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Testing Abrasion Resistance By the Sand Blast Method

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ABSTRACT

A sand blast abrasion technique using a modified commercial spark plug cleaner was evaluated. This technique involves the impinging of a jet of granular particles, carried in a high velocity air stream, against a fabric.

Results show that the most correlatable operating air pressure was 40 pounds per square inch gauge using a 60 mesh alundum refractory grain abradant and that harder abradants shorten testing time which reduces the discriminating aspects of the tester.

It was demonstrated that the Sand Blast Abrader has good correlation with the Taber and Sand Abraders as well as with field wear. This instrument was simple to operate and end-points were reached in significantly shorter time periods than for other testers.

Disadvantages noted were the necessity of a dry air supply, frequent cleaning, the lack of precision machine tolerances, and the self-destructive action of the abradant.

KEY WORD INDEX

Abrasion
Abrasion Resistance
Abrasion Tests
Testing
Testing Machines
Wear
Wear Tests

ABRASION resistance and the related topics of wear and serviceability have been thoroughly investigated by many textile technologists (*1, 2, 3, 4, 5*). Approaches to the problem have been, for the most part, conducted empirically resulting in much progress in defining the true mechanisms of abrasion.

The first systematic study of the abrasion properties of man-made fibers was conducted by Hamburger (*2*) in which he showed that work-to-rupture is an important factor governing the abrasion resistance of different fiber species. He also established an excellent relationship between energy and durability coefficients for various materials.

Backer (*3*) defined the mechanism of abrasion by analyzing the effect of an abrasive particle upon a fiber surface. He explained the fundamental implications of three elements of abrasion: direct frictional wear, surface cutting and fiber rupture or slippage.

An extension of the literature search into the field of metal technology (*6, 7*) led to a more precise definition of wear which seems directly applicable to the machines that are currently used to test abrasion resistance of textile structures.

Work has been done to relate fabric abrasion to wear. Zook (*8*) summed up the problem of relating abrasion testing and wear in his review titled "Historical Background of Abrasion Testing." In it he stated that there are two philosophies regarding the abrasion testing of textile fabrics and the correlation of their results. One theory advocated the duplication of actual wear conditions, while the other favored the selection of the most important causes of wear and then the correlation of them with service results.

Those who have designed their testing machines to duplicate the most important causes of wear have been more successful in correlating their laboratory and service results. It has been demonstrated that this correlation does not always exist (*3, 9, 10*). However, one factor was clearly determined, "Abrasion is the most important single factor in wear" (*11*). The problem according to Ball (*12*) is to measure the effects of abrasion on a fabric. Various criteria have been suggested (*8, 12*) and the important ones are listed below:

- Tensile strength
- Thickness
- Weight
- Surface luster
- Air permeability
- Color
- Character of abraded materials
- Appearance of the surface
- Formation of a hole
- Occurance of broken threads

A change in tensile strength and the formation of a hole are the usual parameters considered for most abrasion testing of textile materials.

Rabinowicz (*7*), Avient (*13*) and results from the National Engineering Laboratory (*14*) have indicated that abrasive wear is a function of abradant hardness, particle size and humidity conditions.

In order to evaluate the reliability of predicting fabric durability under actual wear conditions, workers at the U. S. Army Natick Laboratories have conducted various investigations of the phenomenon of abrasion and have correlated data wtih field results (*4*).

It has been shown (*15*) that essentially all textile abrasion testers are governed by the principles of either adhesive or abrasive wear as proposed by Archard (*6*) and Rabinowicz (*7*) respectively. It has also been shown in various studies (*16, 17*) that testers which are governed by adhesive wear correlate well among themselves, but not so well among testers using the principles of abrasive wear or actual field wear. These testers are more sensitive to finishes than are the ones of the abrasive type. In addition, it was shown that testers using a purely abrasive action correlate well among themselves *and* give a good indication of actual field wear.

The Sand Blast Tester, a modified spark plug cleaner, was originally proposed as a fabric abrasion instrument by Elliott A. Snell of the U. S. Army Natick Laboratories. The tester has had some preliminary testing which indicated that it had great promise in screening military fabrics for further testing under field conditions. It was also shown that this tester is predominately abrasive in action.

Eleven military fabrics (Table I), some of which have extensive past testing records, were tested using the Smith Sand Abrader, Taber Abraser and the Sand Blast Tester. Correlation among these laboratory testers was made and the generated data were analyzed statistically on the IBM 1620 digital computer at Lowell Technological Institute. Laboratory results were compared with actual field wear data previously obtained on these same fabrics.

Others workers (*18*) using an abrasive jet to measure abrasion resistance of organic coatings have indicated that their results were a function of pressure (driving force), angle at which the specimen was abraded and the distance from the nozzle to the specimen. In view of these findings, the variables selected for this investigation were: abradant size and hardness, fabric weight and weave, and the angle at which the abradant strikes the fabric.

Experimental Procedure

Materials

Eleven military fabrics used in this study were supplied by the U. S. Army Natick Laboratories and are described in Table I. These fabrics are representative of the types currently in use by the Army as uniform materials. Some of these materials have been previously evaluated in laboratory and field wear tests (*19*).

Quality particulars were determined by following the procedures detailed in ASTM Standards on Textile Materials (*20*). Six 0.5-inch ravelled strip breaking strength tests were made on each fabric in the warp direction using the Instron instrument. The warp direction was selected because it is in this direction that most fabrics fail. Machine parameters were selected in accordance with the specified ASTM criteria and were found to be:

- Cross-head speed of one inch per minute
- Chart speed of five inches per minute
- Load cell capacity of 200 pounds
- Gauge length of three inches
- Air pressure activated clamps, rubber faced (pressure from 60-90 psig)

Using the established criteria along with the load elongation charts, elongation and breaking strength were determined.

Weight of the fabrics was determined by weighing five 2x2-inch square specimens in grams and converting the average weight to an ounce per square yard basis.

Table I—Description of Test Fabrics

Fabric Code*	Fiber Content (%)	Weave	Weight (oz/yd²)
VEE 949Q†	Cotton 50 Nylon 50	Sateen	11.91
VEE 949	Cotton 50 Nylon 50	Sateen	11.17
VEE 948	Cotton warp Nylon filling	Sateen	9.54
VEE 947	Cotton 50 Nylon 50	Sateen	10.18
VEE 946	Cotton 100	Sateen	9.19
VEE 1265A	Cotton 50 Nylon 50	Poplin	5.84
VEE 1547A‡	Fiber 6	Poplin	5.26
VEE 1983A	Cotton 35 Polyester 65	Poplin	5.74
D 53	Cotton 100	Twill	8.03
A 244	Cotton warp Nylon filling	Oxford	4.93
VEE 1982A	Cotton 100	Poplin	5.36

* Fabric Code No. as used by U.S. Army Natick Labs.
† Fabric treated with water repellent finish is designated with a Q.
‡ Experimental fiber developed by Du Pont and not to be confused with nylon 6.

Methods

Initially, all of the fabrics tested were conditioned for several days in a laboratory in which the atmospheric conditions were maintained at 65±2% relative humidity and 70±2 degrees Fahrenheit. These fabrics were then abraded by three different methods:

- The Rotary Platform, Double Head Method (Taber Abraser).
- The Smith Sand Abrader Method.
- The Sand Blast Method.

Each of the methods is outlined in some detail.

The Rotary Platform, Double Head Method is described in the ASTM Standards. The Taber Abraser meets the requirements of this test and was used with 500-gram head loads and CS 17 abrasive wheels. These conditions of head loads and abrasive wheels were determined experimentally and were selected in order to obtain a significant spread of cycles-to-failure between the most and the least abrasion resistant fabrics.

Three test specimens, approximately five inches in diameter, were taken from each of the fabric samples. Care was used so that the specimens were not taken from the areas of the fabric which were represented by the same warp or filling yarns. The plain weave and twill fabrics were mounted on the rotary table with the face of the material adjacent to the abrasive wheels in accordance with ASTM instructions while the sateens were mounted with the back of the fabric towards the abrasive surfaces. This deviation from standard procedure can be explained by the fact that military garments using sateen fabrics are constructed with the filling float side (back) of the fabric to the outside of the garments. The Taber Abraser used was equipped with a cycle counter and

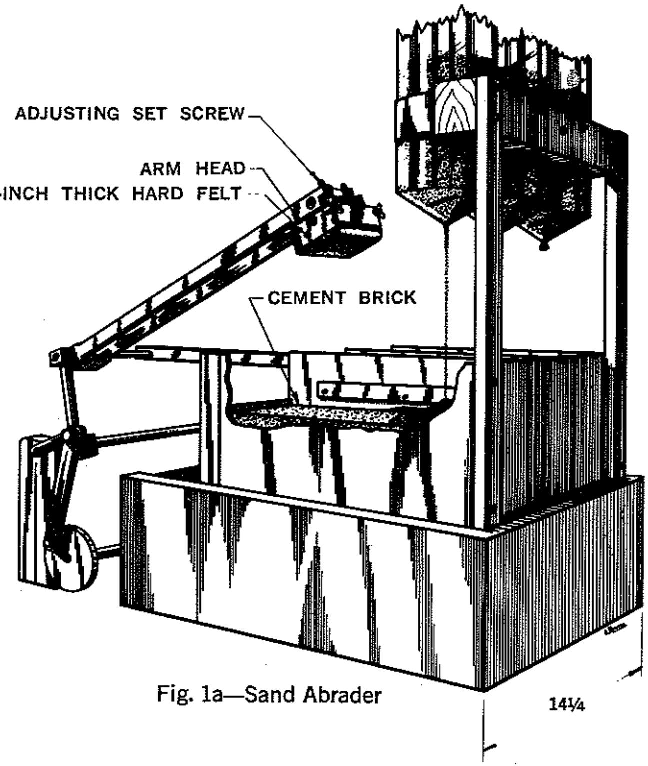

Fig. 1a—Sand Abrader

a vacuum suction device. This vacuum system was used to keep the surface of the fabric clean from debris. After each 500 abrasion cycles, the table containing the specimen was removed from the tester and replaced with one containing a carborundum coated resurfacing disk and the abrasive wheels were resurfaced for 50 cycles. This procedure was repeated until the fabric reached the end point, a hole which showed the rupture of one or more yarns. All of the fabrics were abraded in this manner.

THE SAND ABRADER METHOD was used to evaluate fabric performance because previous experience (*21*) indicated that the wear produced simulates the conditions of the accelerated wear course and actual field wear.

Harry Smith, a textile technologist at the U. S. Army Natick Laboratories, designed the Sand Abrader and formulated the associated method. This instrument is not commercially available, therefore its operation will be described in detail.

The basic instrument as pictured in Figs. 1a and 1b consists of three specially designed raceways into which sand is fed at a relatively constant rate. Rabinowicz's (*7*) concept of three-body abrasion is incorporated along with the fact that the fabric surface is not continually abraded by the same sand particle. These weighted arms on which the samples are mounted rub through the beds of sand at 84 revolutions per minute. The pressure applied to the surface of a fabric is on the order of one-half pound per square inch. This is the same pressure exerted by an average man upon the knee portion of his trousers when he is in a crawling position. The rate of sand flow, pressure on the fabric and the traversals per minute were all fixed parameters and were not changed for this test.

Specimens were cut in accordance to the specifications shown in Fig. 2. Care was taken not to cut specimens from areas which were representative of the same warp or filling yarns. These specimens were clamped onto the moving arms in such a manner as to have the warp direction parallel to the path of the arm's motion in a horizontal plane. The instrument was equipped with a predetermining traversal counter which was set for 500 traversals, at which time the machine automatically stopped and the sand was sieved between a number 16 and a number 30 sieve. This operation was continued until the specimens reached the predetermined end point, a hole in the surface of the fabrics.

THE SAND BLAST METHOD is a simple and rapid procedure which involves relatively inexpensive equipment. The criterion for the test is the time required to wear a hole through a fabric specimen by the impingement of a jet of granular particles, carried in a high velocity air stream.

The Sand Blast Tester (Fig. 3) is basically an AC Model K Sparkplug Cleaner which has been modified by L. P. Berriman (*22*) at Stanford Research Institute to accept a specially designed pressure sensing head (Fig. 4). Air pressure is transduced by an inclined manometer which has mercury and number 30 oil as its working media. The oil has the effect of damping the system, i.e. reducing its sensitivity, to a point where steady state operation is reached within a short time. The inclined manometer was used in-

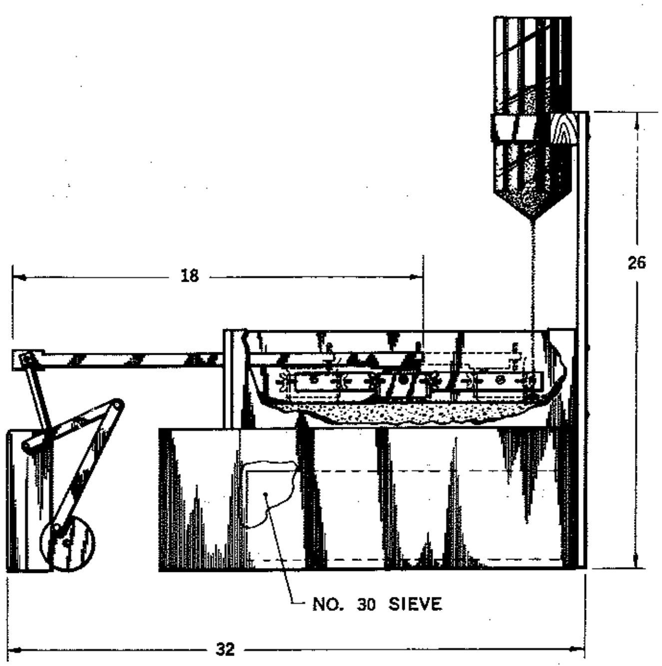

Fig. 1b—Sand Abrader (side view)

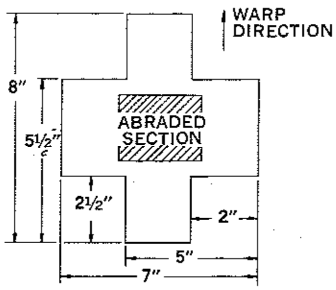

Fig. 2—Abraded Smith Specimen

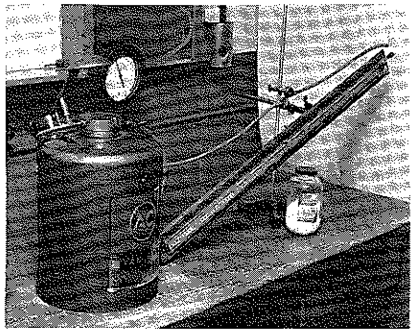
Fig. 3—Sand Blast Tester

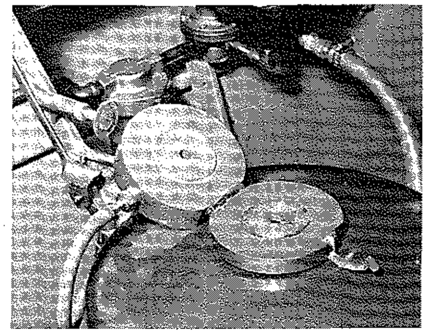
Fig. 4—Pressure sensing head

stead of the pressure gauge (0-15 lb) supplied with the instrument because of the small differences in air pressure that were encountered. In addition, an inclined tube requires a greater displacement of the meniscus of mercury for a given pressure difference than does a vertical tube. This allows a more accurate scale reading if the inclined tube is used.

The Sand Blast Tester requires an adequate supply of dry air. Any moisture present in the air supply would cause the abrasive to agglomerate and clog the orifice of the nozzle resulting in an inconsistent performance of the test instrument. A supply of adequately dry air was accomplished through a specially designed system (Fig. 5). The pressure was controlled by the use of a Bridgeport Pressure Regulator used along with an extremely accurate Bourdon gauge. The source of the air supply is a reciprocating air compressor which builds the air up to a given static pressure. The draw off of the air by the tester has the effect of reducing the static pressure to a lower level. Therefore, the air pressure must be adjusted to the desired level immediately after depressing the actuating lever of the Sand Blast Tester. The abrasives used were Refractory Grain Alundum manufactured by the Norton Co. and CL3 number 5613014 cleaning compound formulated by the AC Spark Plug Division of General Motors Corp. These were screened to pass through a 50 mesh sieve but not through a 70 mesh sieve. The 50 mesh sieve held back the fabric debris while allowing the abrasive particles to pass through and the 70 mesh sieve was used to separate the fine particles which had been generated from the self-destruction action of the abrasive. The abrasive was rescreened after every 80 samples and the supply cone (Fig. 6) within the tester was refilled with the screened particles. New abrasive had to be added to bring this cone to a full level. It is imperative that this level remain constant throughout the testing period or the efficiency of the operation is noticeably reduced. The Air Filter Sleeve (Fig. 6) was removed after processing 80 samples and was vacuumed to remove the fine dust particles from the inner surfaces of the cloth bag. The rubber air nozzle used as the orifice of the mixing chamber was replaced every 300 samples because the nozzle became worn and the enlarged hole size appreciably reduced the abrasive efficiency of the unit. The fine dust particles formed within the head of the sensing unit were removed every 80 samples so that the manometer system would not become contaminated.

The test procedure is described as follows: With the head clamp shut, the actuating lever of the unit is depressed and simultaneously a stopwatch or electric timer with a sweep second hand is started. The sensing pressure gauge, in this case an inclined manometer, is observed at this time and will be indicating a constant pressure level. This pressure level will generally be different with different types of fabrics, but the absolute value is not important. When the sand blast causes a breakthrough in the fabric, the pressure as indicated by the pessure sensor will abruptly increase. At this time, the timing device is stopped and the actuating lever is allowed to return to the off position.

Ten 2x2-inch square specimens were cut from each fabric sample and were tested at four different machine pressures, 30, 40, 50 and 60 pounds per square inch gauge. The type of abrasive used in this case was RR 60 Mesh Alundum. Specimens of each fabric were tested with the face of the material toward the blast of abrasive particles. The sateens and the twill fabrics were further tested with the

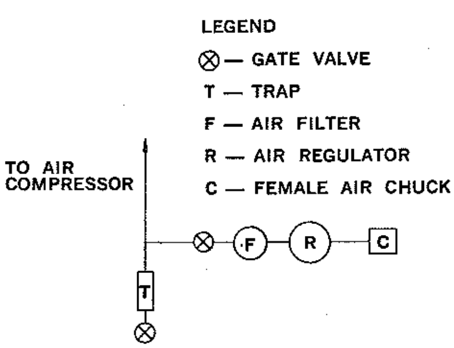

Fig. 5—Dry air supply for Sand Blast test

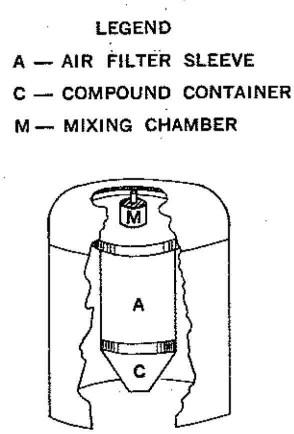

Fig. 6—Sand Blast tester parts breakdown

back side toward the abrasive blast.

The fabrics were further tested to 25, 50 and 75 per cent of the time required to reach destruction using a pressure of 40 pounds per square inch gauge and the alundum abrasive.

These specimens were ravelled to 0.5-inch wide warp strips and were evaluated on the Instron Tester for breaking strength and elongation as described earlier.

The tester was thoroughly cleaned and the alundum was replaced with the CL3 AC compound. The fabrics were again sandblasted to destruction using a 40-pound per square inch gauge pressure.

Results And Discussion

The fabrics described in Table I were abraded in accordance with the criteria proposed in the experimental procedures. Results from this abrasion study are shown in Tables II, III and IV according to the abrasion method followed.

Table II—Mean Taber Cycles to Destruction (Three Tests)

Fabric Code	Cycles	Standard Deviation	Coefficient Of Variation (%)
VEE 949Q	7250	132.3	1.8
VEE 949	6800	754.9	11.1
VEE 948	6110	348.3	5.7
VEE 947	5180	62.4	1.2
VEE 1265A	2330	85.4	5.1
VEE 1547A	2080	238.1	10.2
VEE 946	1660	10.0	0.5
VEE 1983A	1250	20.0	1.6
D 53	1090	43.6	3.9
A 244	770	52.9	6.7
VEE 1982A	660	10.0	1.5

Table III—Mean Sand Abrader Cycles to Destruction

Fabric Code	Mean Cycles	Group
VEE 949Q	9000	
VEE 949	9000	
VEE 948	6700	I
VEE 947	8500	
VEE 1265	3500	
VEE 1547A	4000	II
VEE 946	3500	
VEE 1983A	2000	
D 53	2500	III
A 244	2000	
VEE 1982A	1500	

Taber Abraser Abrasion Resistance

The Taber Abraser was used in a manner previously described and a summary of these data is shown in Table II.

In general, the coefficients of variation associated with the Taber generated data are low, therefore the prescribed number of test samples are considered to be statistically justifiable at a 95% probability level with a 5% sampling error (ASTM Designation D2264-64T).

As shown in Table II, the eleven military fabrics are ranked subjectively according to their resistance to abrasion. As might be expected, the nylon cotton blended sateens ranked the best, while the lighter poplins and other fabrics were not as good. The addition of nylon, whether it be as a fiber blend or an ortho blend, tended to increase the substrate's resistance to abrasion. This phenomenon can be explained in terms of work recovery, where it was shown (*23*) that nylon is outstanding in this respect. At low strains it has been shown (*24*) that nylon has an Elastic Performance Coefficient which approximates 1.0, while cotton is rated at 0.79.

Smith Sand Abrader Abrasion Resistance

The samples listed in Table I were abraded in accordance with the Test Procedures. The data obtained are presented in Table III.

The results from the preceding table show that this test instrument is not as discriminating as is the Taber Abraser. As a point of interest it should be noted that a statistical difference cannot be established between the water repellent treated and the untreated VEE 949 fabrics. This fact adds credence to the theory proposed by Weiner (*16*), which hypothesized the type of abrasive action predominant in these two test instruments.

Using Table III as a basis for fabric ranking, it is evident that the fabrics tend to fall into three groups. For example, the VEE 949 and VEE 949Q fabrics resist abrasion equally as well and are better than any of the other fabrics tested. The other sateens which are cotton/nylon blends also fall into Group I. The second group (VEE 1265A, VEE 1547A and VEE 946) are at best 2700 cycles less than the worse sateen in the first group. This difference is understandable in the case of the two poplins (VEE 1265A and VEE 1547A) because of the large weight difference between the sateens and the poplins. The VEE 946 sateen also falls in Group II, but this is probably because of the cotton fiber used to construct this fabric. As mentioned earlier, an all-cotton fabric does not have the same abrasion resistance characteristics as does a nylon/cotton fabric of the same type. Fabrics in Group III consist of the lighter weight poplins, oxfords and twills.

This ranking is very subjective and the resulting data depended greatly upon the operator as is also the case with the Taber Abraser.

Sand Blast Tester Abrasion Resistance

The Sand Blast Tester was used in accordance with criteria proposed in the Test Procedures. Fabric samples were tested for abrasion resistance using the predetermined conditions of driving pressure and abrasive types. Results of these abrasion tests are shown in Table IV.

As can be seen, the statistical data obtained have low coefficients of variation which indicates that this instrument is capable of good reproducibility. In almost every case, the Sand Blast Tester was able to detect a significant difference between the back and the front of the army sateens. This substantiates the theory that this tester is sensitive enough to be used to evaluate fabric abrasion resistance even though the time required to destroy a fabric is very short compared to the times of the Taber and Sand Abraders.

The data in Table IV indicate that the front (warp) side of the heavier sateens have more resistance to sand blast abrasion than the back (filling) side. However, this is reversed for the other sateens. A comparison of the seconds to failure on the back side of

Table IV—Mean Sand Blast Seconds to Destruction (Alundum 60 Mesh Abrasive) (Ten Tests)

Fabric Code	Driving Pressure (PSIG)	Side Towards Abrasive	Mean Seconds	C.V. (%)	"t" Cal	Significance (5%)
VEE 949Q	30	B	121.7	6.9	5.79	Yes
		F	142.6	5.3		
	40	B	71.8	4.9	6.61	Yes
		F	82.8	4.6		
	50	B	34.0	9.7	3.07	Yes
		F	37.8	5.5		
	60	B	23.0	4.6	0.21	No
		F	22.9	0.21		
VEE 949	30	B	121.4	9.4	6.05	Yes
		F	154.7	8.5		
	40	B	56.9	9.7	5.91	Yes
		F	70.7	6.9		
	50	B	37.4	6.8	7.49	Yes
		F	41.0	9.3		
	60	B	24.9	5.5	4.89	Yes
		F	31.4	12.7		
VEE 948	30	B	131.4	5.3	11.16	Yes
		F	102.3	4.3		
	40	B	56.7	3.7	16.15	Yes
		F	40.1	6.2		
	50	B	39.0	9.7	7.58	Yes
		F	28.7	7.2		
	60	B	31.4	5.2	13.76	Yes
		F	20.3	9.6		
VEE 947	30	B	106.2	3.9	5.97	Yes
		F	97.1	2.4		
	40	B	56.5	5.4	3.20	Yes
		F	52.7	4.2		
	50	B	41.8	4.3	12.17	Yes
		F	32.8	4.5		
	60	B	31.0	6.0	10.01	Yes
		F	23.5	6.1		
VEE 946	30	B	65.2	4.4	9.73	Yes
		F	53.5	4.6		
	40	B	34.2	7.1	7.70	Yes
		F	27.1	5.9		
	50	B	25.7	5.5	14.79	Yes
		F	17.9	4.9		
	60	B	17.6	6.1	12.21	Yes
		F	12.7	5.3		
VEE 1265A	30	F	62.2	5.1		
	40	F	32.9	7.2		
	50	F	23.0	7.7		
	60	F	16.9	5.9		
VEE 1547A	30	F	66.5	4.0		
	40	F	32.4	4.6		
	50	F	21.9	3.4		
	60	F	15.4	3.4		
VEE 1983A	30	F	47.5	5.1		
	40	F	26.9	7.5		
	50	F	18.1	9.2		
	60	F	13.2	7.8		
D 53	30	B	55.6	6.0	7.26	Yes
		F	66.8	5.3		
	40	B	28.2	6.6	2.15	Yes
		F	29.7	3.9		
	50	B	21.7	3.1	0.57	No
		F	21.4	7.0		
	60	B	14.7	3.2	4.57	Yes
		F	16.2	5.7		
A 244	30	F	41.1	4.8		
	40	F	22.5	7.9		
	50	F	15.5	3.4		
	60	F	11.2	7.0		
VEE 1982A	30	F	37.3	4.7		
	40	F	17.5	14.1		
	50	F	12.9	7.7		
	60	F	8.1	10.8		

the nylon/cotton sateens at 40 psig shows no significant difference in abrasion resistance. The cotton/nylon fabrics were judged to be the best able to resist abrasion while the other fabrics were not as good.

From Table IV it can be shown that as the driving pressure is reduced, the time required to destroy a fabric specimen is lengthened. Also it is evident that the fabrics are ranked differently when the four driving pressures are used. For example, the VEE 949Q fabric is better than all fabrics at driving pressures of 30 and 40 psig, but it is poorer than all sateens at 50 psig and poorer than all nylon/cotton blended sateens at 60 psig. One reason for this reversal could be that the (VEE 949Q) fabrics are not as pliant as the untreated sateens, therefore the higher particle energies tend to rupture these stiff fibers more easily. Realizing that reversals are possible, an attempt was made to find the driving pressure which gave the best correlation among the other instruments used. As can be seen in Tables V and VI, the best correlation among machines is effected when the Sand Blast Tester is operated at 40 psig driving pressure.

As expected, the correlation was very good among instruments. This can be explained by the fact that these machines all produce abrasive type wear as was indicated *(22)* in a preliminary investigation of the Sand Blast Tester.

It is evident that the best correlations were obtained between the Taber and the Sand Abrader, the Taber and the Sand Blast Tester (40 psig) and the Sand Abrader and the Sand Blast Tester (40 psig) for all had correlation coefficients of 0.97. 94.8% of the variance can be explained by the interrelationship of the Taber and the Sand Blast Tester at 40 psig, whereas 93.1% of variance can be explained by the interrelationship between the Sand Abrader and the Sand Blast Tester at 40 psig. As was shown in a previous study *(16)*, the Sand Abrader and the Taber both correlate very well. 94% of the variance can be explained by the interrelationship of the Taber and the Smith Abraders.

It is interesting to note that the Taber Abraser is more correlatable to the Sand Blast Tester at lower pressures than is the Sand Abrader, while the reverse is true for higher pressures.

After a satisfactory pressure has been determined, it is important not to deviate from this pressure, as it has been shown statistically by an analysis of variance that a difference in pressure significantly affects resulting data.

An attempt was made to determine the effect of using a harder abradant, CL3, which is of the silicon carbide family. These results are shown in Table VII.

In all cases, the time required to destroy the fabrics has been reduced by using a harder abradant. The results obtained using this type of abradant are consistently lower than the results obtained using the alundum at the same machine pressure.

Strength And Elongation

Using the criteria proposed in the experimental procedures, a study determining the percentage of loss in fabric residual strength at four levels of sand blast abrasion was conducted. Table VIII shows the time required for each sample to reach the selected level of abrasion.

The mean strength and elongation associated with each level of sand blast abrasion along with percentage loss are shown in Tables IX and X. It is evident that the nylon/cotton blended fabrics lose strength at a slower rate than most other fabrics. The one outstanding exception to this fact is the VEE 946 all-cotton sateen. This fabric loses very little strength initially, as do the nylon/cotton blended sateens. This phenomenon is explained by the fact that the warp yarns in sateen fabrics are not damaged excessively because of the protection afforded by the filling yarns.

The fabrics having nylon filament filling yarns were damaged excessively because of the cutting action of the sand blast. The sateen lost utility at a slightly lower rate than did the nylon filled poplin, but this would be due to the geometric construction of the sateen.

The all cotton fabrics generally lose strength at a greater rate than do the nylon/cotton blends, but at a lower rate than fabrics such as VEE 1547A and 1983A.

General Discussion

Abrasion Resistance data is shown in Table XI so that an effective comparison between laboratory abraders can be made. Particular attention should be given to the variety of fiber

Table V—Correlation Coefficients (r)

	Taber	Sand Abrader
Sand Abrader	.97	—
Sand Blast (30 psig)	.96	.94
Sand Blast (40 psig)	.97	.97
Sand Blast (50 psig)	.90	.93
Sand Blast (60 psig)	.85	.87

Table VI — Percentage of Variance Explained by Interrelationships

	Taber	Sand Abrader
Sand Abrader	94.0	—
Sand Blast (30 psig)	93.4	87.8
Sand Blast (40 psig)	94.8	93.1
Sand Blast (50 psig)	81.9	87.1
Sand Blast (60 psig)	72.7	74.8

Table VII—Mean Sand Blast Seconds to Destruction (CL3 Abradant With 40 PSIG Pressure)

Fabric Code	Mean Seconds	C.V. (%)
VEE 949Q	60.7	4.5
VEE 949	49.3	3.8
VEE 948	34.5	8.2
VEE 947	49.5	7.0
VEE 946	24.5	9.1
VEE 1265A	21.8	5.6
VEE 1547A	21.8	7.1
VEE 1983A	22.4	8.9
D 53	27.3	8.1
A 244	16.2	4.9
VEE 1982A	15.0	8.3

Table VIII—Time Required to Reach the Selected Level of Abrasion*

Fabric Code	End Point (Sec)	3/4 EP (Sec)	1/2 EP (Sec)	1/4 EP (Sec)
VEE 949Q	71.8	53.8	35.9	18.0
VEE 949	56.9	42.6	28.5	14.3
VEE 948	56.7	42.5	28.4	14.2
VEE 947	56.5	42.3	28.3	14.2
VEE 946	34.2	25.6	17.1	8.6
VEE 1265A	32.9	24.7	16.5	8.2
VEE 1547A	32.4	24.3	16.2	8.1
VEE 1983A	26.9	20.2	13.5	6.7
D 53	29.7	22.3	14.9	7.4
A 244	22.5	15.9	11.3	5.6
VEE 1982A	17.5	13.1	8.8	4.4

* Alundum abrasive with 40 psig machine pressure.

Table IX—The Effect of Sand Blast Abrasion on Fabric Breaking Strength*

Fabric Code	Strength Before Abrasion (lbs)	Strength at 25% Level	Strength Loss (%)	Strength at 50% Level	Strength Loss (%)	Strength at 75% Level	Strength Loss (%)
VEE 949Q	98.3	68.7	30.0	38.3	61.1	26.5	73.1
VEE 949	94.5	74.0	21.6	47.3	50.0	44.0	45.4
VEE 948	63.3	38.7	38.8	20.8	67.2	17.5	72.3
VEE 947	68.8	70.0	−2.0	51.3	25.4	39.0	43.2
VEE 946	64.5	62.0	3.8	55.2	14.4	40.2	37.7
VEE 1265A	45.8	43.5	5.0	30.7	33.0	18.9	58.7
VEE 1547A	43.5	24.0	44.8	14.8	66.0	10.2	76.6
VEE 1983A	59.8	33.7	43.6	21.5	64.0	16.3	72.7
D 53	73.5	64.8	11.8	30.3	58.7	21.8	70.3
A 244	65.5	29.3	55.3	17.3	73.6	11.5	82.4
VEE 1982A	63.7	50.7	20.3	35.8	43.8	19.7	69.1

* Alundum abrasive with 40 psig machine pressure.

Table X—The Effect of Sand Blast Abrasion on Fabric Elongation*

Fabric Code	Elongation Before Abrasion (%)	Elongation at 25% Level (%)	Loss (%)	Elongation at 50% Level (%)	Loss (%)	Elongation at 75% Level (%)	Loss (%)
VEE 949Q	33.7	22.4	33.6	14.9	55.8	13.1	61.1
VEE 949	28.5	21.4	24.9	14.7	48.5	14.7	48.5
VEE 948	14.1	9.1	35.4	7.5	46.8	6.9	51.1
VEE 947	23.5	19.7	16.2	14.3	39.1	13.7	41.8
VEE 946	13.9	12.3	11.5	12.2	12.2	10.4	25.2
VEE 1265A	24.8	18.1	27.1	15.4	37.9	12.1	51.3
VEE 1547A	72.6	36.3	50.0	24.2	66.7	20.3	72.0
VEE 1983A	34.4	11.9	65.5	7.4	78.5	5.6	83.7
D 53	16.2	12.0	26.0	8.3	48.8	7.6	53.2
A 244	17.1	11.0	35.7	8.0	53.2	6.1	64.3
VEE 1982A	8.9	6.8	23.6	5.4	39.3	5.2	41.6

* Alundum abrasive with 40 psig machine pressure.

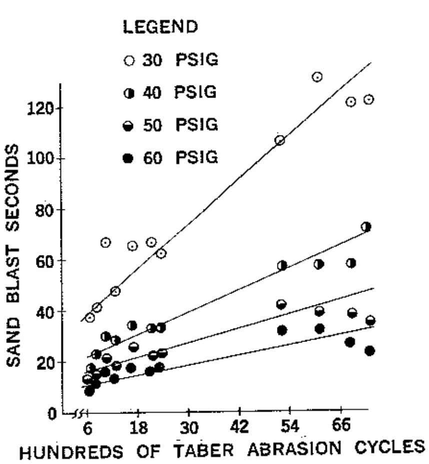

Fig. 7—Regression lines relating Sand Blast and Taber abrasion testers

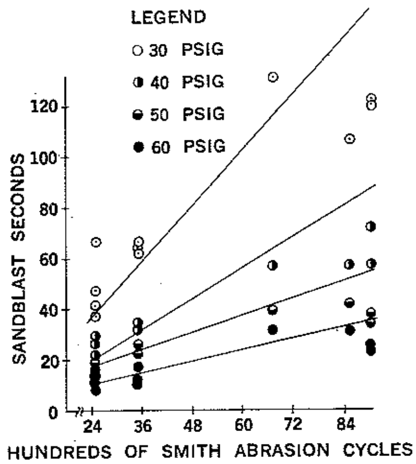

Fig. 8—Regression lines relating Sand Blast and Smith abrasion testers

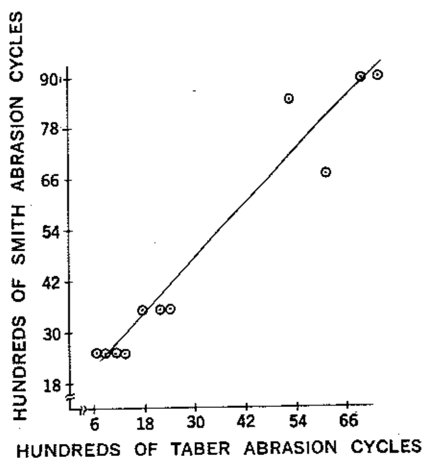

Fig. 9—Regression line relating Taber and Smith abrasion testers

compositions, the range in weights and the different weave types used. The scale values for the different test instruments are worth noting. The Sand Abrader results ranged from 9000 to 1500 cycles with an average of 4745 cycles, while the Taber results were from 7250 to 660 with an average of 3198 cycles. On the other hand, the Sand Blast Tester was rated in seconds with results (at 40 psig) that ranged from 71.8 to 17.5 seconds for all of the fabrics tested. The average was 39.8 seconds for all tests (at 40 psig). If test efficiency is taken as a prime criterion for rating laboratory abraders, the Sand Blast Tester is by far the best. On the other hand, with longer times to failure, it is possible to obtain more precision in results with a larger spread in sample averages. Linear plots of the data presented in Table XI are shown in Figs. 7-9, inclusive. These plots show a definite linear relationship between the three machines. This is a result of the fact that in each of these plots the same type of abrasion is being investigated. The regression equations are shown in Table XII. The constants in these equations can be varied due to differences in abrasion severity and differences that are characteristic of specific fabric types.

Although the Sand Blast Tester is an objective instrument, the resulting data is still subject to error. This error can be caused by such parameters as the self destruction of the abradant used over a period of time, an enlarged rubber air nozzle or a dirty machine. Table XIII shows the effect of running time upon sand blast seconds to destruction when the VEE 949Q fabric is used as a control.

These results from Table XIII are shown in Fig. 10.

The error associated with 40 minutes of running time was 0.42% and was taken as an acceptable level because the magnitude of this error did not significantly affect the results.

It has been shown that the three laboratory abraders tested rank the fabrics according to their merit to withstand abrasion in a very similar manner. As has been previously noted, the three abraders used in this study are predominately abrasive in action. Studies made on the wear course at Fort Lee and some practical wear trials indicate that the type of action prevalent in field wear was of the abrasive types. For this reason, good correlation might be expected between laboratory results and field wear results.

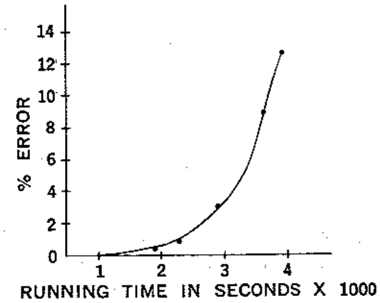

Fig. 10—Error associated with running time

Conclusions

From the data obtained in this investigation, the following conclusions can be drawn:

(1) The Sand Blast Tester is a rapid and reproducible instrument for determining abrasion resistance of textile materials.

(2) The method outlined in the Experimental Procedure must be followed precisely:
- The abrasive must be sieved after 40 minutes of running time (approximately 80 specimens).
- The machine must be cleaned thoroughly at this time.
- The rubber orifice must be changed after 300 specimens.
- The abrasive level must be maintained at the top of the supply cone.
- The air supply must be dry.

(3) The results obtained by the Sand Blast Tester correlate very well with the Taber Abraser and Sand Abrader results at a machine pressure of 40 psig with 60 mesh refractory grain abrasive.

(4) A harder abradant reduces the

Table XI—Fabric Abrasion Resistance Measured by Three Laboratory Abraders

Fabric Code	Taber (Cycles)	Sand Blast Tester (Seconds) (30 psig)	(40 psig)	(50 psig)	(60 psig)	Sand Abrader (Cycles)
VEE 949Q	7250	121.7	71.8	34.0	23.0	9000
VEE 949	6800	121.4	56.9	37.4	24.9	9000
VEE 948	6110	131.3	56.7	39.0	31.4	6700
VEE 947	5180	106.2	56.5	41.8	31.0	8500
VEE 946	2330	62.2	32.9	23.0	16.9	3500
VEE 1265A	2080	66.5	32.4	21.9	15.4	4000
VEE 1547A	1660	65.2	34.2	25.7	17.6	3500
VEE 1983A	1250	47.5	26.9	18.1	13.2	2000
D 53	1090	66.8	29.7	21.4	16.2	2500
A 244	770	41.1	22.5	15.5	11.2	2000
VEE 1982A	660	37.3	17.5	12.9	8.1	1500

Table XII—Regression Equations Between Various Laboratory Abraders

Sand Blast at	Equation Number	Taber	Smith
60 psig	(1)	SB(60 psig) = 0.0025TA + 10.8	SB(60 psig) = 0.0022SM + 8.3
50 psig	(2)	SB(50 psig) = 0.0035TA + 15.2	SB(50 psig) = 0.0031SM + 11.5
40 psig	(3)	SB(40 psig) = 0.0066TA + 18.7	SB(40 psig) = 0.0057SM + 12.8
30 psig	(4)	SB(30 psig) = 0.0129TA + 37.7	SB(30 psig) = 0.0109SM + 27.0
Smith	(5)	SM = 1.11TA + 1200	
Taber	(6)		TA = 0.92SM − 1040

time to destroy a fabric substantially.

(5) The regression relationships cover the complete range of fabric types. These equations are not absolute from lab to lab because of possible changes in abradants, machine variability and special fabric types.

(6) The nylon/cotton blended fabrics (sateen in particular) resist abrasion better than other fabrics.

(7) In general, the heavier fabrics (the sateens in particular) lose durability at a slow rate initially and then proceed to a rapid rate of destruction towards the end of their life, while the reverse is true for most poplins.

(8) This instrument showed excellent potential as an abrader, but precision machining must be used to make it a more practical laboratory abrasion tester.

Acknowledgements

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Table XIII—Effect of Running Time on Sand Blast Seconds to Destruction at 40 psig Machine Pressure

Running Time (Seconds)	Sand Blast Seconds to Destruction	% Error
1000	71.8	0
2000	72.0	0.28
2400	72.1	0.42
3000	74.0	3.1
3500	78.0	8.6
4000	81.0	12.8

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