8 (12)	1/8 (14)																							
11.Cotton, FR (pyrovatex)	1/2 (1)	1/2 (2)																							
12.Rayon/PET/ cotton (FR backcoated)	1/8 (24)	1/4 (2)																							
13.Cotton/nylon sateen, FR treated	5/16 (4)	1/2 (1)																							
14. wool	1/8 (14)	1/16 (13)																							
15. silk	3/8 (14)	5/8 (1)																							
16.Std. FR polyester	5/8 (2)	3/8 (123)																							
17.100% nylon (FR backcoated)	1/4 (1)	1/8 (14)																							
18.Rayon/nylon (FR backcoated)	3/8 (124)	1/4 (13)																							
19.100% cotton	1/2 (24)	2 (2)	9/16 (4)	1/2 (4)																					
20.Acrylic/PET/ olefin	1/2 (1)	1/2 (1)																							
21.100% olefin	¾ (1)	**1 5/8 (2)**	1 ½ (1)	1/2 (24)	1/2 (1)	5/8 (12)	**7/8 (2)**	**5/8 (2)**	1 1/2 (1)					**5/8 (12)**	**7/8 (1)**	**5/8 (12)**	5/8 (12)					**7/8 (2)**	**2 (2)**		
22.100% olefin	1 1/4 (1)	1 (1)																							
23.Cotton twill	1 3/8 (26)	**2 1/2 (6)**	9/16 (4)	1/2 (4)	1/2 (13)	**2 (26**	**2 (2)**	**2 (2)**	5/8 (2)	**2 (2)**	**2 1/2 (6)**	**1 3/4 (2)**	**2 (2)**	**2 1/4 (6)**	**2 (5)**	**2 (2)**	**1 3/8 (2)**	**2 (2)**	**1 3/4 (4)**	**2 (2)**	3/4 (2)	**2 (2)**	**2 1/2 (5)**		
24.Cotton velvet (TB117)	1 3/4 (4)	**2 3/4 (56)**	5/8 (4)	3/8 (124)	3/4 (1)	**2 (2(**	**2 (2)**	1 (2)	3/4 (2)	**2 (2)**	1 1/8 (2)	**1 3/4 (2)**	1 (2)	**2 (12)**	**2 (2)**	1 1/2 (12)	1 (1)	**2 (2)**	**2 (2)**	2 (2)	¾ (2)	**2 (2)**	**2 1/2 (5)**	**1 7/8 (2)**	5/8 (24)
25.UFAC type I	3/8 (124)	3/4 (2)	1/2 (24)	1/2 (4)	3/8 (13)	5/8 (2)	1 (126)	1/2 (13)	7/16 (2)	5/8 (2)	5/8 (3)	1/2 (2)	1/2 (2)	5/8 (2)	1 1/8 (2)	3/4 (12)	1/2 (123)	3/4 (1)	1 1/4 (2)	3/4 (2)	1/2 (134)	1 7/8 (2)	**2 (2)**	1 (2)	1/2 (24)
26.UFAC type II	3/4 (1)	1 1/4 (2)	1/2 (4)	7/16 (4)	7/8 (1)	**1 1/4 (1)**	1 1/4 (2)	1 1/4 (12)	9/16 (2)	5/8 (2)	7/8 (2)	3/4 (2)	9/16 (2)	1 (2)	**2 (2)**	3/4 (2)	3/4 (12)	7/8 (2)	1 1/2 (2)	5/8 (2)	3/4 (1)	2 (2)	**2 (2)**	7/8 (2)	9/16 (4)
27.100% cotton	**2 ½ (6)**	**2 (2)**	1/2 (12)	7/16 (4)	1/2 (15)	5/8 (2)	5/8 (2)							1 (2)	7/8 (2)							**2 (26)**	**2 1/2 (5)**		

Appendix 2. Mockup Smoldering Test Maximum Char Length (inch) (continue)

Fabric	UFAC batting (top)/ Interliner V under + foam				Interliner V (top)/ UFAC batting under +foam				Interliner D + foam				Interliner T + foam				Interliner D + UFAC batting + foam				Interliner T + UFAC batting + foam				Cotton batting	cotton+poly batting
	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P	T	T
6.Cotton twill	1/2 (13)				**4 (1)**																					
24.Cotton velvet (TB117+)	3/4 (1)				**5 (1)**				1 1/2 (2)	**1 7/8 (2)**	3/4 (24)	1/2 (24)	**2 1/2 (4)**	**2 1/2 (26)**	1 1/4 (2)	1/2 (24)		5/8 (1)				**3 1/2 (1)**			**2 1/2 (5)**	**4 (13)**

Bold number blocks – Still smoldering at 45 minutes

Char length direction
1 Vertical up
2 Vertical down
3 Horizontal out
4 Horizontal in
5 Side left
6 Side right

Appendix 3 (a)
Mockup Smoldering Test Average Foam Weight Loss (%)

Fabric	Foam U	Foam T	foam Y	foam P	UFAC batting	Interliner S + foam				Interliner M + foam				Interliner V+ foam				Interliner L + foam				Interliner O + foam			
					Foam U	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P
1.Acetate/cotton	0.6	0.2		1.3																					
2.Cotton print	0.1	0.1		1.1																					
3.Acrylic/PET/ olefin	0	0.1																							
4.Cotton corduroy	0.2	0.5																							
5.Rayon/PET/ cotton	0	0	0	0.1		0.2	0	0.1	0.2					0	0	1.1	0.2					0.4	0.3		
6.Cotton twill	0	**1.0**	0.1	0.2	0	0.2	0.4	0.3	0.5	0.4	0.4	0.6	0.2	0.2	0.5	0.3	0.2	0	**2.5**	0.2	0.4	**1.0**	**10.7**	1.5	0.8
7.Cotton/rayon chenille	**1.5**	**16.4**	**2.1**	1.1	**0**	**10.3**	**12.4**	**4.8**	**1.9**	**10.2**	**16.3**	**7.4**	**1.6**	**6.9**	**19.1**	**3.8**	**2.5**	**6.2**	**20.5**	**3.3**	**3.0**	**19.5**	**15.2**	**5.1**	**1.6**
8.Cotton/rayon chenille (FR backcoated)	**2.7**	**3.3**	0	0	0	**0.8**	**6. 8**	**0**	**2.5**	**3.2**	**3.5**	0.4	**0.2**	**5.0**	**4.6**	**1.3**	**3.5**	**8.4**	**13.8**	**0.1**	**3.6**	**1.4**	**24.6**	0.3	**1.3**
9.Cotton twill (FR backcoated)	**4.1**	**0.7**	0.7	0																					
10.cotton/PET (1/2 FR backcoated)	0.1	0.1																							
11.Cotton, FR (pyrovatex)	0.2	0.2																							
12.Rayon/PET/ cotton (FR backcoated)	0	0																							
13.Cotton/nylon sateen, FR treated (proban)	0.2	0.2																							
14. wool	0.2	0																							
15. silk	0	0.2																							
16.Std. FR polyester	0	0.1																							
17.100% nylon (FR backcoated)	0.1	0																							
18.Rayon/nylon (FR backcoated)	0	0																							
19.100% cotton	0.2	1.4	0.7	0.7																					
20.Acrylic/PET/ olefin	0.2	0.2																							
21.100% olefin	0.1	**0.9**	0.3	0.6	0	0	**0**		0.5					**0**	**0**	**0.4**	0.6					**0.1**	**1.6**		
22.100% olefin	0	0																							
23.Cotton twill	0.3	**3.8**	0.2	0.3	0	**3.3**	**8.9**	**1.2**	0.8	**2.0**	**3.0**	**0.9**	**0.7**	**4.8**	**8.6**	**0.9**	**1.0**	**5.3**	**7.9**	**2.1**	0.8	**4.5**	**12.3**		
24.Cotton velvet (TB117+)	0.9	**11.2**	0.4	0.4	0	**2.2**	**6.5**	0.1	1.0	**0.9**	0.5	**0.2**	0.3	**3.8**	**11.0**	1.3	0.9	**1.7**	**2.2**	1.0	0.9	**7.7**	**14.1**	**3.2**	1.1
25.UFAC type I	0	0.6	2.0	0.4	0	0.1	0.3	0.6	0.7	0.3	0.3	0.4	0.5	0.1	0.4	0.9	0.8	0	0.3	0.7	0.3	0.4	**10.4**	1.6	0.9
26.UFAC type II	0	0.8	0	0.3	0	**0.3**	0.2	0.8	0.7	0.5	0.4	0.5	0.4	0.3	**0.7**	0.9	1.8	0.3	0.4	0.2	0.5	1.4	**9.5**	1.4	1.0
27 100% cotton	**10.3**	**1.5**	0	0.7	0	0	0							0	0							**3.7**	**12.8**		

Mockup Smoldering Test Average Foam Mass Loss (%) (continue)

Fabric	UFAC batting (top)/ Interliner V under + foam				Interliner V (top)/ UFAC batting under +foam				Interliner D + foam				Interliner T + foam				Interliner D + UFAC batting + foam				Interliner T + UFAC batting + foam				Cotton batting	cotton+poly batting
	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P	U	T	Y	P	T	T
6.Cotton twill	0.4				**1.7**																					
24.Cotton velvet (TB117+)	0.1				**19.9**				1.4	**2.7**	1.1	1.1	**5.4**	**7.7**	1.6	1.0		0.2				**0.8**			**20.9**	**7.8**

Bold number blocks – Still smoldering at 45 minutes

Appendix 3(b)
Mockup Smoldering Test Average Foam Weight Loss (%)

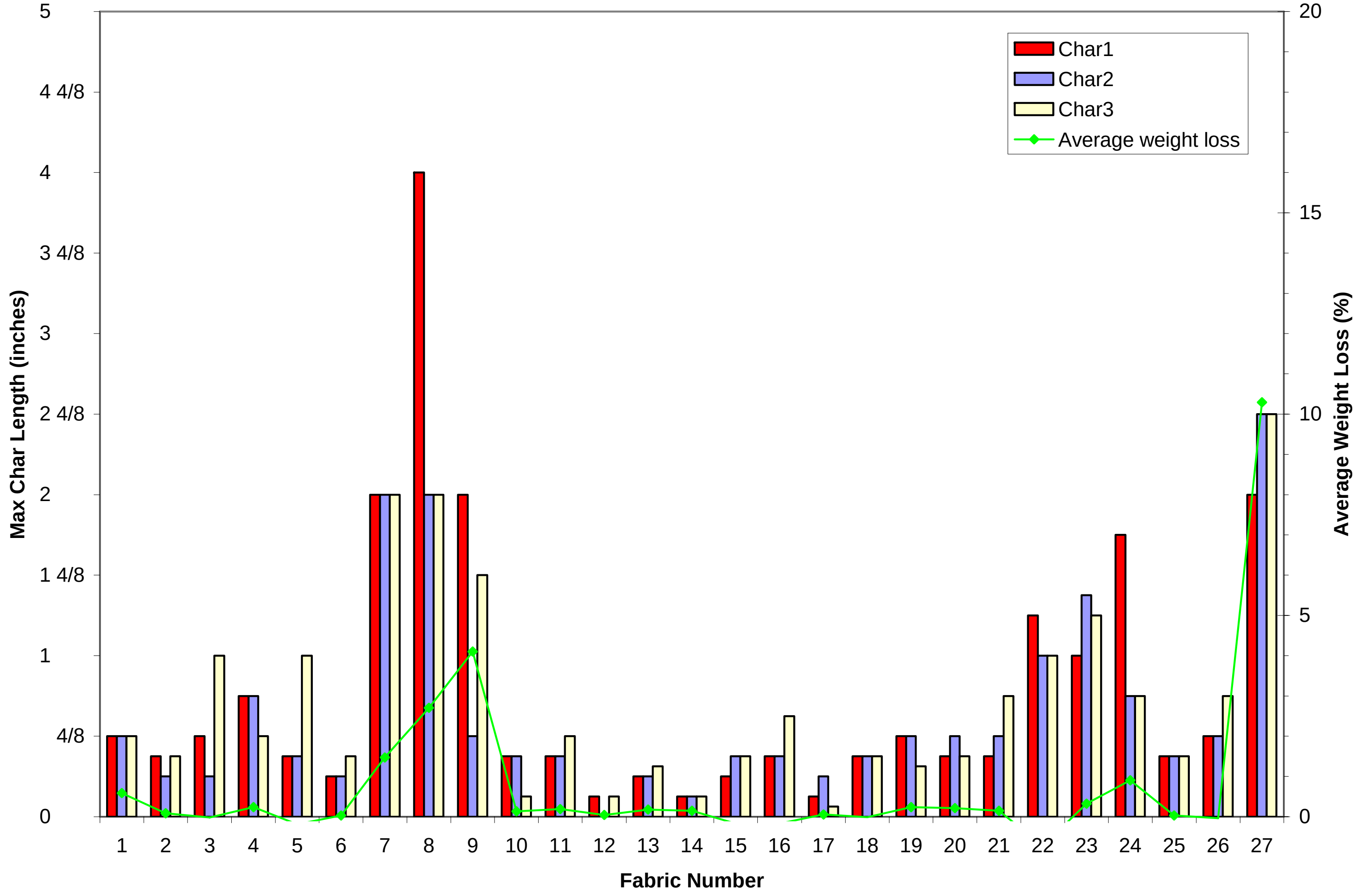
Fabric		Foam								Foam T				
										Interliner				
Type	Weight (oz/yd^2)	T	Z	J	K	L	N	R	S	G	W	$	¢	K
24. 100% cotton velvet	10.0	**11.2**	**8.1**	0.9	1.3	1.4	0.1	**9.5**	**12.5**	0.6	**14.2**	1.0	0.7	**26.4**
31. Leather1	7.0	**3.4**												
32. Leather2	12.0	**5.2**												
33. 100% wool	12.5	0.4												
34. Vinyl	21.5	0												
35. 100% olefin	10.0	1.0												
36. 100% olefin	10.0	0.8												
37. 100% polypropylene	11.5	0.8												
38. Cotton/polyester	10.0	0.9												
39. Cotton/polyester	8.3	1.0												
40. Cotton/polyester	11.0	0.9												
41. Rayon/polyester	13.8	0.9												

Appendix 3(c)
Mockup Smoldering Test Average Foam Weight Loss (%)

Fabric	Test Duration (minutes)	2" Foam				3" Foam			
		T	R	Z	U	T	R	Z	U
7. cotton/rayon chenille	30	**3.93**				**7.20**	**13.11**		
	45	**16.40**			1.47	**21.40**			
24. cotton velvet	30	**4.13**	**6.83**	**13.98**	2.51	**6.78**	**13.24**	**19.55**	1.25
	45	**11.18**	**9.48**	**8.14**	0.90	**16.63**	**40.12**	**39.42**	0.70

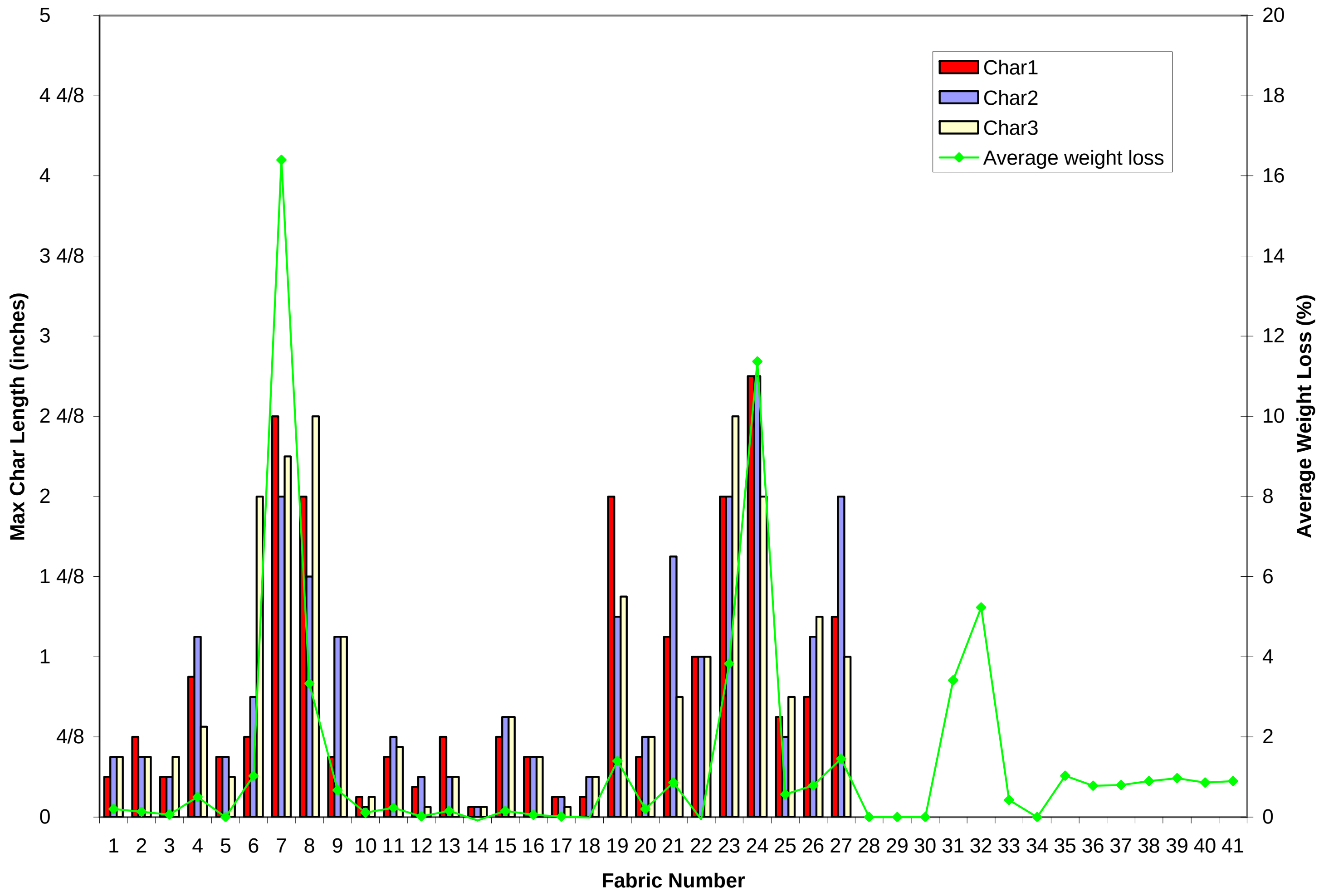
Appendix 4

Char Length and Weight Loss – Foam U, No Interliner



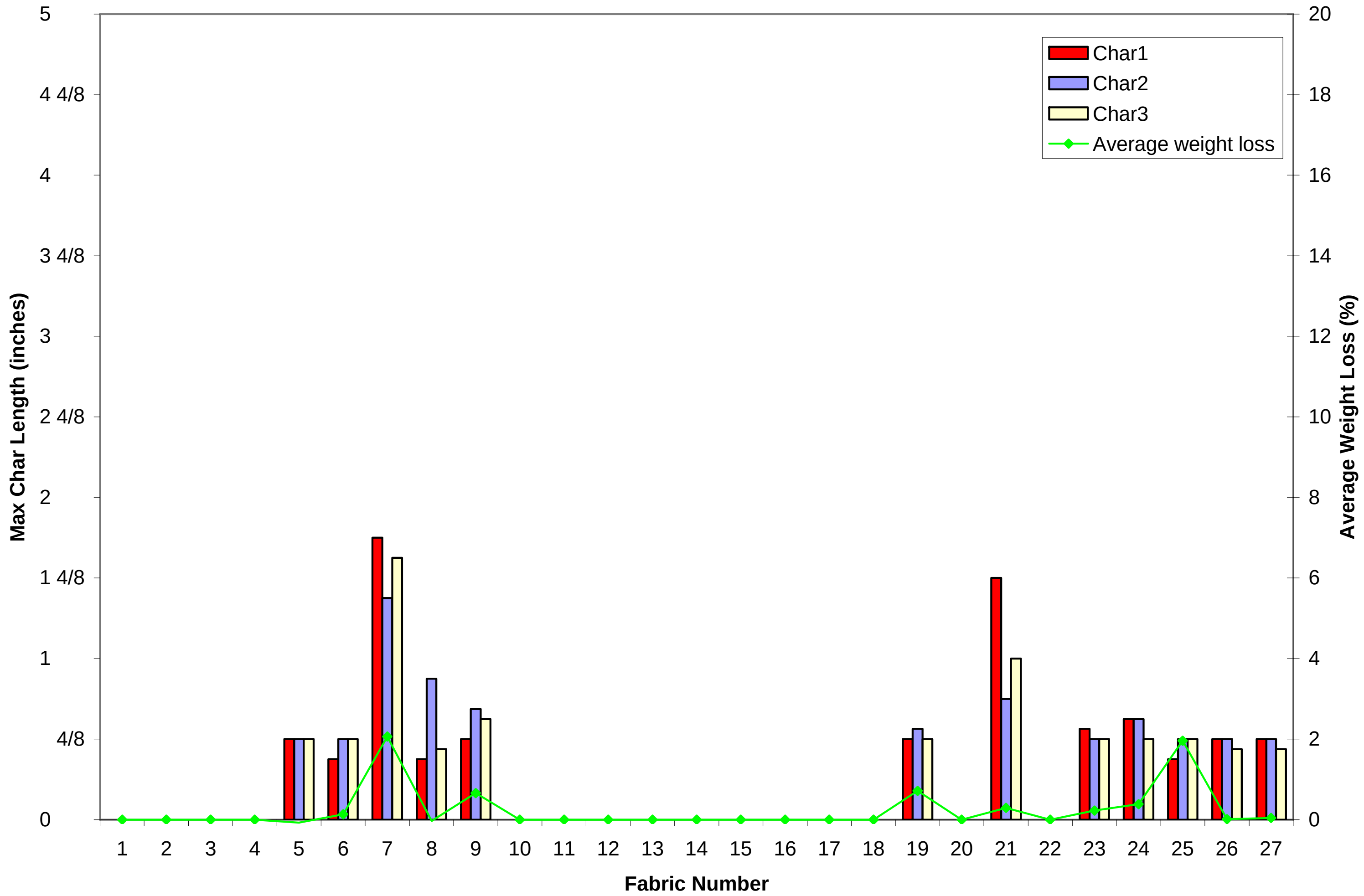
Appendix 5

Char Length and Weight Loss – Foam T, No Interliner



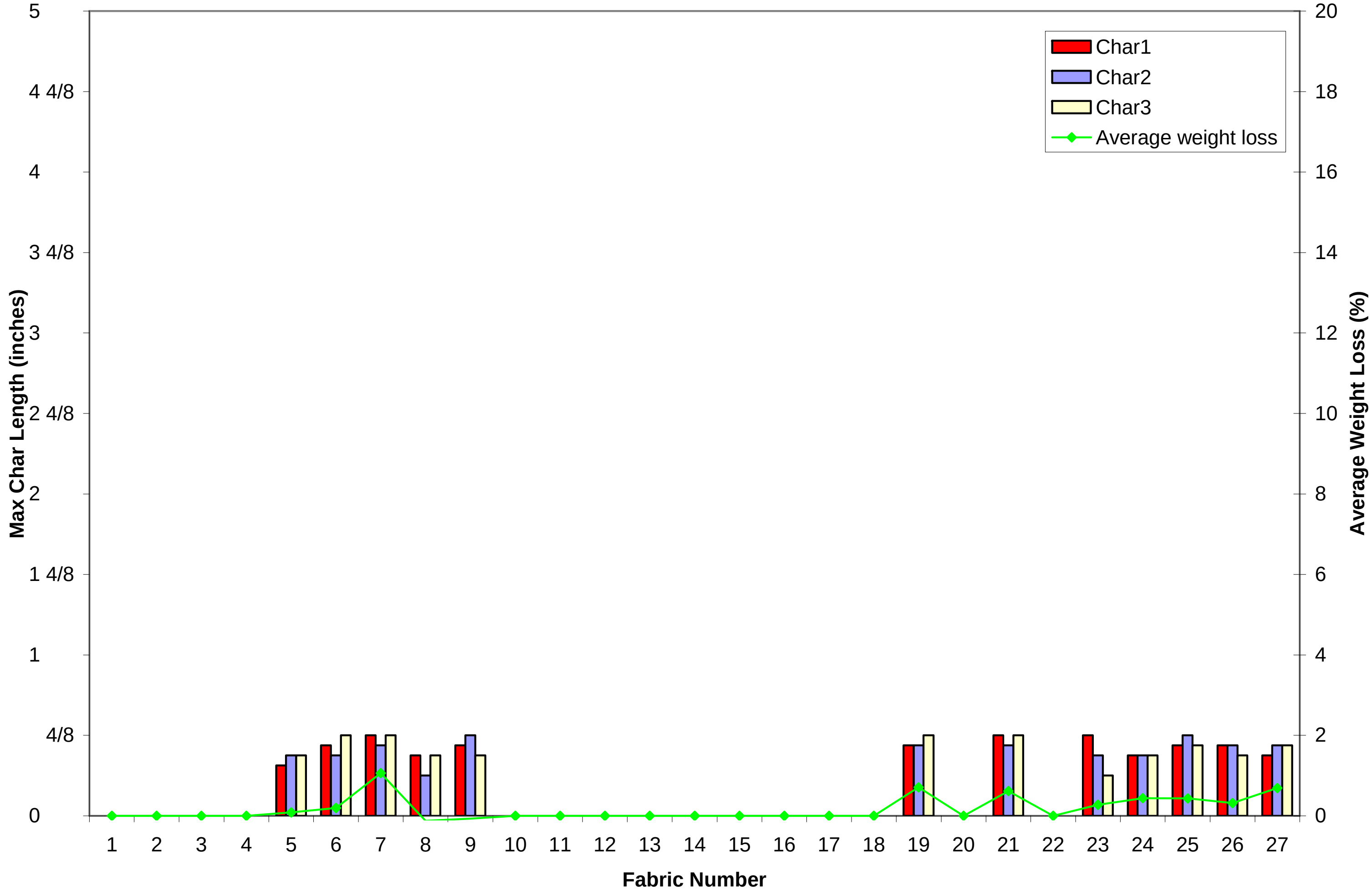
Appendix 6

Char Length and Weight Loss – Foam Y, No Interliner



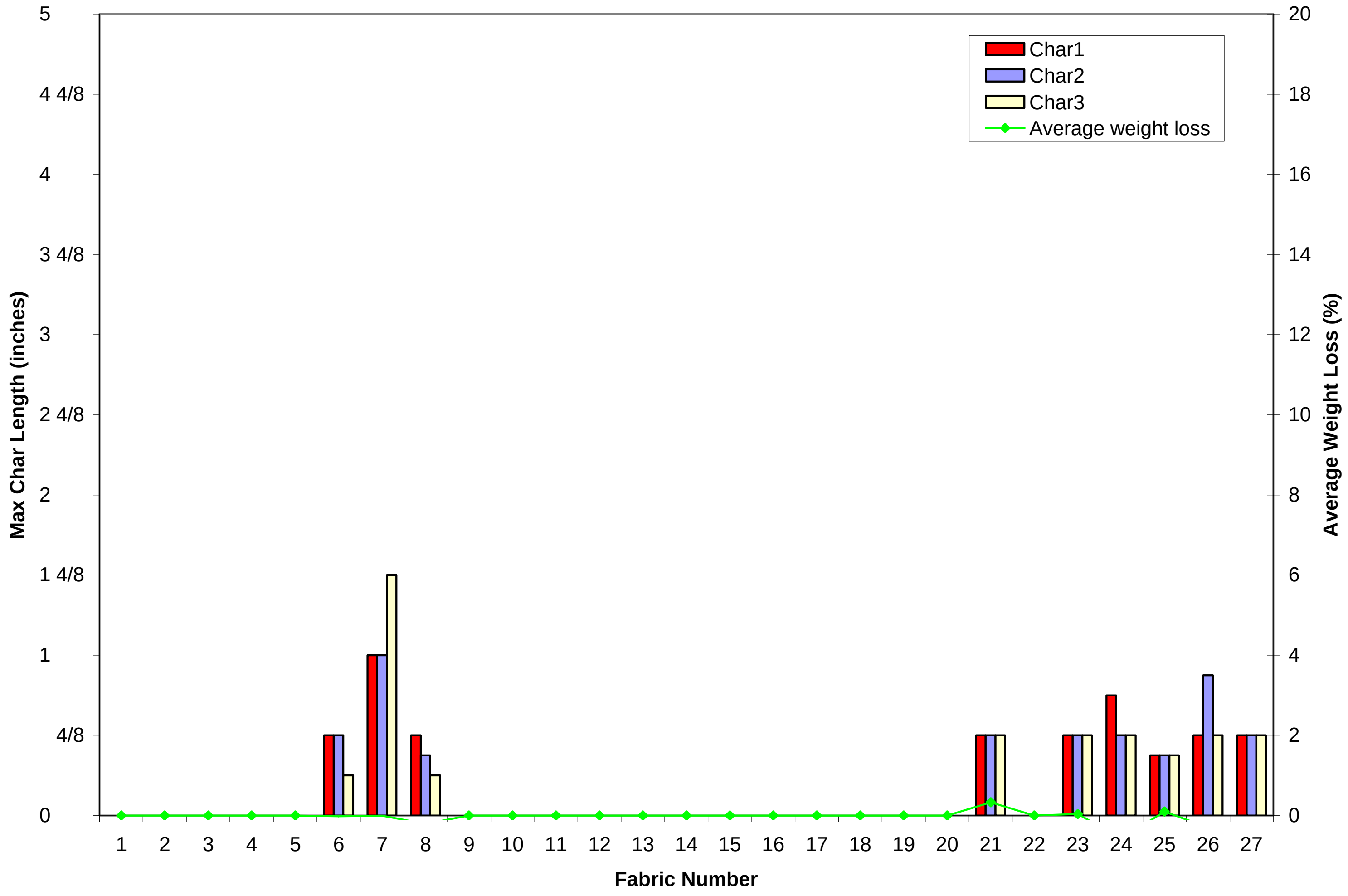
Appendix 7

Char Length and Weight Loss – Foam P, No Interliner



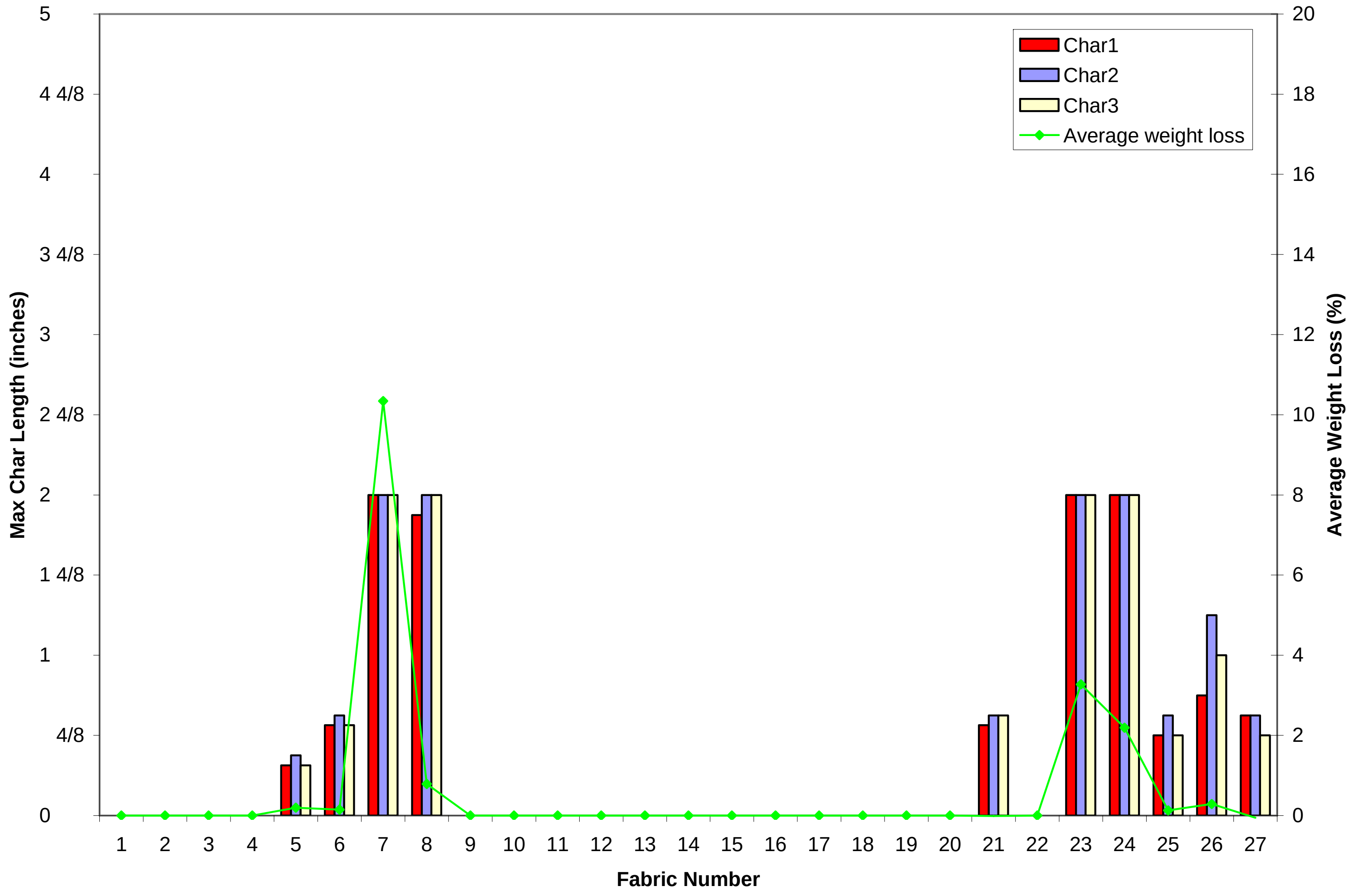
Appendix 8

Char Length and Weight Loss – Foam U, UFAC Polyester Batting



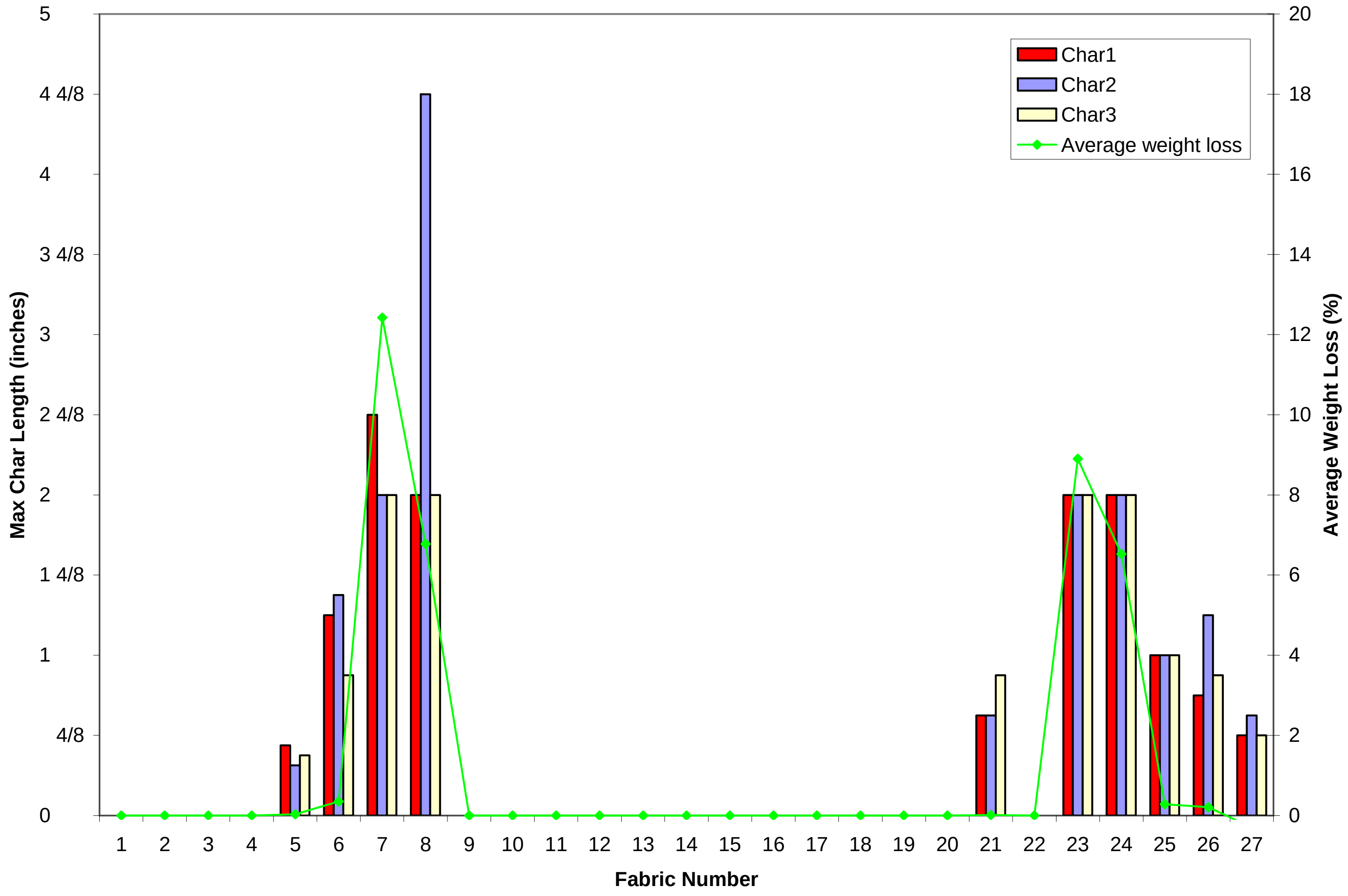
Appendix 9

Char Length and Weight Loss – Foam U, Interliner S



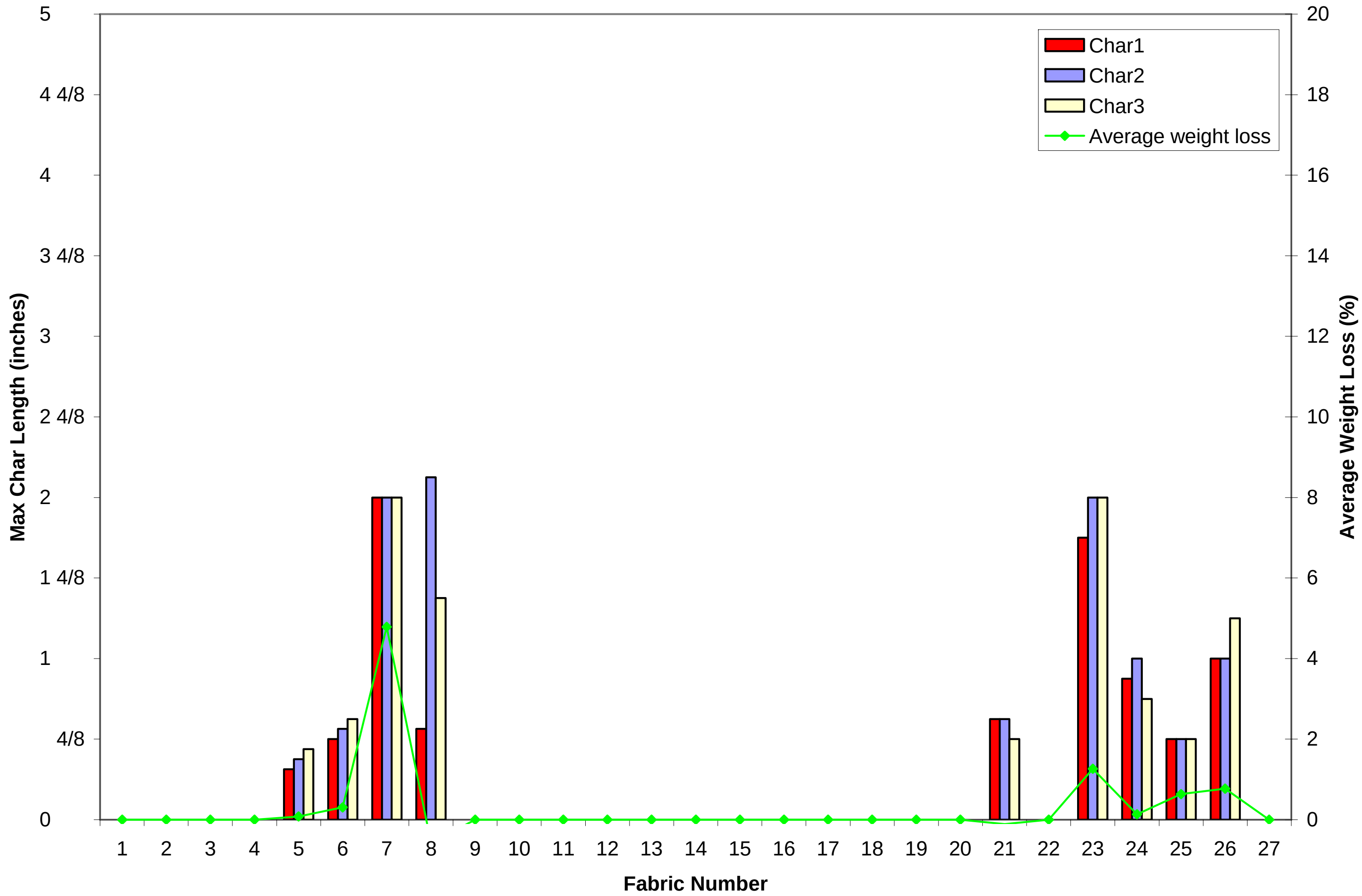
Appendix 10

Char Length and Weight Loss – Foam T, Interliner S



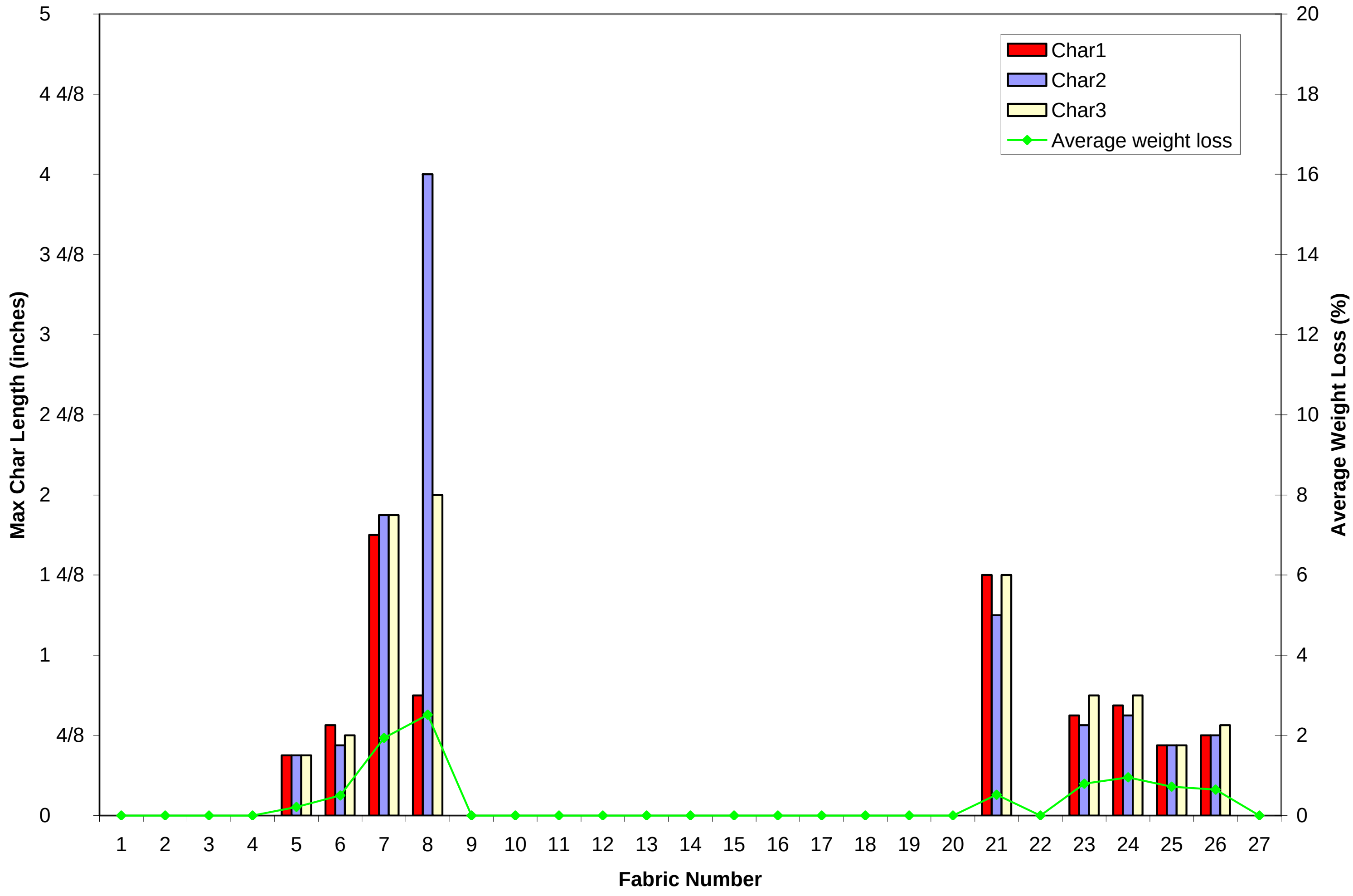
Appendix 11

Char Length and Weight Loss – Foam Y, Interliner S



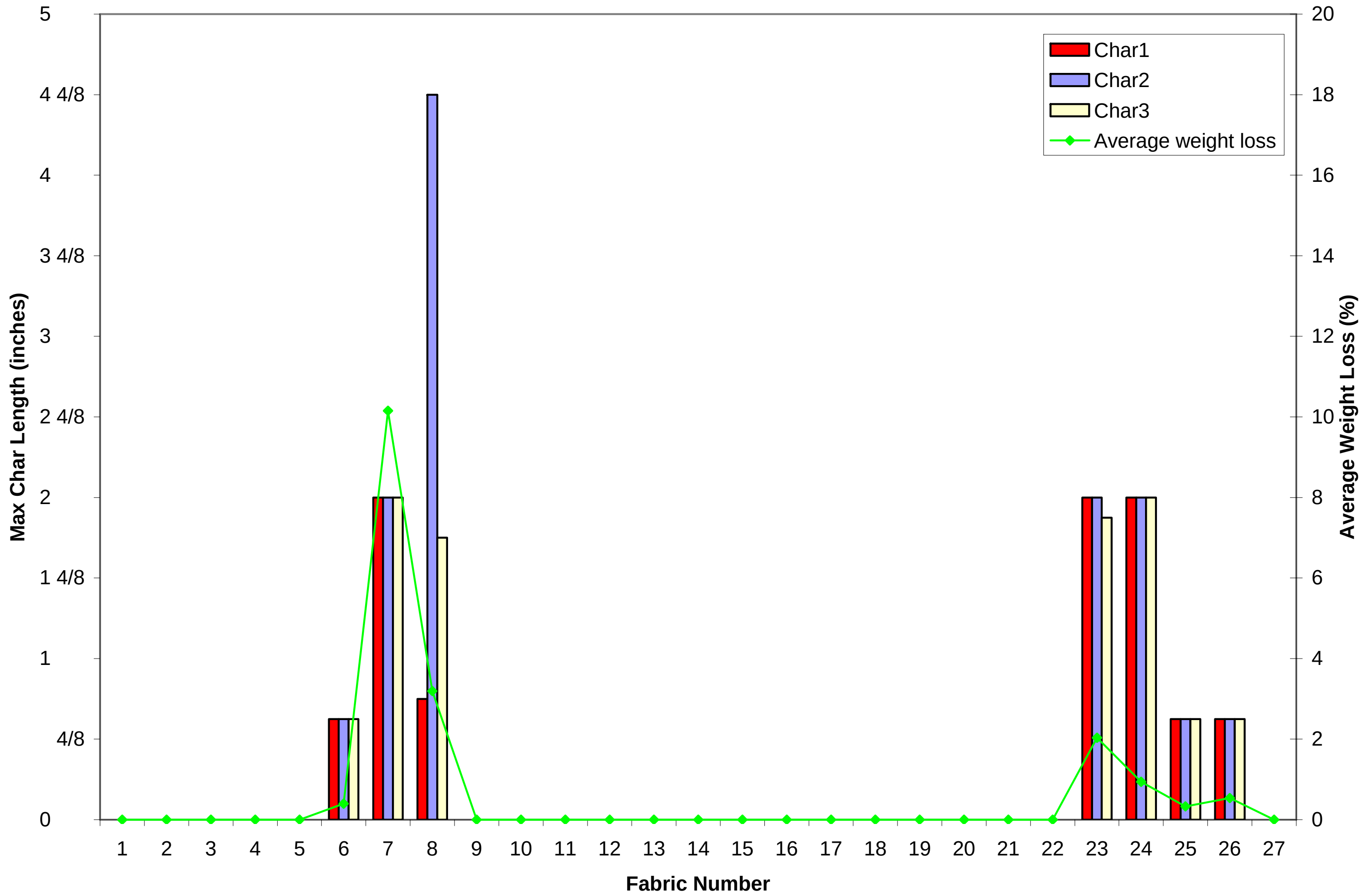
Appendix 12

Char Length and Weight Loss – Foam P, Interliner S



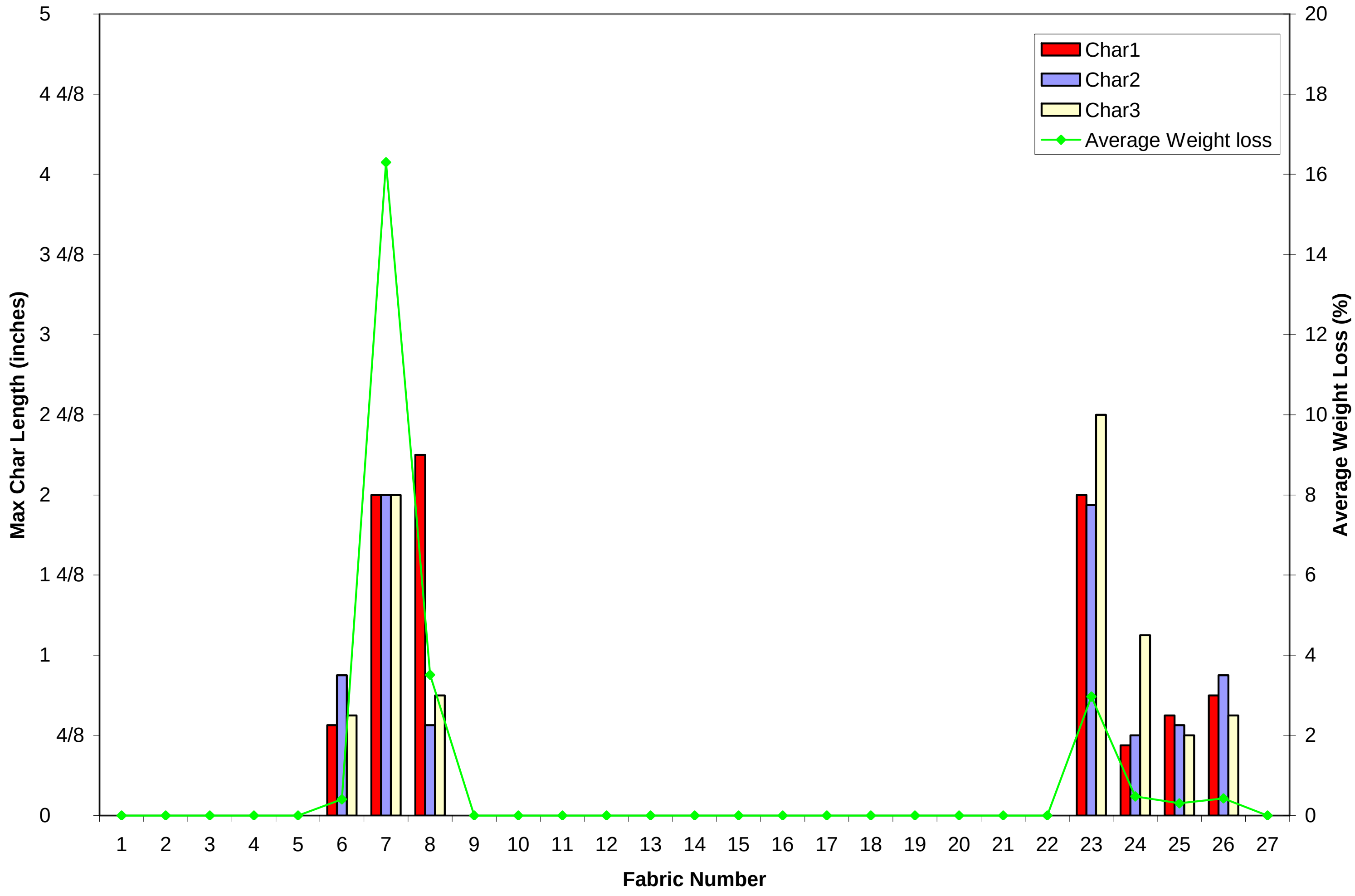
Appendix 13

Char Length and Weight Loss – Foam U, Interliner M



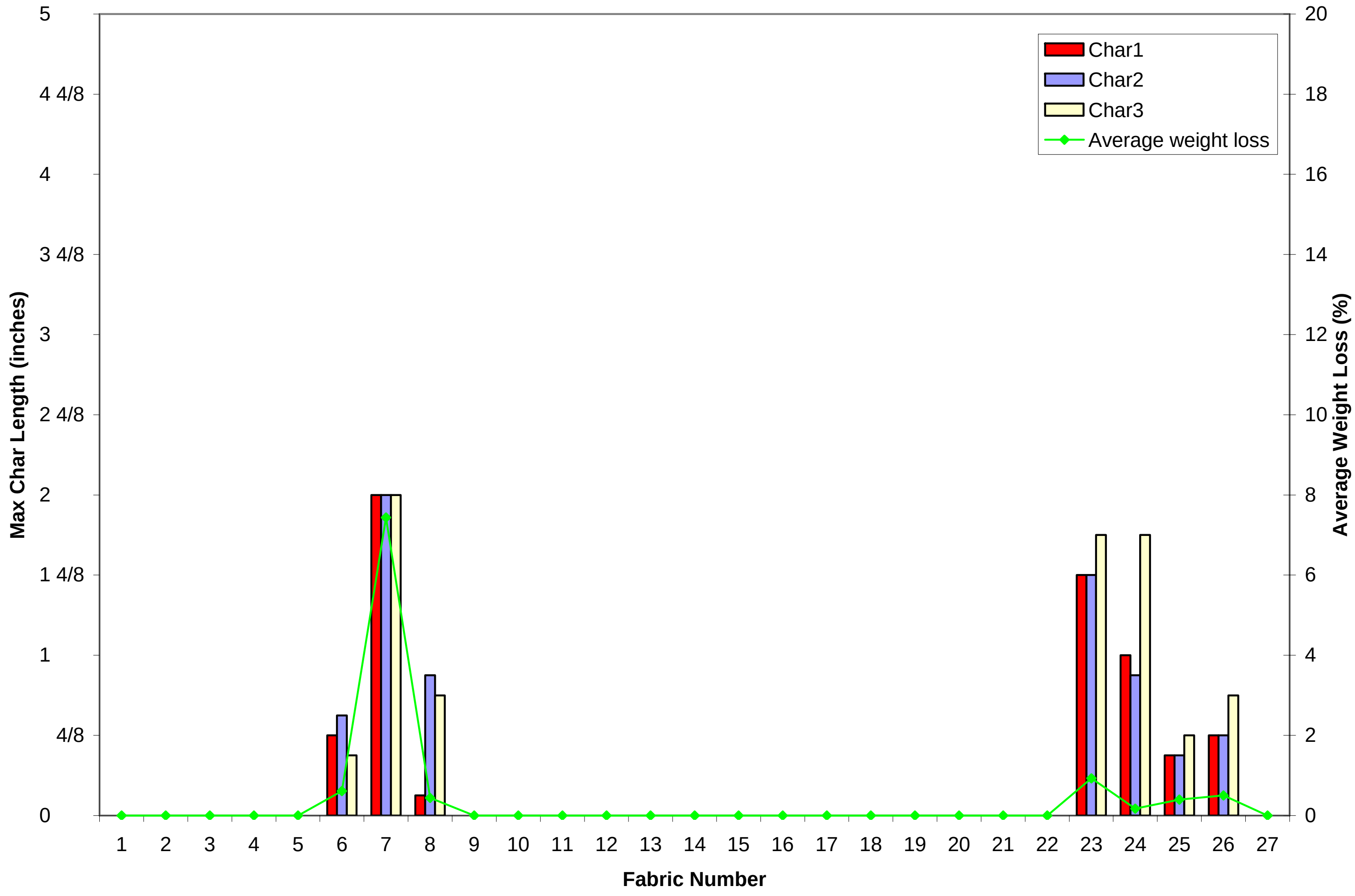
Appendix 14

Char Length and Weight Loss – Foam T, Interliner M



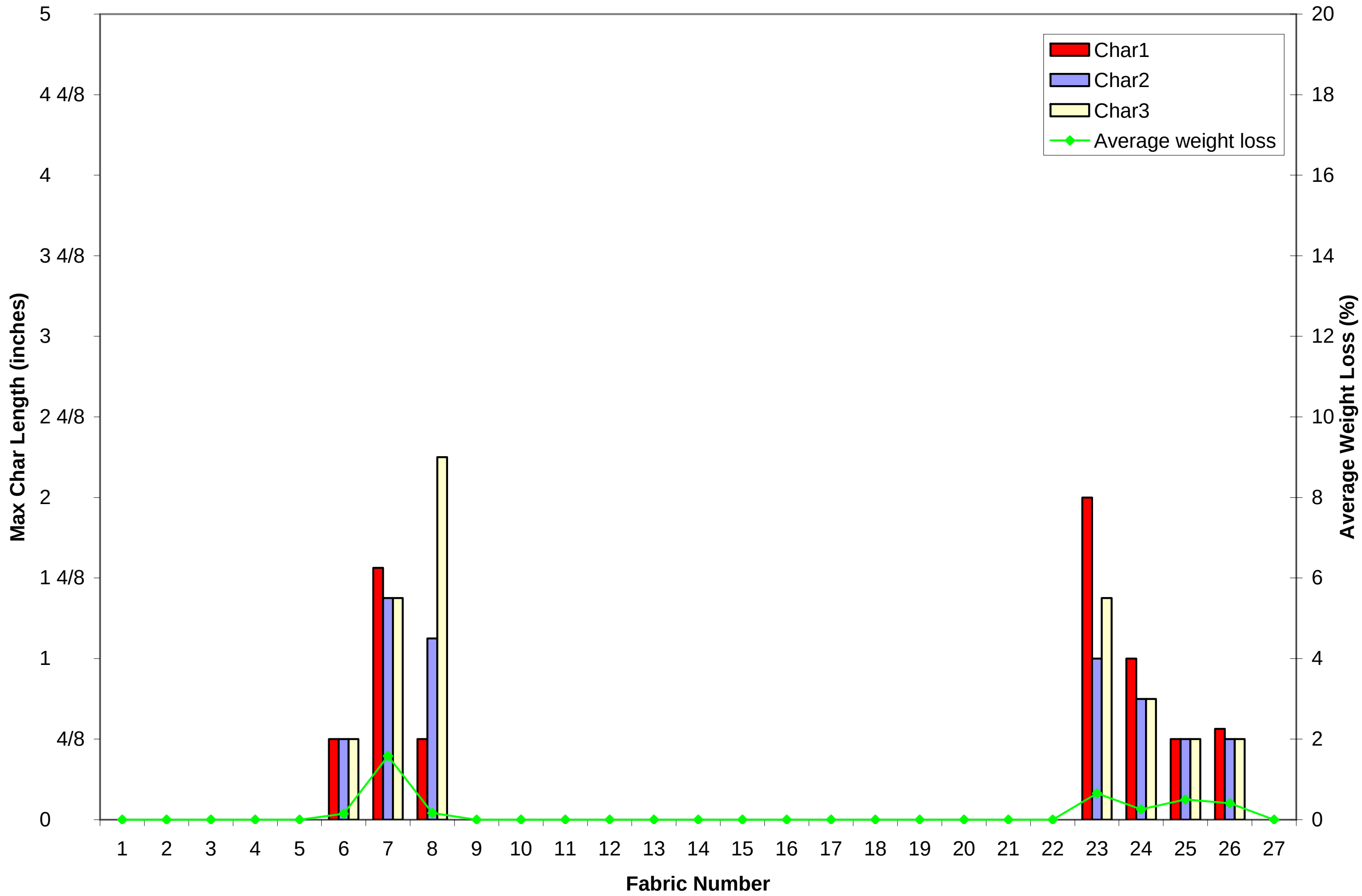
Appendix 15

Char Length and Weight Loss – Foam Y, Interliner M



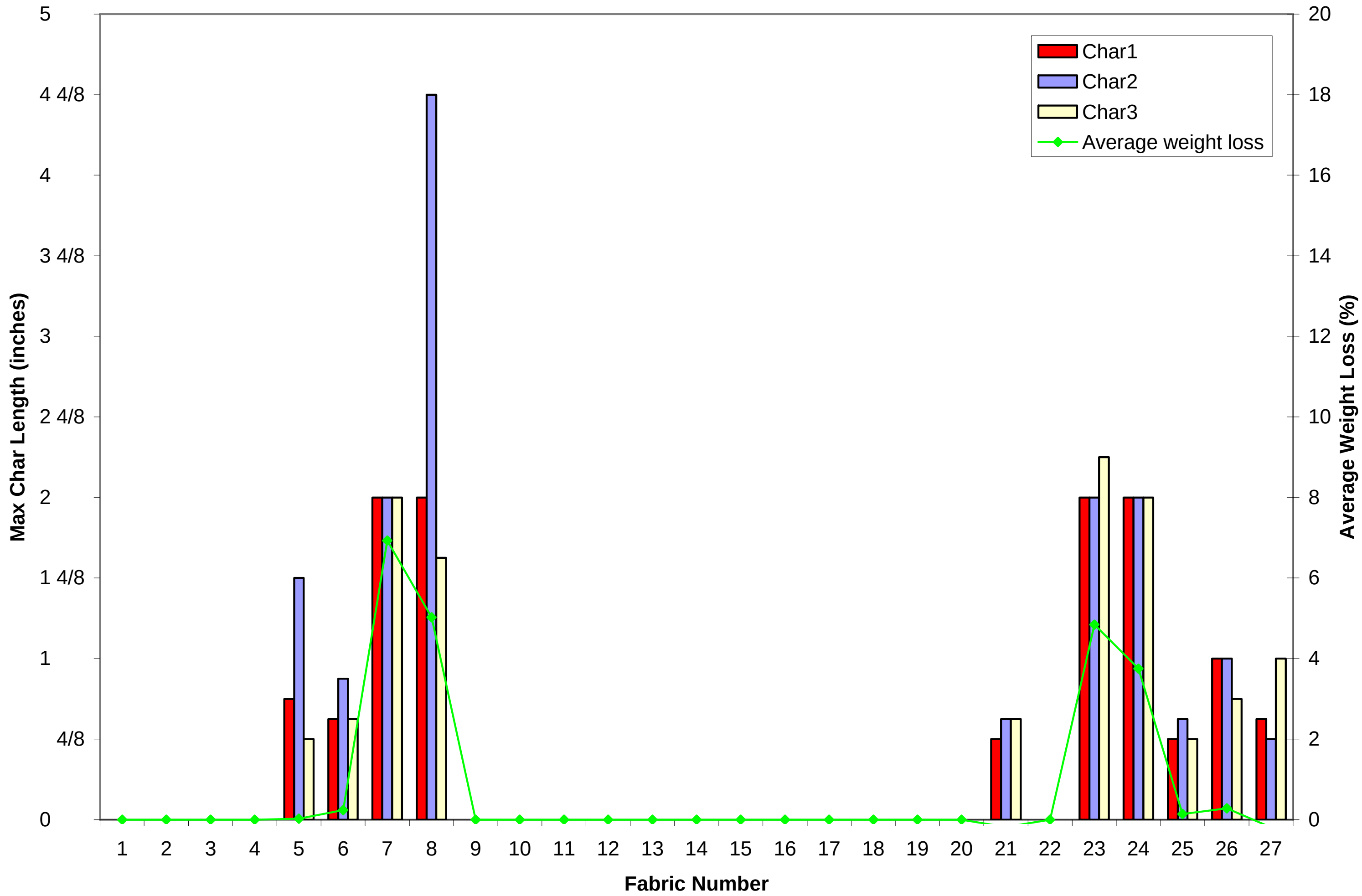
Appendix 16

Char Length and Weight Loss – Foam P, Interliner M



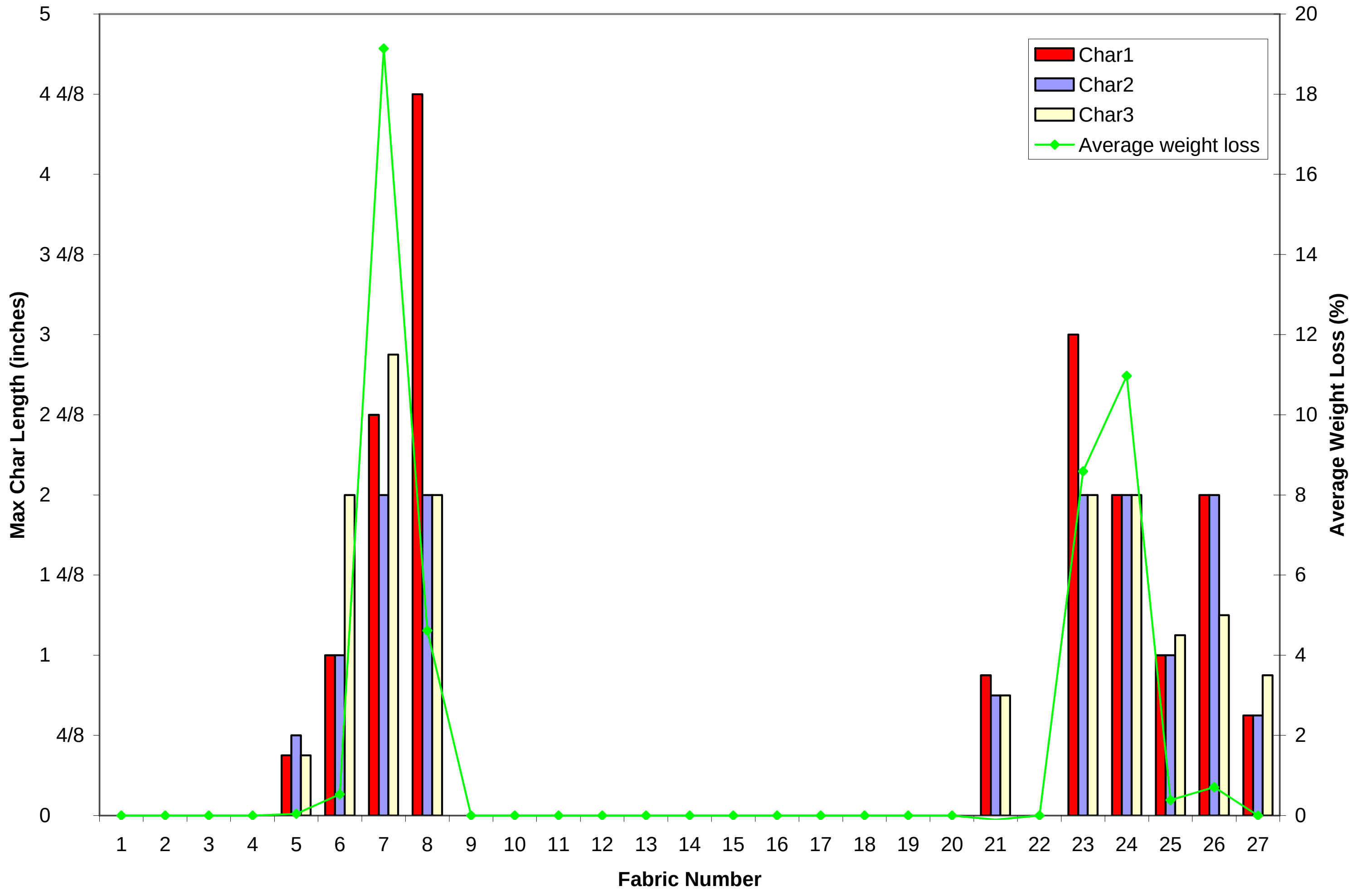
Appendix 17

Char Length and Weight Loss – Foam U, Interliner V



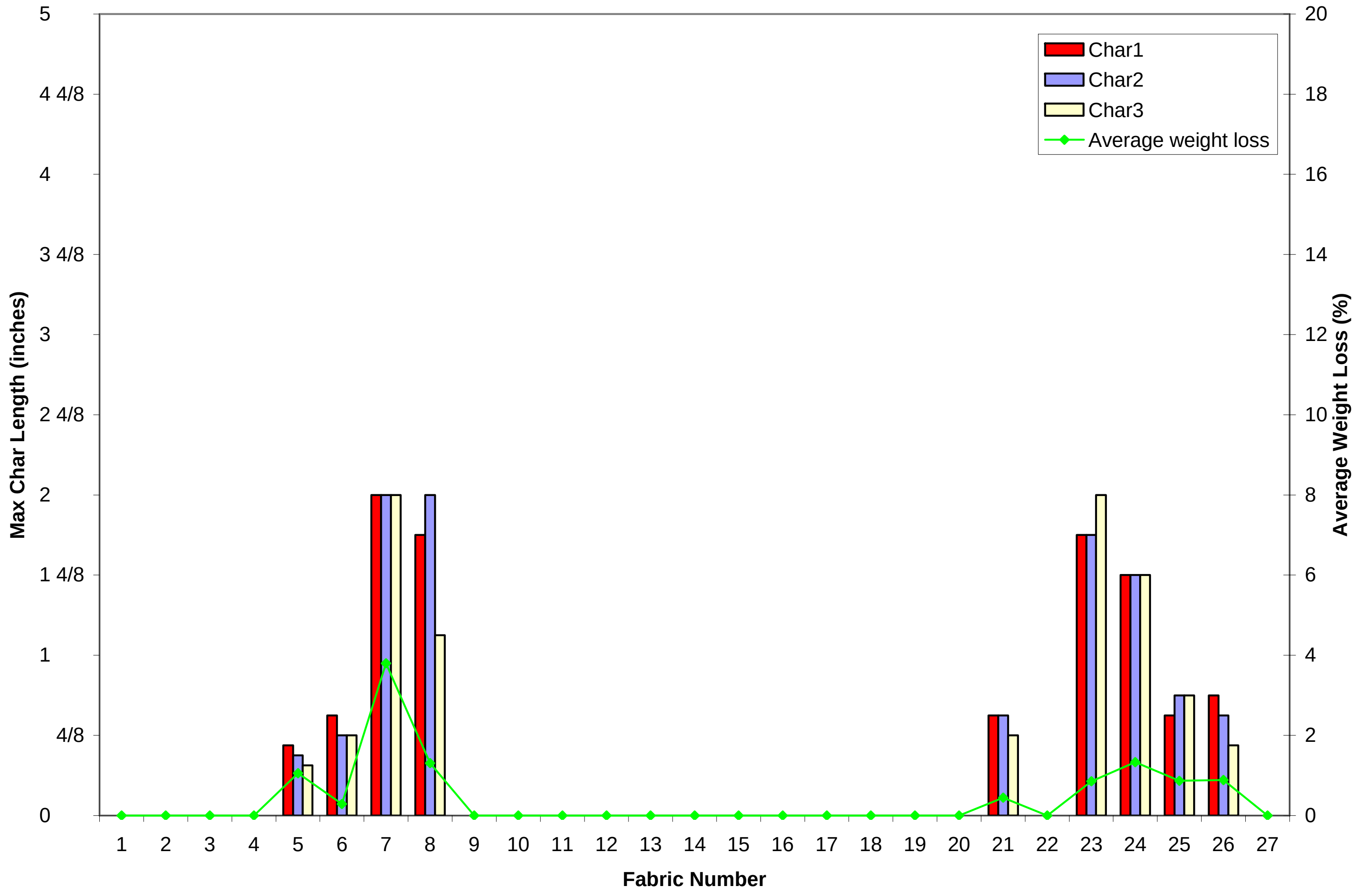
Appendix 18

Char Length and Weight Loss – Foam T, Interliner V



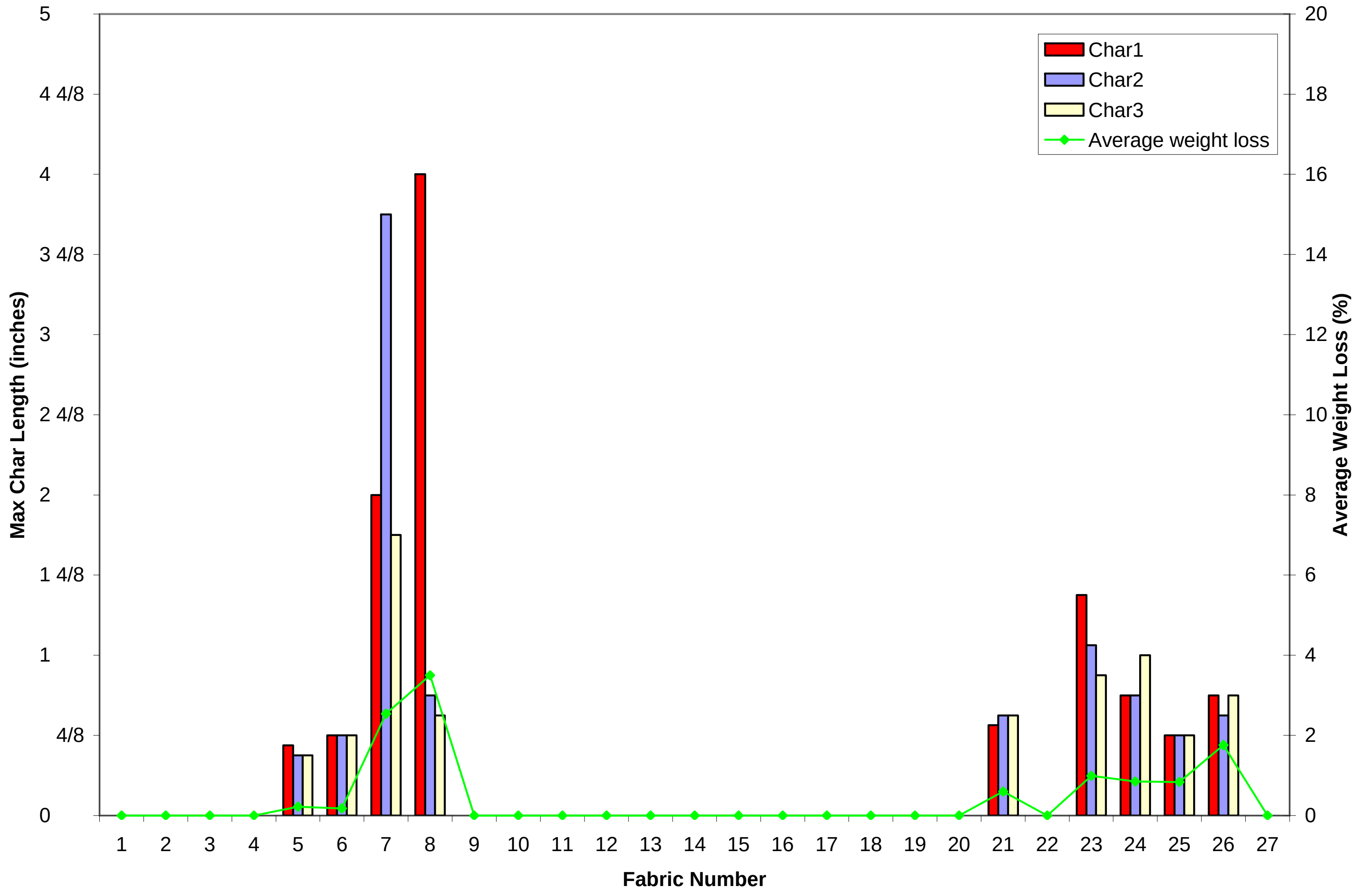
Appendix 19

Char Length and Weight Loss – Foam Y, Interliner V



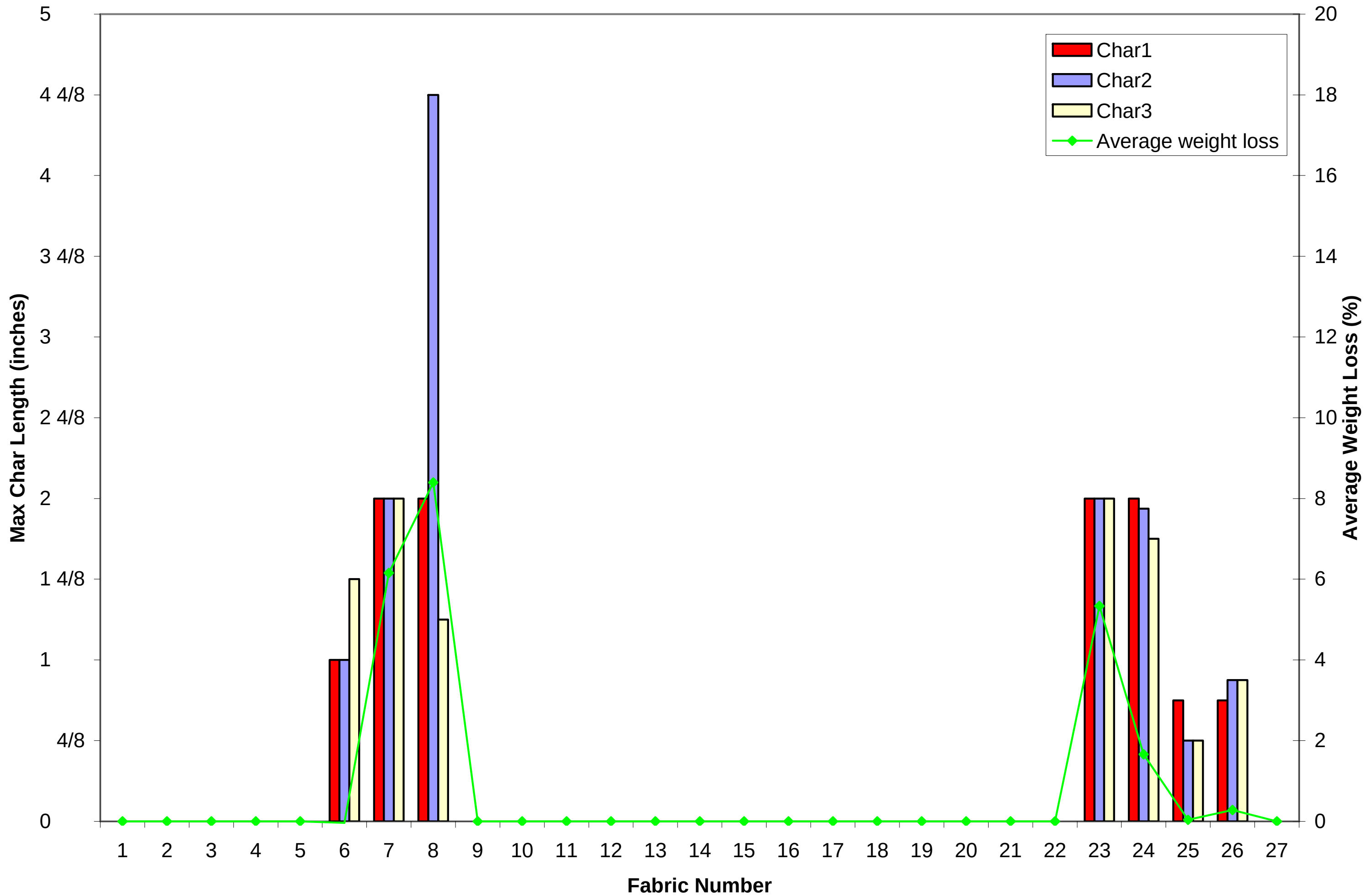
Appendix 20

Char Length and Weight Loss – Foam P, Interliner V



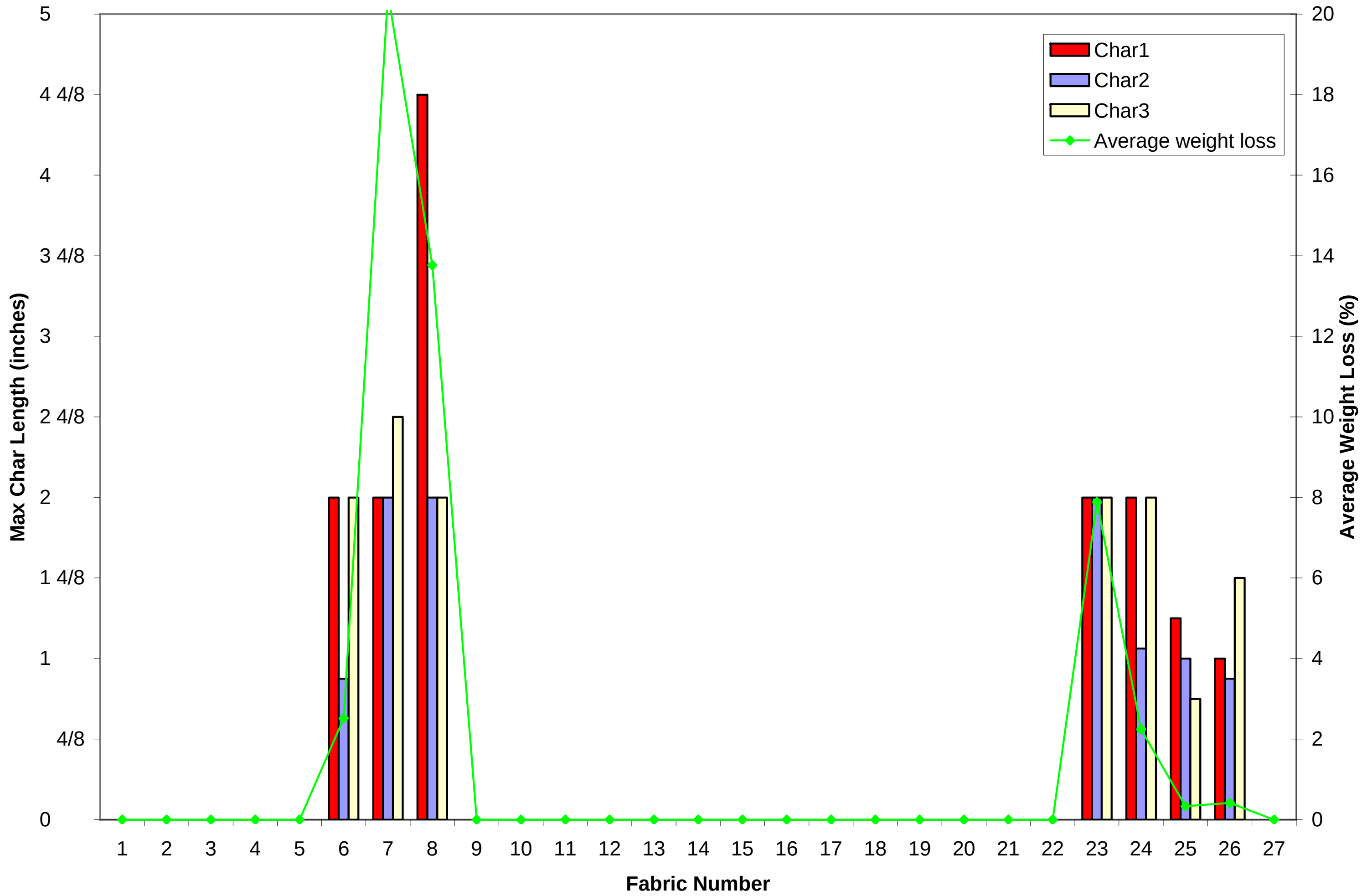
Appendix 21

Char Length and Weight Loss – Foam U, Interliner L



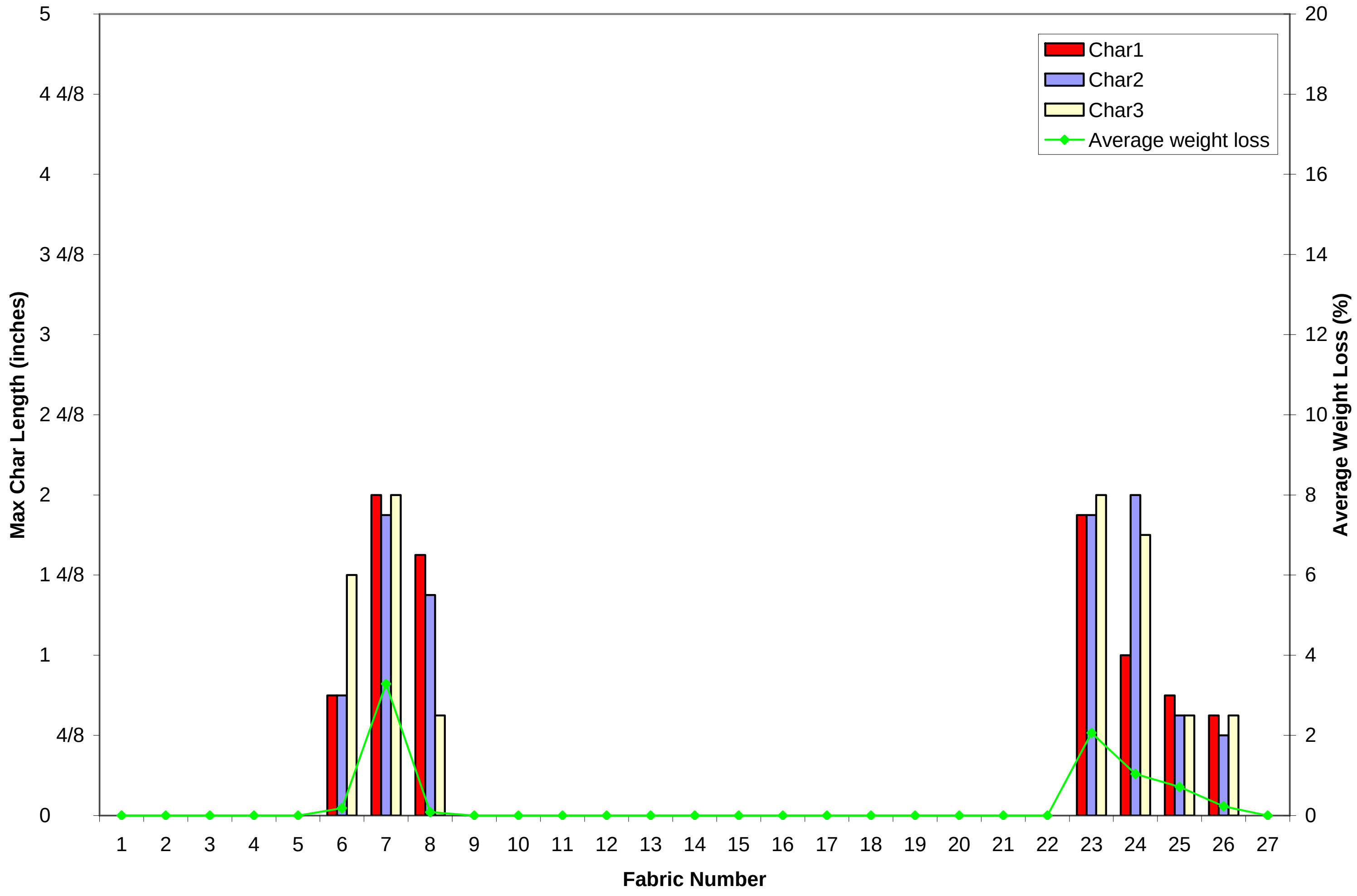
Appendix 22

Char Length and Weight Loss – Foam T, Interliner L



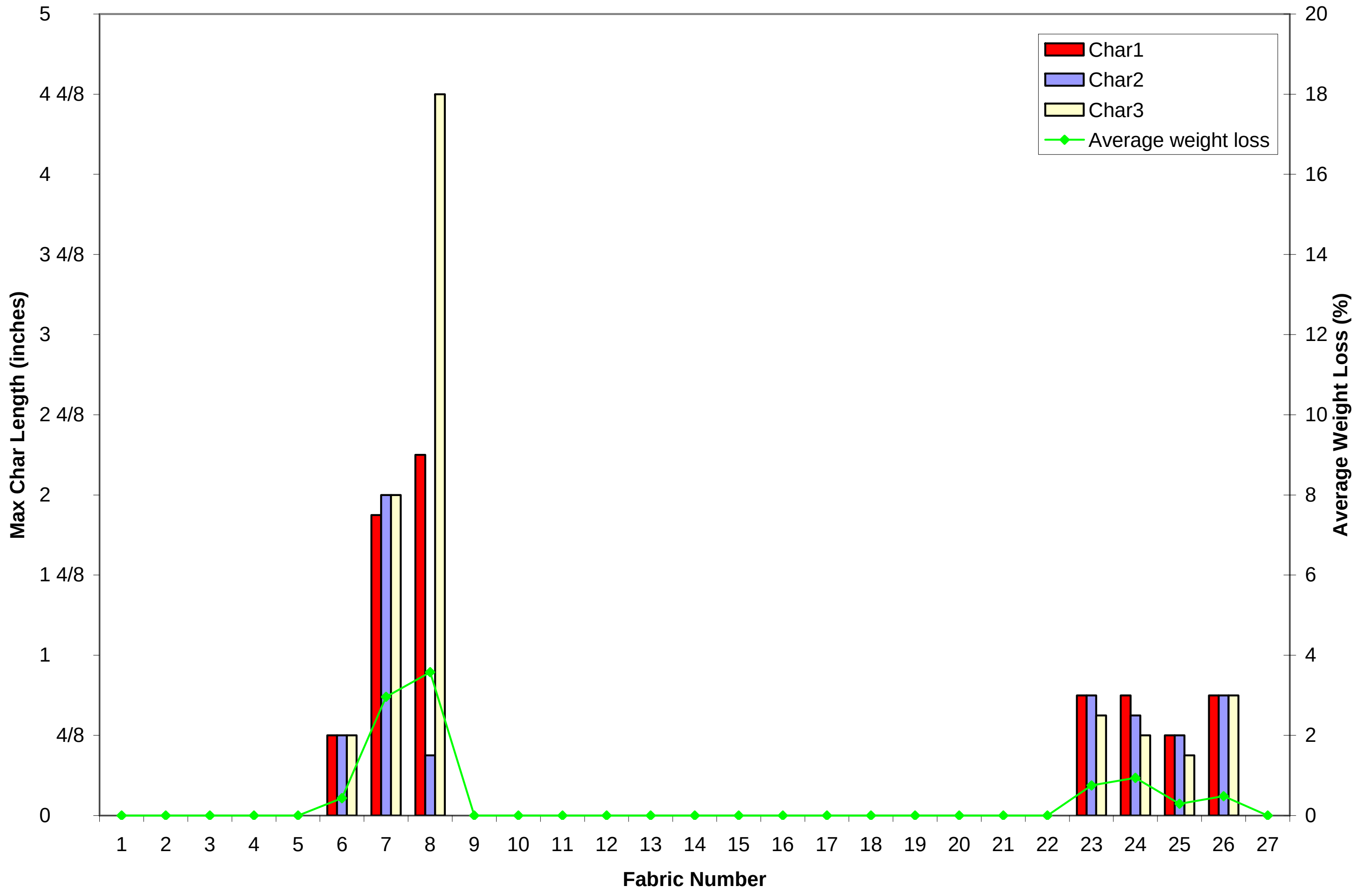
Appendix 23

Char Length and Weight Loss – Foam Y, Interliner L



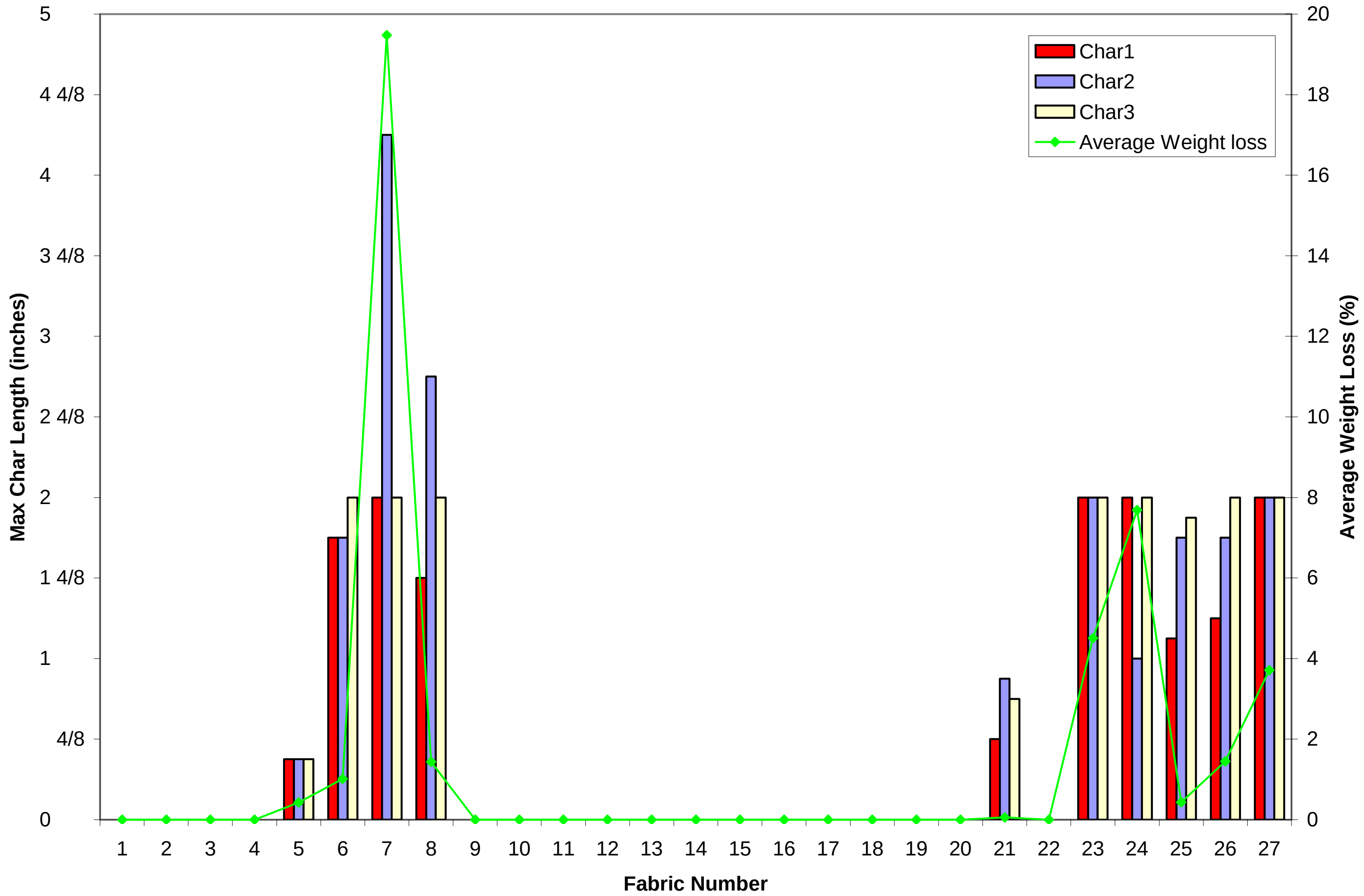
Appendix 24

Char Length and Weight Loss – Foam P, Interliner L



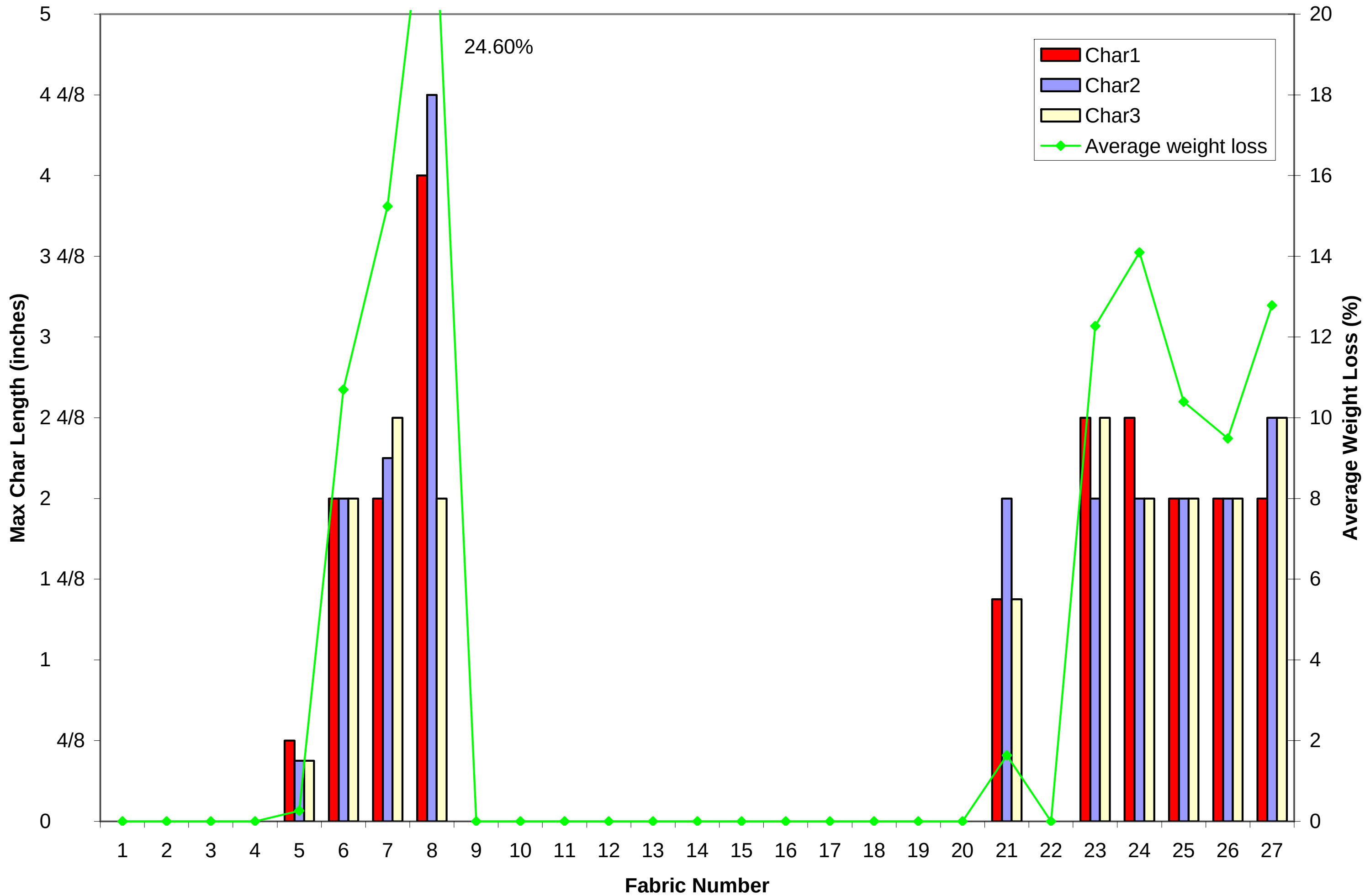
Appendix 25

Char Length and Weight Loss – Foam U, Interliner O



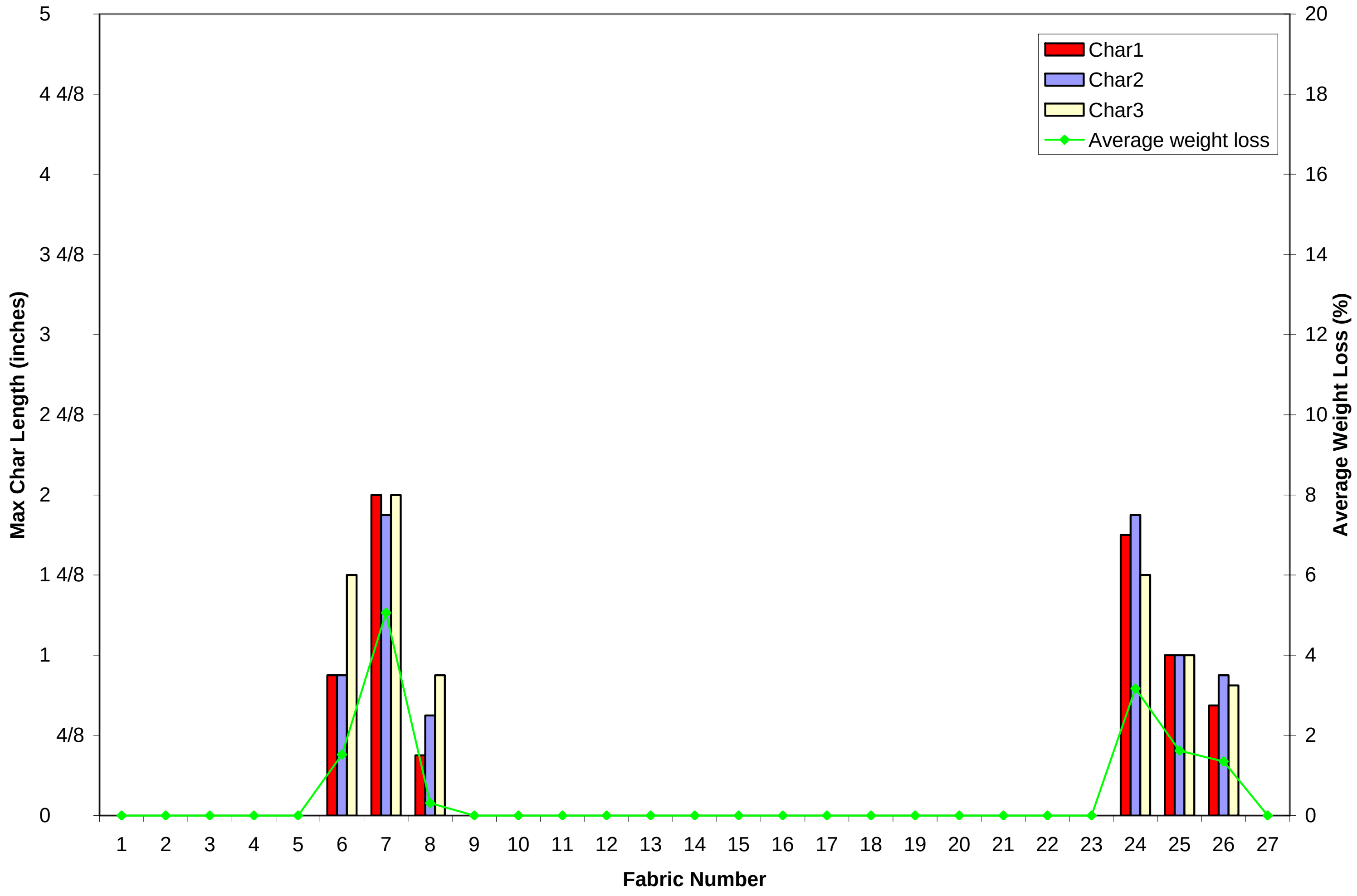
Appendix 26

Char Length and Weight Loss – Foam T, Interliner O



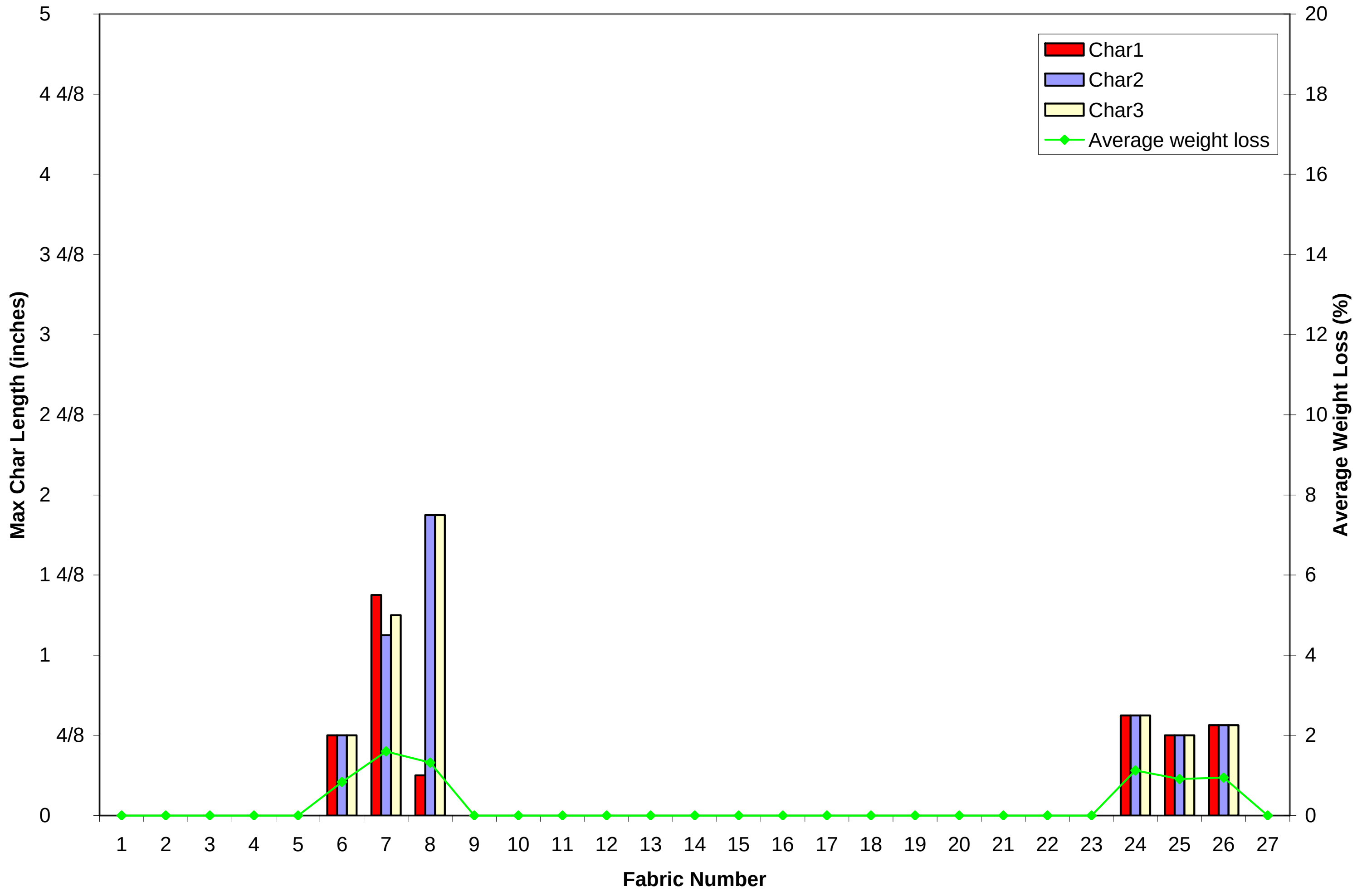
Appendix 27

Char Length and Weight Loss – Foam Y, Interliner O



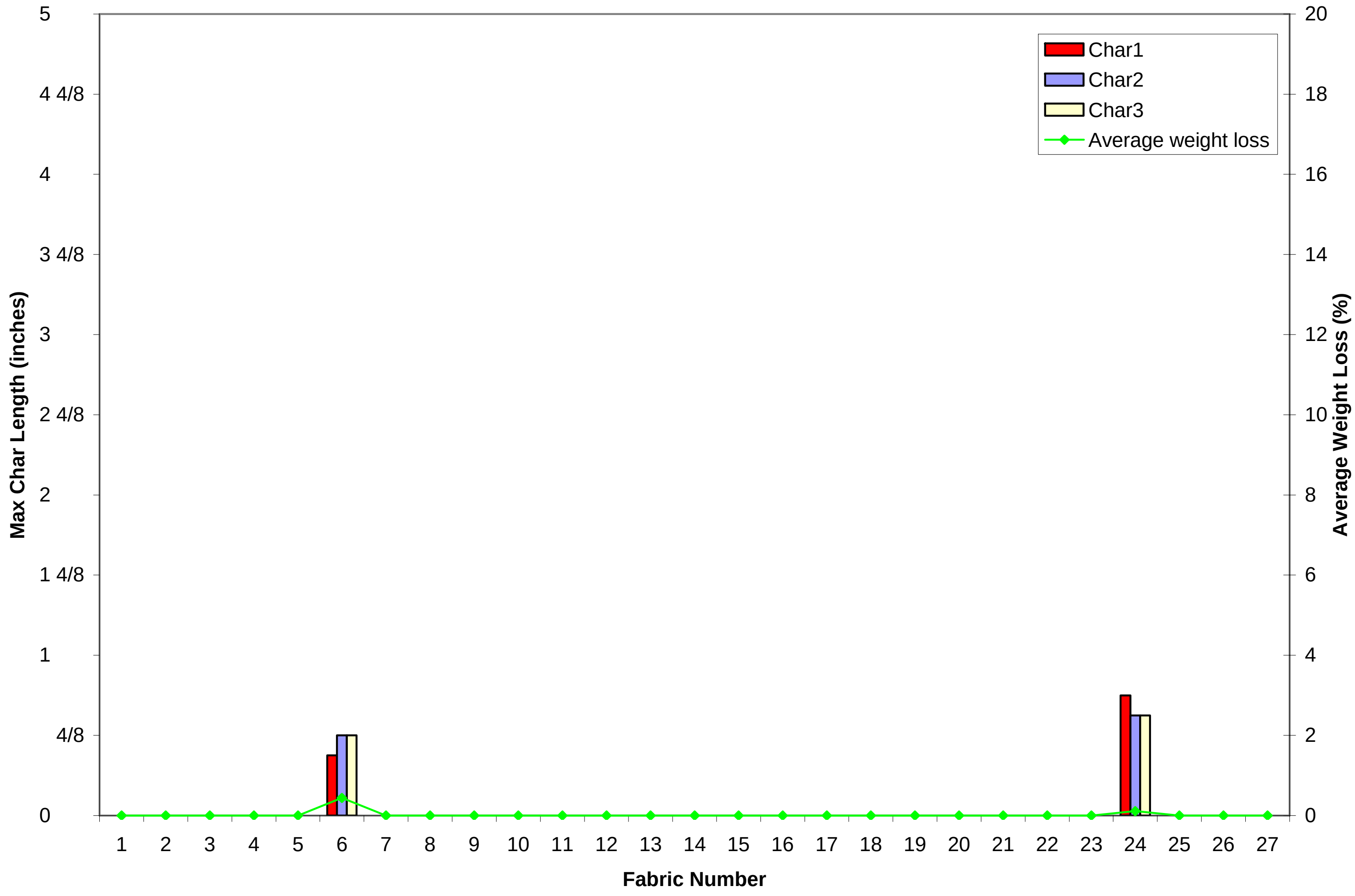
Appendix 28

Char Length and Weight Loss – Foam P, Interliner O



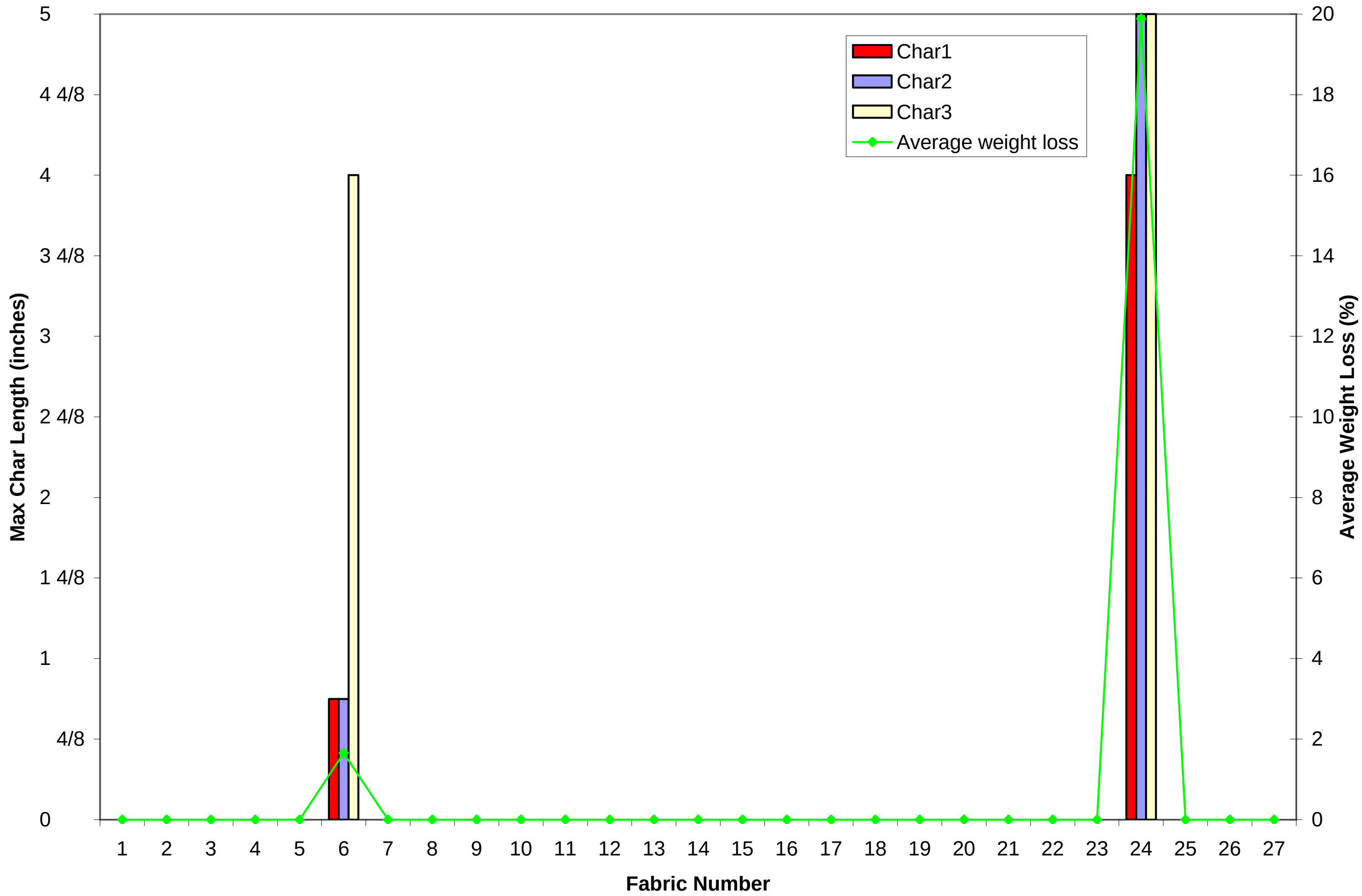
Appendix 29

Char Length and Weight Loss – Foam U, UFAC Polyester Batting/Interliner V



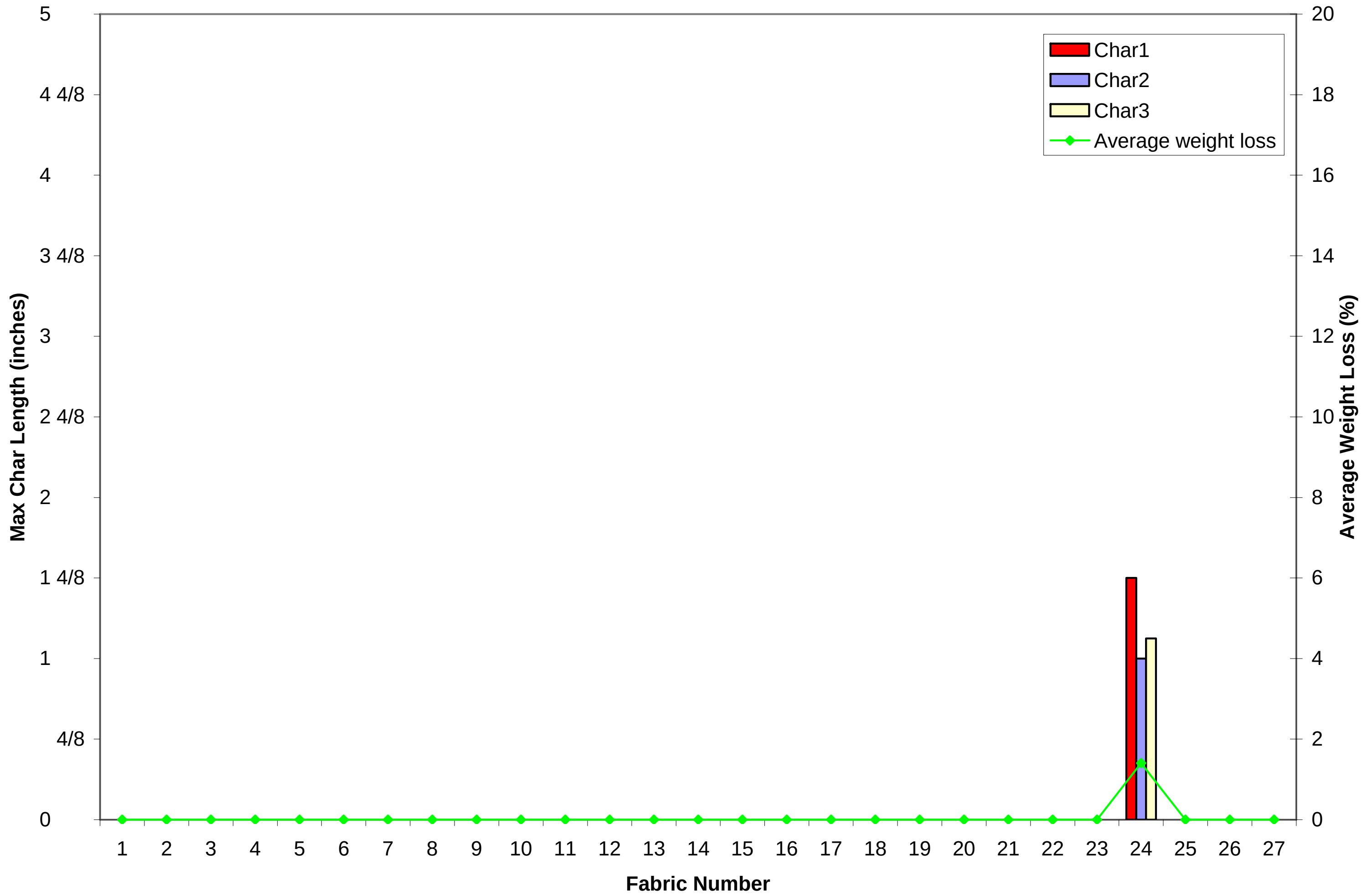
Appendix 30

Char Length and Weight Loss – Foam U, Interliner V/UFAC Polyester Batting



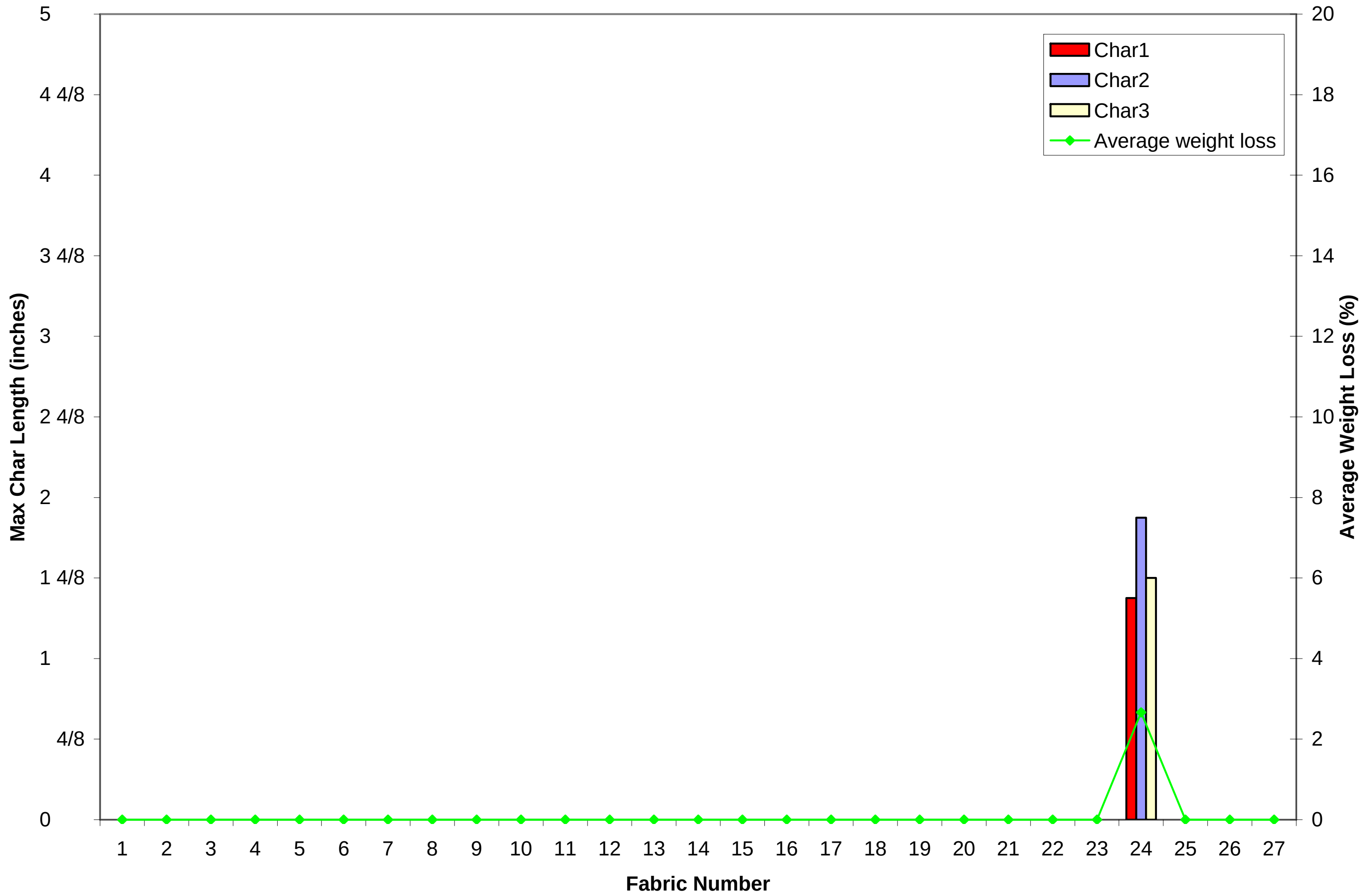
Appendix 31

Char Length and Weight Loss – Foam U, Interliner D



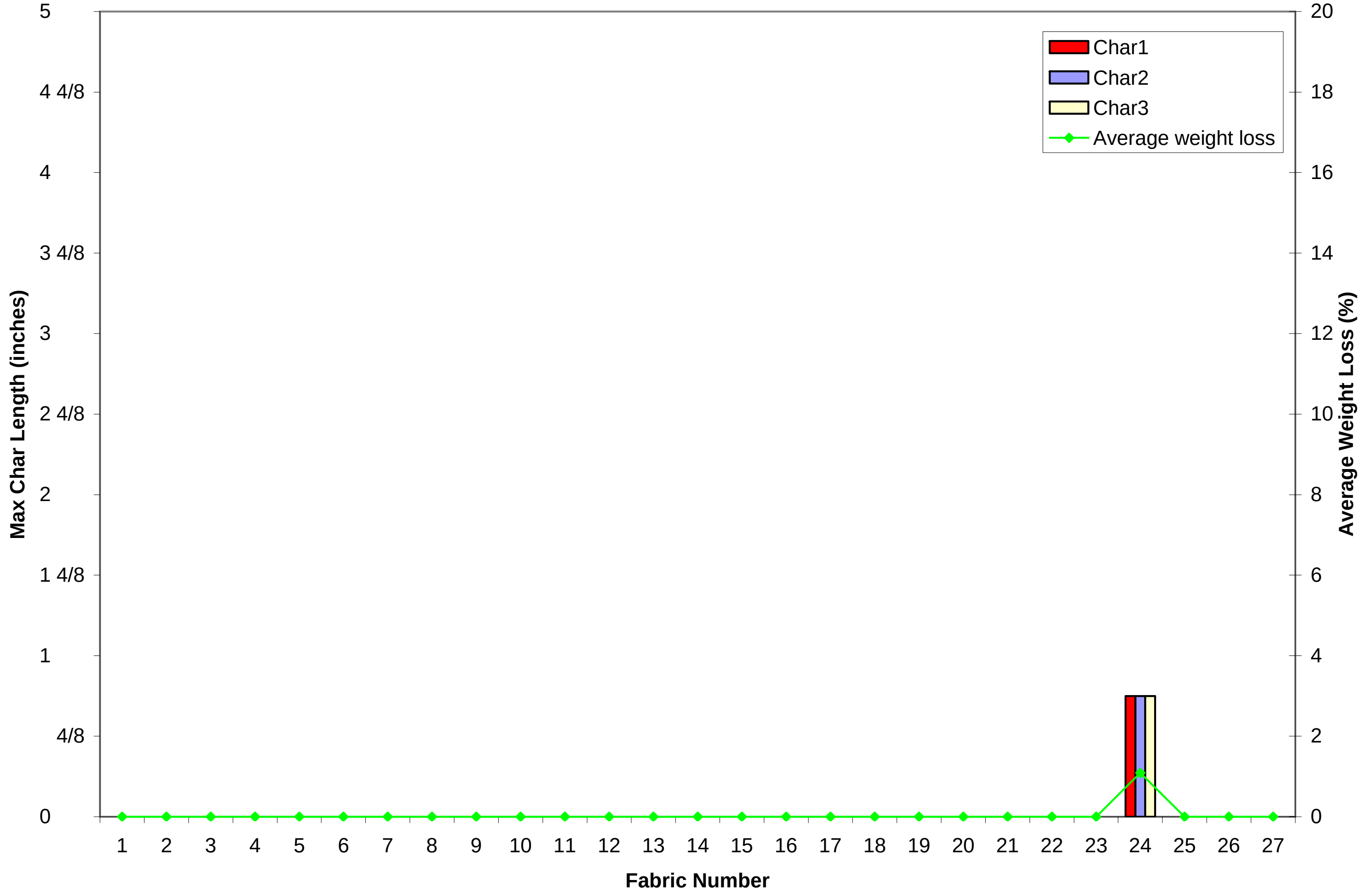
Appendix 32

Char Length and Weight Loss – Foam T, Interliner D



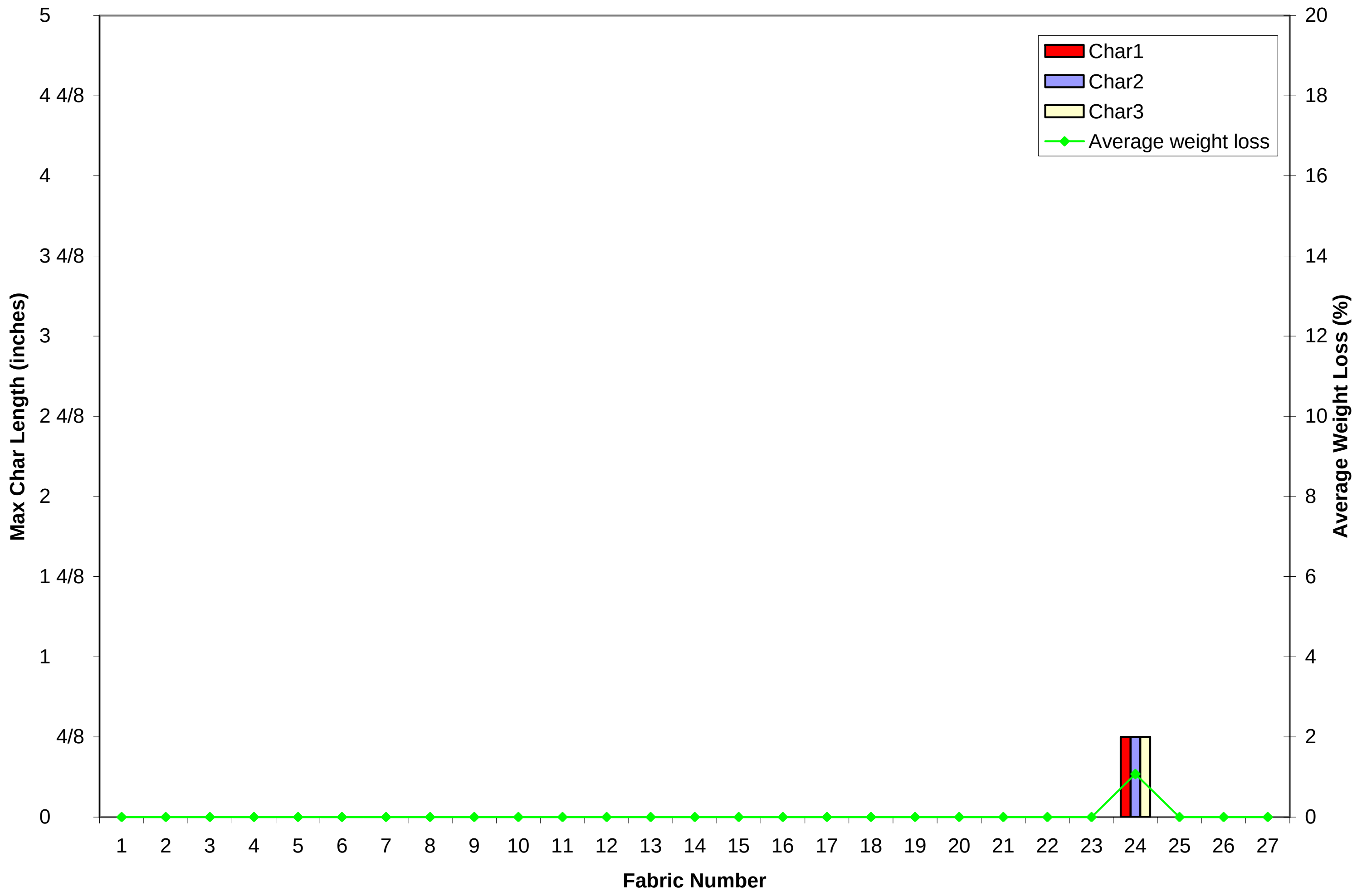
Appendix 33

Char Length and Weight Loss – Foam Y, Interliner D



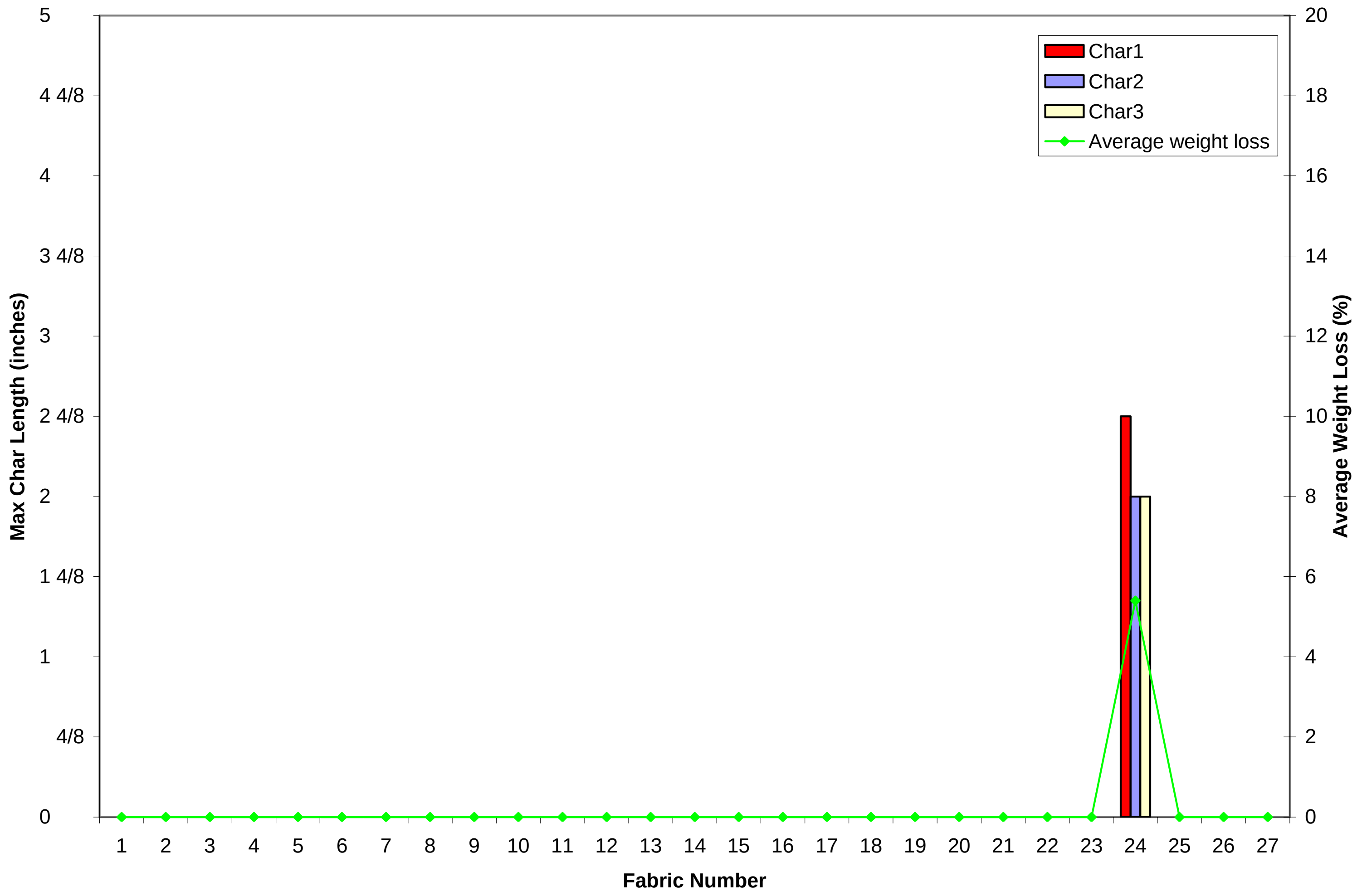
Appendix 34

Char Length and Weight Loss – Foam P, Interliner D



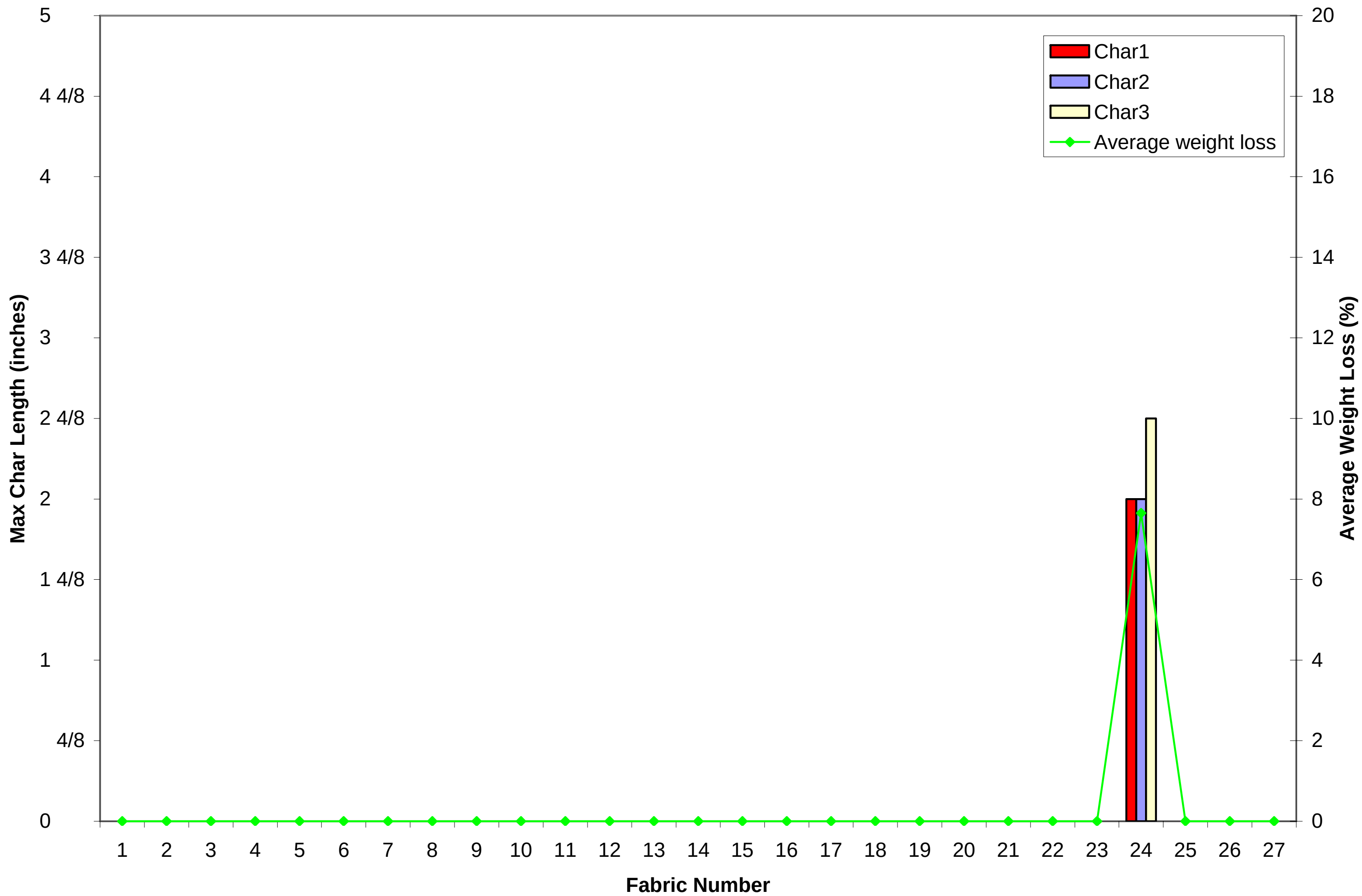
Appendix 35

Char Length and Weight Loss – Foam U, Interliner T



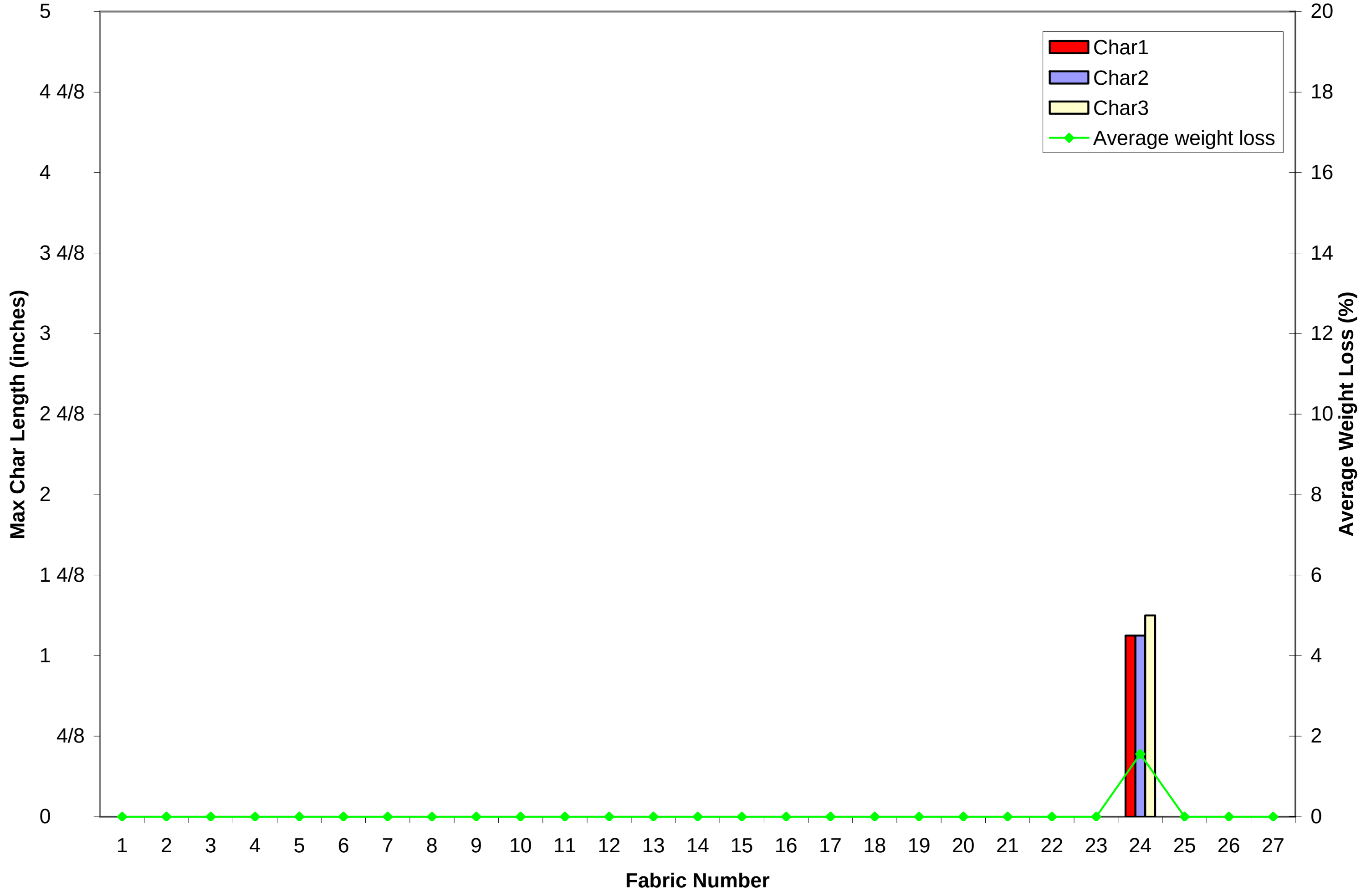
Appendix 36

Char Length and Weight Loss – Foam T, Interliner T



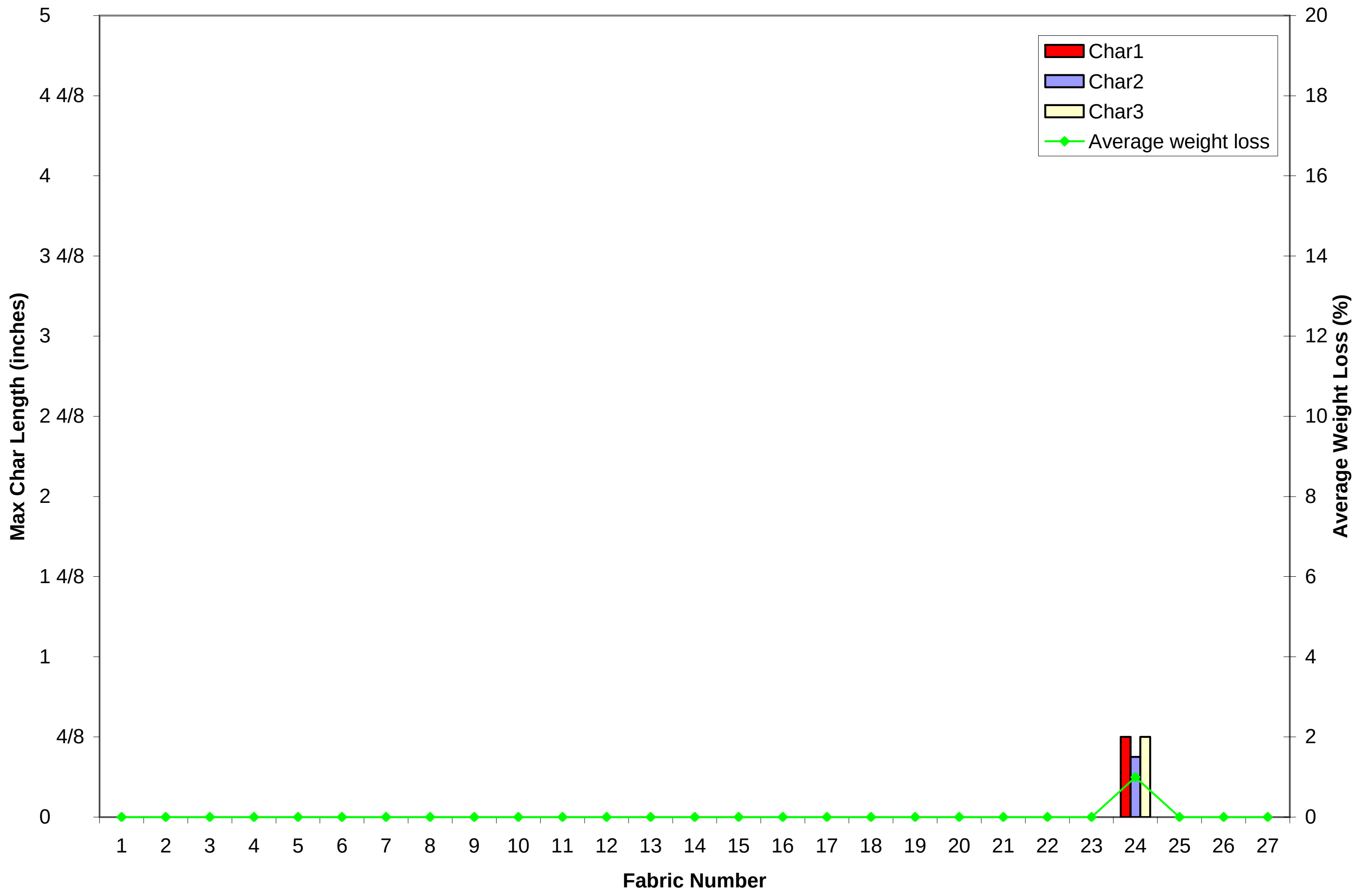
Appendix 37

Char Length and Weight Loss – Foam Y, Interliner T



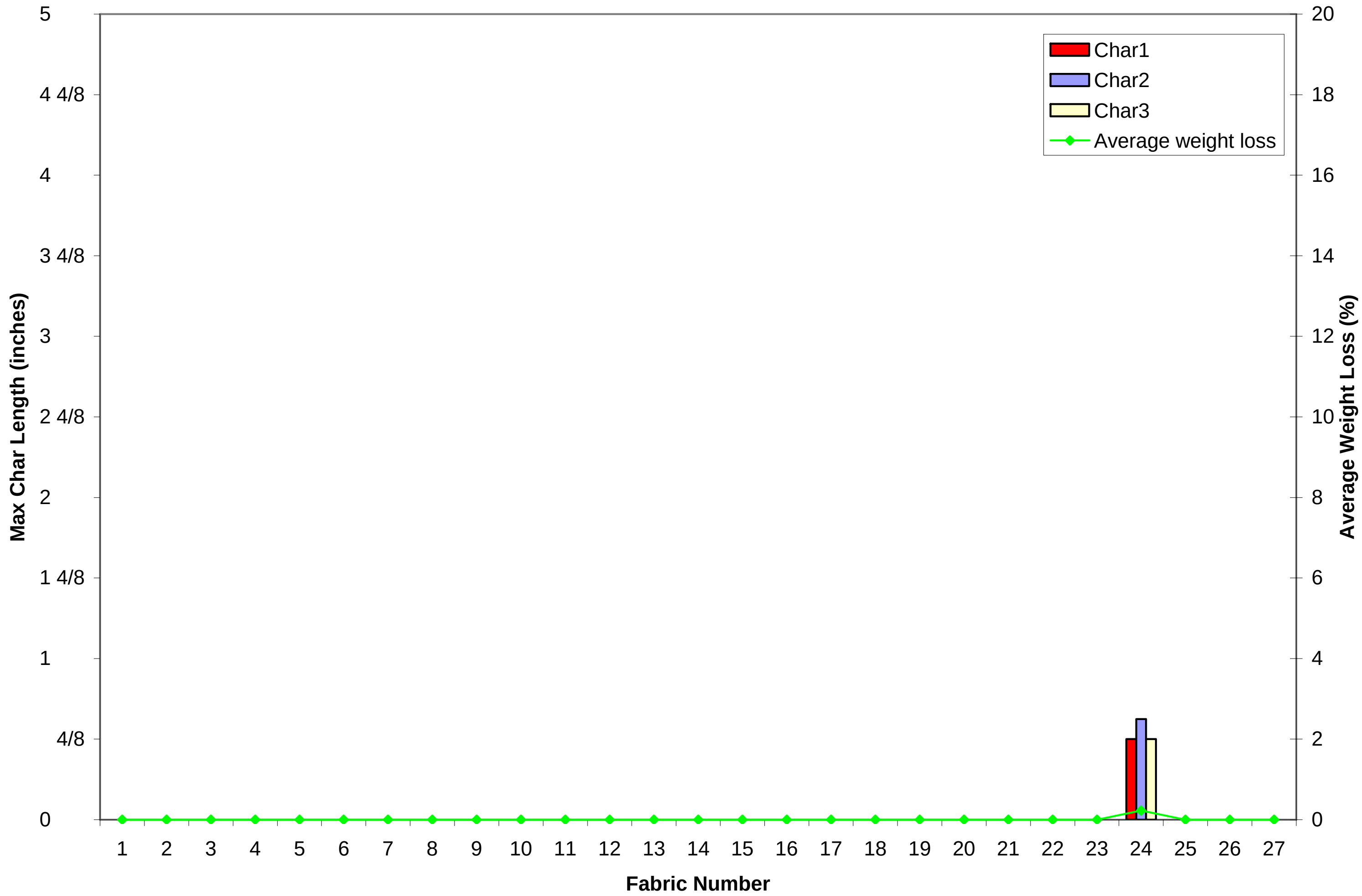
Appendix 38

Char Length and Weight Loss – Foam P, Interliner T



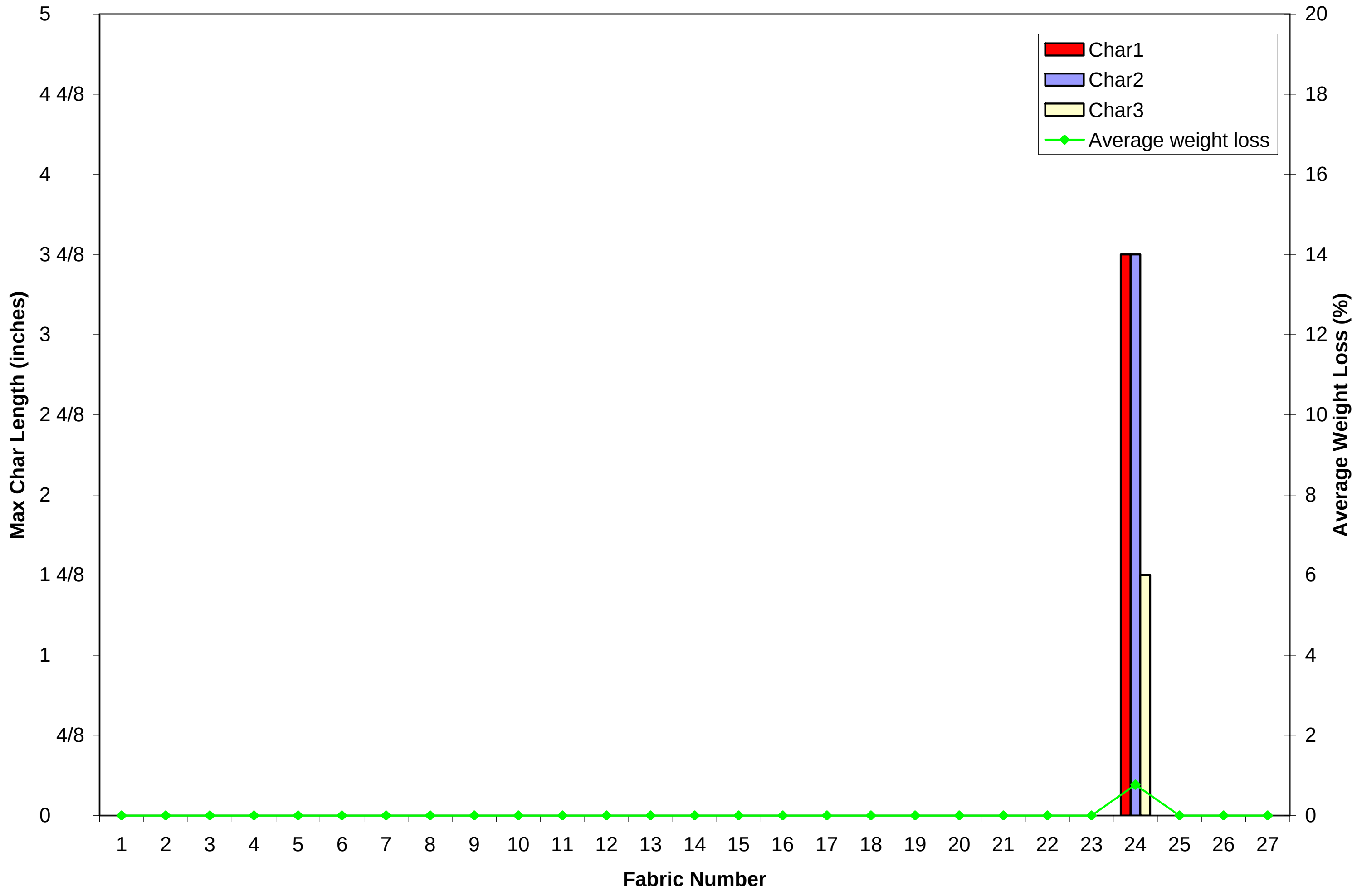
Appendix 39

Char Length and Weight Loss – Foam T, Interliner D/UFAC Batting



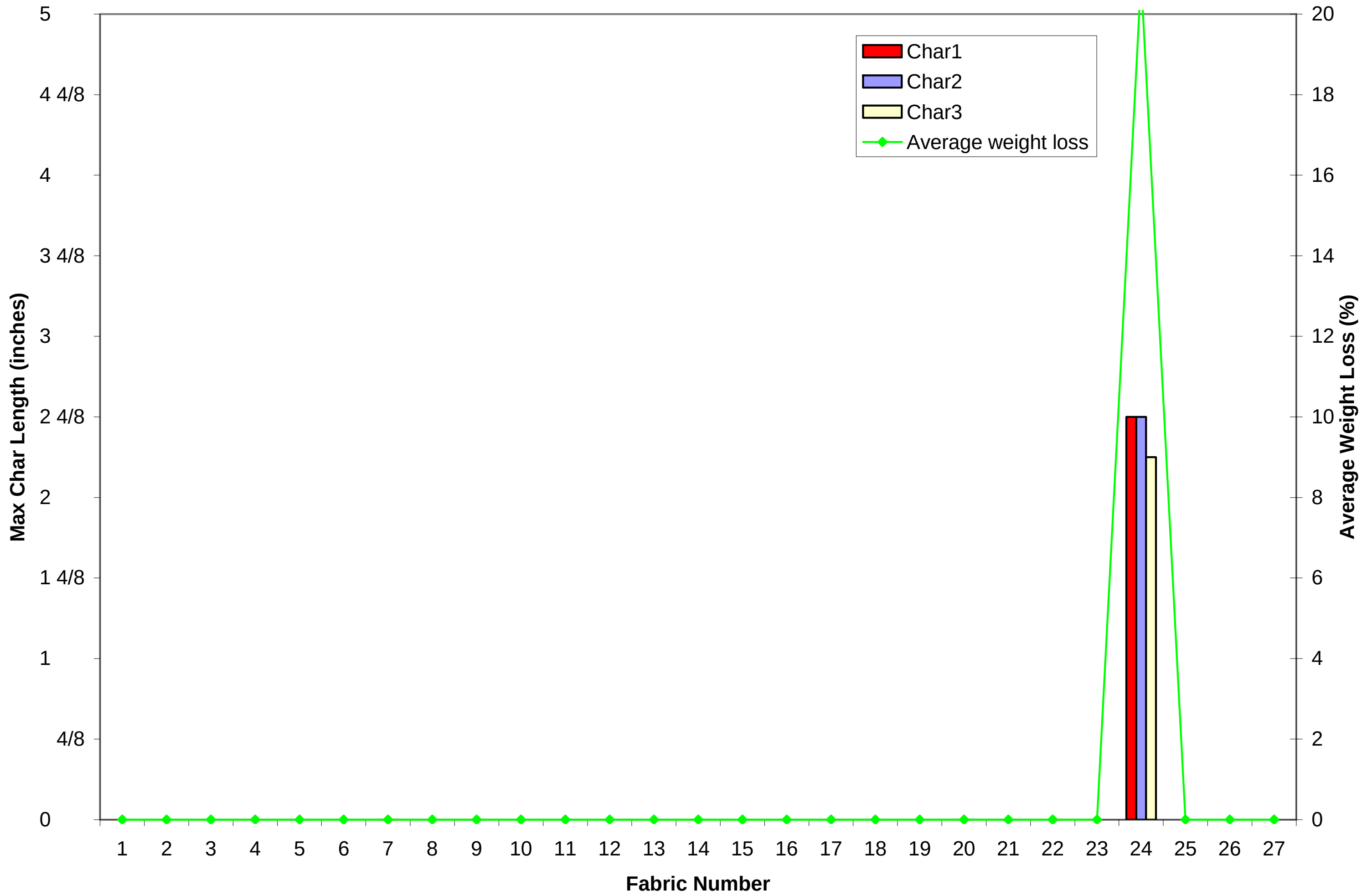
Appendix 40

Char Length and Weight Loss – Foam T, Interliner T/UFAC Batting



Appendix 41

Char Length and Weight Loss – Foam T, Organic Cotton Batting



Appendix 42

Char Length and Weight Loss – Foam T, Organic Cotton Batting/UFAC Polyester Batting